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Field Application Engineer
Würth Elektronik Nederland B.V.

A collection of various electronic components is displayed on a red and white checkered surface. The components include resistors (one labeled R22), capacitors (one labeled 100nF), diodes (one labeled 1N4148), transistors (one labeled 2N2222), integrated circuits (one labeled 74LS00), and connectors (one labeled 106K). There are also several other components like a potentiometer, a relay, and various passive components. The components are arranged in a scattered manner, with some larger components like the relay and the potentiometer in the foreground, and smaller components like the resistors and capacitors in the background. The red and white checkered surface provides a clear contrast for the components, making them easy to identify.

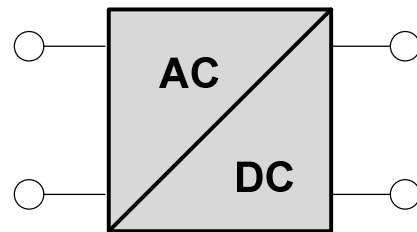
Basics

When do you need a DC/DC converter ?

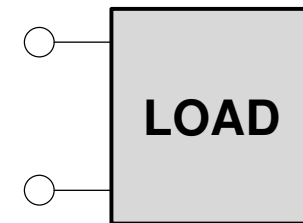
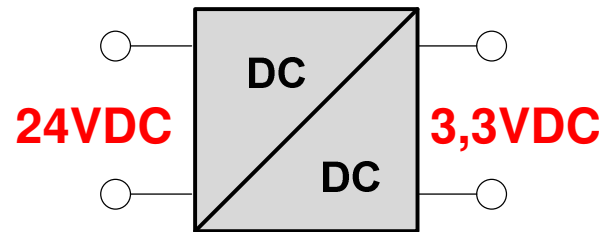


If your source voltage does not match to your load requirement

Example:



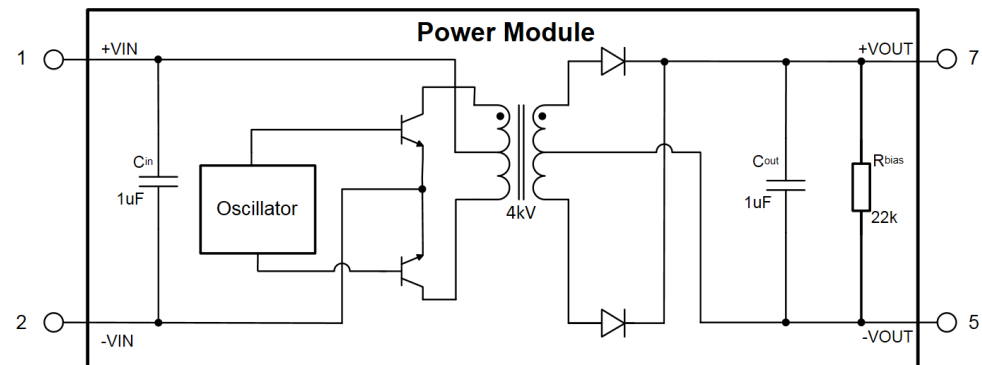
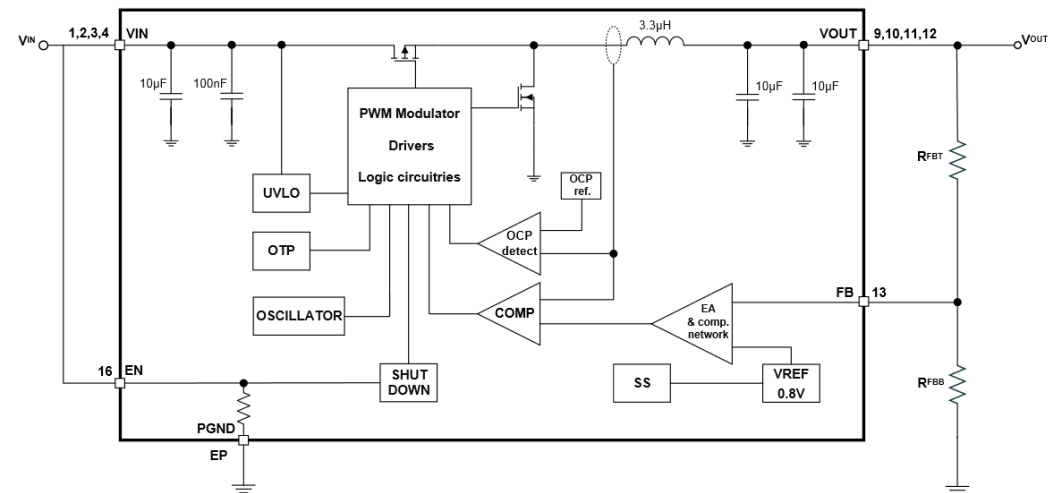
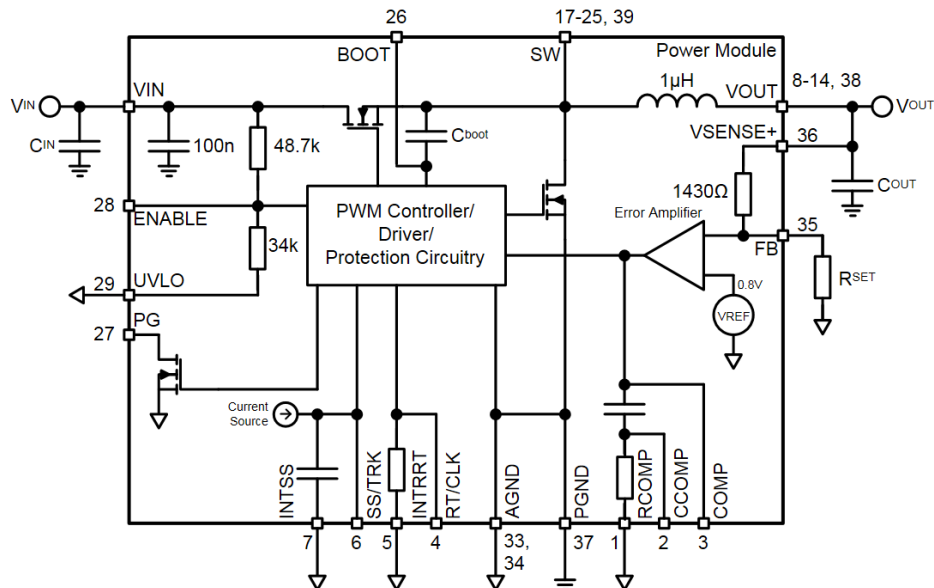
Power Supply
(230VAC / 24VDC)



Processor
(3,3V)

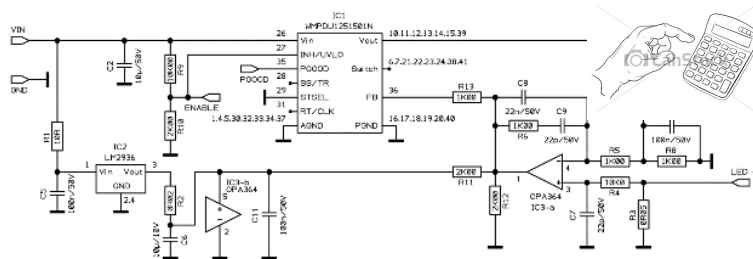
Basics

MagI³C Power Modules Architecture

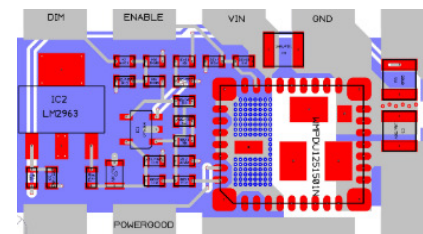


Magl³C – Power Modules

more than you expect service

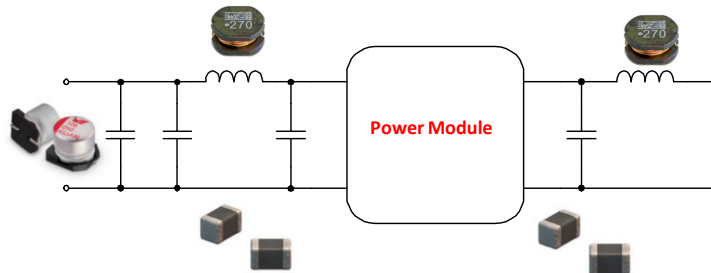


Design-in support
(product-related and application specific)



Layout review
(send your PCB files)

EMI filter
design support



In-house trainings
(technical seminars)



