

171960501

MagI³C® Power Module

VDMM – Variable Step Down MicroModule

2.7V – 5.5V / 0.6A / 0.6V – 5.5V Output



DESCRIPTION

The VDMM 171960501 MagI³C MicroModule provides a fully integrated DC-DC power supply including the controller IC with integrated MOSFETs, compensation and shielded inductor in one package.

The 171960501 offers high efficiency and delivers up to 0.6A of output current. It operates with an input voltage from 2.7V to 5.5V and is designed for small solution size.

The selectable forced PWM or PFM/PWM mode allows for the choice between high efficiency and low output voltage ripple at light load.

It is available in an LGA-6EP package (3.2 x 2.5 x 1.6mm).

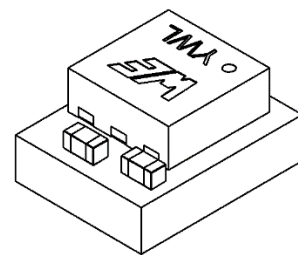
This MicroModule has integrated protection circuitry that guards against thermal overstress with thermal shutdown and protects against electrical damage using overcurrent, short-circuit and undervoltage protections.

TYPICAL APPLICATIONS

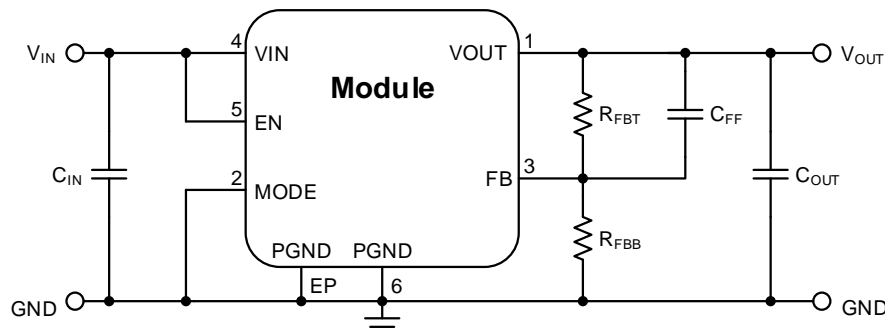
- General point of load power supply for low power systems
- Replacement of linear regulators
- DSP and FPGA power supply auxiliary voltages
- Portable instruments
- Battery powered equipment

FEATURES

- Peak efficiency up to 96%
- Current capability up to 0.6A
- Input voltage range: 2.7V to 5.5V
- Output voltage range: 0.6V to 5.5V
- 30 μ A typical quiescent current
- Integrated shielded inductor
- Integrated input and output auxiliary capacitors
- Low output voltage ripple: 10mV typ.
- Output voltage accuracy over temperature: 2% max.
- Fixed switching frequency: 2.25 MHz
- Voltage Mode control
- Synchronous operation
- Selectable forced PWM or PFM/PWM mode
- Undervoltage lockout (UVLO)
- Internal soft-start
- Thermal shutdown
- Short-circuit protection
- Cycle-by-cycle current limit
- RoHS und REACH compliant
- Operating ambient temperature up to 85°C
- No output current derating within the operating temperature range
- Operating junction temp. range: -40 to 125°C
- Complies with EN55032 (CISPR-32) class B radiated emissions standard



