power integrations™

GaN Switches Will Dominate the Market

Chris Lee – Director of Product Marketing

Aug 6th 2020

ac-dc converters led drivers gate drivers motor drivers

GaN Switches Increase Efficiency of Offline Power Conversion

GaN Brings Increased Efficiency

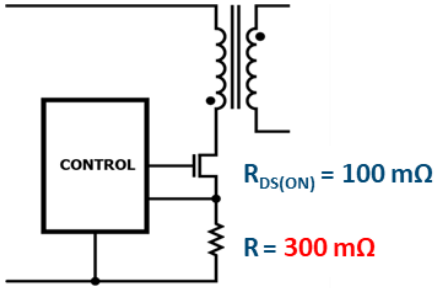
- **GaN switches conduct via a two-dimensional electron-gas (2DEG)**
  - Less impedance than traditional silicon channel structures

Technology	Normalized per Unit Area			Gate Voltage
	$R_{DS(ON)}$	C_{OSS}	Switch Transition Time	$V_{GS(ON)}$
Lateral Si MOSFET	**1**	**1**	**1**	**~5 V**
PowiGaN™ Switch	**0.07**	**< 0.18**	**0.05 to 0.1**	**~5 V**

- **GaN devices smaller and switch more efficiently for a given $R_{DS(ON)}$**
  - Eliminates heatsinks, heat-spreaders, increases lifetime and reliability
- **GaN switching devices turn on/off very fast**
  - ✓ Low switching loss
  - ✗ High potential for EMI

Using GaN Switches is Challenging

- **Require optimized driver**
  - Uncontrolled fast switching can cause EMI problems
  - Parasitics can cause VHF oscillation that can be destructive
    - Especially for discretely packaged GaN devices

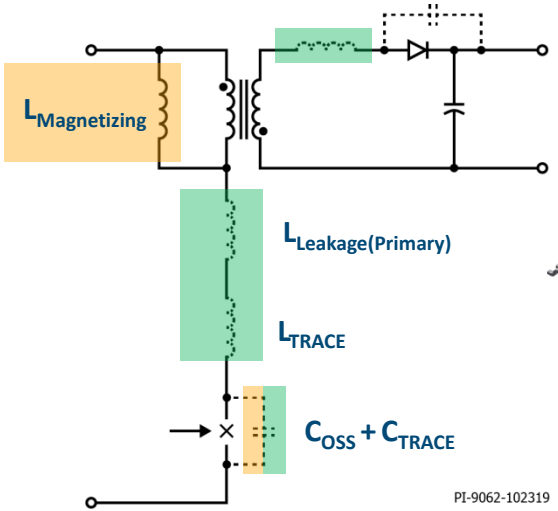


- **External current sensing reduces the efficiency benefit**
  - Discrete designs use current sense resistors with $R_{DS(ON)}$ ≥ GaN switch!
    - Needed to provide sufficient voltage drop for fast current limit loop response

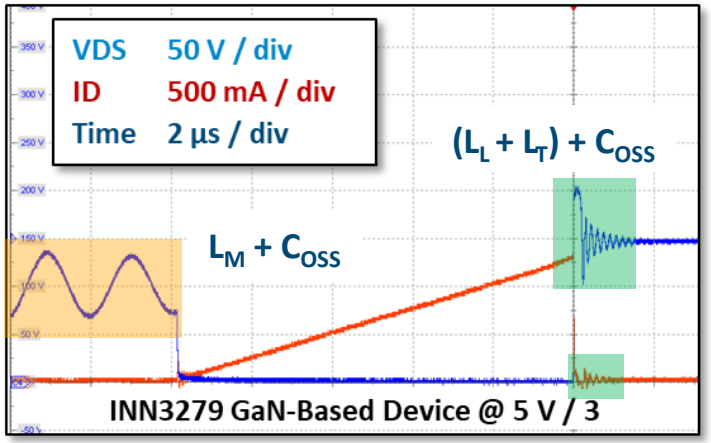
- **Continuous voltage rating ≥650 V is needed for reliable flyback operation**
  - Many HV GaN devices are rated at 480 V continuous – only good for HB circuits
  - Voltage spikes due to parasitic inductance could be a problem even for HB circuits

Integrated Drive and Control Eliminates Switching Challenges

- **Fast GaN operation presents challenges for discrete implementation**
  - Trace inductance plus fast switch transition will increase voltage stress and ringing
  - Bringing control functions inside the device dramatically reduces trace inductance



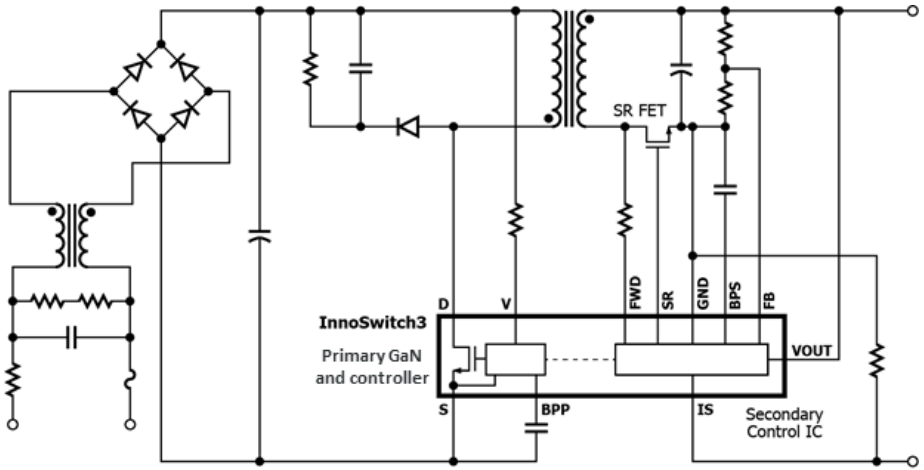
Integrated Controller + GaN Switch



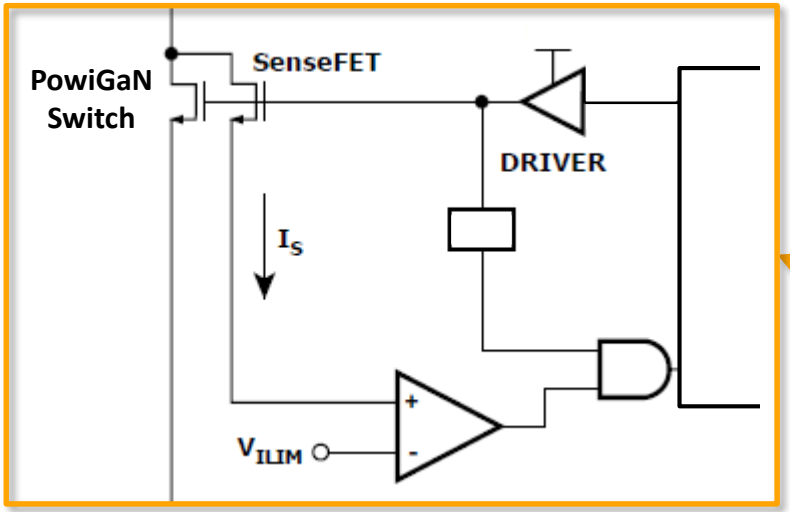
Integration greatly reduces resonant ringing in flyback switching (DCM shown)

