

# Automotive USB Type-C Power Delivery Buck-Boost Products

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ADI Asia Power Systems Engineering Director

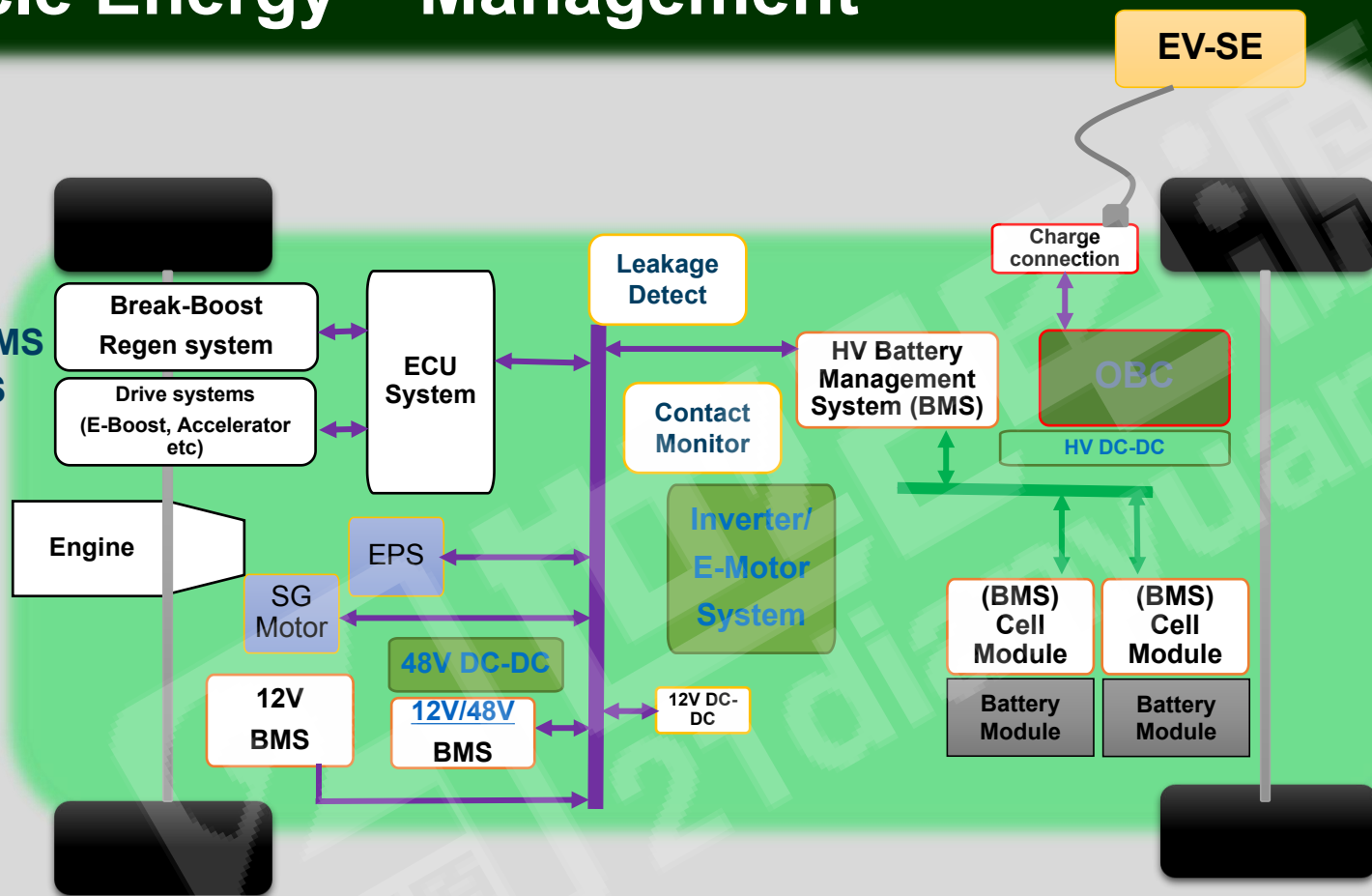
August 13, 2019



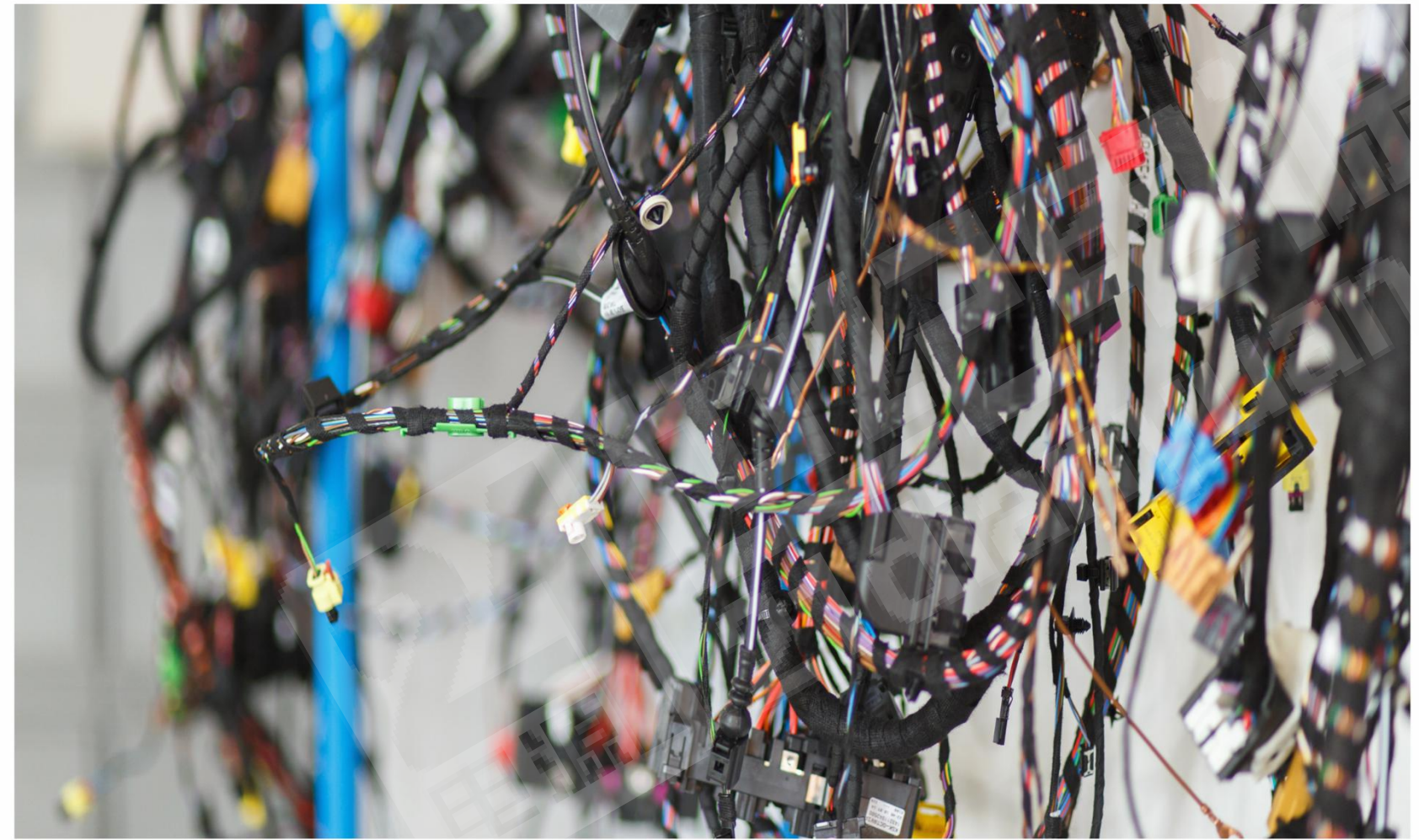
- ▶ Automotive USB Type-C Power Delivery
  - Specification, Requirement, and System
- ▶ ADI Value Proposition
  - Technology, Advantage, and Service
- ▶ USB-C PD Buck-Boost Products
- ▶ 15W/27W/45W/60W USB-C PD Demo Solutions

# Vehicle Energy – Management

- ◆ Pb-Acid BMS
- ◆ Li-ion BMS
- ◆ Isolation
- ◆ DC-DC
- ◆ Inverter
- ◆ On Board Charging