TYPICAL CIRCUIT DIAGRAM

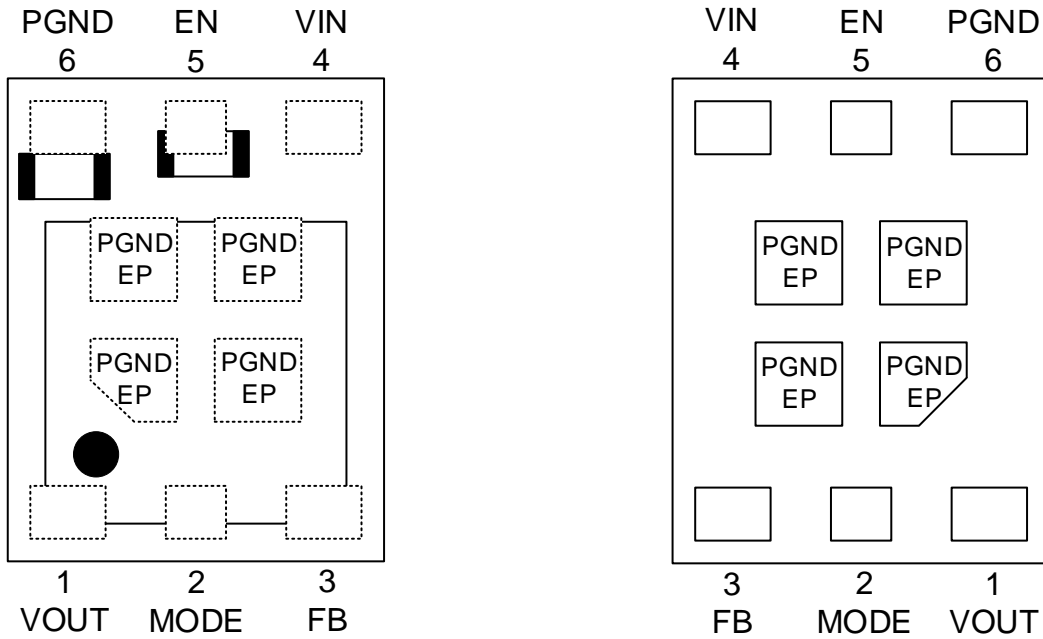


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PACKAGE



Top View

Bottom View

MARKING DESCRIPTION

MARKING	DESCRIPTION
WE	Würth Elektronik tradename
Y	Year
W	Calendar week
L	Lot number



PIN DESCRIPTION

SYMBOL	NUMBER	TYPE	DESCRIPTION
VOUT	1	Power	Output voltage. Place output capacitor(s) as close as possible to VOUT and GND. For best thermal performance use copper plane(s) at this pin.
MODE	2	Input	Forced PWM or PFM/PWM mode selection pin. Setting this pin high, the forced PWM mode is selected for any load current. Setting this pin low, PFM/PWM is selected, with the transition happening automatically between the two operations according to the load. This pin must not be left floating.
FB	3	Input	Feedback pin. This pin must be connected to the external resistor divider (between VOUT and GND) to adjust the output voltage.
VIN	4	Power	Input voltage. Place the input capacitor(s) as close as possible to VIN and GND.
EN	5	Input	Enable pin. Setting this pin high enables the device, while setting this pin low shuts down the device. This pin must not be left floating.

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PGND	6	Power	Power ground. It must be connected to the ground plane of the board and the exposed pads of the power module.
PGND	EP	Exposed Pads	Exposed pads. These pins are internally electrically connected to PGND. It is recommended to connect them to the ground plane for device heat dissipation

ORDERING INFORMATION

ORDER CODE	SPECIFICATIONS	PACKAGE	PACKAGING UNIT
171960501	0.6A / 0.6-5.5Vout version	LGA-6EP	Tape and reel with 2000 pieces
178960501	0.6A / 0.6-5.5Vout version	Eval Board	Box with 1 piece

SALES INFORMATION

SALES CONTACTS
Würth Elektronik eiSos GmbH & Co. KG EMC & Inductive Solutions Max-Eyth-Str. 1 74638 Waldenburg Germany Tel. +49 (0) 7942 945 0 www.we-online.com/powermodules Technical support: powermodules@we-online.com

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ABSOLUTE MAXIMUM RATINGS

Caution:

Exceeding the listed absolute maximum ratings may affect the device negatively and may cause permanent damage.

SYMBOL	PARAMETER	LIMITS		UNIT
		MIN ⁽¹⁾	MAX ⁽¹⁾	
V _{IN}	Input voltage pin	-0.3	6	V
V _{OUT}	Output voltage pin	-0.3	V _{IN}	V
FB	Feedback pin	-0.3	V _{IN}	V
EN	Enable pin	-0.3	V _{IN} +0.3	V
MODE	Mode pin	-0.3	V _{IN}	V
T _{storage}	Assembled, non-operating storage temperature	-65	150	°C
V _{ESD}	ESD voltage (HBM), V _{IN} and V _{OUT} vs. PGND (C=100pF, R= 1.5kΩ) according to AEC-Q100-002 ⁽³⁾	-4	4	kV
V _{ESD}	ESD voltage (HBM), EN, MODE and FB vs. PGND (C=100pF, R= 1.5kΩ) according to AEC-Q100-002 ⁽³⁾	-2	2	kV

OPERATING CONDITIONS

Operating conditions are conditions under which the device is intended to be functional. All values are referenced to GND.

MIN and MAX limits are valid for the recommended ambient temperature range of **-40°C to 85°C**. Typical values represent statistically the utmost probable values at the following conditions: V_{IN} = 5V, V_{OUT} = 1.8V, C_{IN} = C_{OUT} = 10μF X5R 0805 10V ceramic (external), unless otherwise stated.