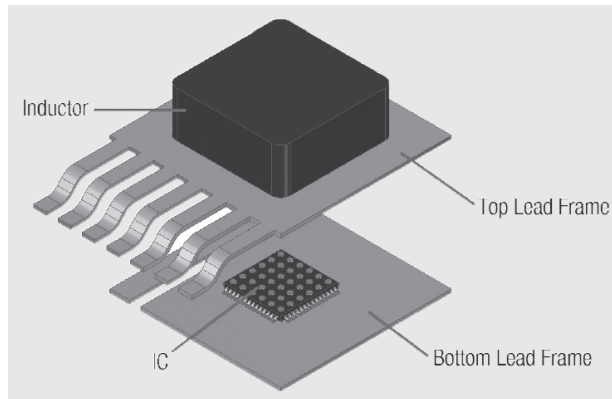
Reference designs
(application examples)



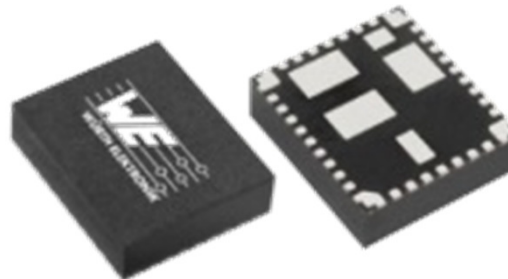
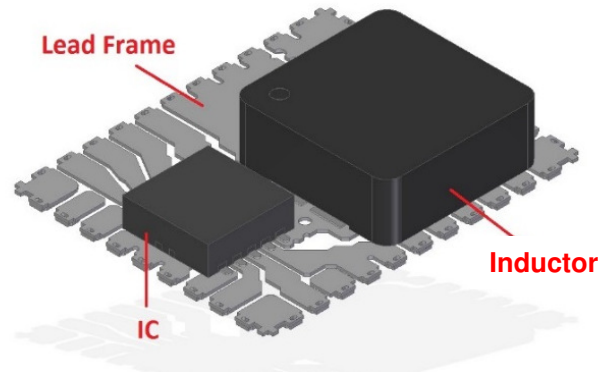
Basics

Package and Construction

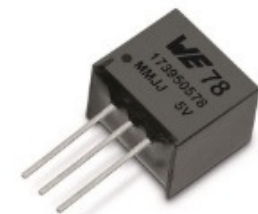
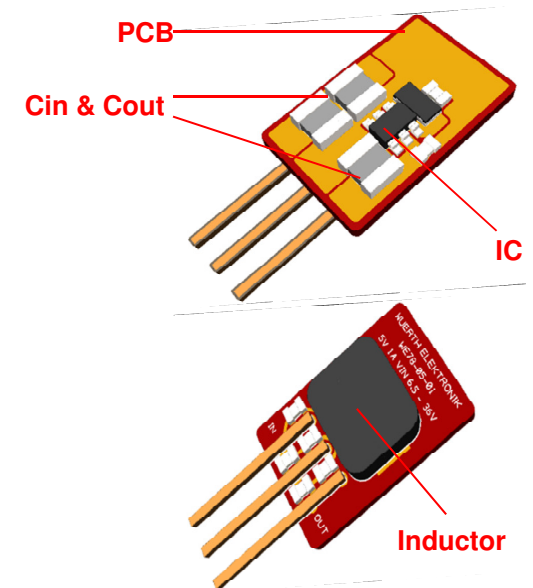
VDRM/LDHM TO263



VDRM BQFN



FDSM SIP3



Choosing a DC/DC Converter

Parameters



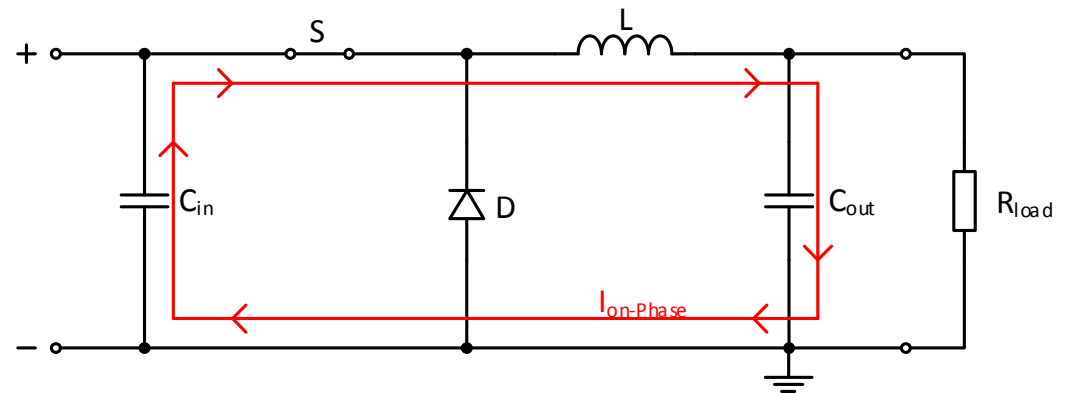
- **Input voltage range** V_{in} (min/max)
- **Output voltage range** V_{out} (min/max)
- **Output current (nominal, peak)** I_{out} (min/max)
- **Ambient temperature** - $^{\circ}\text{C}$ / + $^{\circ}\text{C}$
- **Package (type, size)** SMD/THT, mm
- **EMI norms** ... international /national
- **Output voltage ripple** mV
- **Switching frequency** MHz
- **Efficiency** %
- **Options / Features**