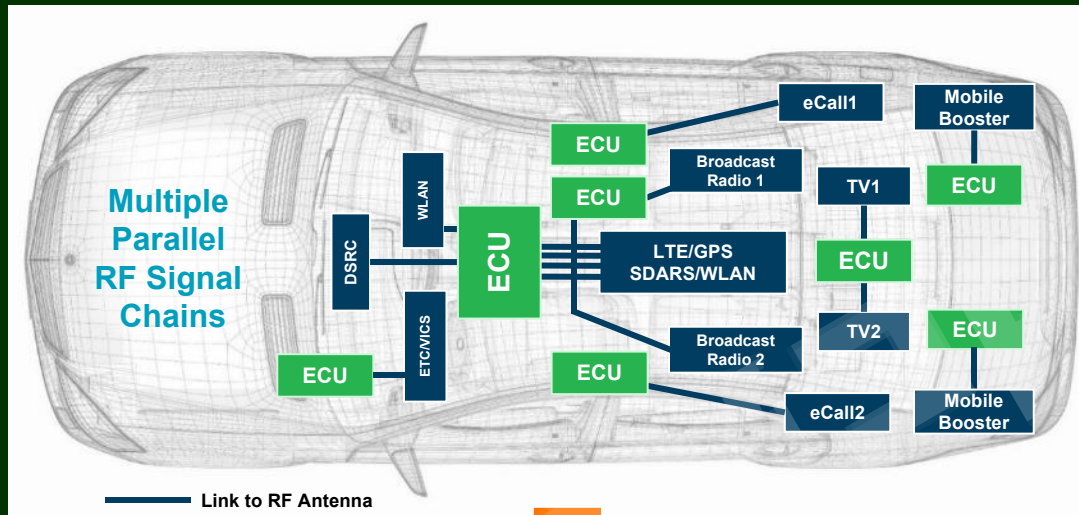


# Existing Wiring Harnesses are Complex, Heavy, and \$

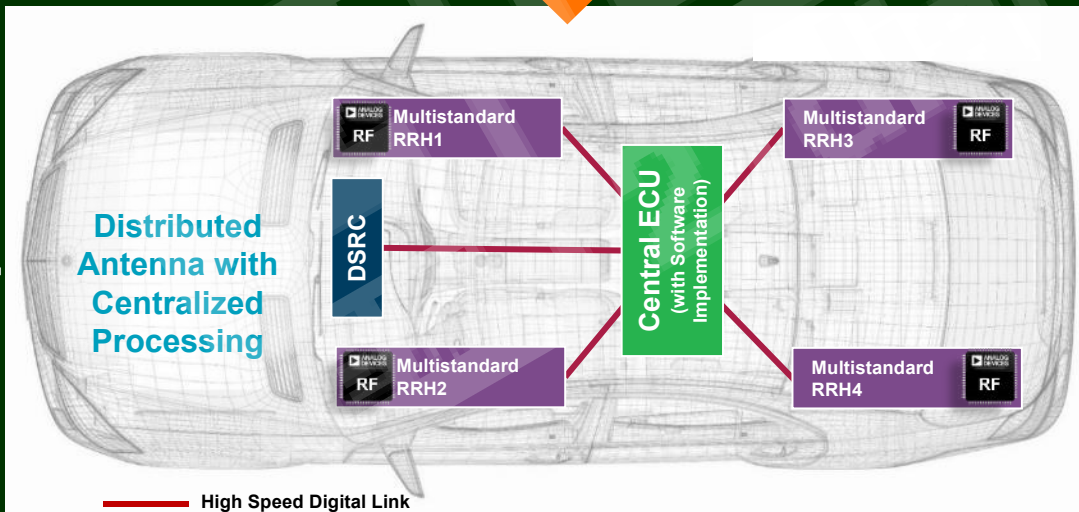


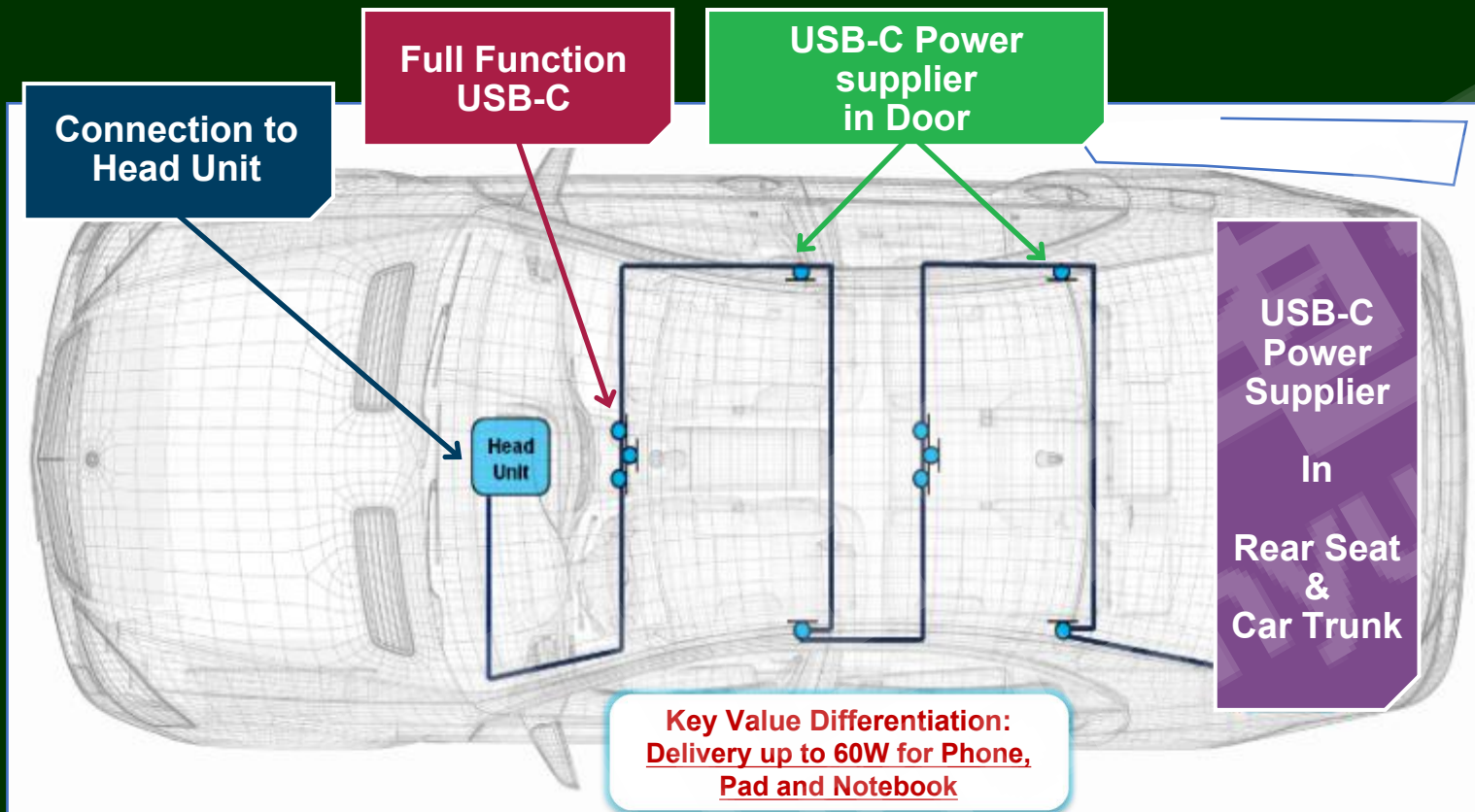
# Advanced Telematics

TODAY



FUTURE





# Why Select USB-C ??

Standard interface

Easy to use

Power up to 60W

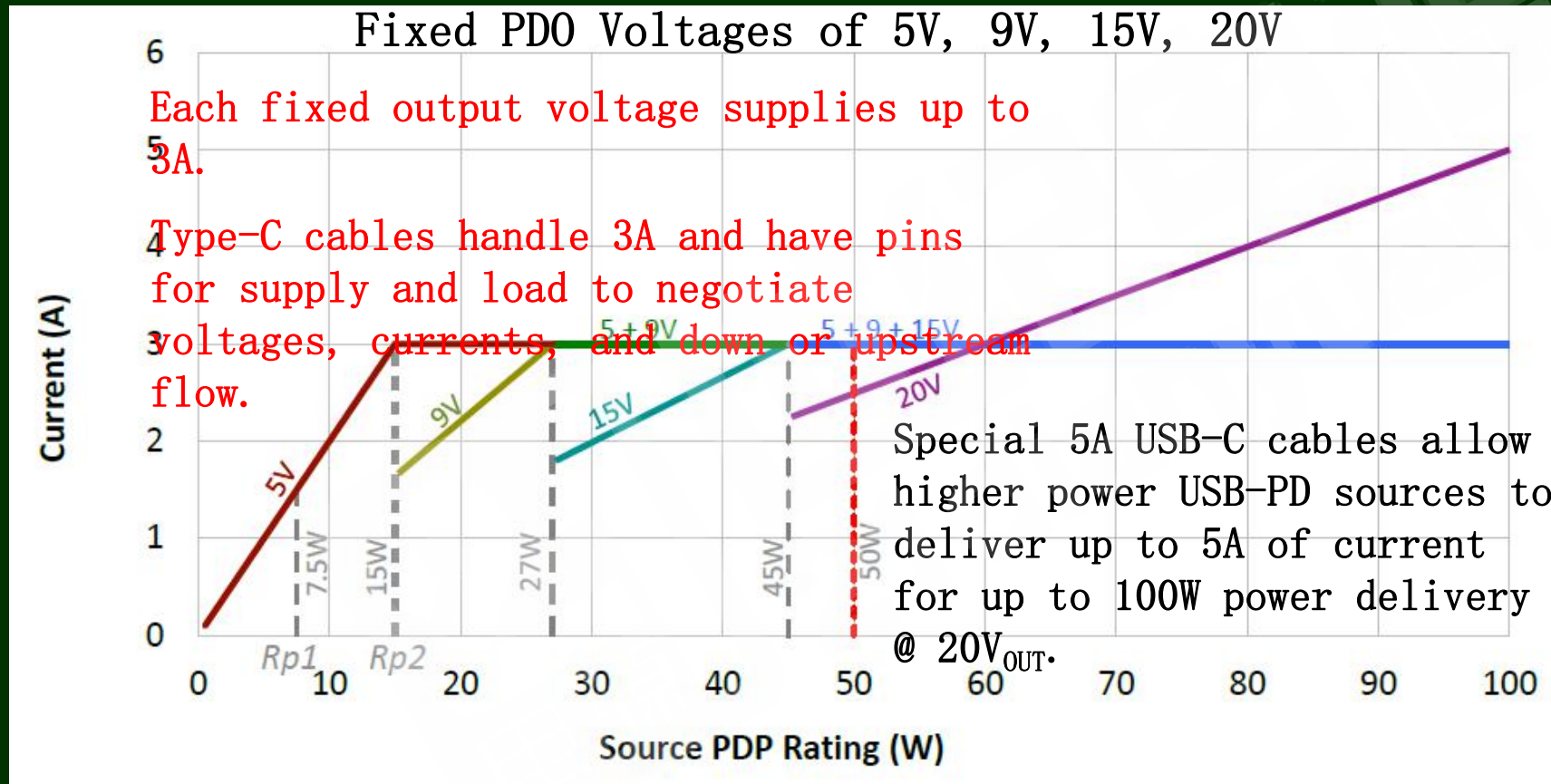
Data

Video

Audio

- 
-

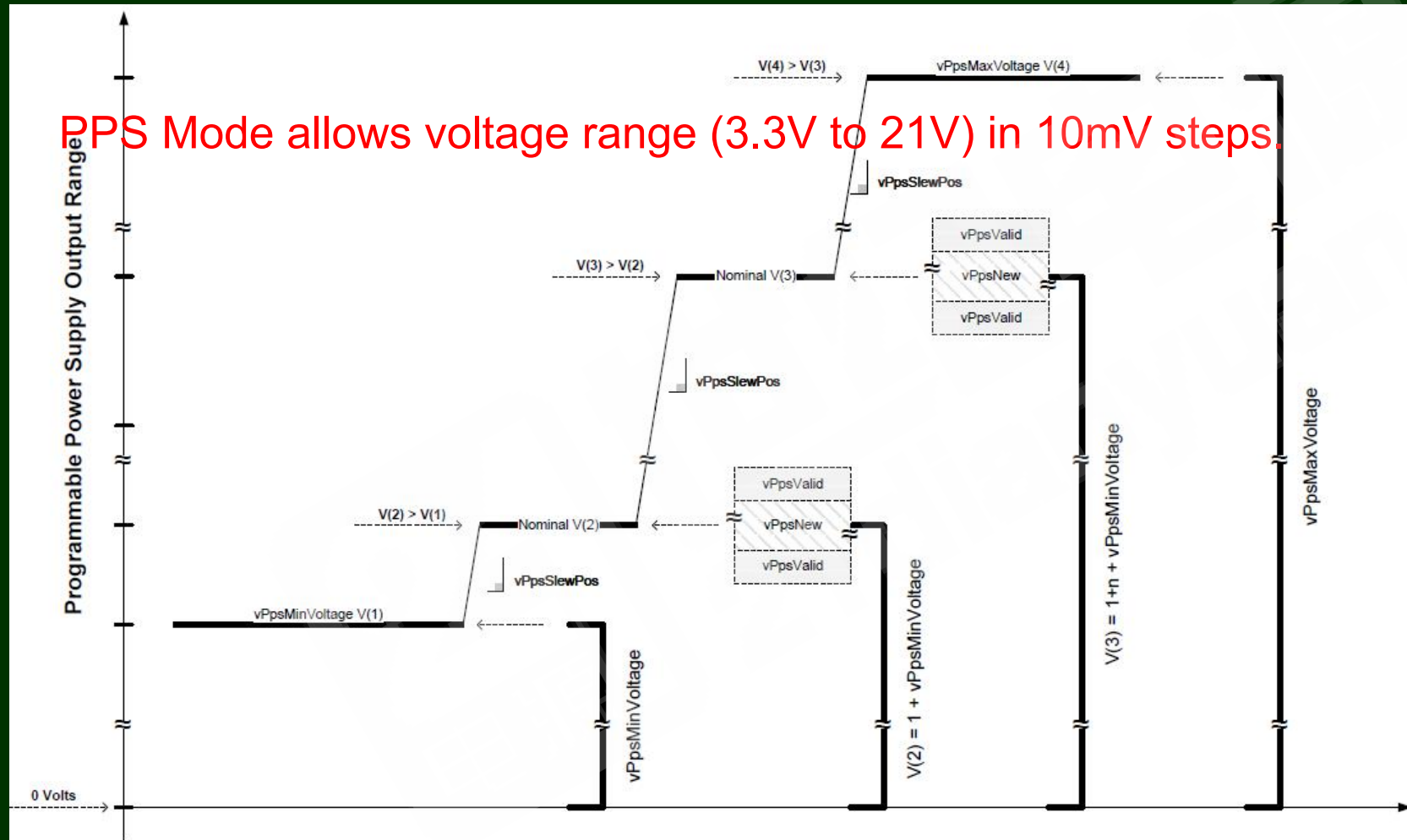
# USB-C Power Delivery Spec – Popular now PD 3.0 – Fixed PDO (Power Data Object) Mode





# USB-C Power Delivery Spec – Future Market PD 3.0 – PPS (Programmable Power Supply) Mode

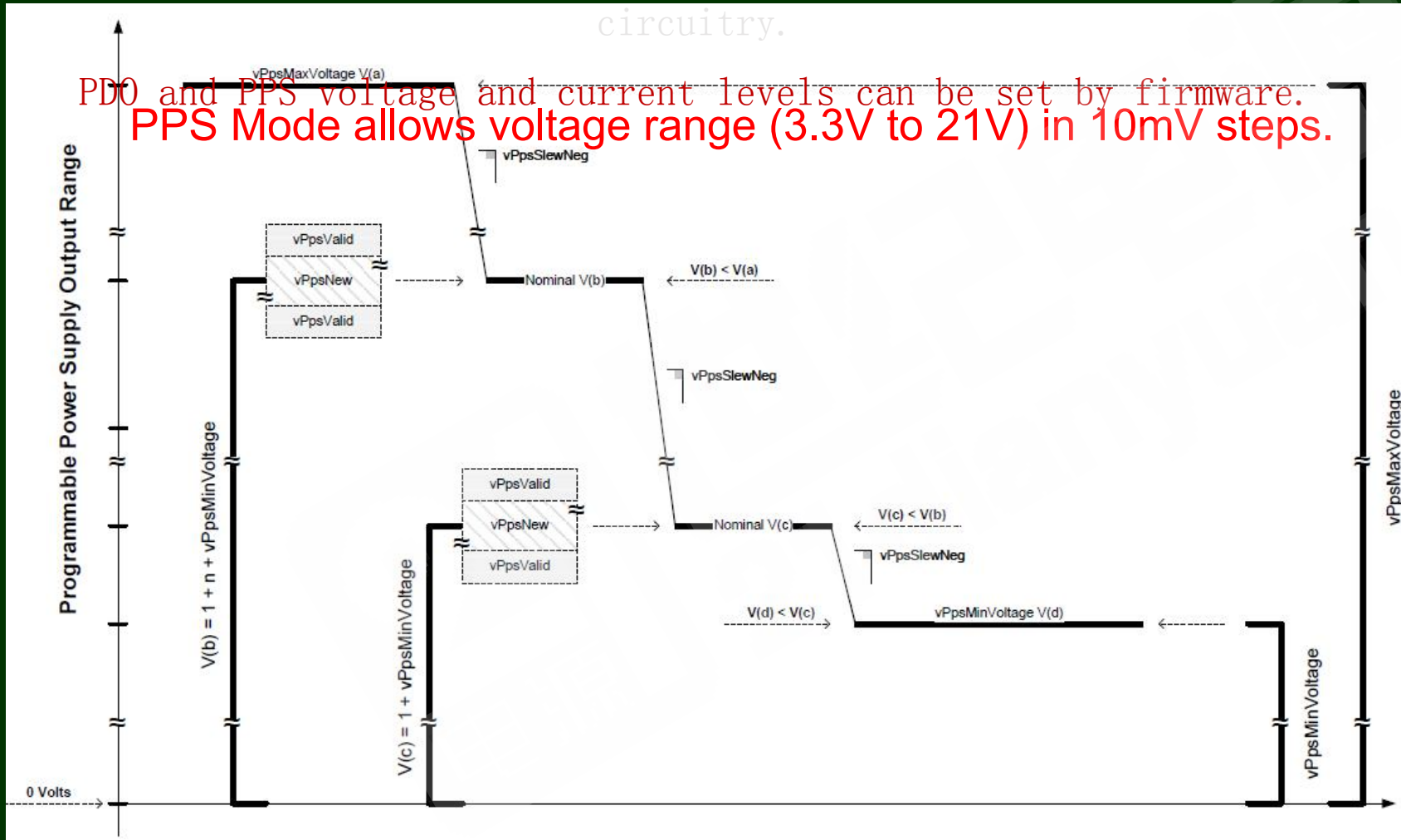
PPS Mode allows voltage range (3.3V to 21V) in 10mV steps.



Connected devices can utilize PPS mode to reduce conversion losses incurred during tasks such as recharging batteries, resulting in lower losses (less heat) in the associated battery charging

circuitry.

PDO and PPS voltage and current levels can be set by firmware.  
PPS Mode allows voltage range (3.3V to 21V) in 10mV steps.