SYMBOL	PARAMETER	MIN ⁽¹⁾	TYP ⁽²⁾	MAX ⁽¹⁾	UNIT
V _{IN}	Input voltage	2.7	-	5.5	V
V _{OUT}	Output voltage	0.6	-	5.5	V
T _A	Ambient temperature range	-40	-	85 ⁽⁴⁾	°C
T _J	Junction temperature range	-40	-	125	°C
I _{OUT}	Output current			0.6	A

THERMAL SPECIFICATIONS

SYMBOL	PARAMETER	TYP ⁽²⁾	UNIT
θ _{JA}	Junction-to-ambient thermal resistance ⁽⁵⁾	150	°C/W
T _{SD}	Thermal shutdown, rising	150	°C
	Thermal shutdown hysteresis, falling	20	°C

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SYMBOL	PARAMETER	TEST CONDITIONS	MIN ⁽¹⁾	TYP ⁽²⁾	MAX ⁽¹⁾	UNIT
Output current						
I _{OC} P	Overcurrent protection	T _A = 25°C	-	2.4	-	A
Output accuracy						
V _{FB}	Reference voltage	T _A = 25°C	0.594	0.6	0.606	V
	Temperature variation	-40°C ≤ T _A ≤ 85°C	0.588	0.6	0.612	V
I _{FB}	Feedback pin input current		-100	-	100	nA
V _{OUT}	Line regulation	V _{IN} = 2.7V to 5V, T _A = 25°C, MODE = high	-	±0.2	-	%/V
	Load regulation	V _{IN} = 2.7V, V _{OUT} = 1.8V over I _{OUT} range, MODE = high, T _A = 25°C	-	±0.5	-	%/A
	Output voltage ripple	V _{IN} = 3.6V, V _{OUT} = 1.8V, I _{OUT} = 600mA MODE = high, T _A = 25°C ⁽⁶⁾	-	1	-	mV
V _{IN} = 3.6V, V _{OUT} = 1.8V, I _{OUT} = 50mA MODE = low, T _A = 25°C ⁽⁶⁾		-	30	-	mV	
C _{OUT}	External output capacitance		4.7	10	11 ⁽⁷⁾	μF
Switching frequency						
f _{SW}	Switching frequency	Forced PWM mode (see LIGHT LOAD OPERATION section)	1.65	2.25	2.76	MHz
Enable and undervoltage lockout						
V _{UVLO}	V _{IN} undervoltage threshold	V _{IN} decreasing	-	2.15	2.3	V
	V _{IN} undervoltage hysteresis	T _A = 25°C	-	0.15	-	V
V _{ENABLE}	Enable threshold	Enable high threshold	2	-	-	V
		Enable low threshold	0	-	0.3	V
I _{ENABLE}	Enable input current		-500	-	500	nA
MODE selection						
V _{MODE}	MODE threshold high	T _A = 25°C	V _{IN} -0.5	-	-	V
	MODE threshold low	T _A = 25°C	0	-	0.3	V
I _{MODE}	MODE current consumption	MODE = high, T _A = 25°C		30		nA
		MODE = low, T _A = 25°C		-40		nA
Soft-Start						
t _{SS}	Soft-start duration	T _A = 25°C (increasing to 90% of V _{OUT})		550		μs

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SYMBOL	PARAMETER	TEST CONDITIONS	MIN ⁽¹⁾	TYP ⁽²⁾	MAX ⁽¹⁾	UNIT
Efficiency						
η	Peak efficiency	$V_{IN} = 5V$, $V_{OUT} = 3.3V$, $I_{OUT} = 275mA$	-	93	-	%
		$V_{IN} = 3.6V$, $V_{OUT} = 3.3V$, $I_{OUT} = 150mA$	-	97	-	%
		$V_{IN} = 3.3V$, $V_{OUT} = 2.5V$, $I_{OUT} = 150mA$	-	93	-	%
Input quiescent/shutdown current						
I_{SD}	Shutdown current	$V_{ENABLE} = 0V$ $T_A = 25^\circ C$	-	0.1	1	μA
I_{IN}	No load input current	MODE = high, EN = high, switching with no load, $V_{OUT} = 1.8V$, $T_A = 25^\circ C$	-	6	-	mA
		MODE = low, EN = high, switching with no load, $V_{OUT} = 1.8V$, $T_A = 25^\circ C$	-	3	-	mA
I_Q	Quiescent current	MODE = low, EN = high no switching, $T_A = 25^\circ C$	-	30	-	μA

RoHS, REACH

RoHS directive		Directive 2011/65/EU of the European Parliament and the Council of June 8th, 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.
REACH directive		Directive 1907/2006/EU of the European Parliament and the Council of June 1st, 2007 regarding the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH).