Basics

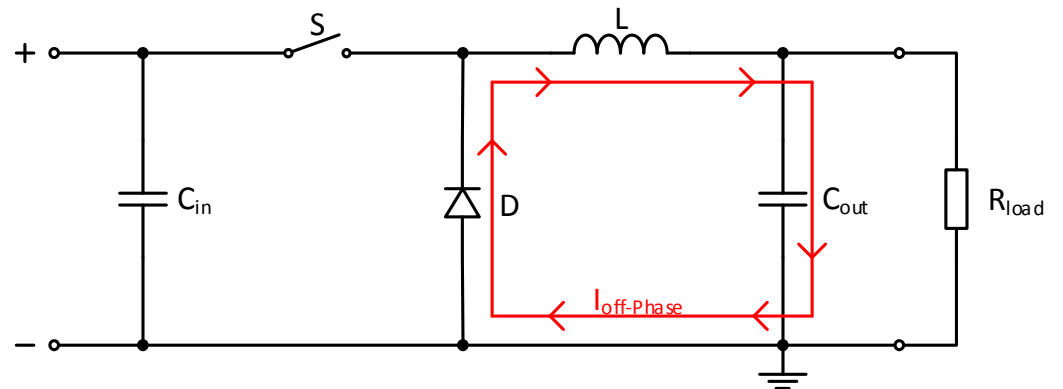
On-/Off-Phase



On-Phase

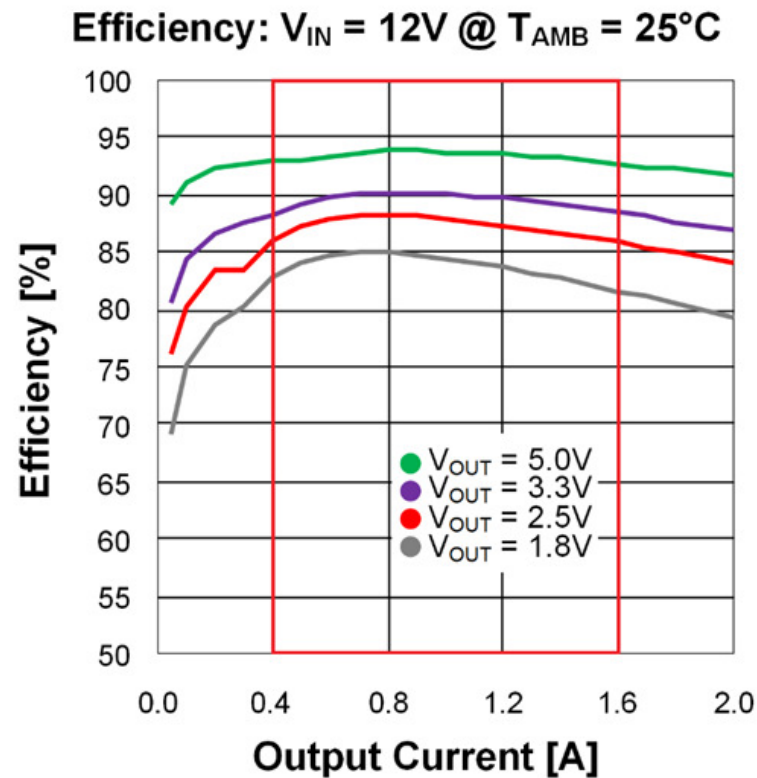


Off-Phase



Basics

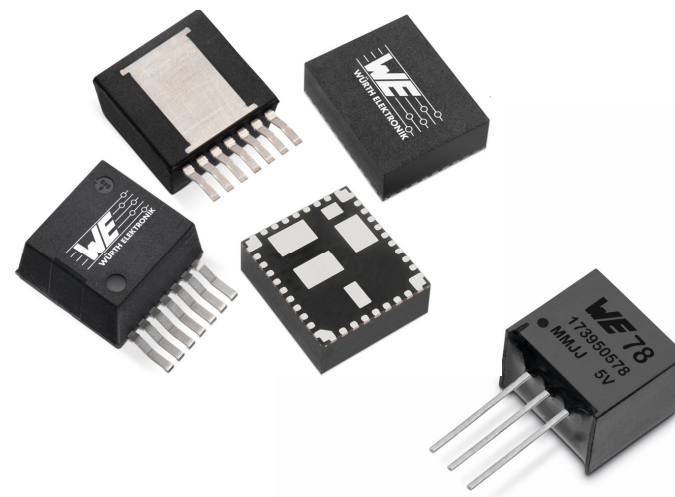
Efficiency



**Best practice to use the power module within the
red marked area**

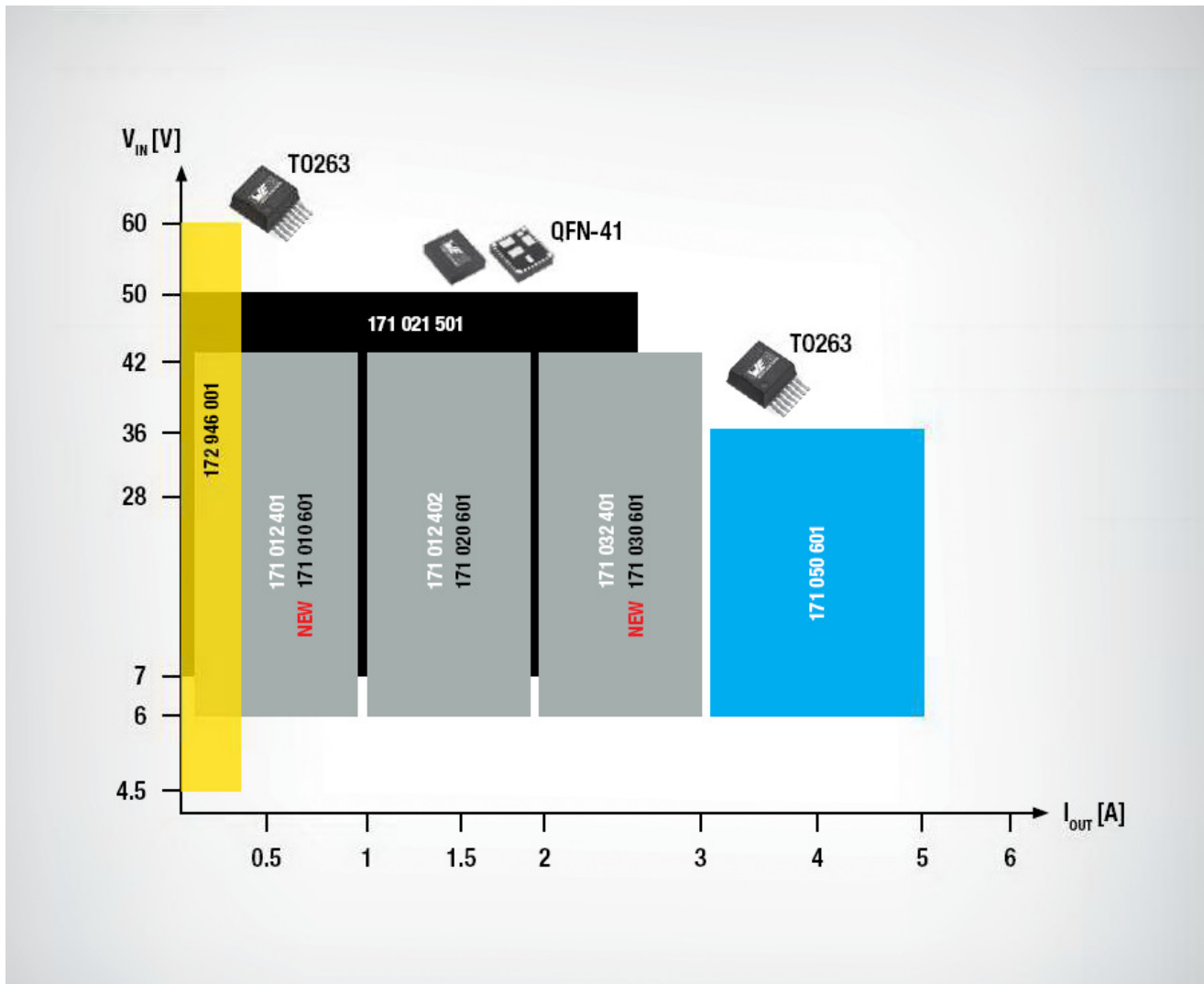
What is an Magic Power Module?

- **A fully integrated DC-DC power supply**
- **Fully integrated meaning**
 - Integrated MOSFETs
 - compensation network
 - shielded inductor
 - Input and output capacitors for some models
 - All in a single small package
- **Typically applications**
 - Point-of-Load DC-DC applications from 12V and 24V industrial rails
 - Industrial, Test & Measurement, Medical applications
 - System power supplies
 - DSPs, FPGAs, MCUs and MPUs supply
 - I/O interface power supply
 - High density distributed power system



MagI³C Power Modules Overview

VDRM / LDHM High voltage Portfolio



9 V / 12 V / 18 V / 24 V Input Rail / Variable Output:

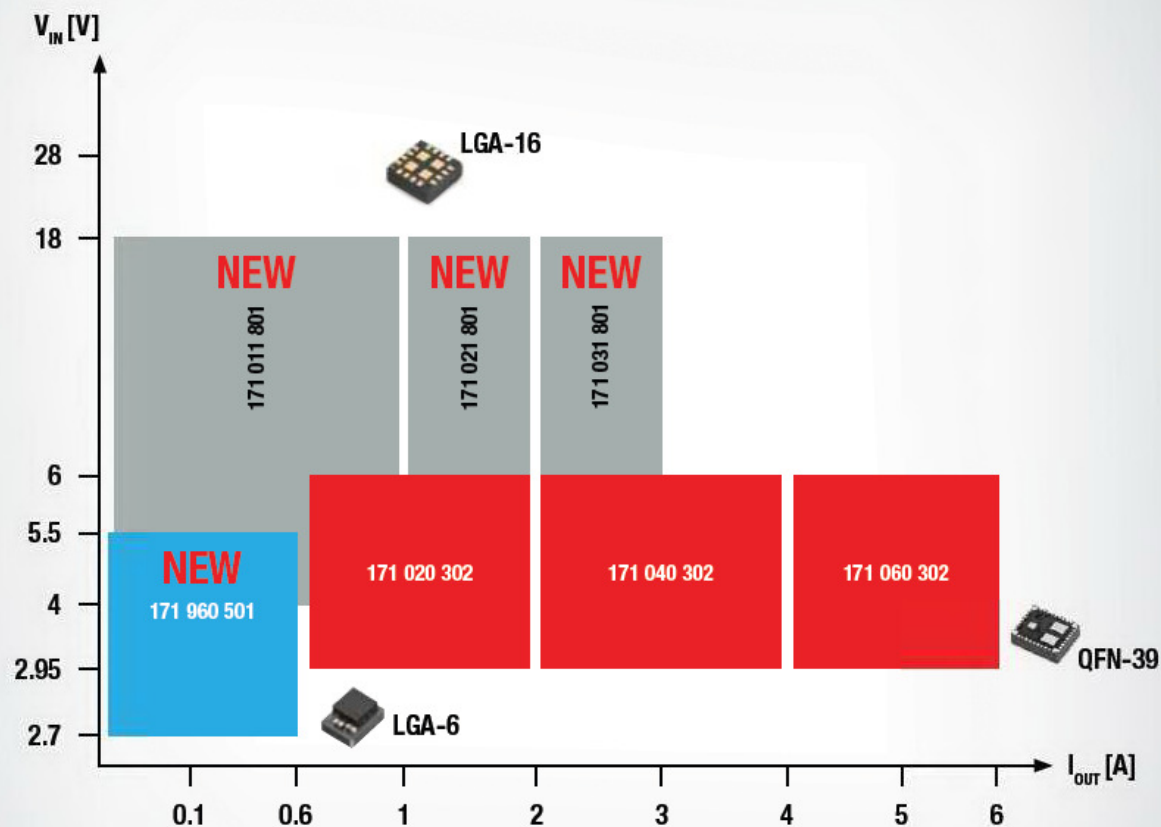
- T0263 6-42 V / 1 A, 2 A, 3 A / 5-24 V Output
- NEW** T0263 6-42 V / 1 A, 2 A, 3 A / 0.8-6 V Output
- QFN-41 7-50 V / 2.5 A / 2.5-15 V Output
- T0263 6-36 V / 5 A / 0.8-6 V Output