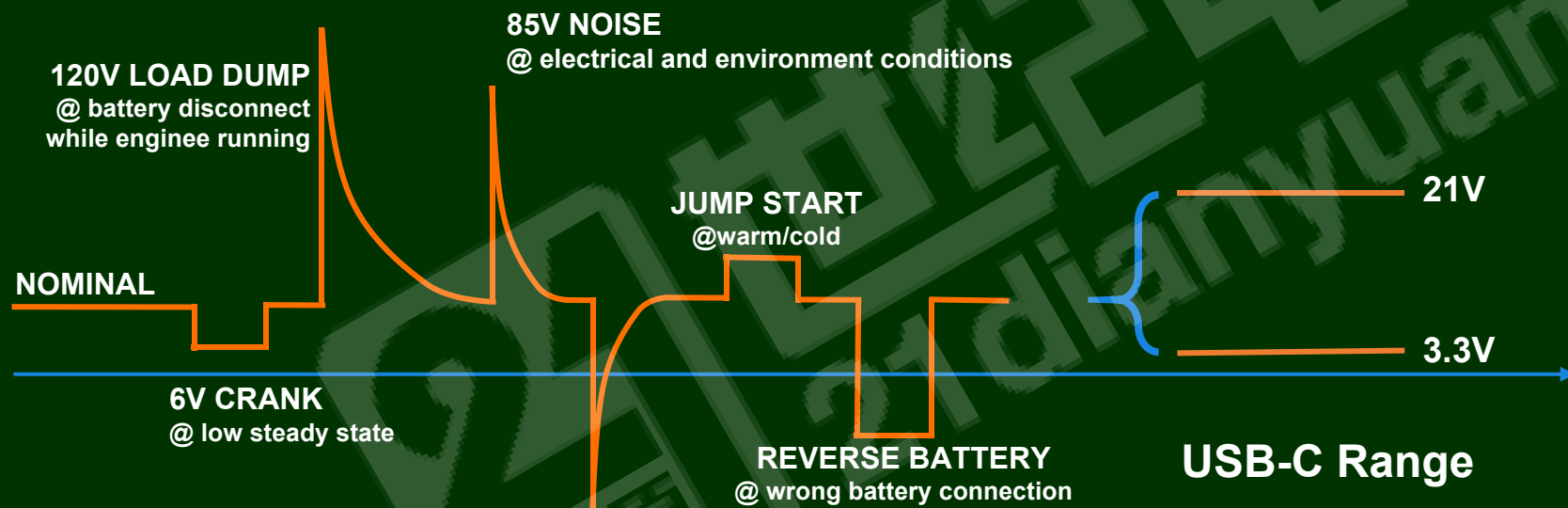


## Automotive USB Type-C PD Requirement

- ▶ USB Type-C applications inside the car:
  - Head units (charger + data)
  - Rear-seat entertainment (charger + data + video)
  - Rear-seat charger (charger)
  - Rear side-door charger (charger)
- ▶ Requirement:
  - Customers are looking for a complete solution
  - Size, form factor, efficiency, EMI, cost, flexibility, load-sharing, thermal throttling
  - Heat sink is okay, but no cooling fan
  - Maximum ambient temperature 85° C, up to 140° C hottest part
  - Different power level across OEMs, but 45W~60W is popular
  - Dual-port is very common, Type-A + Type-C or 2 Type-C ports

# 3 Major Design Challenge in Automotive

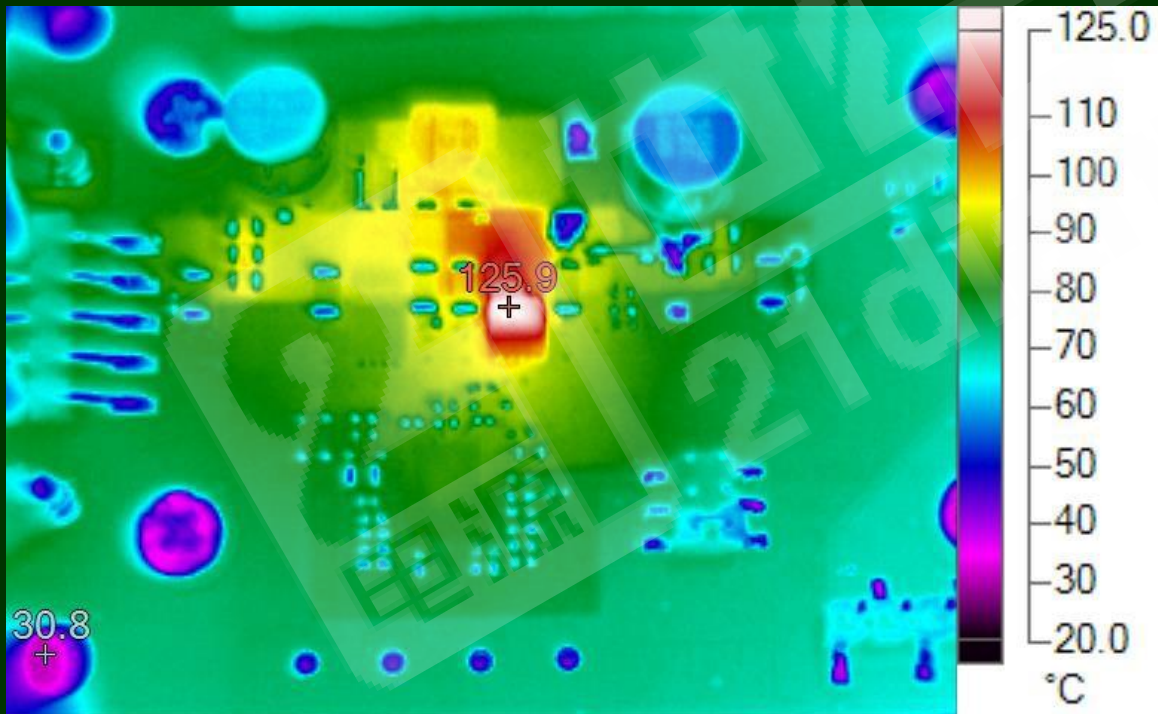
## \* Buck-Boost Topology



## 3 Major Design Challenge in Automotive

### \*Thermal Issue

- DC/DC efficiency
- Switcher Frequency limitations (AM Radio: 535KHz-1602KHz)  
<500KHz (higher inductor loss) or >2MHz (higher switch loss)
- Heat sink is okay, but no cooling fan

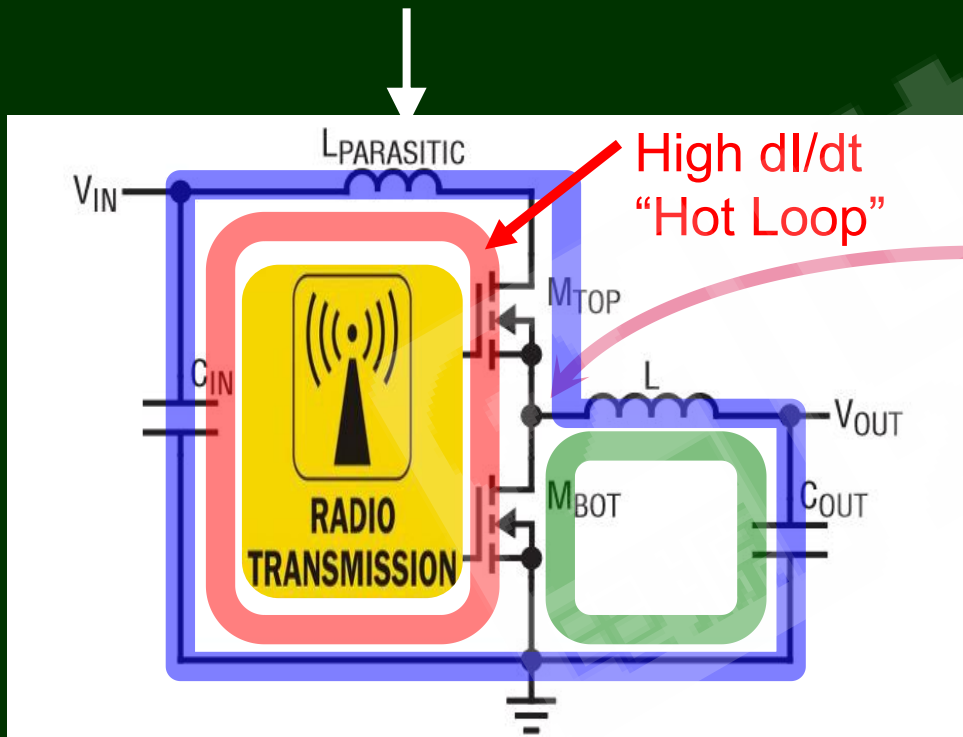


### 3 Major Design Challenge in Automotive

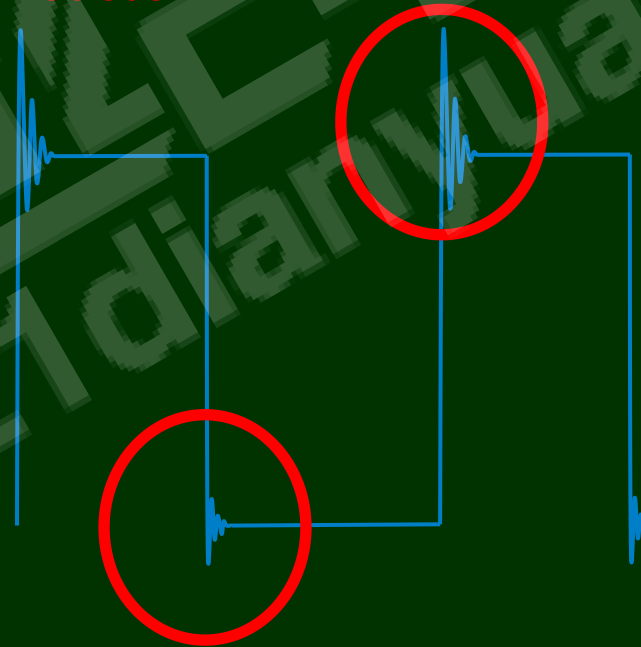
#### \* EMI

- CISPR 25 CLASS 5

Parasitic inductance due to copper traces, bond wires, ESL of capacitors and FET internal metal



Excessive rings at the switching edges cause conductive noise and radiation

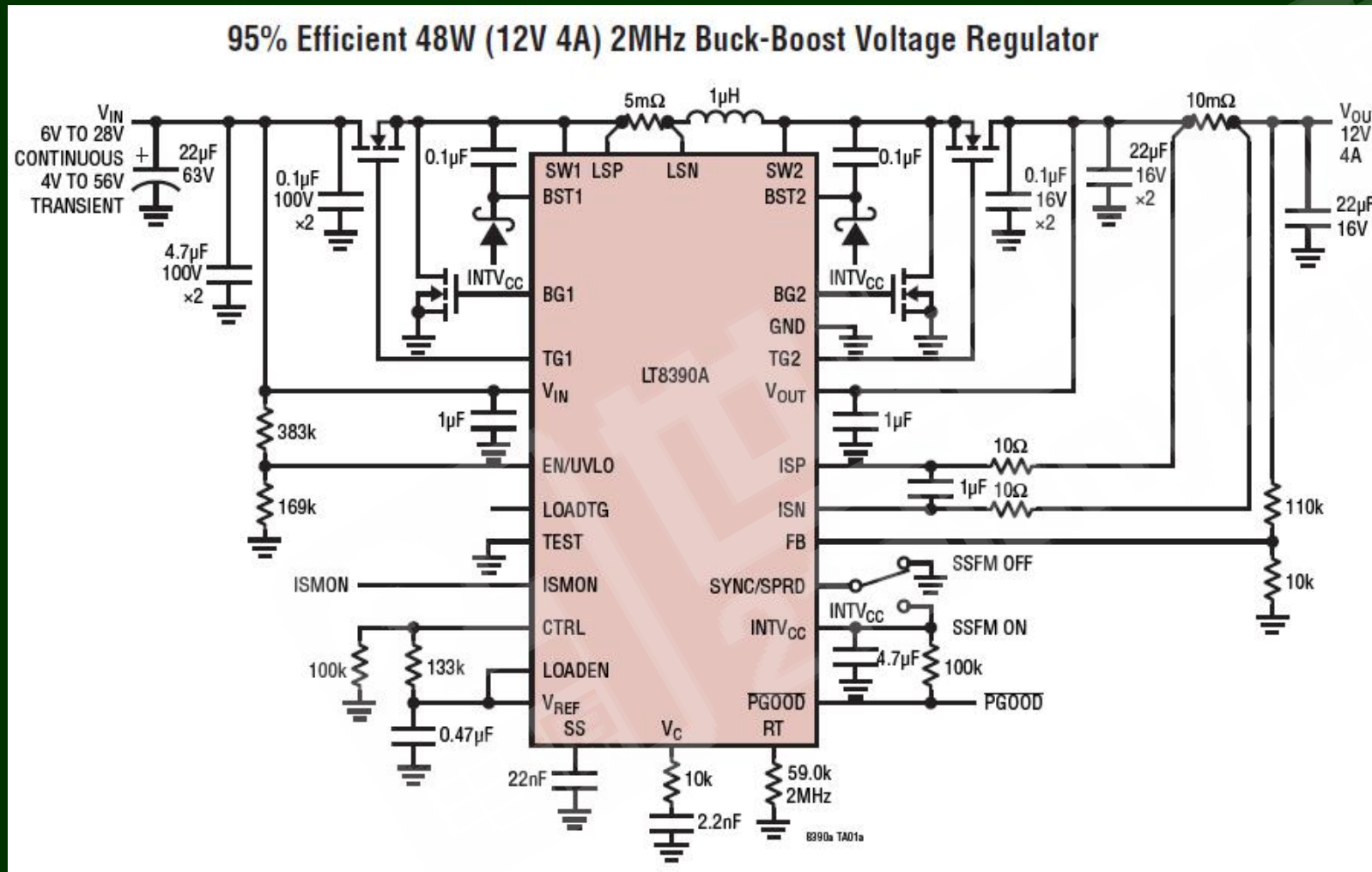


# How to improve traditional Buck/Boost

LT8390: 60V Synchronous Buck-Boost Controller

LT8390A: 60V 2MHz Synchronous Buck-Boost Controller

## LT8390A: 60V 2MHz Synchronous Buck-Boost Controller





### ▶ LT8390 Features

- Synchronous: up to 98% efficiency
- Low EMI buck-boost architecture
- Proprietary peak current mode
- Constant-voltage/-current regulation
- $60V_{IN}$ ,  $60V_{OUT}$ , up to 300W
- 150kHz~650kHz with SYNC and SSFM

### ▶ Package

- FE28 and QFN4x5

### ▶ Status

- Released in 2016

### ▶ LT8390A Features

- Synchronous: up to 95% efficiency
- Low EMI buck-boost architecture
- Proprietary peak current mode
- Constant-voltage/-current regulation
- $60V_{IN}$ ,  $60V_{OUT}$ , up to 50W
- 600kHz~2MHz with SYNC and SSFM