InnoSwitch™3 Exploits GaN Efficiency and Eliminates Challenges

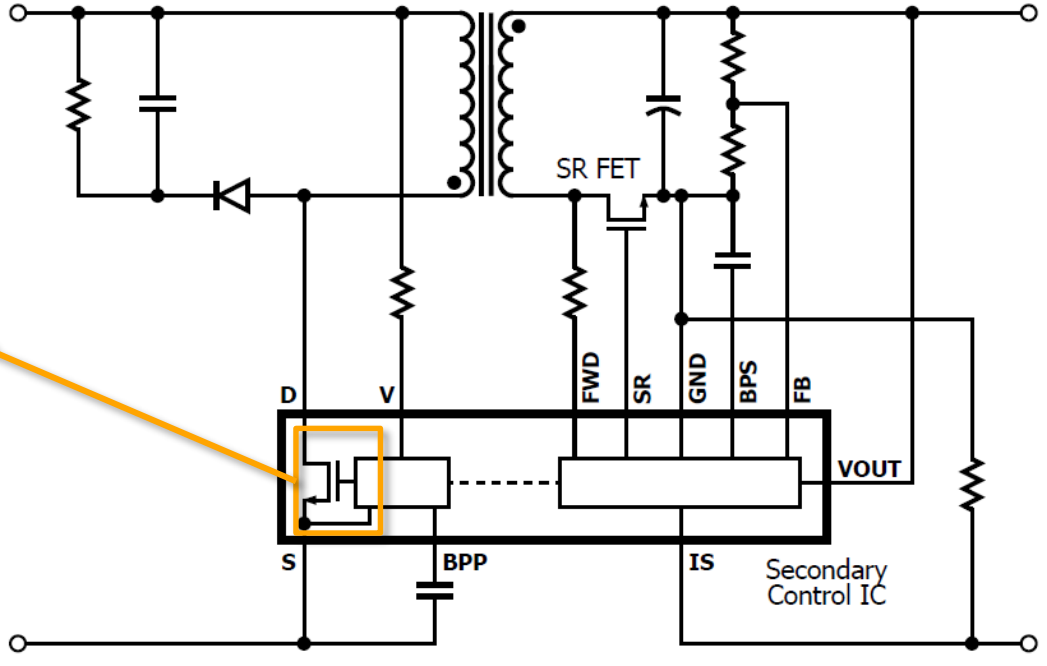
- **Driver matched to GaN switch**
  - Controls slew rate and di/dt
- **Allows integrated current limit**
  - Extremely fast control
  - No false triggering
- **Reduces parasitic components**
  - Less trace inductance
  - Reduced voltage transient spikes



Integrated Lossless Current Sensing Eliminates Series Resistors



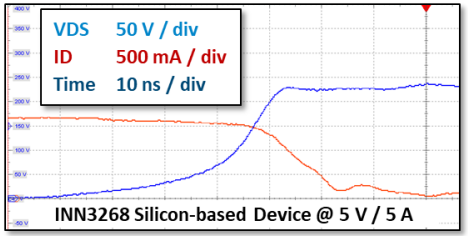
SenseFET Technology allows lossless monitoring of drain current

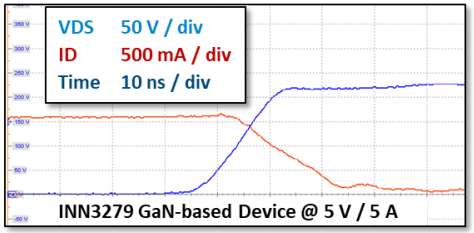


InnoSwitch3 simplified schematic

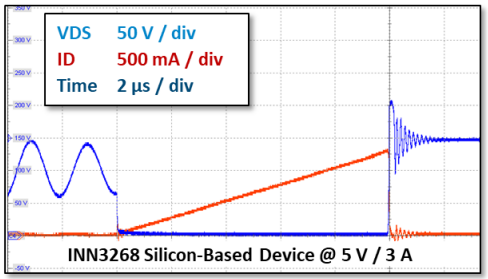
InnoSwitch3 Solves Fast Switching Challenges

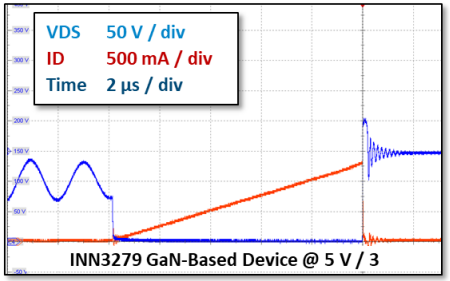
- **Control of gate drive and circuit impedance via integration of driver stage controls switch transition rates**
  - Switch transition maximum slope same for silicon and GaN devices
  - No special EMI issues for GaN
  - Reduces fast di/dt voltage overshoot
- **Integrated switch and control stage**
  - Optimized gate drive for each switch size
  - Very accurate and fast SC/detection
  - No external current sense elements
    - Reduces circuit losses
  - Reduces circuit inductance and capacitance
    - Reduces voltage overshoot
    - No false-triggering of protection





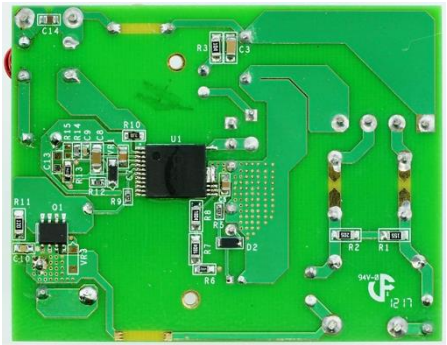
Low-line CCM Turn-off Comparison (100 V_{DC})