LED Driver:

- T0263 4.5-60 V / 450 mA / 1-16 LEDs

MagI³C Power Modules Overview

VDRM / VDMM Low voltage Portfolio



5 V / 9 V / 12 V Input Rail / Variable Output:

NEW ■ LGA-16 4-18 V / 1 A, 2 A, 3 A / 0.8-17 V Output

3.3 V / 5 V Input Rail / Variable Output:

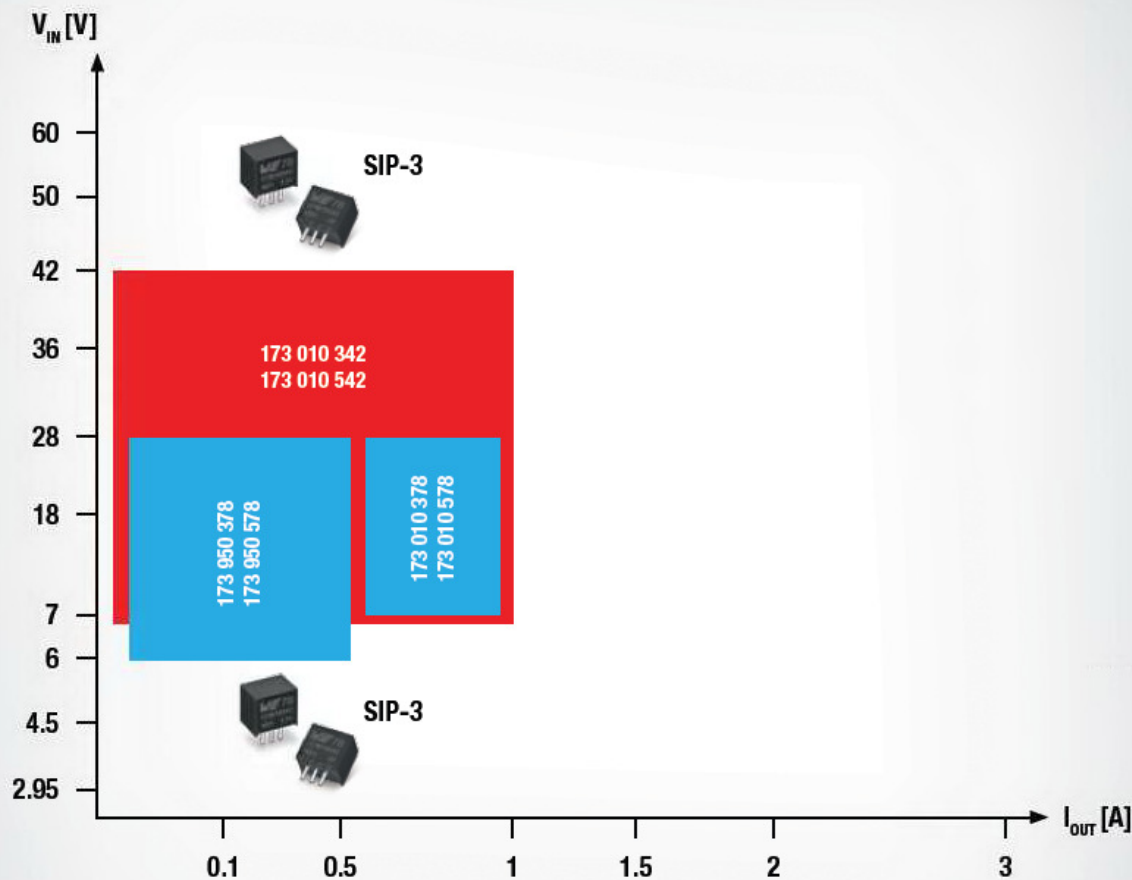
■ QFN-39 2.95-6 V / 2 A, 4 A, 6 A / 0.8-3.6 V Output

MicroModule:

NEW ■ LGA-6 2.7-5.5 V / 0.6 A / 0.6-5.5 V Output

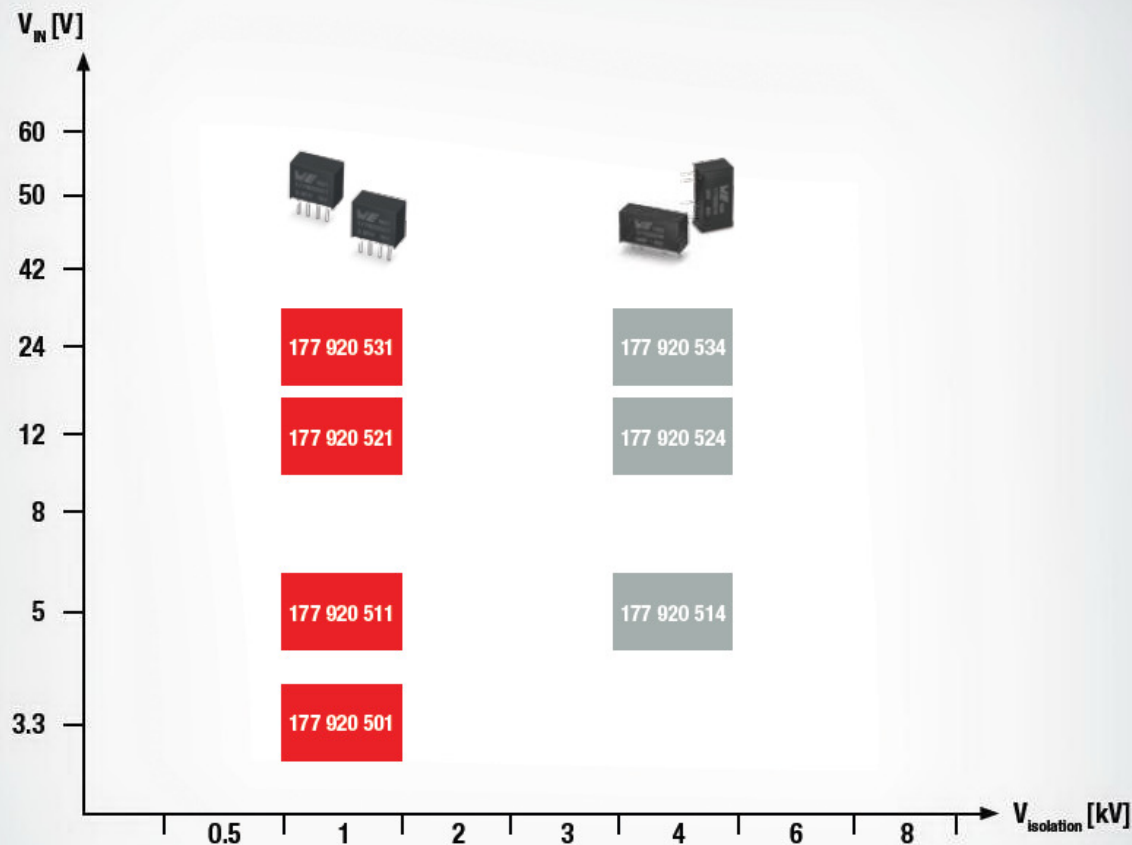
MagI³C Power Module Overview

FDSM Portfolio



MagI³C Isolated Power Module Overview

FISM Portfolio



3.3 V / 5 V / 12 V / 24 V Input Rail / Fixed Isolated Output:

- SIP-4 3.3 V / 1 W / 5 V Output / 1 kV
- SIP-4 5 V / 1 W / 5 V Output / 1 kV
- SIP-4 12 V / 1 W / 5 V Output / 1 kV
- SIP-4 24 V / 1 W / 5 V Output / 1 kV