PACKAGE SPECIFICATIONS

Weight	Molding compound	UL class	Certificate number
0.047g	None	Not applicable	Not applicable

171960501**MagI³C[®] Power Module**
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- (1) Min and Max limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods.
- (2) Typical numbers are valid at 25°C ambient temperature and represent statistically the utmost probable values assuming a Gaussian distribution.
- (3) The human body model is a 100pF capacitor discharged through a 1.5 kΩ resistor into each pin. Test method is per ESDA/JEDEC JTR001-01-12.
- (4) Depending on heat sink design, number of PCB layers, copper thickness and air flow.
- (5) Measured on a 101.5 x 114.5 mm one layer board, with 70μm (2 ounce) copper, no air flow, according to JESD51-9.
- (6) The industry standard for comparison of the output voltage ripple between switching regulators or modules requires a 10μF ceramic (sometimes additional 1μF ceramic in parallel) at the point of load where the voltage measurement is done using an oscilloscope with its probe and probe jack designed for low voltage/high frequency (low impedance) measurement. The external output capacitor required for operation of the MicroModule should be used for this purpose. The oscilloscopes bandwidth is limited at 20MHz.
- (7) If 11μF is to be used for the external output capacitance, it is recommended to use a 10μF capacitor (recommended part numbers 885012107014 or 885012107010) and a 1μF capacitor (recommended part numbers 885012106017 or 885012106010) in parallel.

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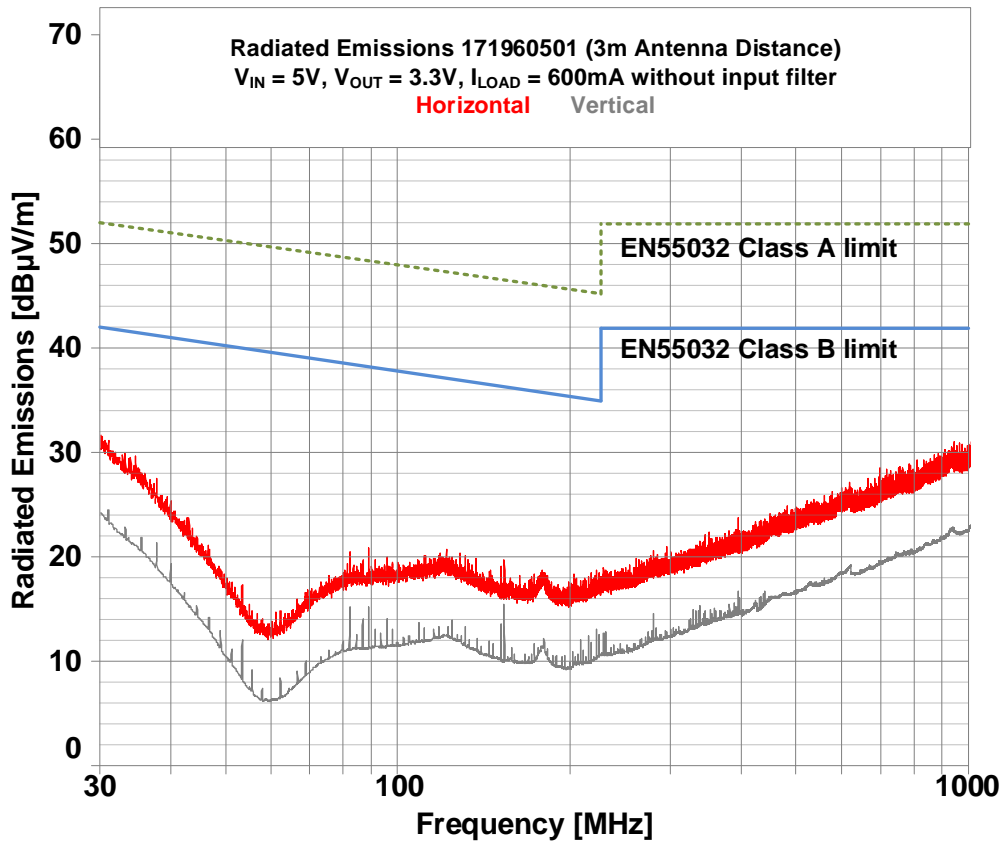
TYPICAL PERFORMANCE CURVES

If not otherwise specified, the following conditions apply: $V_{IN} = 5V$; $C_{IN} = C_{OUT} = 10\mu F$ X5R 0805 10V ceramic (external), $C_{FF} = 22pF$, $T_{AMB} = 25^{\circ}C$.