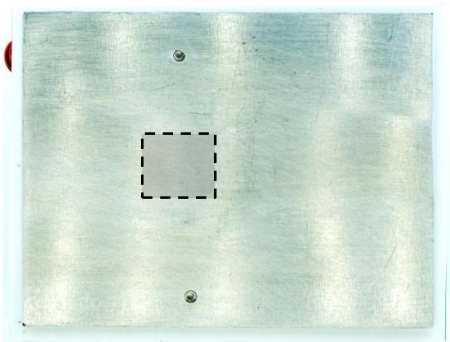




Low-line DCM Turn-on Comparison (100 V_{DC})

InnoSwitch3 + PowiGaN = Highest Efficiency



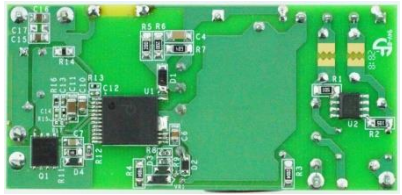


Heat-spreader with outline of power device shown

InnoSwitch3-CP
Size 8 MOSFET
(Requires large heat-spreader)

DER-535
65 W 20 V / 3.25 A

InnoSwitch3-CP
Size 9 PowiGaN



DER-747
65 W 20 V / 3.25 A

PowiGaN is Winning in the Market

- **More GaN power devices shipped than anyone else**
  - Proprietary PI technology developed for power switching
  - Cost-effective solution for increased efficiency requirements

- **Easy-to-use**
  - Integrated protection, drive and control eliminates challenges of discrete GaN
  - Looks like a conventional part – easy to change between designs
  - 750 V maximum operating voltage – ideal for offline flyback applications
  - Very high reliability – more than 6 million shipped with no field failures

- **Provides major benefits across markets**
  - Smaller lighter power supplies
  - Simplifies meeting existing and emerging energy standards
  - Ideal for adapters, USB PD, industrial, and appliances

No heatsinks makes open frame /embedded power more mechanically stable

5 PI IC Families Already Feature PowiGaN Switches

- **Integrated GaN switch used across multiple families**
  - InnoSwitch3-EP
  - InnoSwitch3-CP
  - InnoSwitch3-Pro
  - LYTSwitch™-6
  - InnoSwitch3-MX

Designing for Smallest Size and Highest Efficiency

Design Considerations for Reducing Size

- **Minimize component count**
  - Integrated solution
- **Select the smallest-sized part that will do the job**
- **Optimize utilization of 3D space**
  - Multiple PCBs may help but consider cost
- **Iterate design to optimize performance**
  - Especially transformer parameters
- **Optimize efficiency**
  - Must eliminate the heatsink to achieve a compact design
- **Effective thermal management**
  - Reduce component stress to increase lifetime

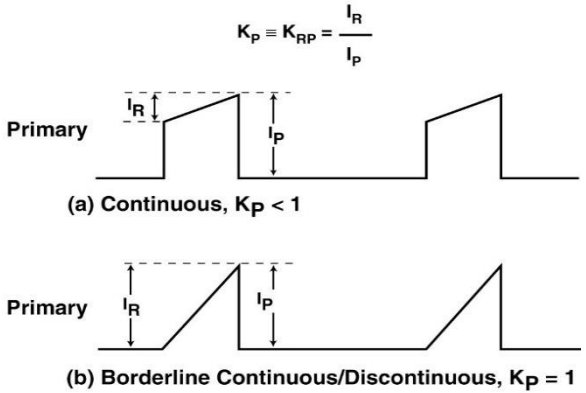
DER-602: 100 W No Heatsink USB PD

How to Minimize Losses

- **GaN devices excel – PowiGaN is ideal for switching applications**
  - Lower conduction losses from very low R_{DSON}
  - Lower switching losses from very low device capacitance
- **Quasi-resonant switching**
  - Valley-switching reduces turn-on loss for primary switch
- **Current limit and switching frequency control losses**
  - Balance conduction loss and switching loss of primary switch
- **Transformer selection**
  - Selecting the right transformer can improve overall efficiency
  - Iterate design to optimize performance
  - Design tools simplify transformer optimization – take advantage of PI Expert/PI Xls
- **SR FET selection and optimization**
  - SR MOSFETs are already widely used – optimize timing to increase efficiency

Transformer Optimization is Critical

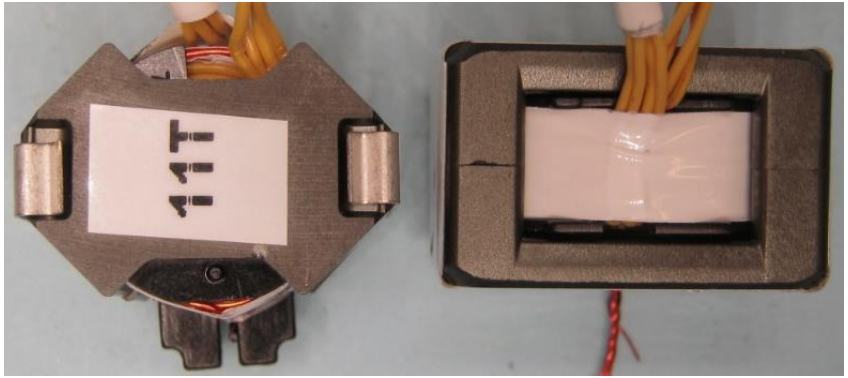
- **Design target**
  1. K_P close to 1
     - At low-line Kp > 0.85
  2. Optimize by selecting lowest voltage rating SR FET
  3. Minimize $V_{DS(PEAK)}$
  4. Reduce secondary turns