5 V / 12 V / 24 V Input Rail / Fixed Isolated Output:

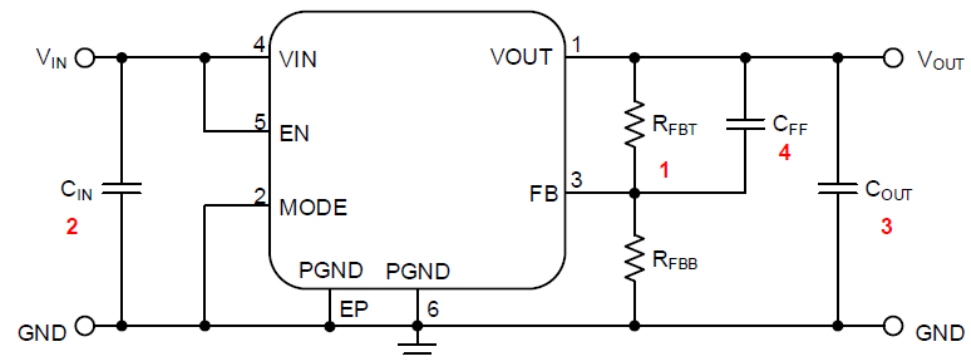
- SIP-7 5 V / 1 W / 5 V Output / 4 kV
- SIP-7 12 V / 1 W / 5 V Output / 4 kV
- SIP-7 24 V / 1 W / 5 V Output / 4 kV

DESIGN FLOW – Variable Micro Module

- The next steps will show how to select the external components to design your power application.

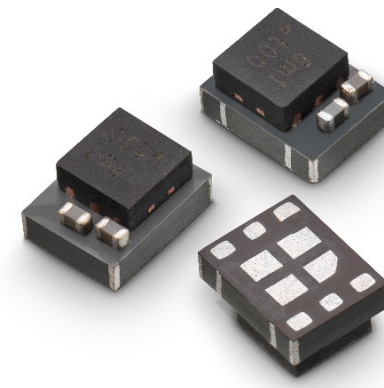
- **Essential Steps (depends on type)**

1. **Set output voltage**
2. **Select input capacitor**
3. **Select output capacitor**
4. **Select the feed-forward capacitor**



- **Optional Steps (depends on type)**

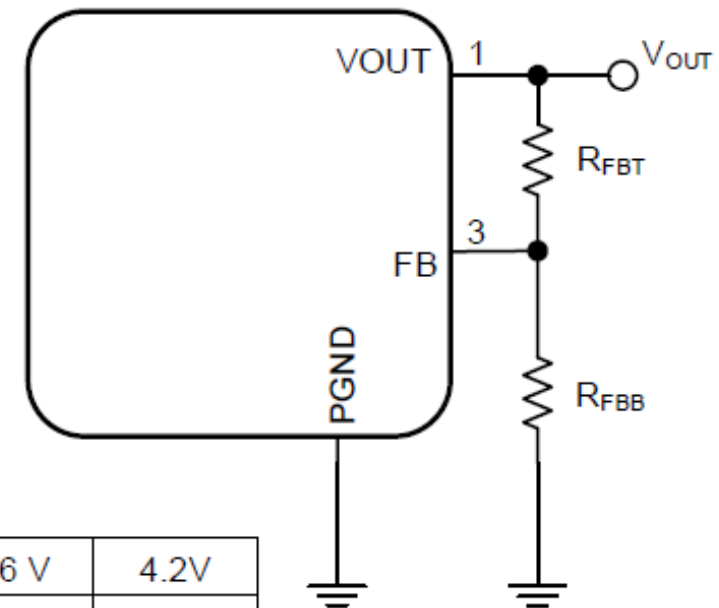
- Select soft-start capacitor
- Select under voltage lockout divider
- Select switching frequency
- Enable / Disable
- Voltage tracking
- Synchronization to an external clock
- Power Good



Essential Step 1 - Set output voltage

- The output voltage is selected with a resistor divider across FB pin and AGND.
- Example based on part 171960501
 - Output voltage can range from 0,6V to 5.5V

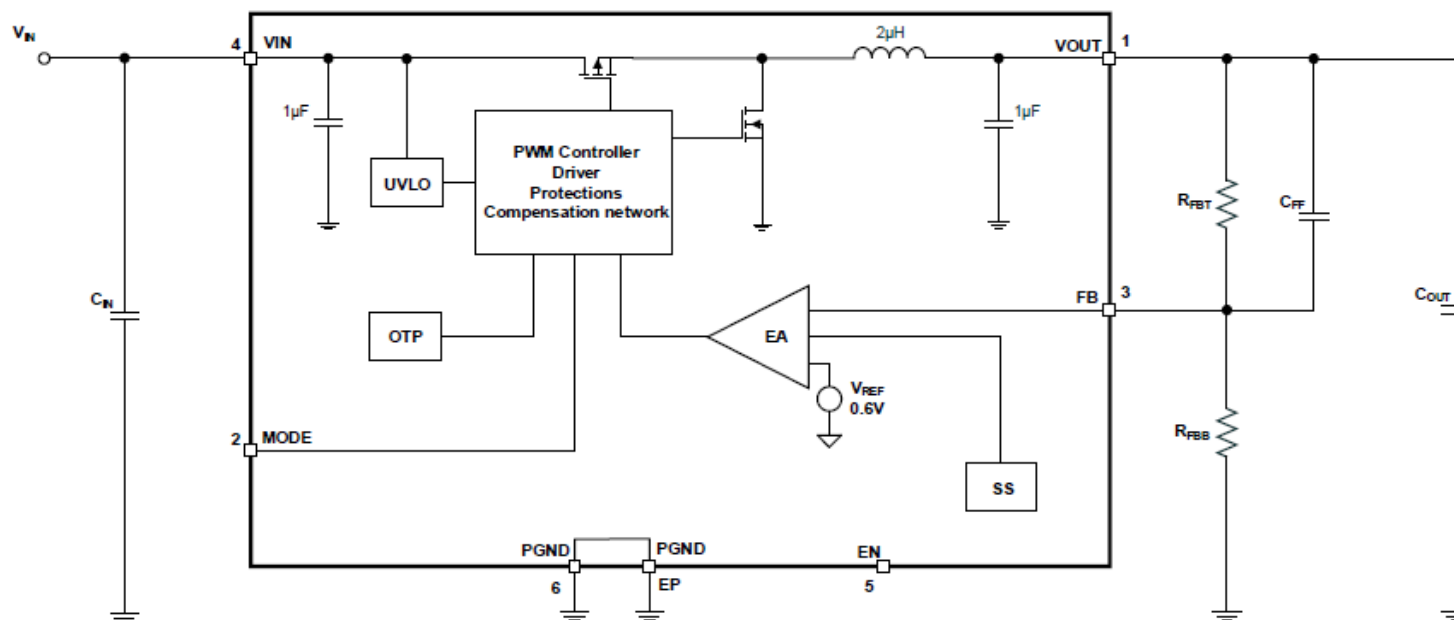
$$V_{OUT} = V_{FB} \cdot \left(\frac{R_{FBT}}{R_{FBB}} + 1 \right)$$



V _{OUT}	1.2V	1.5V	1.8V	2.5V	3.3V	3.6 V	4.2V
R _{FBB} (E96)	100kΩ	66.5kΩ	49.9kΩ	31.6kΩ	22.1kΩ	20kΩ	16.5kΩ

Essential Step 2 - Selecting the input capacitor

- Internal input capacitor present
 - For improved EMI performance
 - Increase protection to transients
- Recommended to add 10uF externally



DC-Bias behavior of MLCC capacitors

REDEXPERT®

CERAMIC CAPACITORS (MLCC'S)

APPLICATIONS




HOW TO

18 ITEMS

SHARE

ALEX

Filters: 4.70 μ F \leq C \leq 7.00 μ F $V_R \geq 10.0$ V Size = 0805 3 items

	Order Code	Series	Size	Sp...	T...	Description	C	V_R	R_{iso}	$\Delta C(V_{DC-Bias}) @ 3.30$ V	DF	Q	Length	Width
✓	885012107009	WCAP-CSGP	0805		X5R	X5R0805475M010DFCT10000	4.70 μ F	10.0 V	> 20.0 M Ω	-9.78 %	10 %		2.00 mm	1.25 mm
✓	885012107013	WCAP-CSGP	0805		X5R	X5R0805475M016DFCT10000	4.70 μ F	16.0 V	> 20.0 M Ω	-9.48 %	10 %		2.00 mm	1.25 mm
✓	885012107018	WCAP-CSGP	0805		X5R	X5R0805475M025DFCT10000	4.70 μ F	25.0 V	> 20.0 M Ω	-12.3 %	10 %		2.00 mm	1.25 mm