RADIATED EMISSIONS EN55032 (CISPR-32) CLASS B COMPLIANCE

Measured with a MicroModule on an Evaluation Board 178960501 in a fully anechoic room (FAR) at 3m antenna distance.

Radiated emissions measured without input filter

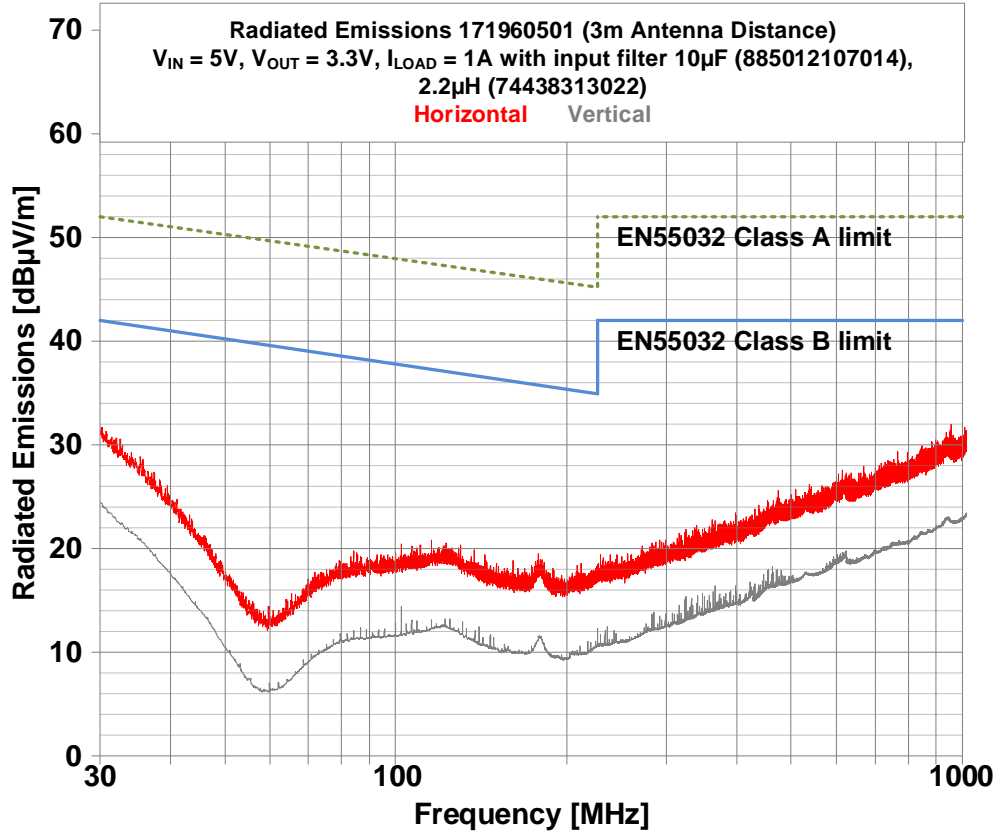


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Radiated emissions measured with input filter



The diagrams above refers to forced PWM mode. Nevertheless, the same results would be obtained in PFM/PWM mode because at a load current of 600mA the MicroModule will be in PWM mode regardless of the condition being applied to the MODE pin.