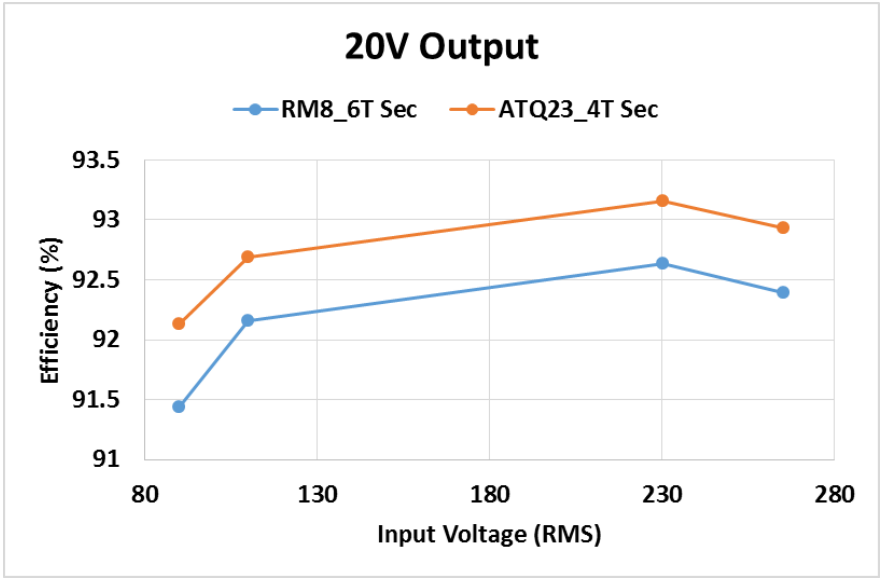
- **High value of VOR improves design**
  - Reduces duty-cycle especially at low-line
  - Enables use of lower V_{DS} for SR MOSFET – reduces cost
  - Easier to keep K_P close to 1 – enables valley-switching, to reduce switching loss and improve efficiency
- **Select operating frequency of 75 - 85 kHz**
  - Higher frequency reduces size of transformer
  - Highest frequency increases switching loss
  - Reduce frequency further if design is CCM (K_P < 1) will improve efficiency at low line
- **Minimize secondary number of turns**
  - Helps to reduce number of turns and also layers of primary winding
  - Helps to reduce copper loss

Select Core with Largest Area

RM8 vs. ATQ23.7/14



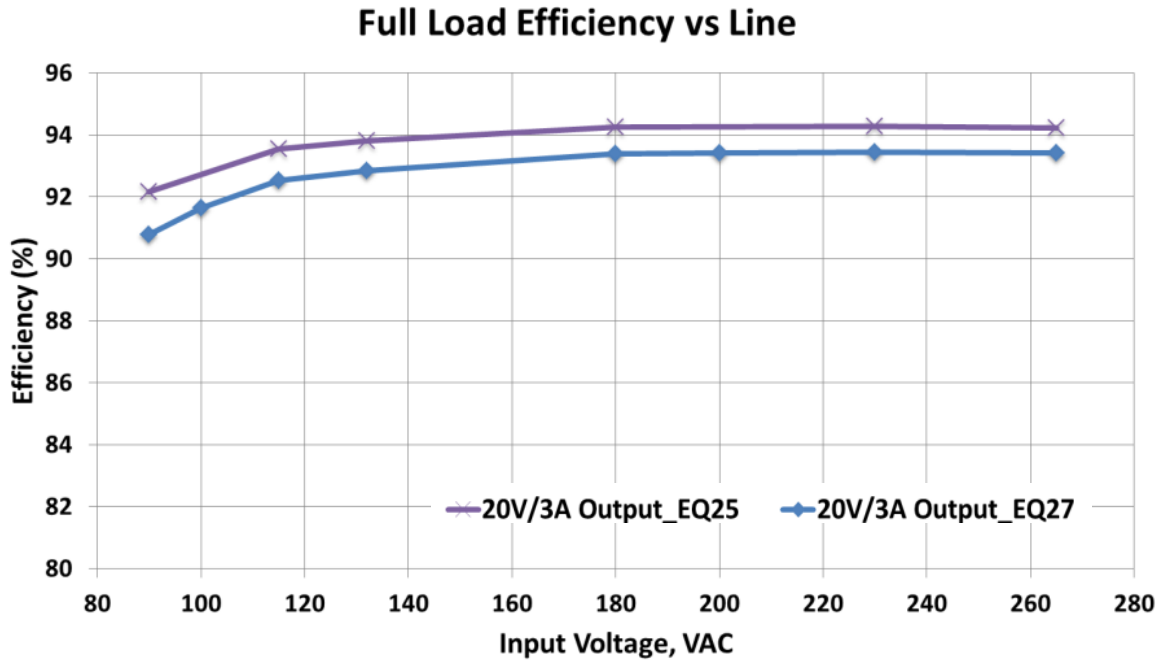
~38% bigger core area but fits in same space

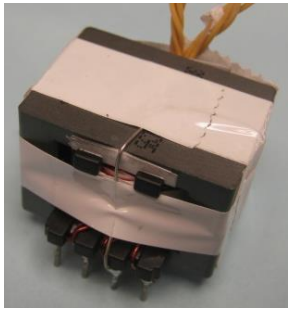


~0.7-0.8% efficiency improvement

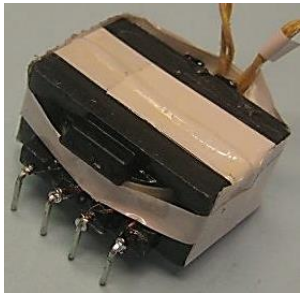
Look for Widest Bobbin Width

- **Significant efficiency improvement with increased width**
  - 4.3 mm vs 8.1 mm





EQ25 Bobbin & Core



EQ2506/EQ27 Bobbin & Core

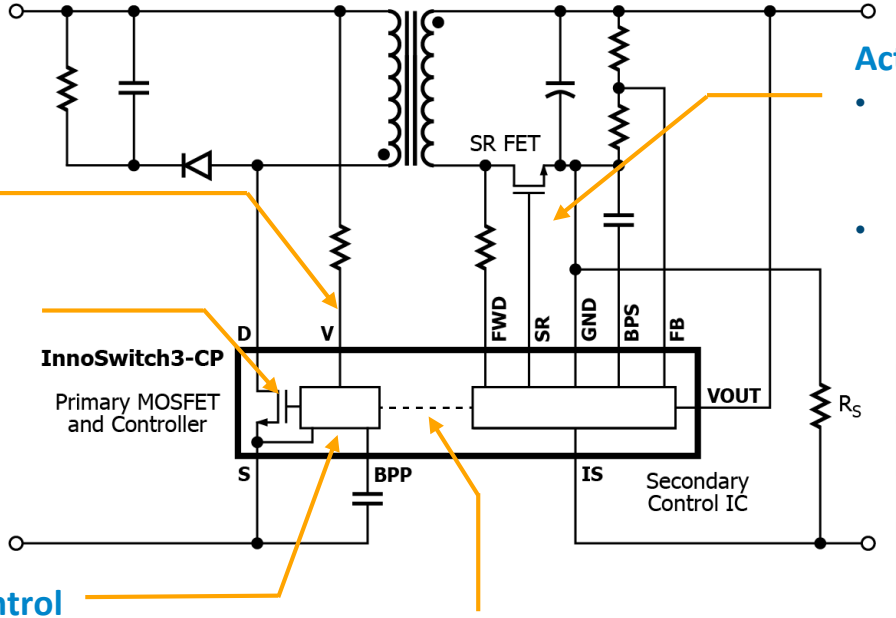
60 W design results

InnoSwitch Advantage

InnoSwitch3 Isolated Flyback Employs FluxLink™ Digital Feedback to Eliminate Optocouplers