885012107009
 WCAP-CSGP · X5R · 0805
 4.70 μ F · 10.0 V

885012107013
 WCAP-CSGP · X5R · 0805
 4.70 μ F · 16.0 V

885012107018
 WCAP-CSGP · X5R · 0805
 4.70 μ F · 25.0 V

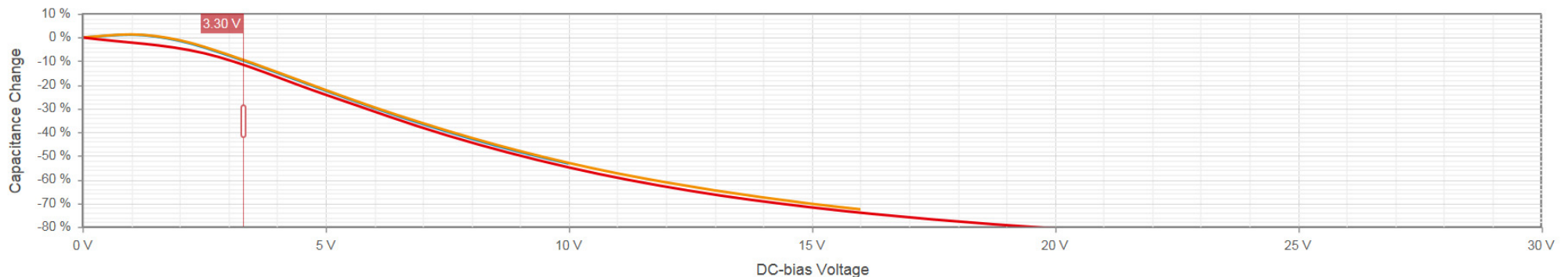
Drop Order Codes in the tray to add

Add to Cart

More...

Show Panel: Z vs. F ESR vs. F C vs. F ΔC vs. $V_{DC-Bias}$ ΔC vs. V_{AC}

Capacitance change / DC-Bias Voltage



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DC-Bias behavior of MLCC capacitors

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CERAMIC CAPACITORS (MLCC'S)

APPLICATIONS

HOW TO

18 ITEMS

SHARE

ALEX

Filters: $10.0 \mu\text{F} \leq C \leq 22.0 \mu\text{F}$ $V_R \geq 10.0 \text{ V}$ Size = 0805 Is selected 2 items

	Order Code	Series	Size	Sp...	T...	Description	C	V _R	R _{iso}	$\Delta C(V_{DC-Bias}) @ 3.30 \text{ V}$	DF	Q	Length	Width
✓	885012107010	WCAP-CSGP	0805	PDF	X5R	X5R0805106M010DFCT10000	10.0 μF	10.0 V	> 10.0 M Ω	-19.8 %	10 %		2.00 mm	1.25 mm
✓	885012107011	WCAP-CSGP	0805	PDF	X5R	X5R0805226M010DFCT10000	22.0 μF	10.0 V	> 2.00 M Ω	-38.0 %	10 %		2.00 mm	1.25 mm

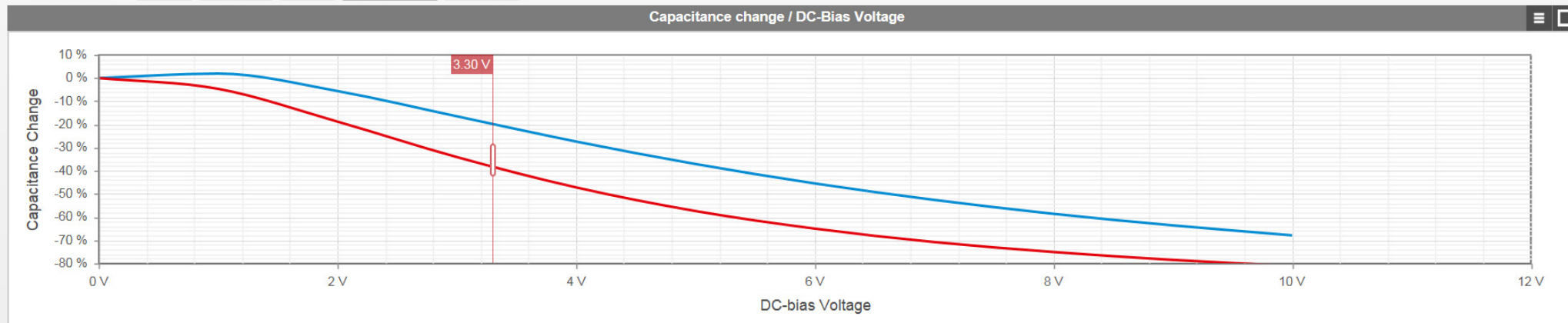
885012107010
WCAP-CSGP · X5R · 0805
10.0 μF · 10.0 V

885012107011
WCAP-CSGP · X5R · 0805
22.0 μF · 10.0 V

Drop Order Codes
in the tray to add

Add to Cart

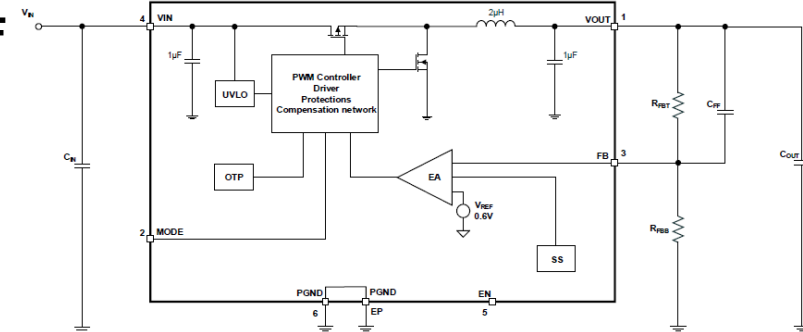
More...

Show Panel: Z vs. F ESR vs. F C vs. F ΔC vs. V_{DC-Bias} ΔC vs. V_{AC}

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Essential Step 3 - Select output capacitor

- Recommended is additional 10uF to the internal 1uF
- Main selection criteria
 - Required output voltage ripple



$$V_{OUT\ ripple} = \Delta I_L \cdot ESR + \Delta I_L \cdot \frac{1}{8 \cdot f_{SW} \cdot C_{OUT}}$$

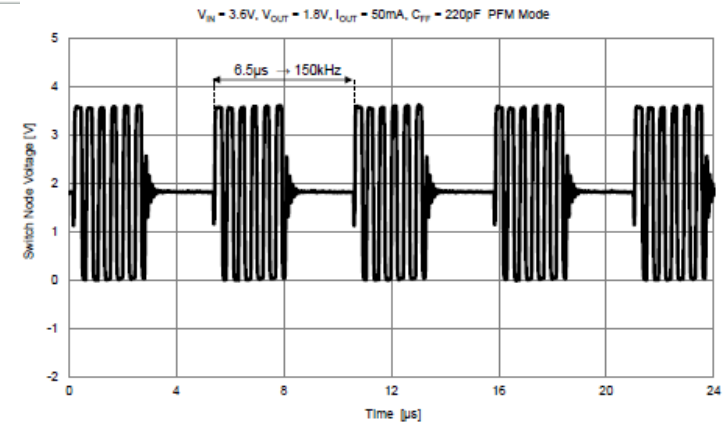
$$\Delta I_L = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{f_{SW} \cdot L \cdot V_{IN}}$$

- Use low ESR parts like MLCC and/or Polymer capacitors
- Consider DC-Bias behavior for MLCC