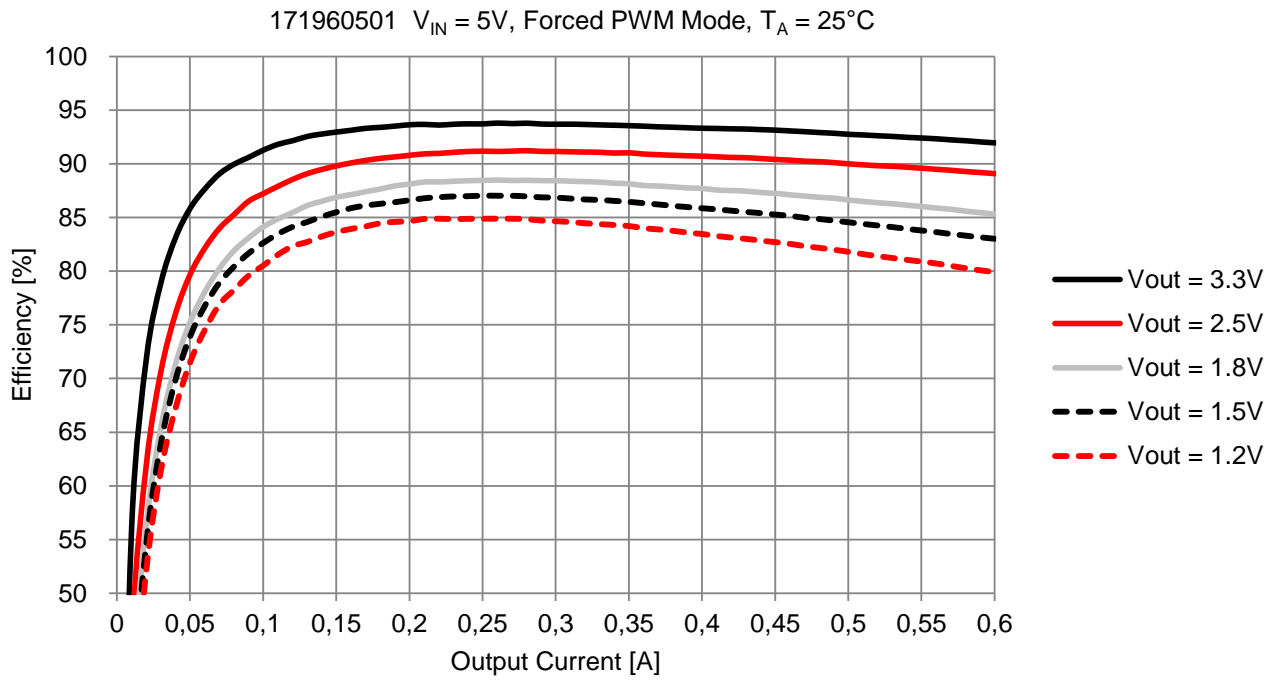
The diagram without an input filter includes the radiation emitted by 0.8m of horizontal input cable, 0.8m of vertical input cable and 1m of output cable that are exposed to the antenna. The diagram with an input filter shows the radiation of the MicroModule without the additional emissions from the input lines and is closer to an actual application environment for the MicroModule.

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EFFICIENCY

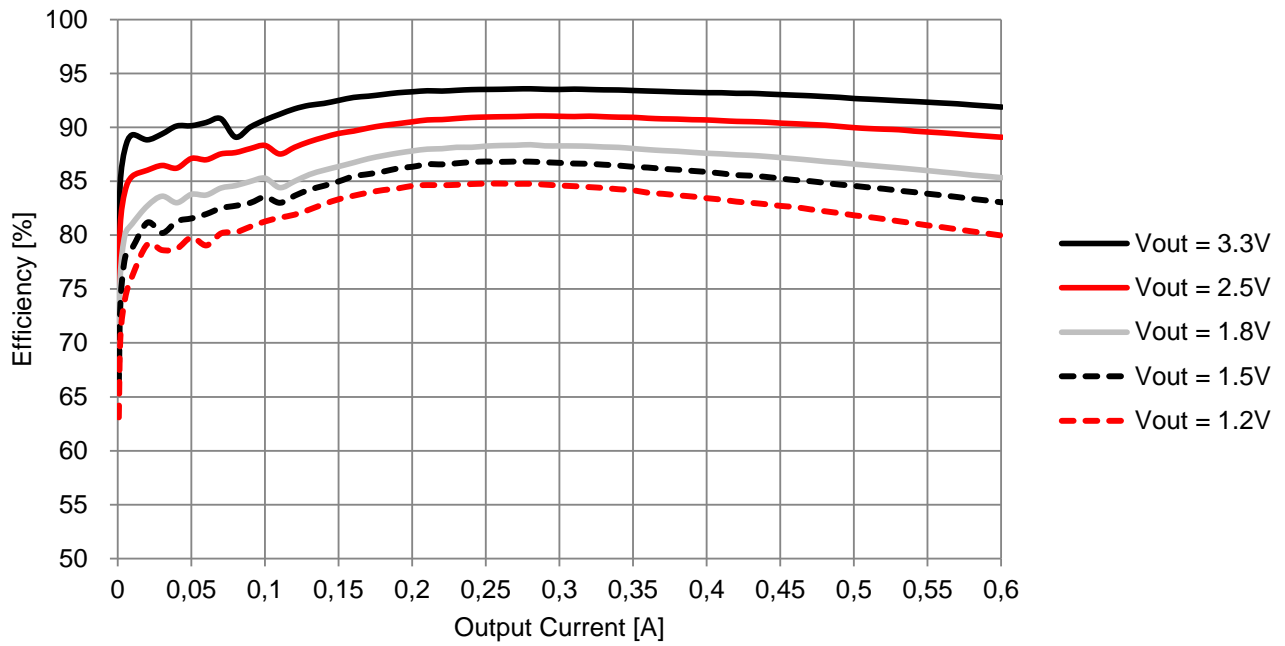


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171960501 $V_{IN} = 5V$, PFM/PWM Mode, $T_A = 25^\circ C$