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

Integrated Power MOSFET
- 650 V / 725 V / 750 V



Active Control of SR MOSFET
- Reduced diode conduction increases SR FET conduction time for best efficiency
- Seamless DCM-CCM transitions

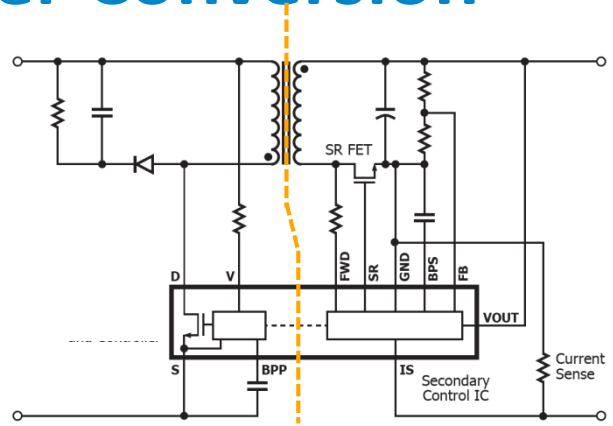
Characteristic	Specification
Voltage Tolerance	± 3%
Current Tolerance	± 5%
Transient Response	Excellent
No-Load Input Power inc. line sense	< 15 mW

Proprietary Switch and Control
- CCM and Quasi-resonant switching
- Highest efficiency
- Lowest losses

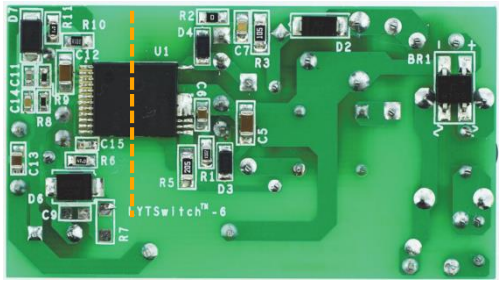
FluxLink – Isolated Feedback
- High reliability, lifetime

FluxLink Accurately Controls Power Conversion

- **Magneto-inductive coupling primary-to-secondary**
  - Benefits of secondary-side control
  - Simplicity of primary-side driver
  - Isolation without optocouplers
- **Crosses isolation barrier**
  - Controls both primary and secondary switching
    - Optimizes performance for highest efficiency
  - Meets all regulatory and hi-pot isolation requirements
- **Directly monitors output**
  - Accurate output voltage and current
- **Drives synchronous rectification MOSFET**
  - Simple design
  - Highly reliable under all conditions



FluxLink: Magneto-inductive coupling crosses the isolation barrier



CQC, UL and TUV certified isolation as barrier component

InnoSwitch3 Family

InnoSwitch3 ICs with PowiGaN Technology Achieve >100 W

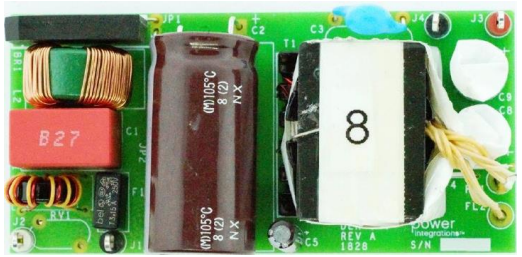
- **InnoSwitch3 silicon transistors are highly effective up to 65 W**
- **PowiGaN switches provide more power**
  - Lower $R_{DS(ON)}$ per unit area
  - Lower switching losses
- **PowiGaN devices**
  - InnoSwitch3-CP – constant power
  - InnoSwitch3-EP – for open-frame
  - InnoSwitch3-Pro – digital control

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

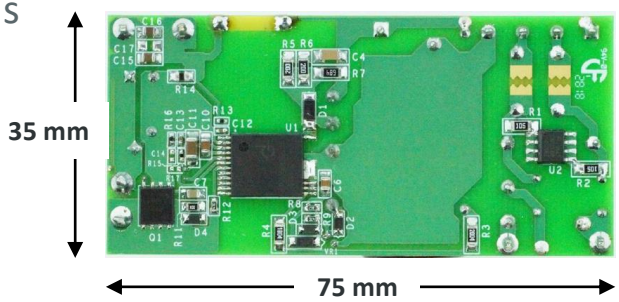
PowiGaN switches

PowiGaN Delivers Best Performance

- **Highest efficiency conversion**
  - 95% efficient – flat across line and load
  - No heatsinks
  - Highest power density for smart-charging adapters