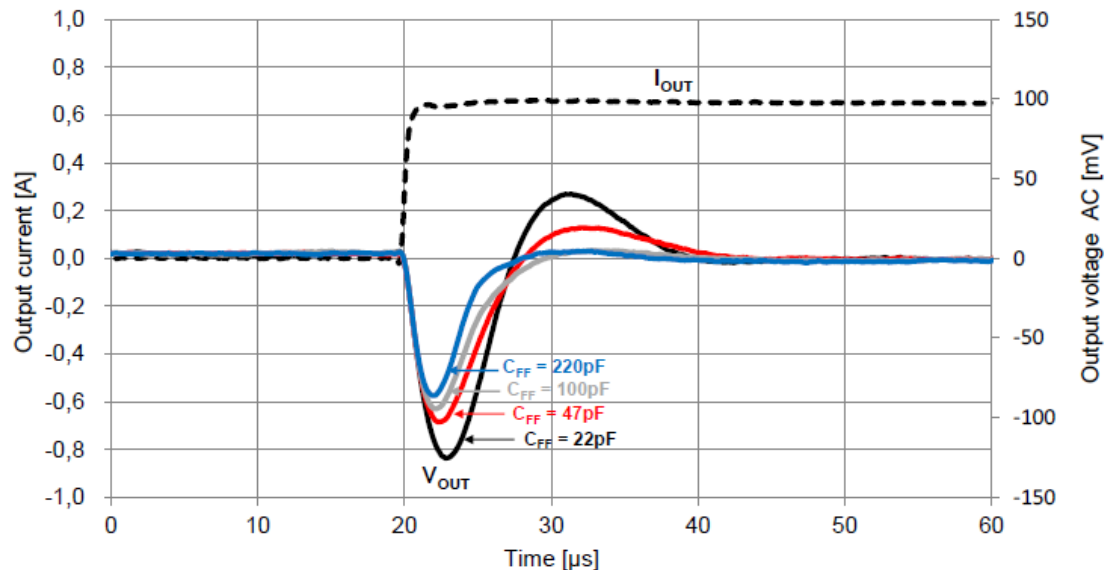


Essential Step 4 - Select the feed-forward capacitor (C_{ff})

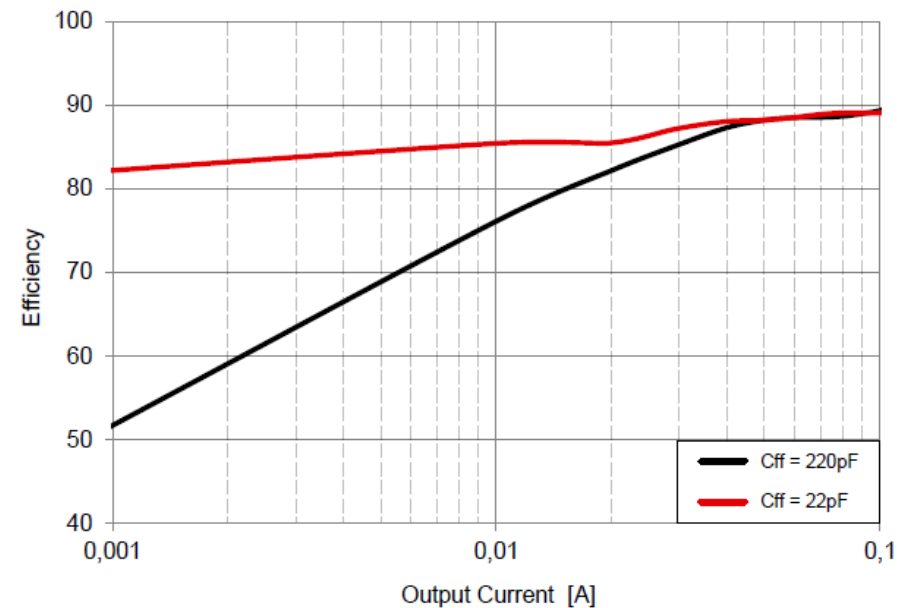
- The Feed-forward capacitors influences
 - Transient response
 - Over and undershoots
 - Efficiency in low power mode
- Typically an 22pF type provides best compromise



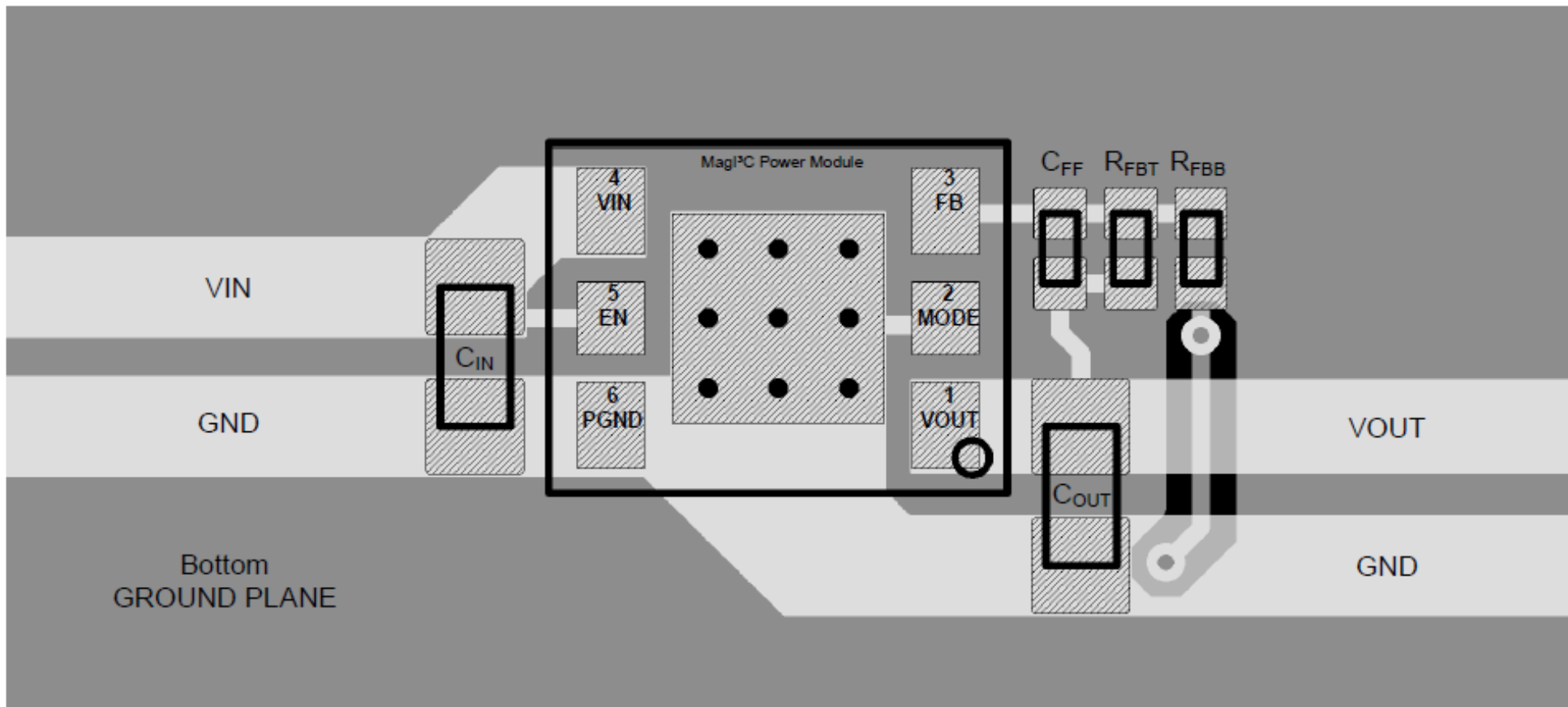
Load Transient $V_{IN} = 3.6V$, $V_{OUT} = 1.8V$, from 0A to 600mA, $T_A = 25^\circ C$