### ▶ Package

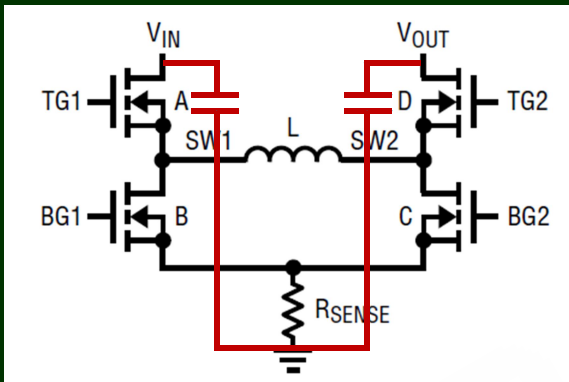
- FE28 and QFN4x5

### ▶ Status

- Released in 2017

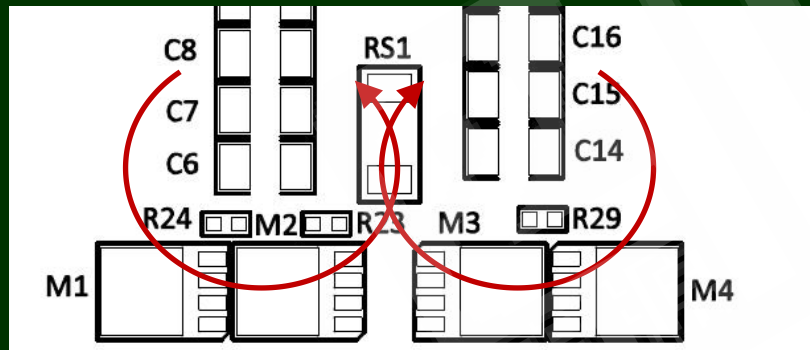
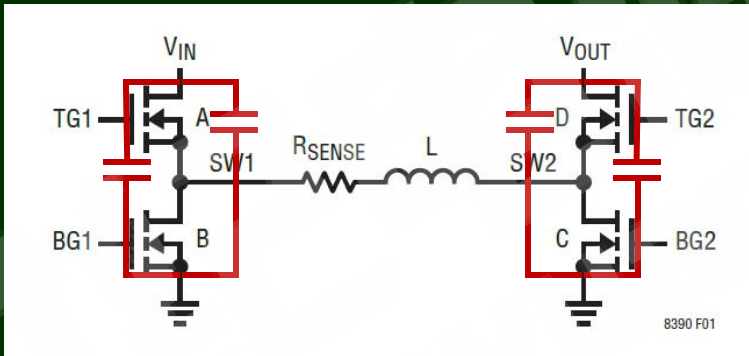
# Low EMI Buck-Boost Architecture for Controller

## LT3790/Competition Ground Current Sense

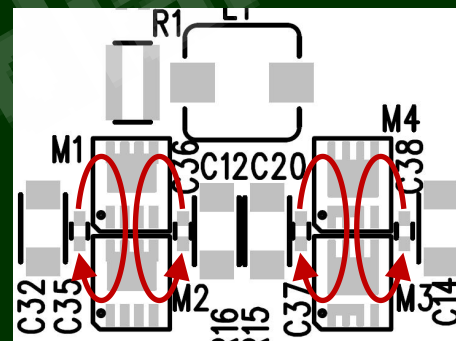


Low EMI

## LT8390/90A Inductor Current Sense



Single big hot loop  
for both  $V_{IN}$  and  $V_{OUT}$

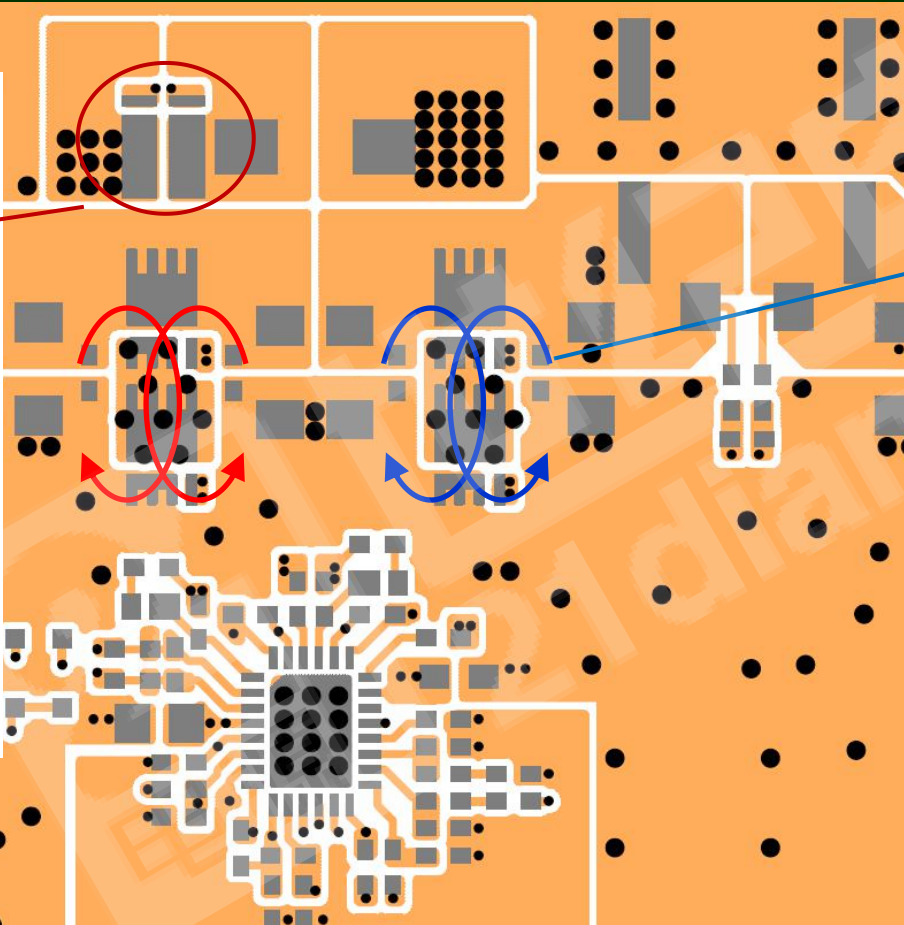


“Silent Switcher” style  
small dual hot loops  
for both  $V_{IN}$  and  $V_{OUT}$

# Sense Resistor Layout – A Major Advantage

## Hot Loops Can Be Small and Duplicated for Low EMI

- Peak boost, peak buck low EMI sense resistor ( $R_S$ ) architecture
- 4-terminal sense resistor layout for highest accuracy.

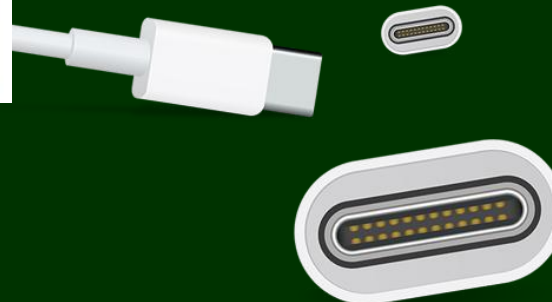


- Small switching hot-loop is smaller without sense resistor in path
- Opposing hot-loops are possible with this architecture, giving lower EMI with cancelling magnetic fields – “Discrete Silent Switcher”

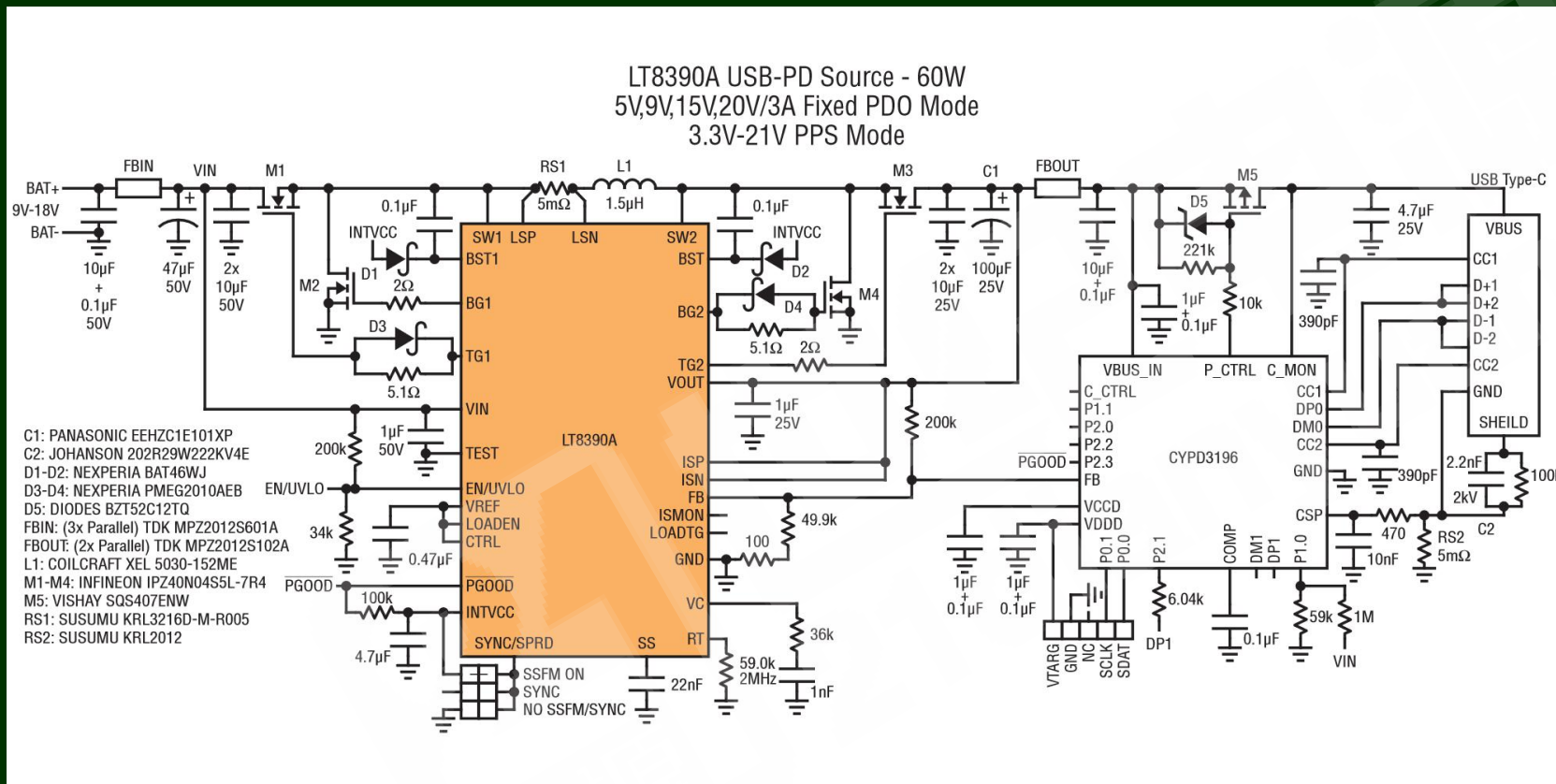
# EZ-PD CCG3PA USB Type-C Port Controller Family: Power Delivery with CYPD-3195 and -3196

 **ADVANCE** CYPD319X-24LDXS  
USB Type-C Port Controller

## EZ-PD™ CCG3PA USB Type-C and Power Delivery



# Typical Automotive USB-C Power Delivery System



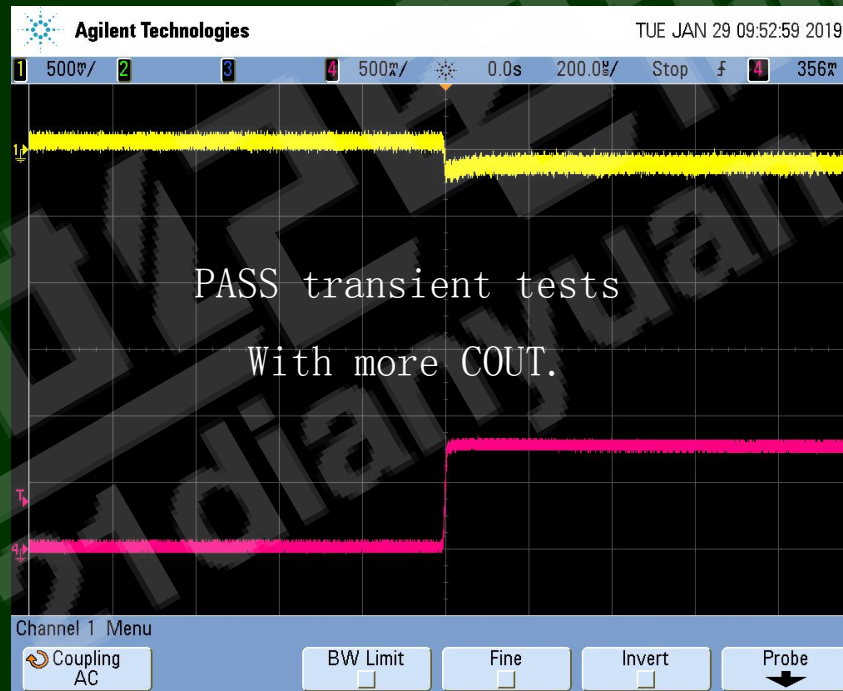
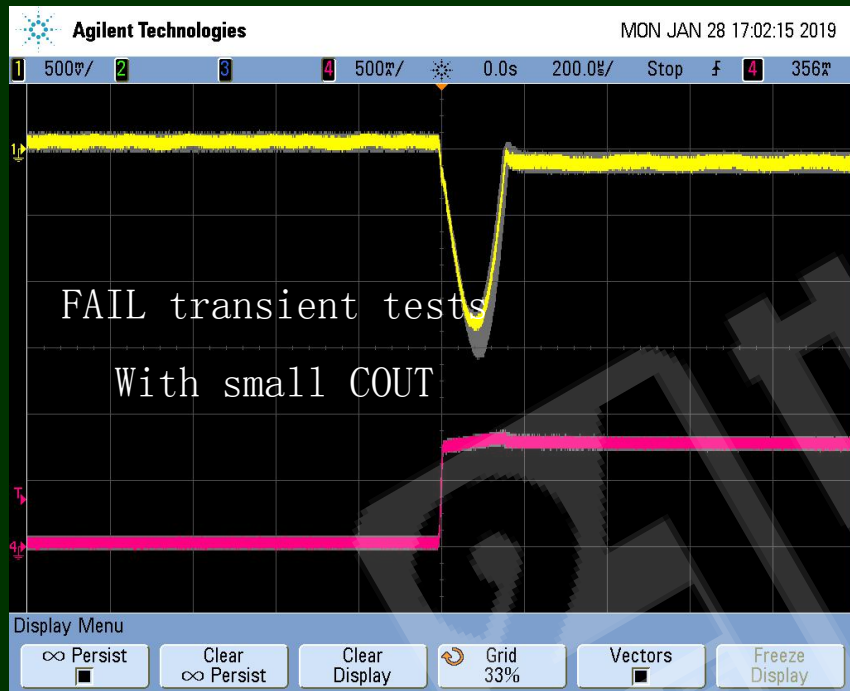
## ADI USB PD Product Value Proposition

- ▶ Core Technology:
  - ADI offers both monolithic and controller products covering solutions from 15W to 100W
  - Low-EMI direct-inductor-current-sense buck-boost architecture for Controller
  - Silent Switcher™ architecture for Monolithic
- ▶ Key Advantage:
  - Low EMI – easy to pass CISPR25 class 5 limits
  - High power efficiency – 95%~98%
  - Small solution size – achieved by 2MHz switching frequency operation
  - Great automotive quality with AEC-Q100 qualification
- ▶ Customer Service:
  - Applications and demo board support
  - Expert EMI design and on-site testing

# USB 3.0 PD Testing Transients – Had to Bulk up COUT to pass

$V_{IN}$ : 12V  $V_{BUS}$ : 9V

Load step: 0 to 0.75A (0% – 25% Full Scale Current)