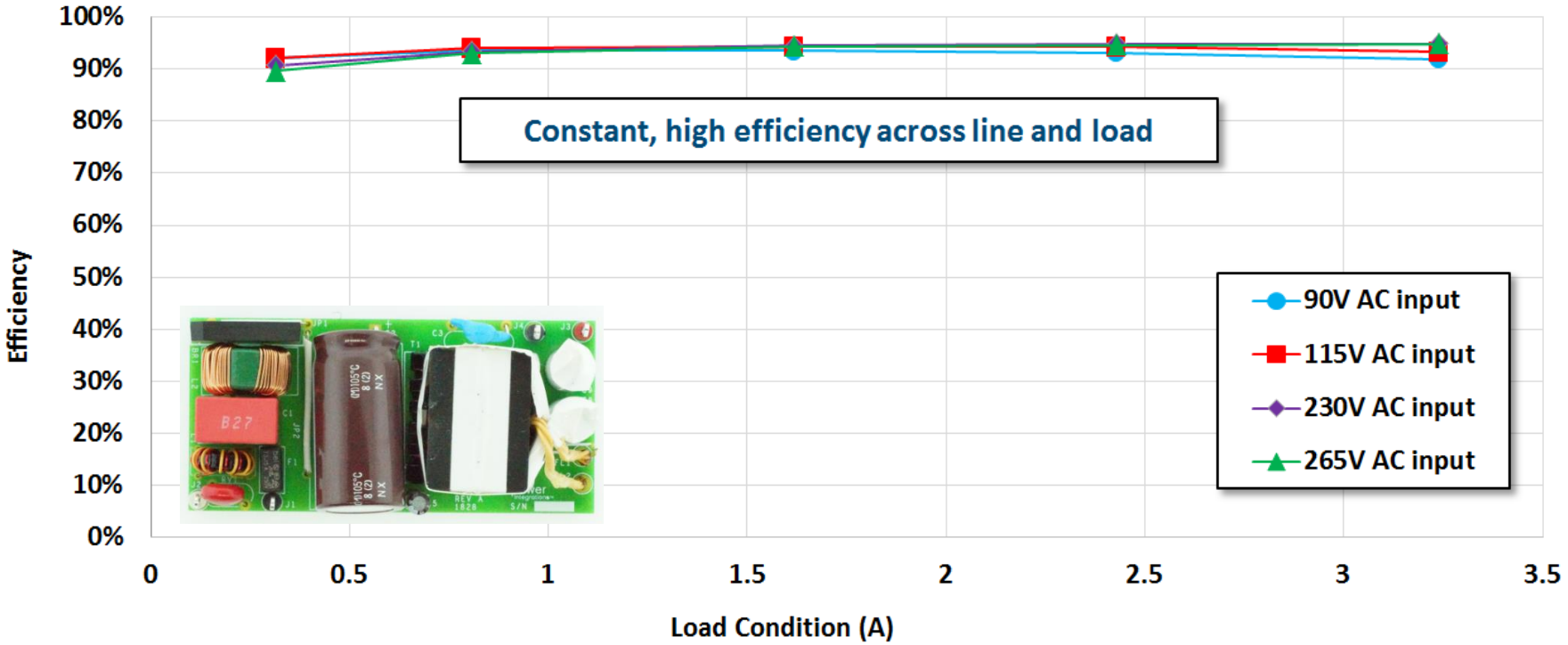
- **Safe, familiar, reliable – it just works**
  - Just another switching technology from Power Integrations
  - Looks and behaves like a silicon MOSFET
  - No EMI challenges
  - High operating voltage and increased surge margin
  - Less than 40 mW no-load consumption at 265 VAC



DER-747
65 W 20 V / 3.25 A

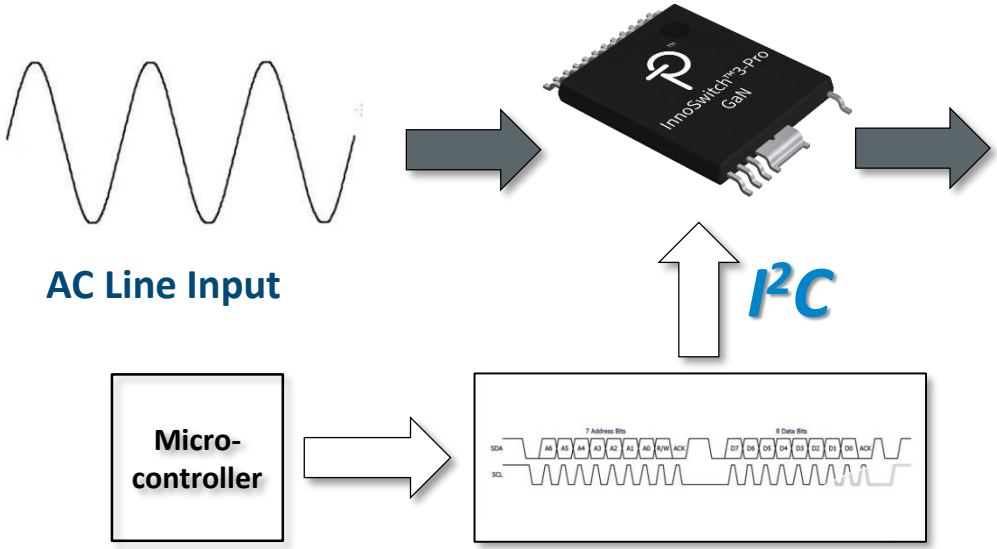
- **In production now**
  - More than 6 million parts shipped-to-date

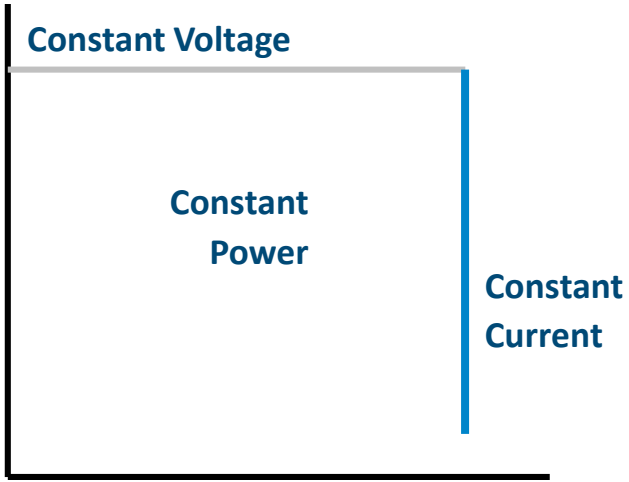
65 W DER-747 PowiGaN Constant High Efficiency Across Line and Load