$V_{IN} = 3.6V$, $V_{OUT} = 1.8V$, $T_A = 25^\circ C$



Layout recommendation

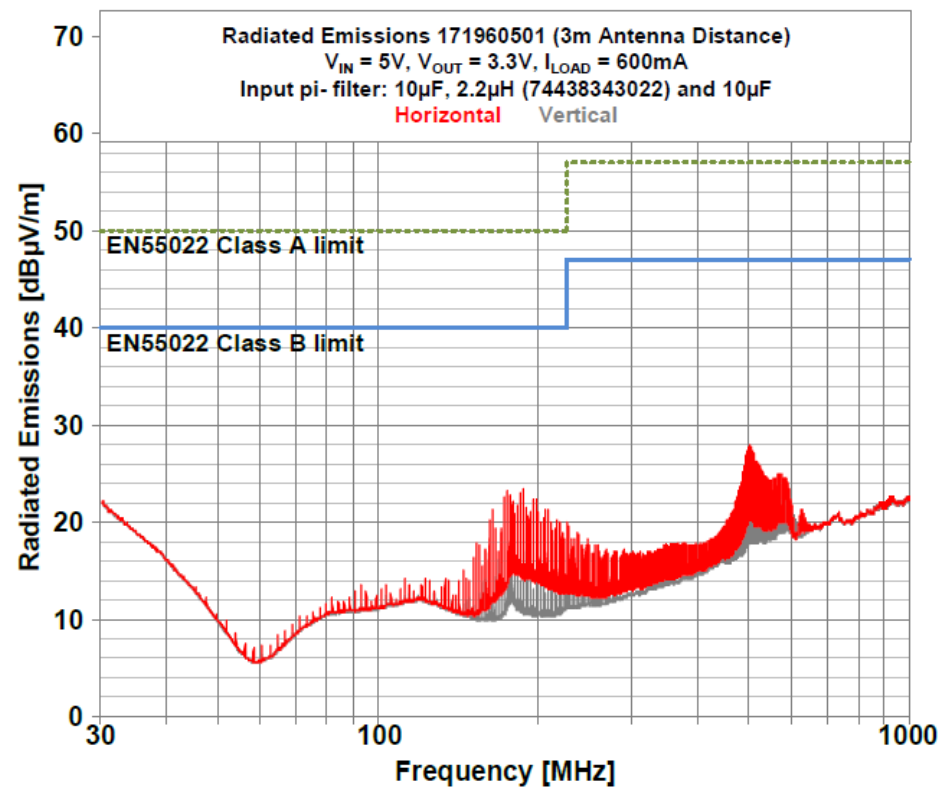


Bottom layer Top layer Pads

EMC considerations

RADIATED EMISSIONS EN55022 (CISPR-22) CLASS B COMPLIANT

Measured with module on Eval Board 178960501 at 3m antenna distance.



RedExpert – Online selection and simulation tool



REDEXPERT®

MAGiC POWER MODULES

APPLICATIONS

HOW TO

18 ITEMS

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ALEX

Order Code	Series	Sp...	V _{in}	V _{in,min}	V _{in,max}	V _{out,min}	V _{out,max}	I _{out,max}	P _{out}	Package	Architecture	Adjustable Switching Frequency	Externally adjustable Soft-Start	Power Good	Adjustable UVLO	Tracking	Sync
171011801	VDRM			4.00 V	18.0 V	0.800 V	17.0 V	1.00 A	17.0 W	LGA-16EP	CM						
171021801	VDRM			4.00 V	18.0 V	0.800 V	17.0 V	2.00 A	34.0 W	LGA-16EP	CM						
171031801	VDRM			4.00 V	18.0 V	0.800 V	17.0 V	3.00 A	51.0 W	LGA-16EP	CM						
171960501	VDMM			2.70 V	5.50 V	0.600 V	5.50 V	600 mA	3.20 W	LGA-6EP	VM						
171010601	VDRM			6.00 V	42.0 V	0.800 V	6.00 V	1.00 A	6.00 W	TO263-7EP	COT	✓			✓		
171030601	VDRM			6.00 V	42.0 V	0.800 V	6.00 V	3.00 A	18.0 W	TO263-7EP	COT	✓			✓		
171021501	VDRM			7.00 V	50.0 V	2.50 V	15.0 V	2.50 A	37.5 W	QFN-41	CM	✓	✓	✓	✓	✓	✓
171012401	VDRM			6.00 V	42.0 V	5.00 V	24.0 V	1.00 A	24.0 W	TO263-7EP	COT	✓	✓		✓		

Show parts that are

☐ Adjustable Switching Frequency

☐ Not Adjustable Switching Frequency

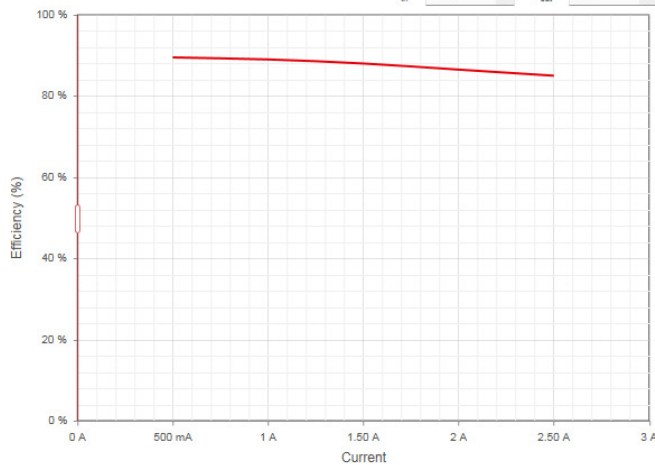
Reset Continue

Drop Order Codes in the tray to add

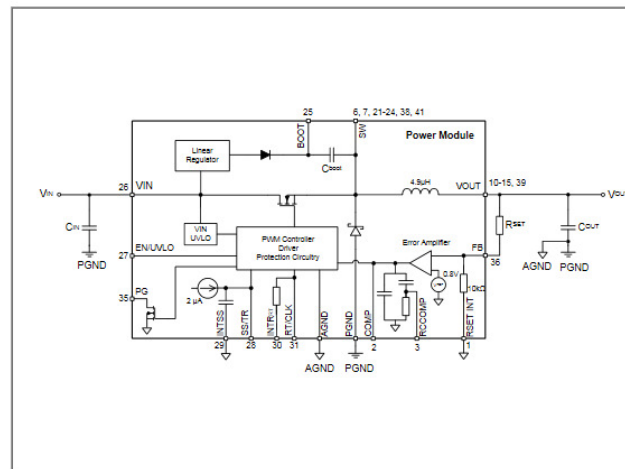
Add to Cart

More...

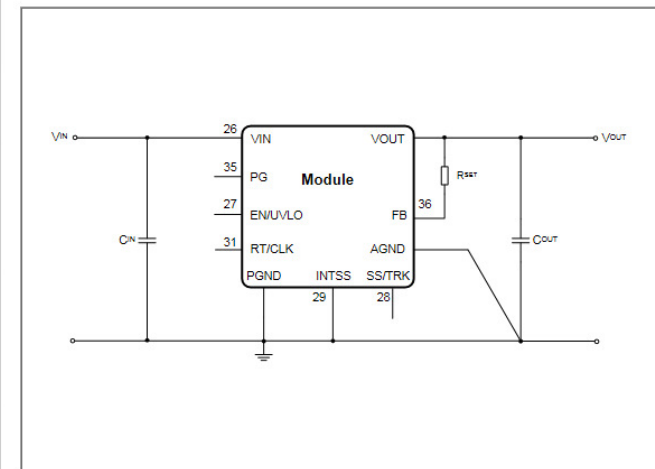
Efficiency / Current

V_{in} = 12 V V_{out} = 5 V

Block Diagram



Typical Circuit Diagram



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DC/DC Converter

- > ANP006: Influence of control loop by an Outputfilter
- > ANP008: Negative input resistance of switching regulators
- > ANP009: Loss-Free Filtered
- > ANP010: Measurement of the interference voltage on DC/DC switching regulators
- > ANP013: Quiet switching controller for audio amplifiers
- > ANP017: Designing Low-cost, Multiple Output DC/DC Converters
- > ANP044: Impact of the layout, components and filters on the EMC of modern DC/DC switching controllers

Filter

- > ANP004: Balunless measurement of mixed-mode scattering parameters
- > ANP005: EMC Filter for DC/DC switching controller optimized
- > ANP015: Line filter – The last barrier in the switch mode power supply

Interfaces

- > ANP002: The Protection of USB 2.0 Applications
- > ANP024: The USB Interface from EMC Point of View

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WEBENCH® Designer

Power

FPGA/PLD

Sensors

LED

Enter your power supply requirements:
Min: 14.0 V Max: 22.0 V
Vin: 14.0 V Vout: 22.0 V

> Simulate your circuit

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COMPONENT SEARCH ENGINE

Date 17.06.2016 Technical Academy Internal Use | Power Day Advanced Switch Basics

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Benefits & Performance Overview

It's MagI³C



Best Thermal Performance

Integrated inductor

Saves up to 75% Design In time

Tracking Function

Efficiency up to 97% &
Adj. Switching Frequency

Sync. Function

Power Good Function

High Power in Small Package
- Delivers up to 5A/100mm²

Soft Start
(to reduce inrush currents)

Low Ripple for quite circuits (<20mV)

Protections:
Under Voltage Lockout, Short
Circuit, Over temperature

EMC compliant to EN55022 class B



14 juni 2018
1931 Congrescentrum Den Bosch

**POWER
ELECTRONICS** 2018



Any questions?