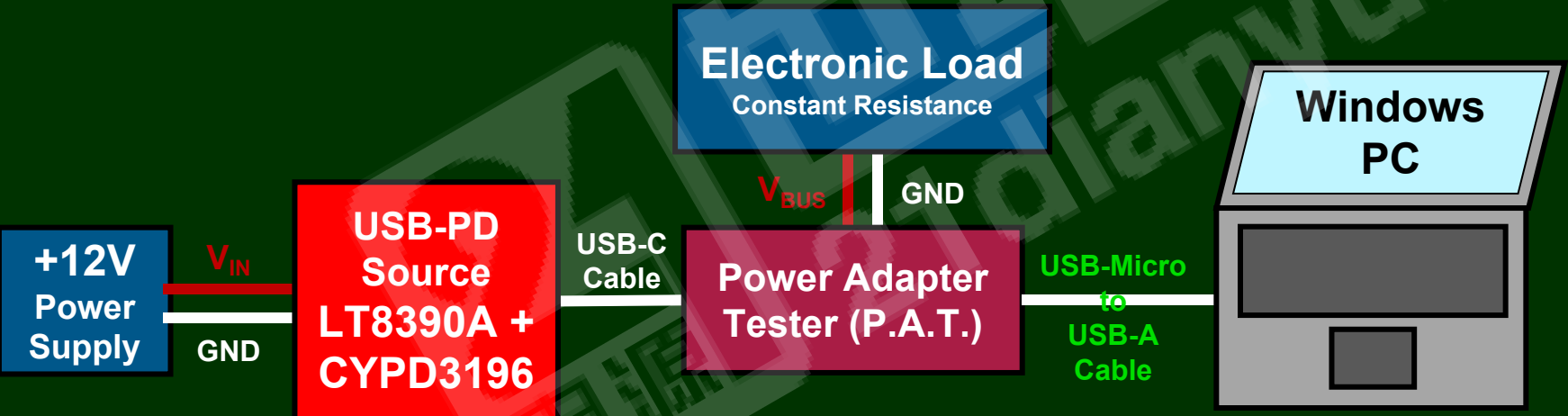
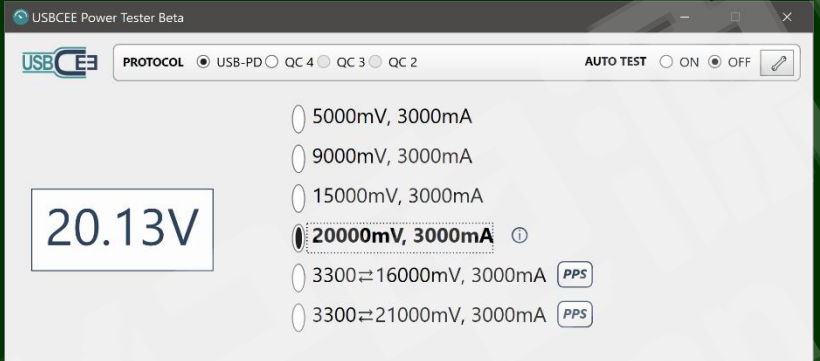
Ceramic Output Capacitors Only

Ceramic + 2x 47uF Electrolytic Output Capacitors

Compensation: R:12k C:2200pF

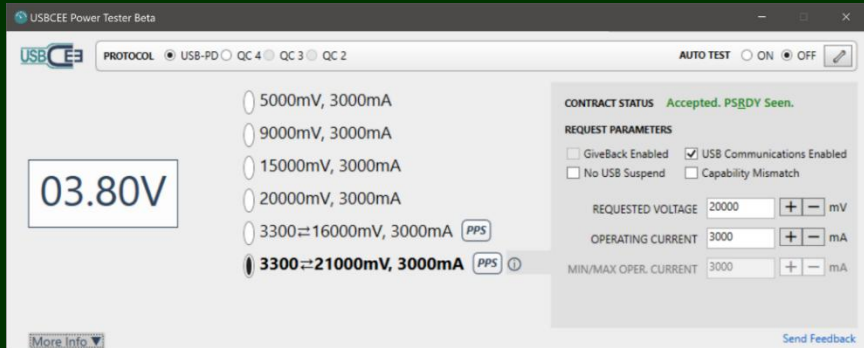
Compensation: R:82k C:470pF

# USB 3.0 PD PDO and PPS Tests





# USB 3.0 PD Overcurrent Foldback Tests



Overcurrent foldback is tested with the PD source configured to operate in PPS mode with a requested voltage of  $20V_{BUS}$  using a USB-C power adapter tester.

An attached electronic load set to operate in constant resistance mode is adjusted to draw current from the bus ( $20V/2.5A = 8\Omega$ )

As the load resistance is decreased so that the current begins to exceed 3A, the USB-PD source reduces the output voltage until the bus reaches 3.3V.

$$V_{BUS\_SET} : 20V$$

$$V_{BUS\_MEAS} : 3.80V$$

PASSES OVERLOADED OUTPUT TEST

$$R_{LOAD} : \sim 1.26 \Omega$$

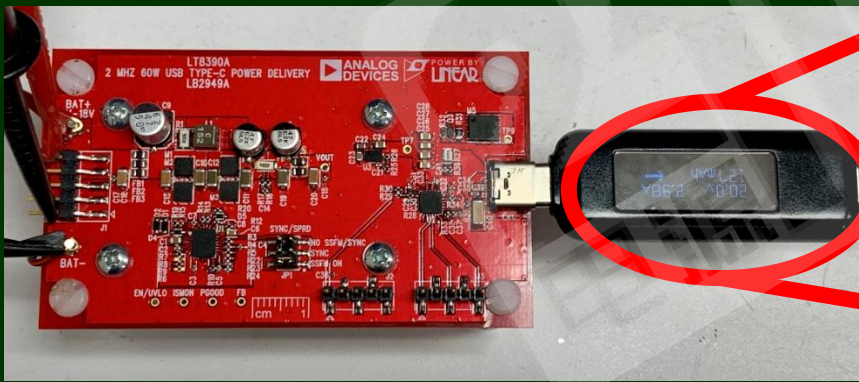
$$I_{LOAD} : \sim 3A$$

# Cypress PD Testing is Now Complete for This Board



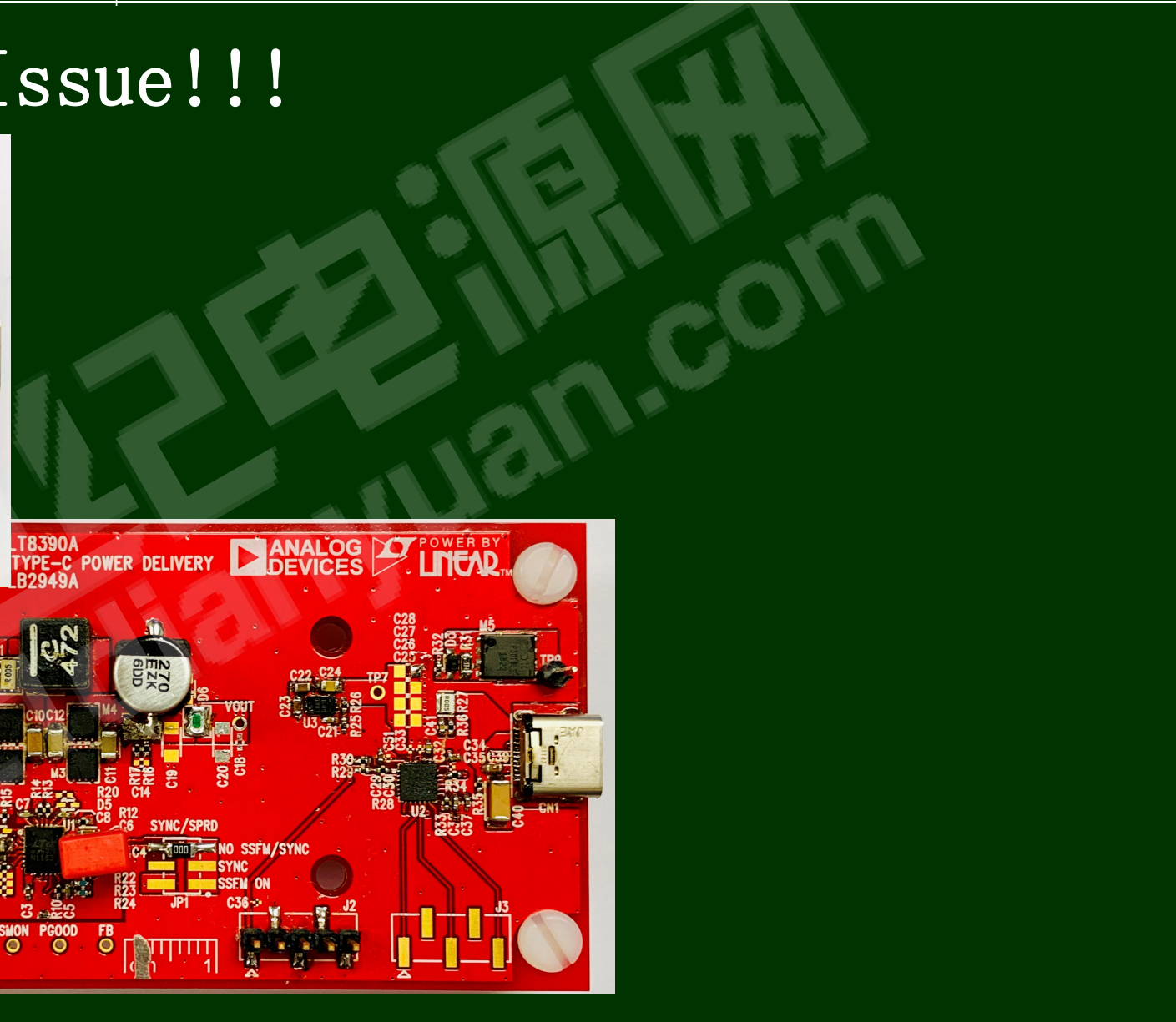
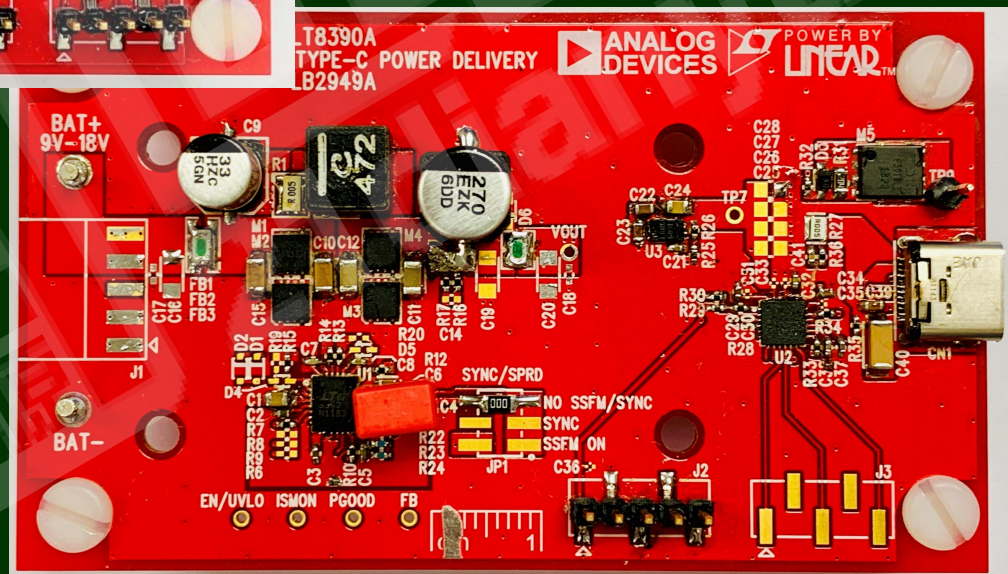
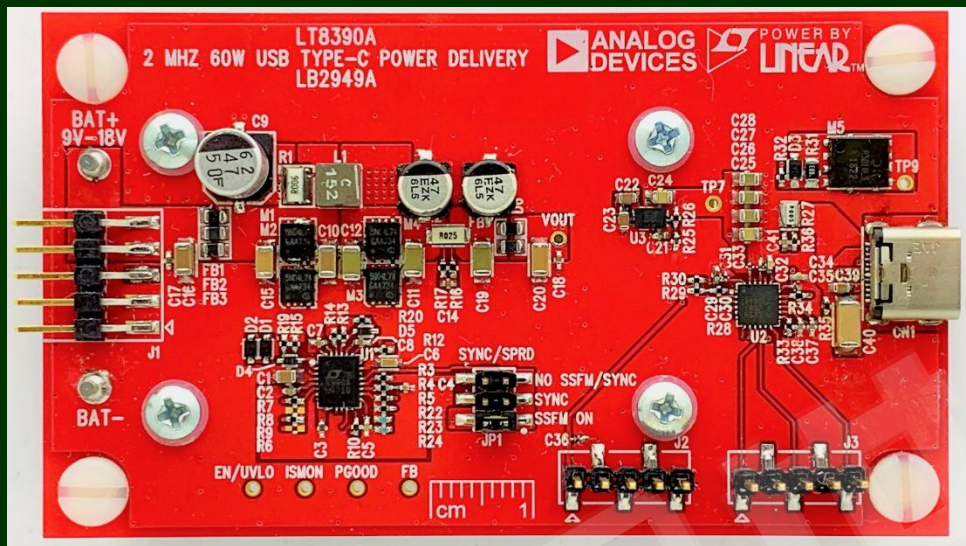
Low battery on your phone, tablet, or laptop? It works!