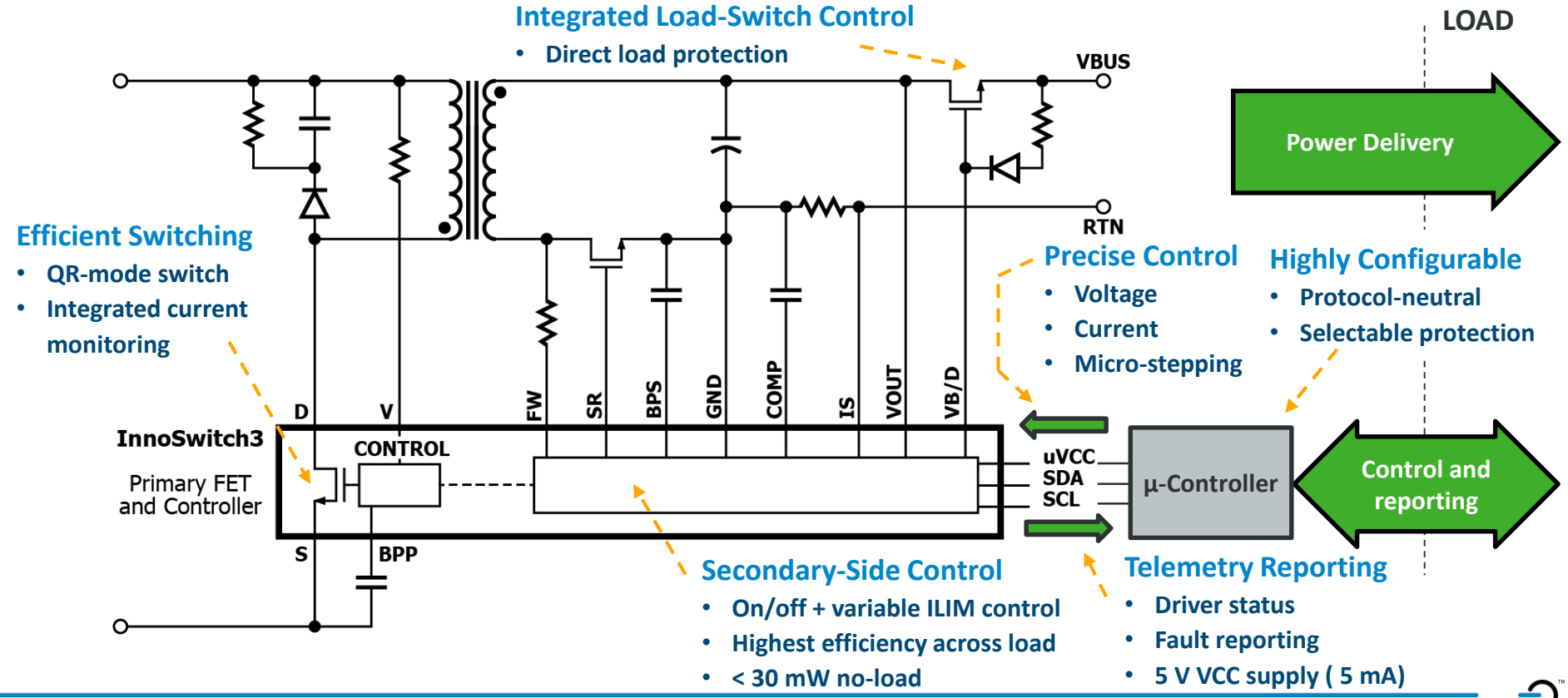
InnoSwitch3-Pro: Digitally Programmable Power Conversion

- **Advanced control engine with digital interface (I²C)**
  - Output voltage and current control – CV/CC/CP output characteristic
  - Configurable protection – enable/disable, shutdown/auto-restart, trigger-points





Adding Output Control to InnoSwitch3



InnoSwitch3-Pro Supports a Wide Range of Applications

- **Any dynamic rapid-battery-charging protocol**
  - Smart phones, notebooks/laptops/tablets, smart speakers
  - USB PD 3.0 + PPS “load-directed” charging protocol
  - Supports all rapid charge protocols including USB PD, Rapid Charge

- **Field-programmable and region-centric protection**
  - Multi-voltage lighting ballasts, DIN-rail power supplies
  - Protection features that match regional preferences

- **Programmable performance in non-charging applications**
  - Multiple solutions from single power supply design
  - Reduces design-time, reduces production, approvals and inventory costs

LYTSwitch-6

LYTSwitch-6 High Efficiency Versatile Ballast Designs

Lossless Line Voltage Sensing
- Minimizes no-load

Transformer
- Shield windings reduce EMI

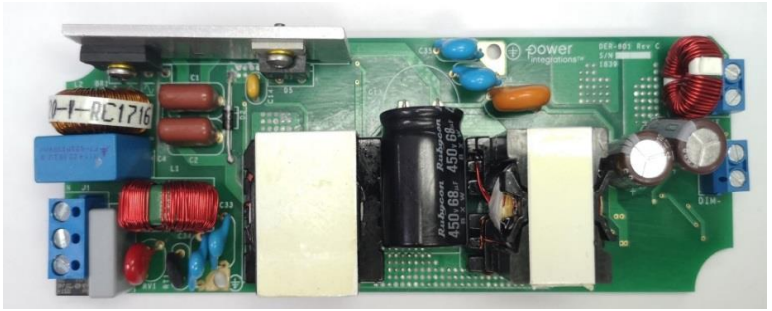
Proprietary Switch and Control
- Highest full load efficiency
- Lowest light load losses
- Accurate reliable fault detection
- Frequency jitter – reduced EMI

Proprietary InSOP-C Package
- Widest creepage and clearance
- Source potential heat transfer
- Multiple pins for sense/control

Integrated Start-Up
- Internal tap driven
- No external start-up components

DER-801: 100 W Wide-Range Ballast

- **Features**
  - Constant voltage and constant current mode LYTSwitch-6 (LYTSwitch-6079C)
  - 90-305 VAC and active PFC with HiperPFS-4
  - 3-in-1 dimming (0-10 V, PWM and resistor)
    - Dimmable to 1% and dim-to-off
  - Low component count
  - Flicker-free operation
- **Typical Specification**
  - Output voltage: 48 V
  - Output current: 2080 mA
  - Output ripple current: <5% of nominal
  - Efficiency: >90% at 230 VAC
  - Power factor: >0.9 at full-load
  - Surge withstand: 2.5 kV differential



LYTSwitch-6: Provides Best Performance

- **± 3% CV and CC output characteristic**
  - Single design covers multiple applications
- **Low no-load <15 mW (without PF)**
  - Easily meets DOE-6 and ENERGY STAR® for North America
- **Supports analog and PWM dimming**
- **Very high efficiency**
- **Fast control reduces output ripple**
  - Less output capacitance required
- **Excellent load regulation and instantaneous transient response**
  - Ideal for multi-string applications, such as RGB with highly variable independent loads

Expanding the LYTSwitch-6 Power Range

Part Number	MOSFET $V_{DS(max)}$	Output Power - Open Frame		
		277 VAC (± 15%)	90-305 VAC	380 - 450 VDC
LYT6063C	650 V	15 W	12 W	
LYT6073C	725 V			25 W
LYT6065C	650 V	30 W	25 W	
LYT6075C	725 V			40 W
LYT6067C	650 V	50 W	45 W	
LYT6077C	725 V			60 W
LYT6068C	650 V	65 W	55 W	
LYT6078C	750 V	75 W	65 W	90 W
LYT6079C	750 V	85 W	75 W	100 W
LYT6070C	750 V	95 W	85 W	110 W