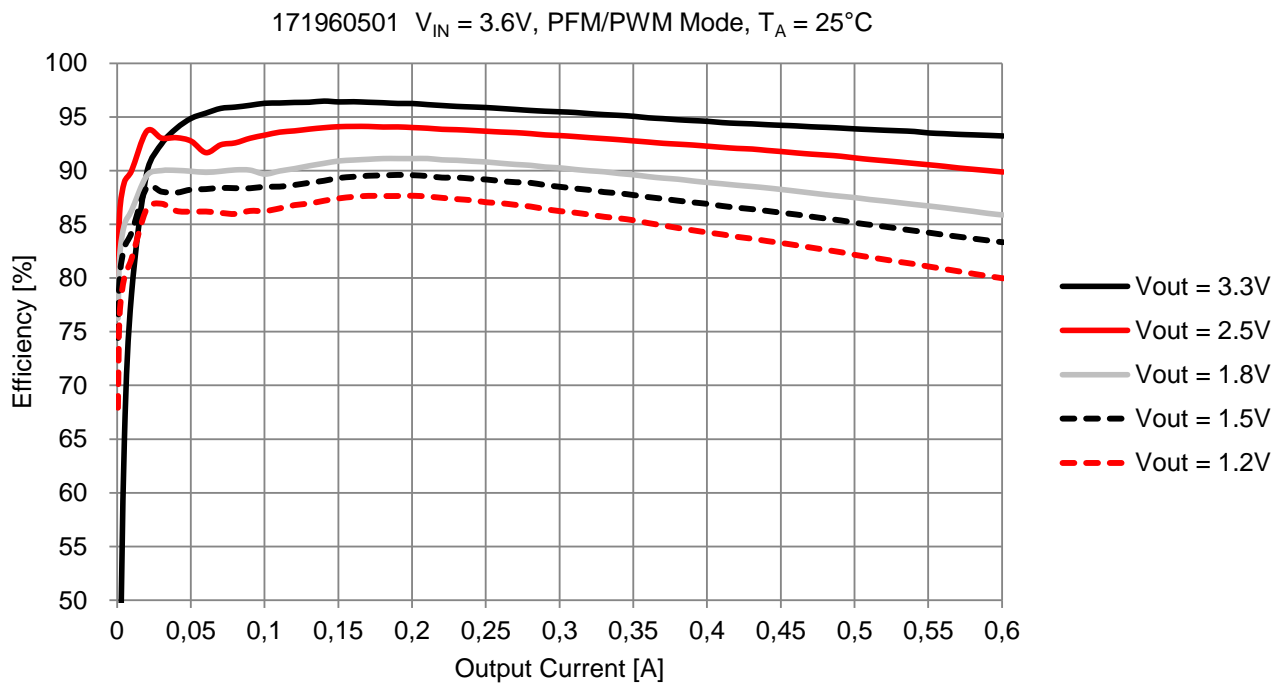
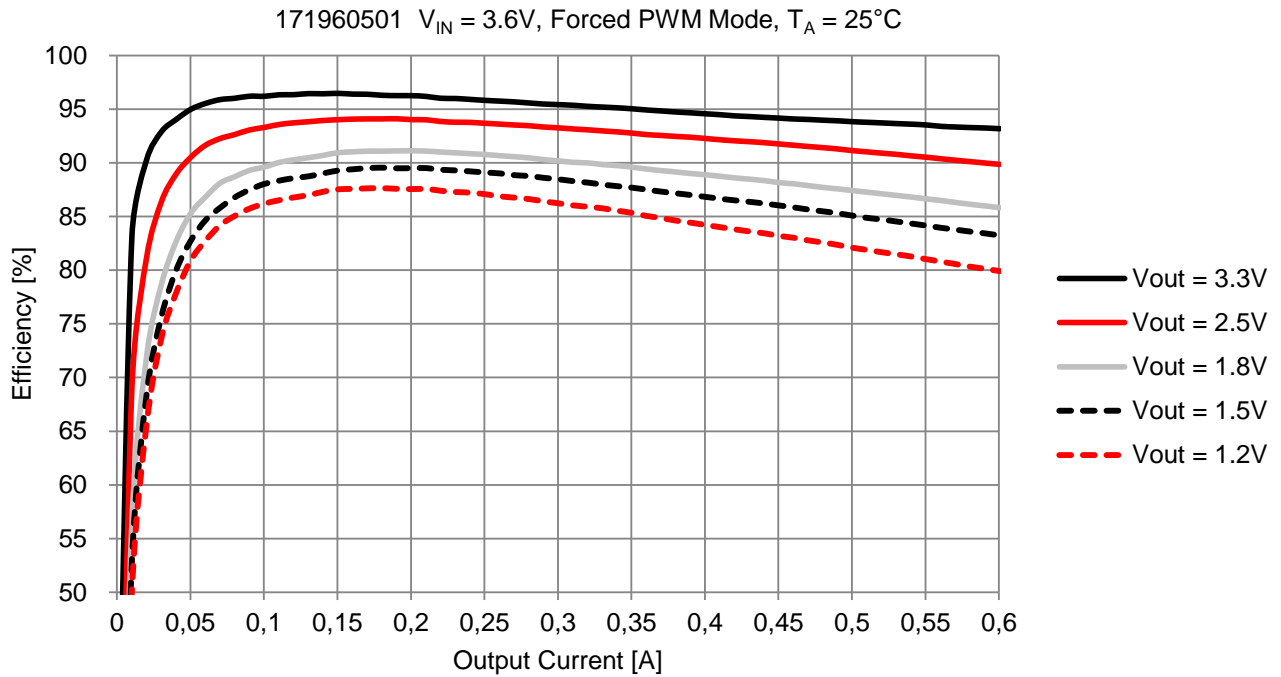