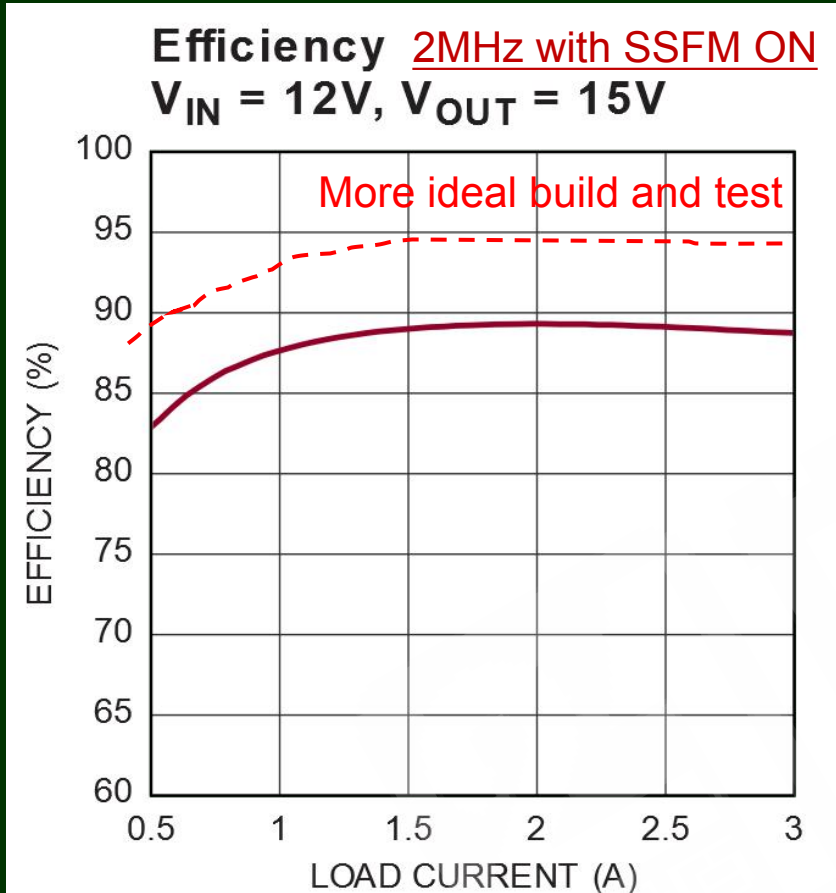
- ▶ Charges Type-C PD devices
- ▶ Charges **Micro-USB** devices
- ▶ Charges **Lightning** (Apple) devices
- ▶ Charges **USB-A** devices



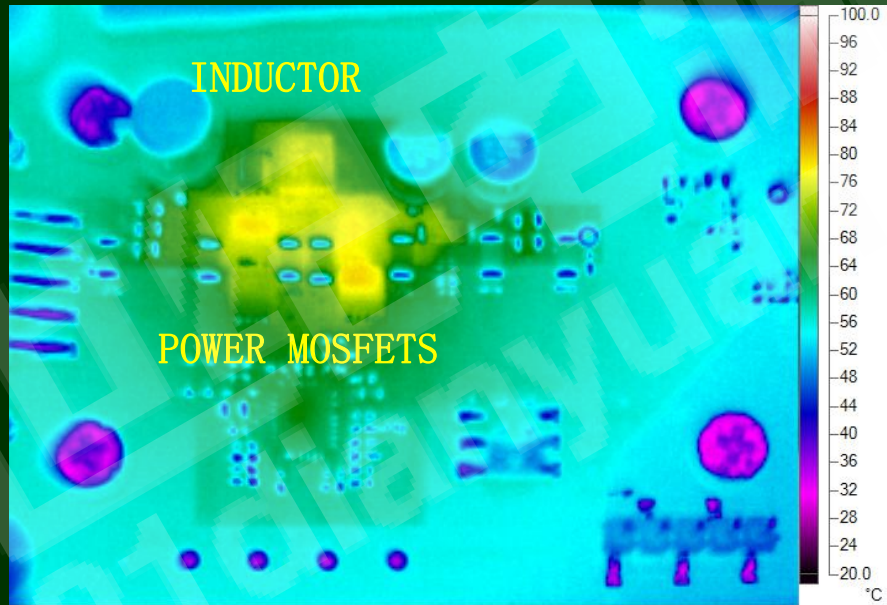
**60w**

# Thermal Issue!!!





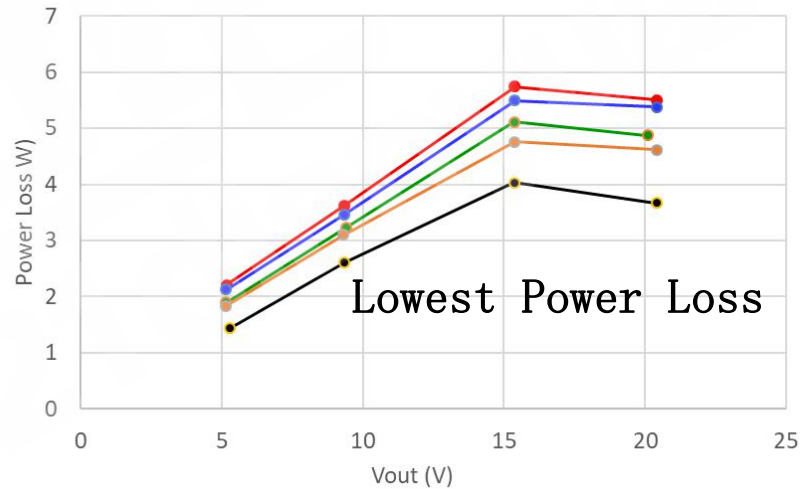
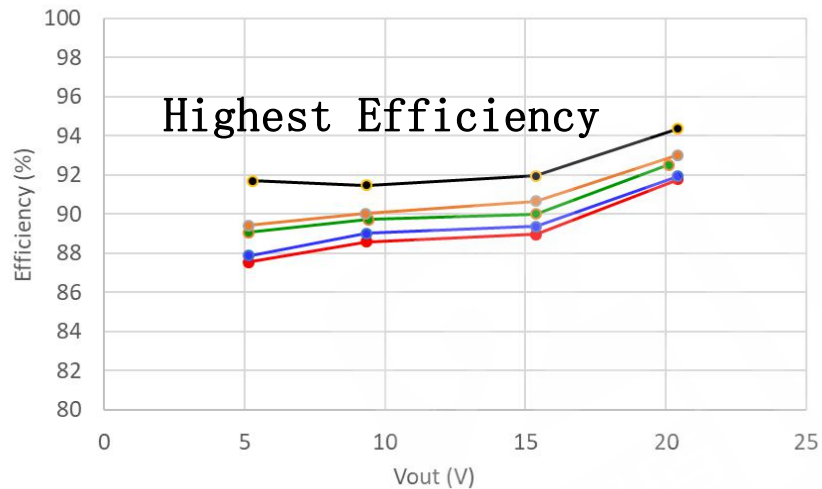
45W



With EMI filters, automotive components, and gate resistors = some drop in efficiency due to original output sense resistor.

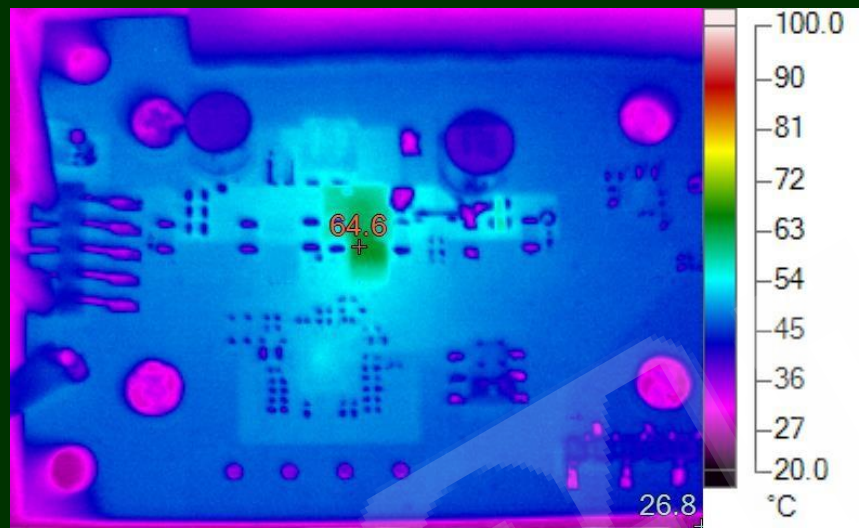
## 12V<sub>IN</sub> Efficiency with Reduced Components and EMI Treatment

Color	Approaches	Gate R	Rsense	Inductor	EMI filters
Black	Remove ferrite bead	0	0	XEL5030	none
Orange	Larger L case size	0	0	XEL5030	yes
Green	Rsense removed (output)	0	0	XEL4030	yes
Blue	Gate R removed	0	0.025	XEL4030	yes
Red	45W/60W Full Solution	5.1 and 2	0.025	XEL4030	yes



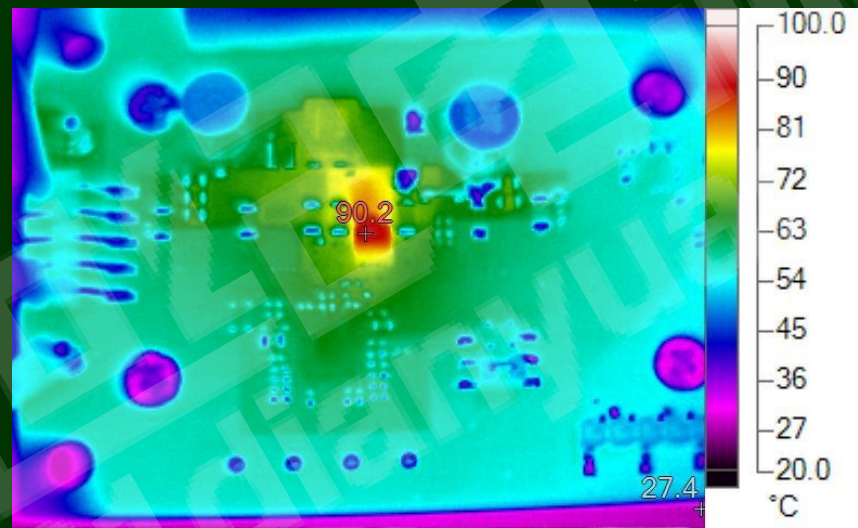
# LB2949A LT8390A 2MHz Buck-Boost USB-C PD 45W, 60W Thermals at 12V<sub>IN</sub> with Heatsink, SSFM On

45W



64.6° C MOSFET M3 from 23° C ambient

60W

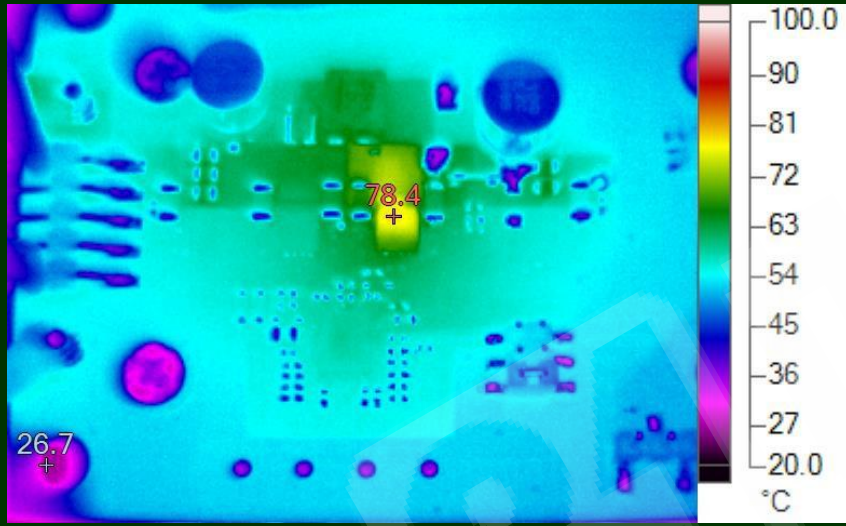


90.2° C MOSFET M3 from 23° C ambient

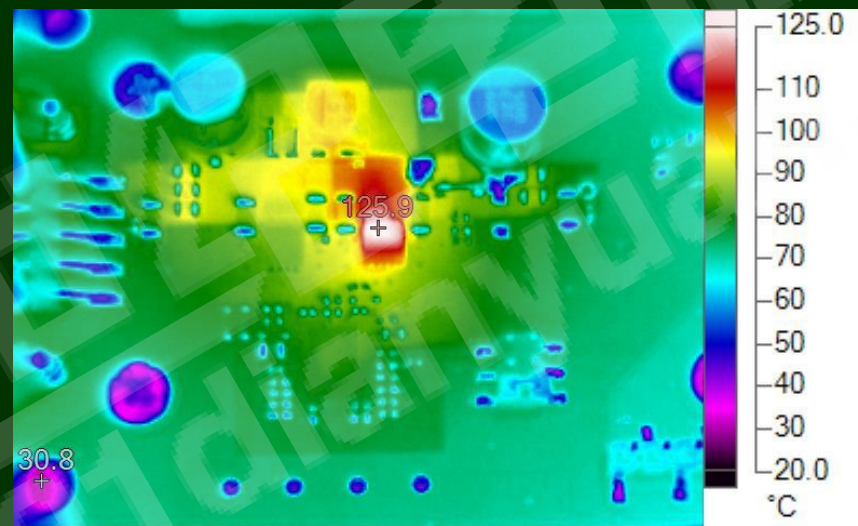
This is the tradeoff of small size and 2MHz.