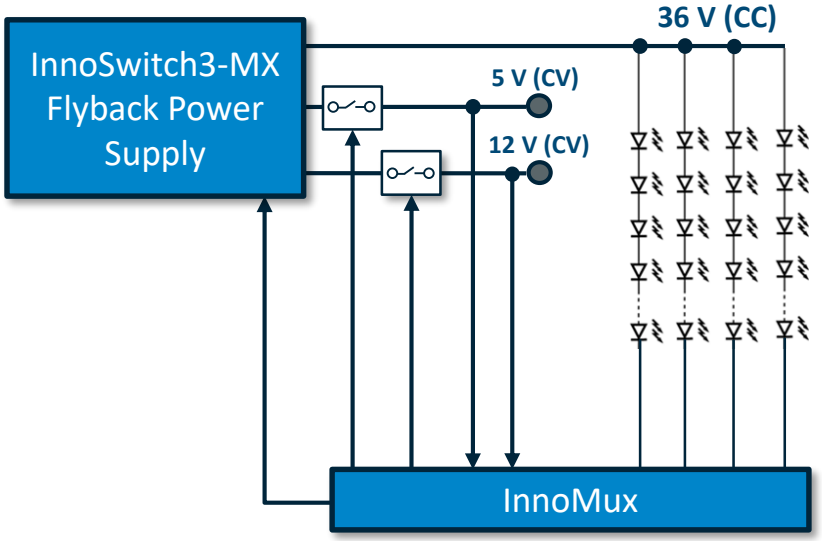
Advanced InSOP-24 package

- Reduced board space
- No heatsinks required
- Extended creepage and clearance

PowiGaN

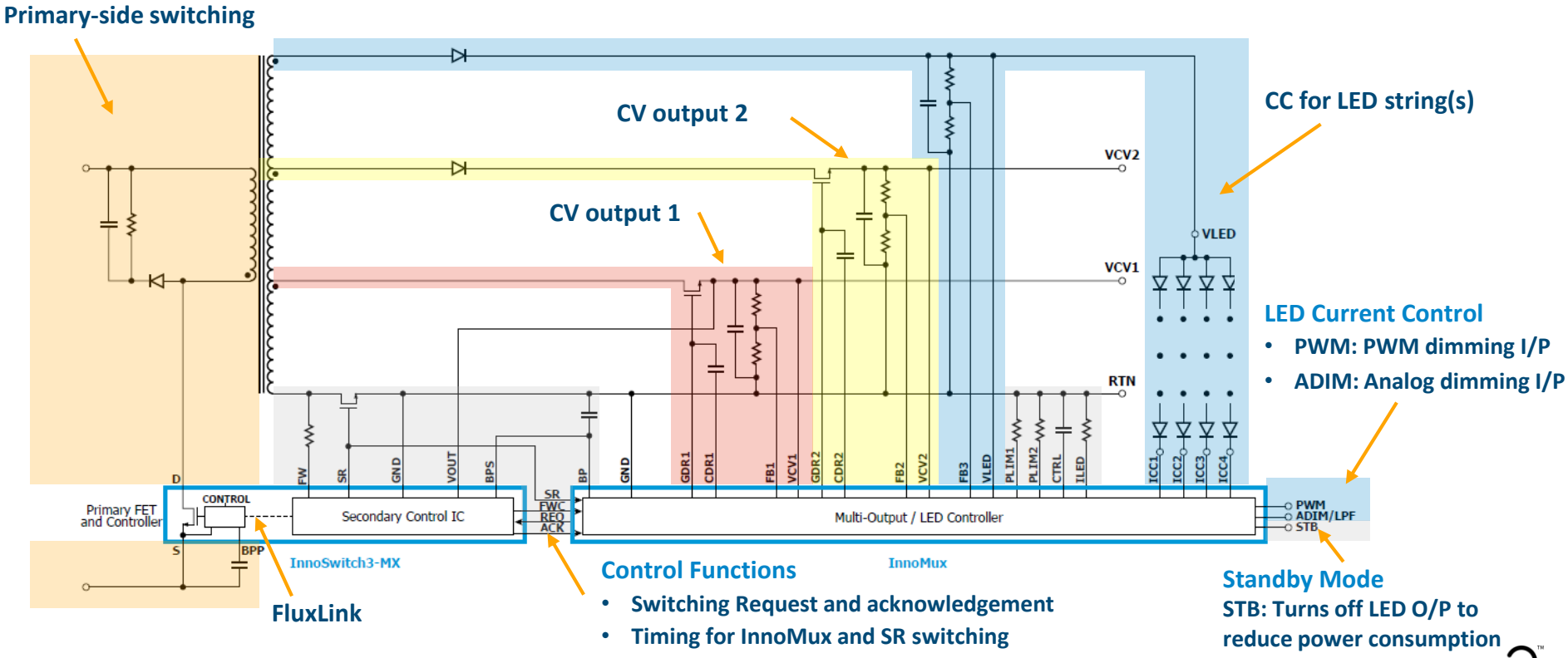
InnoSwitch3-MX

InnoMux™ – Single-Stage Structure for Display Applications



InnoSwitch3-MX Plus InnoMux Single-Stage Conversion Provides CV and CC Outputs

InnoSwitch3-MX Provides Power When Required
InnoMux IC Sends it Only Where Needed



InnoMux Chipset Provides Up to 75 W Output

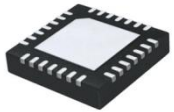
InnoSwitch3-MX

Part Number	Primary MOSFET ($V_{DS(MAX)}$)	Power (W) 85 – 264 VAC
INN34X5C	650/725	20
INN34X6C	650/725	25
INN34X7C	650/725	32
INN3468C	650	40
INN3478C	750	55
INN3479C	750	65
INN3470C	750	75

InSOP-24D (C-Package)
MSL-3 rated – wave solder and reflow

InnoMux

Part Number	Channels		Package
	LED strings	CV O/Ps	
IMX101J	1	1	QFN
IMX101U	1	2	HSOP
IMX102U	4	1	HSOP



QFN-28 (J-Package)
MSL-1 rated – reflow

HSOP-28 (U-Package)
MSL-1 rated – wave solder

Reference Design	Typical Application	Input (VAC)	Power (W)	Part Number		O/P 1 Const. Voltage	O/P 2 Const. Voltage	O/P 3 Const. Current	Dimming
				InnoSwitch3-MX	InnoMux				
DER-636	Monitors	90 - 264	40	INN3468C	IMX102U	5 V @ 3 A	-	36 V @ 0.6 A	PWM/Analog

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