# LB2949A LT8390A 2MHz Buck-Boost USB-C PD 45W, 60W Thermals at 9V<sub>IN</sub> with Heatsink , SSFM On

45W



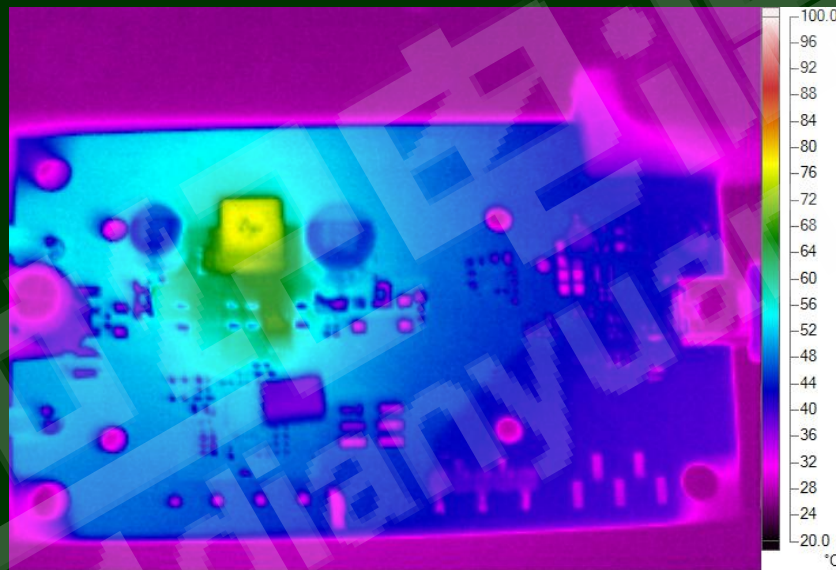
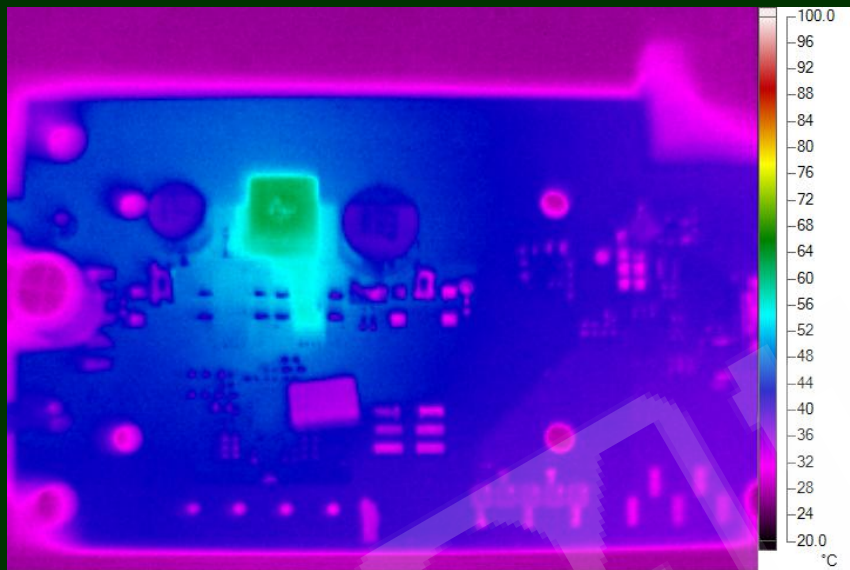
60W – worst case at low VIN



# LT8390 400kHz 60W Thermal Performance

12V<sub>IN</sub> – 20V<sub>OUT</sub> / 3A

9V<sub>IN</sub> – 20V<sub>OUT</sub> / 3A



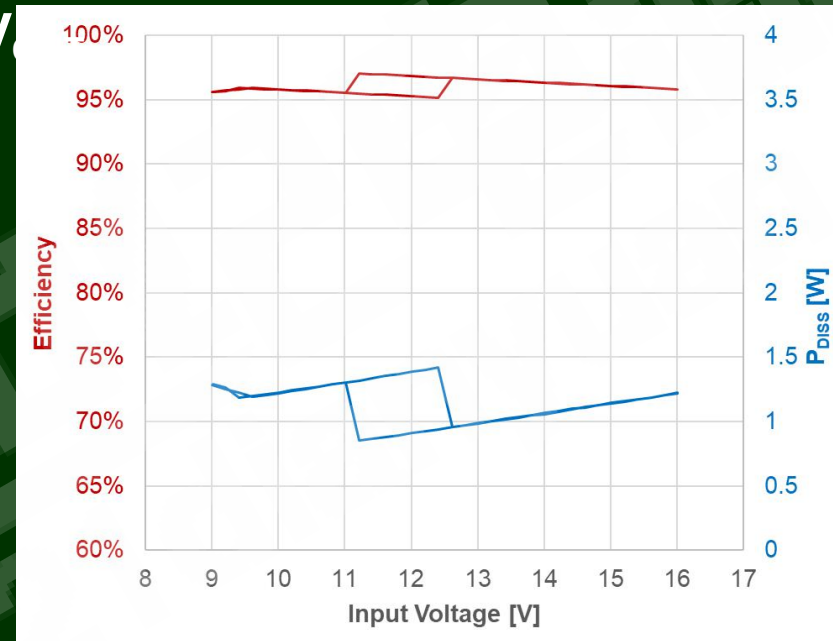
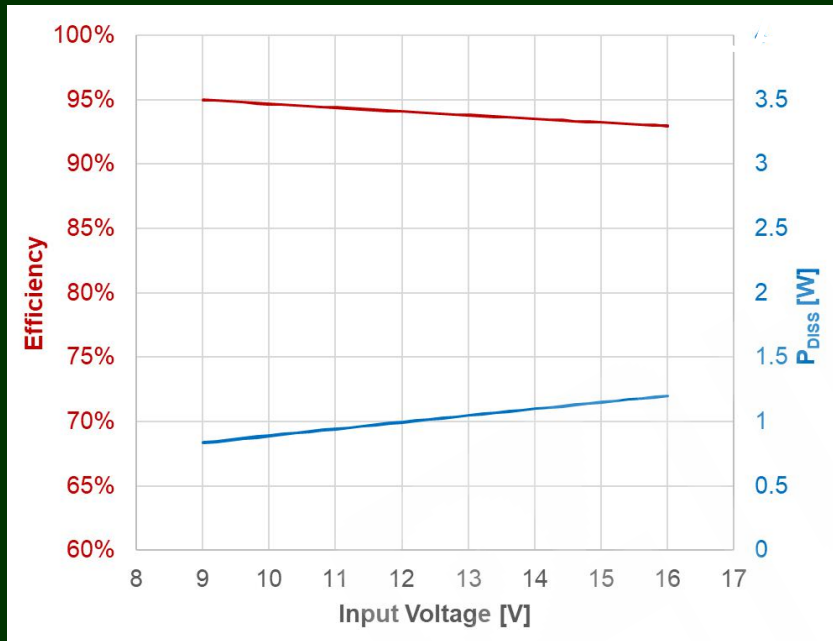
60W Power Delivery from 9V-16Vin (36Vtransient) with **NO HEATSINK**



# Efficiency and Power Dissipation vs Input Voltage

## LT8390 400kHz 60W USB-C PD

3A 5V<sub>OUT</sub>

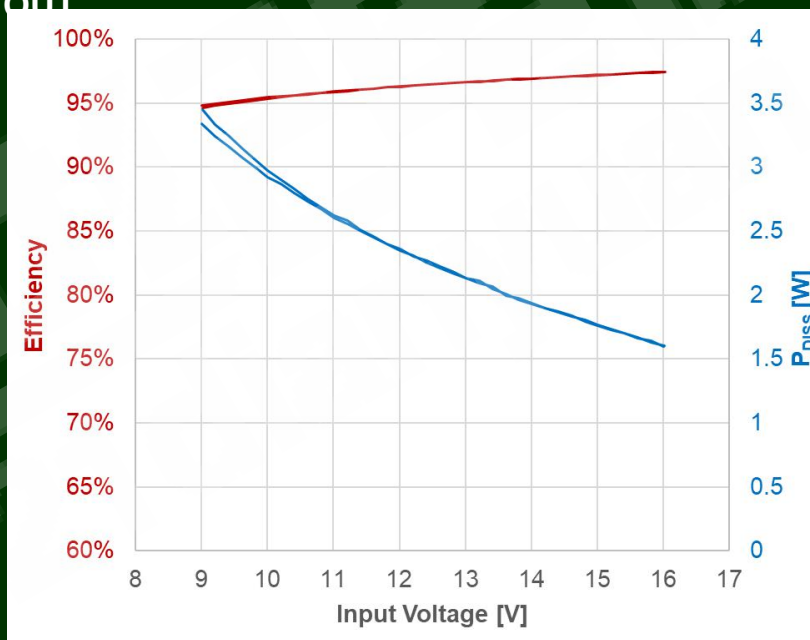
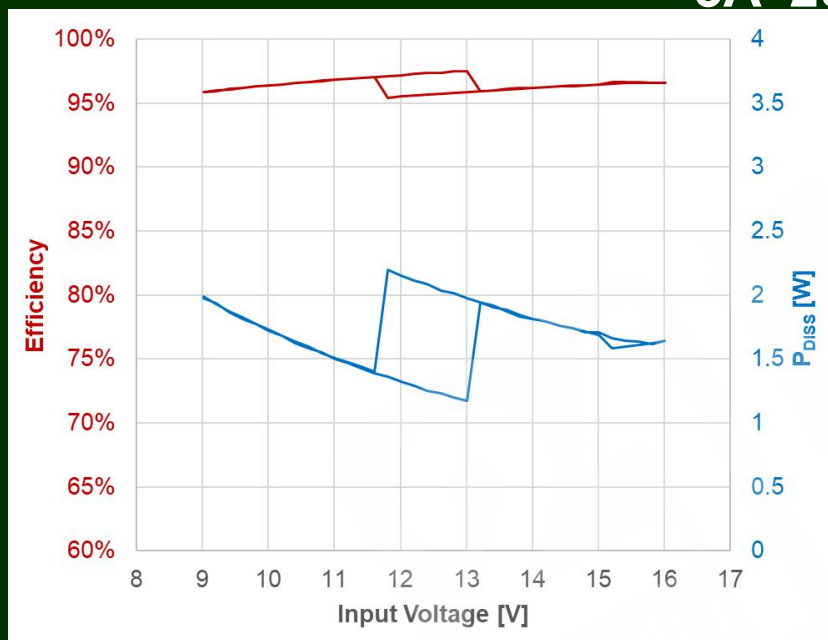


# Efficiency and Power Dissipation vs Input Voltage

## LT8390 400kHz 60W USB-C PD

3A 15V<sub>OUT</sub>

3A 20V<sub>OUT</sub>



# Transient Response is Small (25% Load Steps) 16V<sub>IN</sub> - 5V<sub>OUT</sub>



0A – 750mA Load Step

2250mA – 3000mA Load Step

# Transient Response is Small (25% Load Steps) 15V<sub>IN</sub> - 15V<sub>OUT</sub>



0A – 750mA Load Step

2250mA – 3000mA Load Step

# Transient Response is Small (25% Load Steps) 9V<sub>IN</sub> - 20V<sub>OUT</sub>



0A – 750mA Load Step

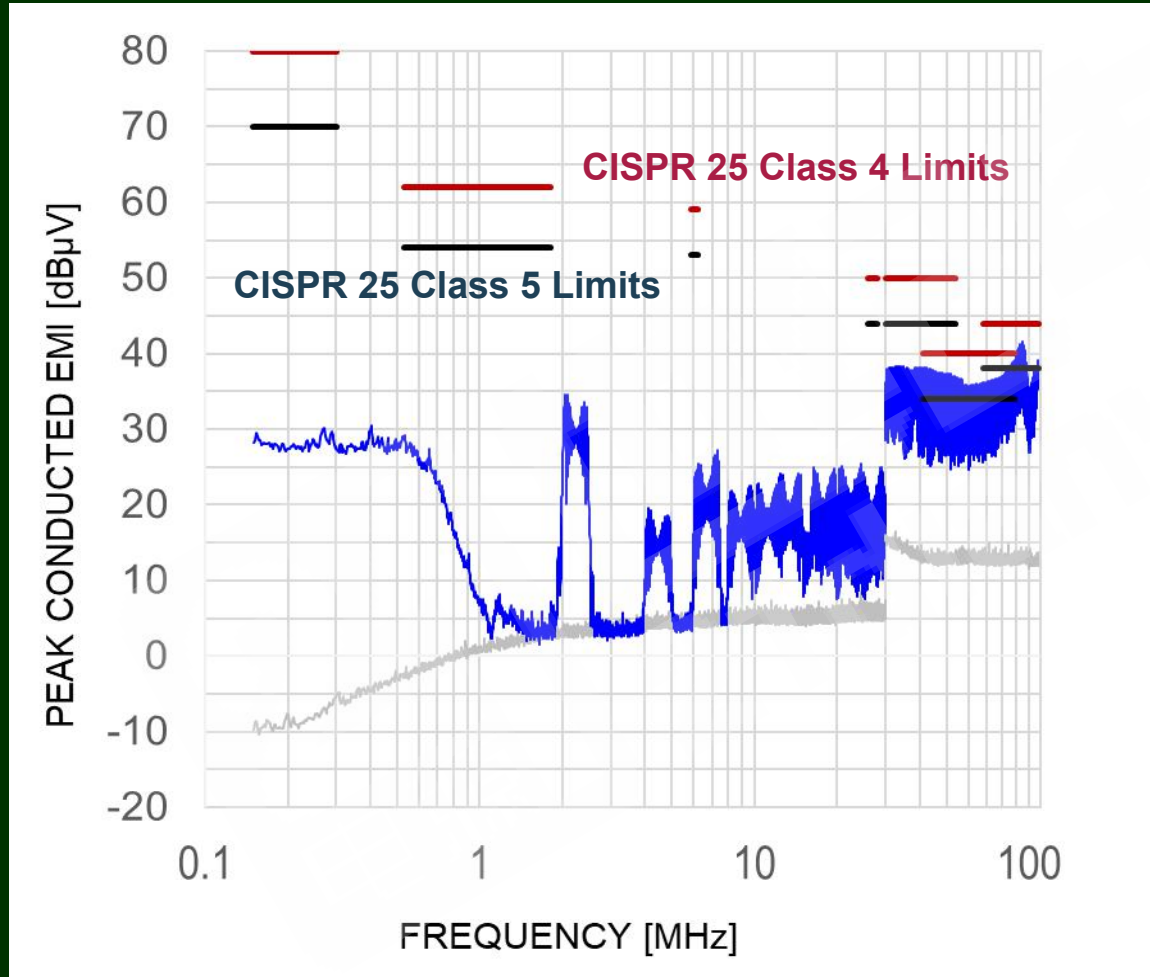
2250mA – 3000mA Load Step

EMI Test result !!!



21世纪电源网  
21dianyuan.com

# LB2949A LT8390A Buck-Boost USB-C Power Delivery Conducted EMI Results – 20V 3A 60W 2MHz



电源网  
dianyuan.com

# New Product Road Map



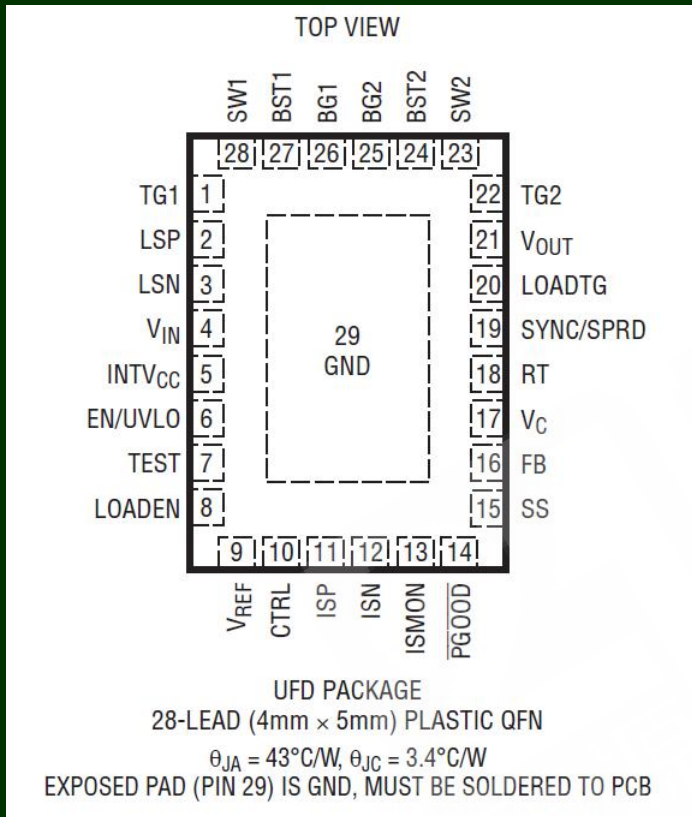
21世纪电源网  
21dianyuan.com



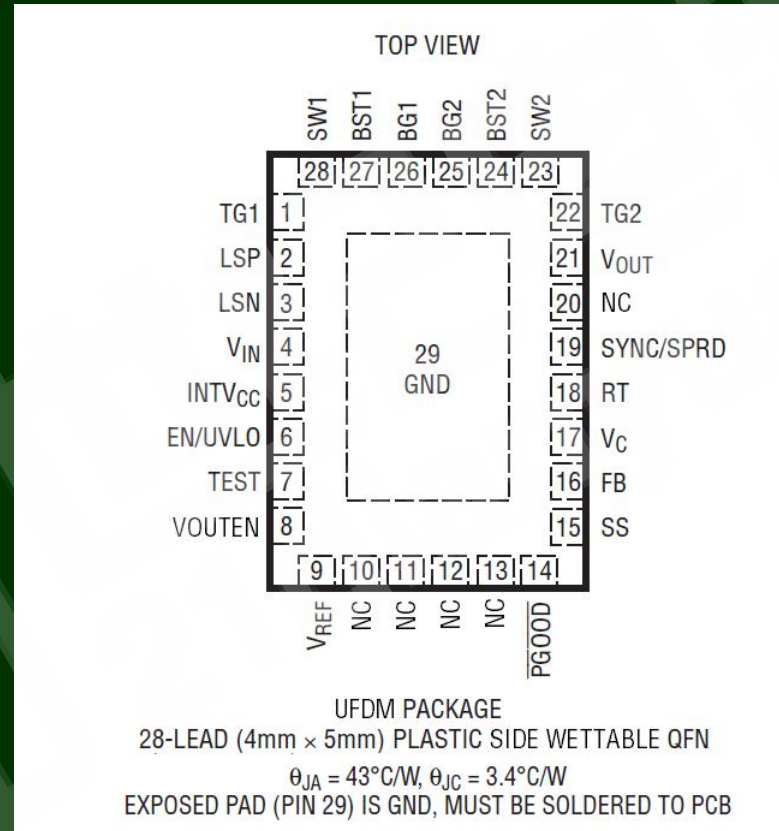
- ▶ LT8253/53A: 40V USB-C PD Buck-Boost Controller
  - LT8253 – 150kHz to 650kHz, Side wettable QFN4x5, up to 100W
  - LT8253A – 650kHz to 2MHz, Side wettable QFN4x5, up to 60W
- ▶ LT8350/50S: 40V<sub>IN</sub>, 18V<sub>O</sub>, 5A Synchronous Buck-Boost Silent Switcher
  - LT8350 – no cap inside, LQFN6x4, up to 27W
  - LT8350S – caps inside, LQFN6x4, up to 27W

# LT8253/53A: 40V USB-C PD Buck-Boost Controller

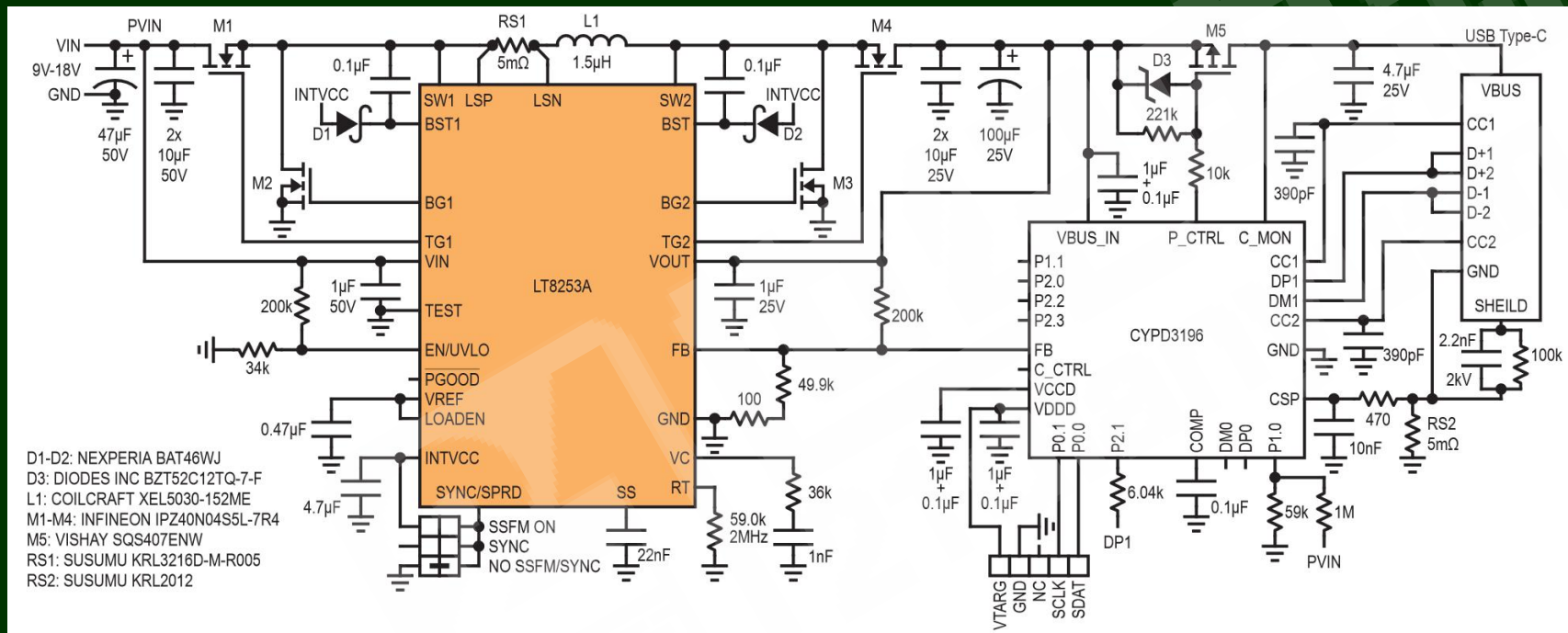
LT8390/90A



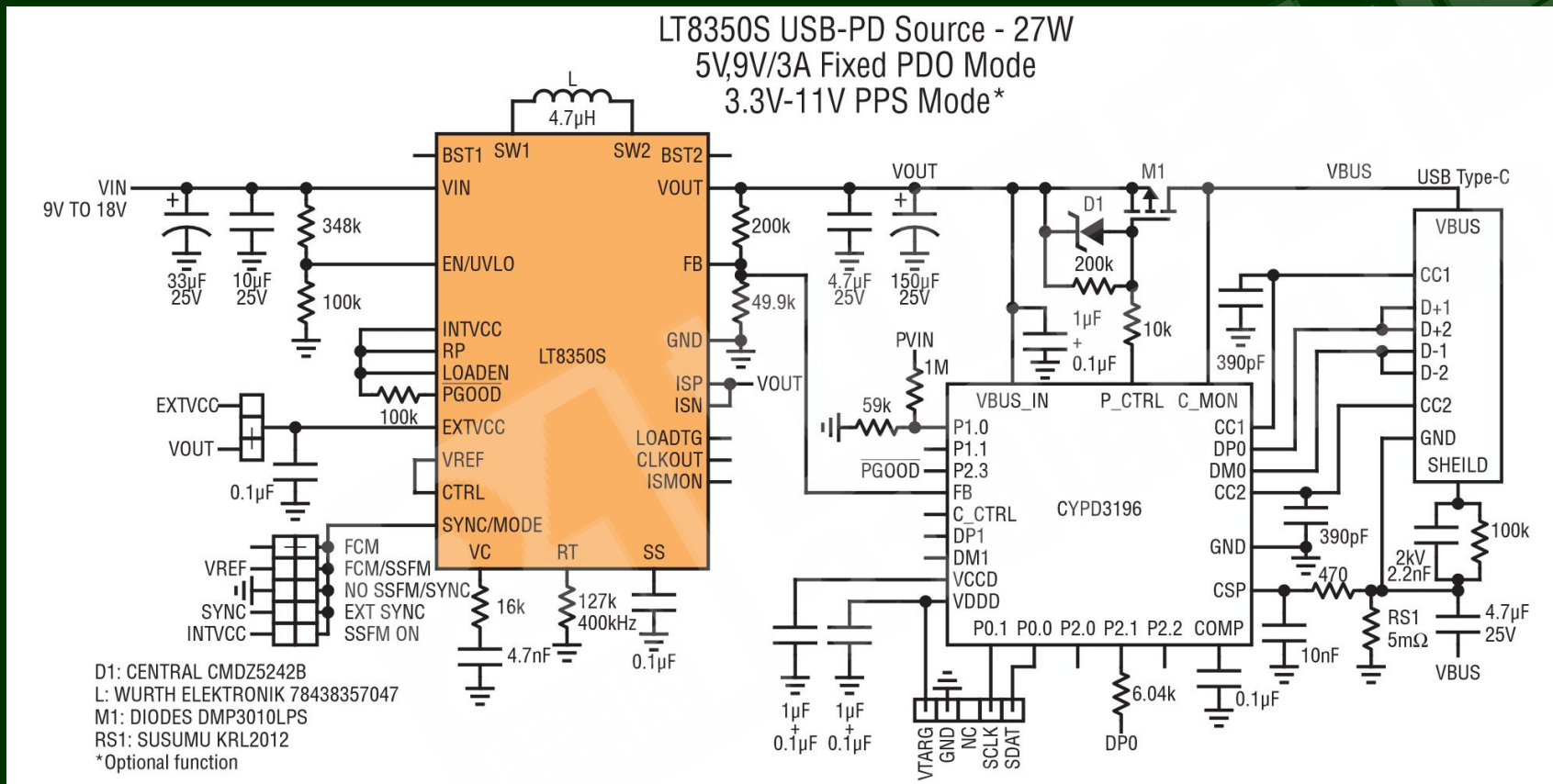
LT8253/53A



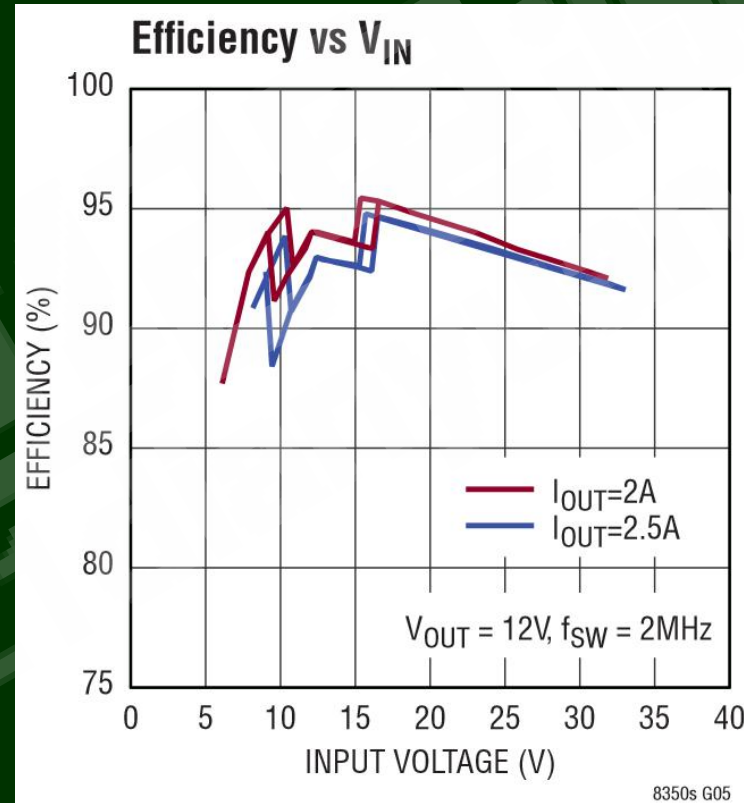
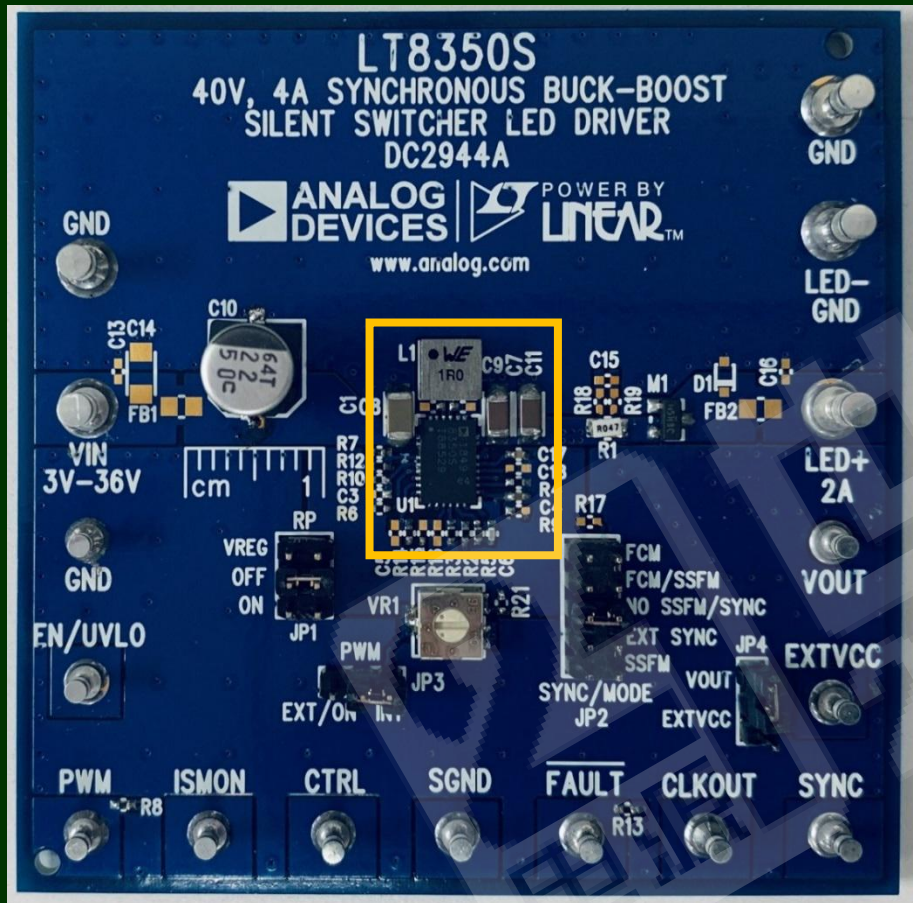
# LT8253A 45W USB-C PD 3.0



# LT8350/50S – 40V 27W Monolithic USB-C PD Buck-Boost Silent Switcher



# Small Solution Size and High Efficiency



8350s G05

The End!

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