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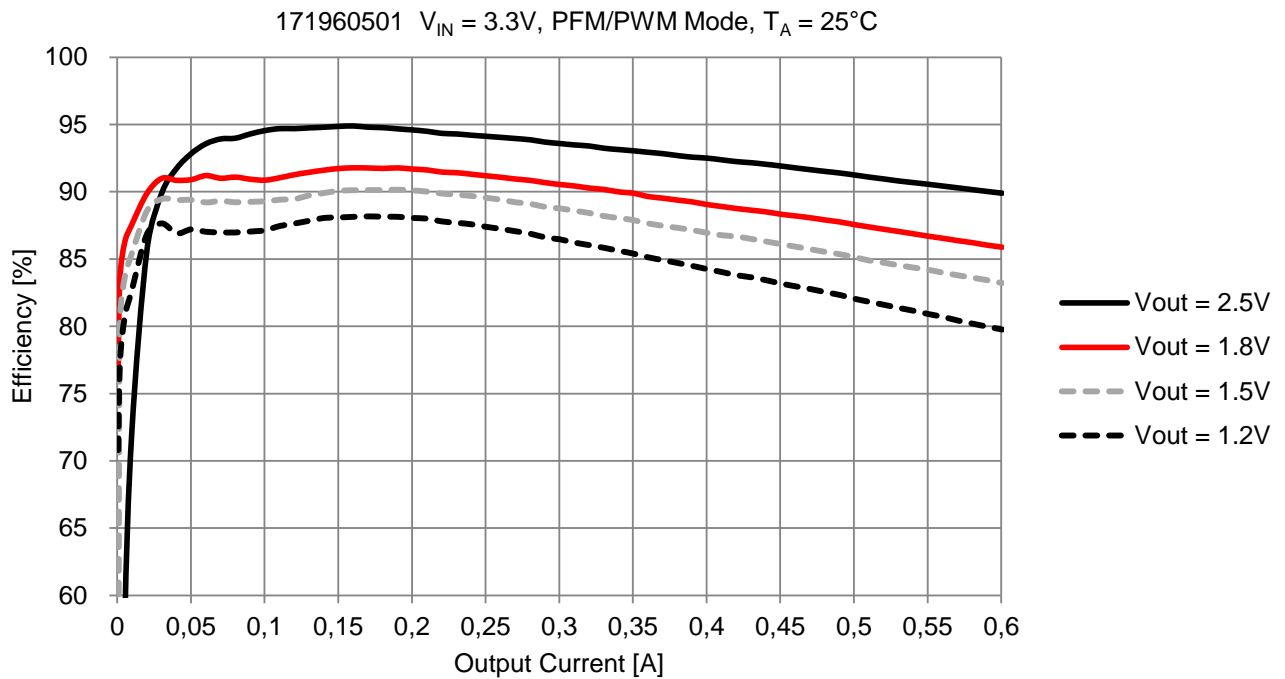
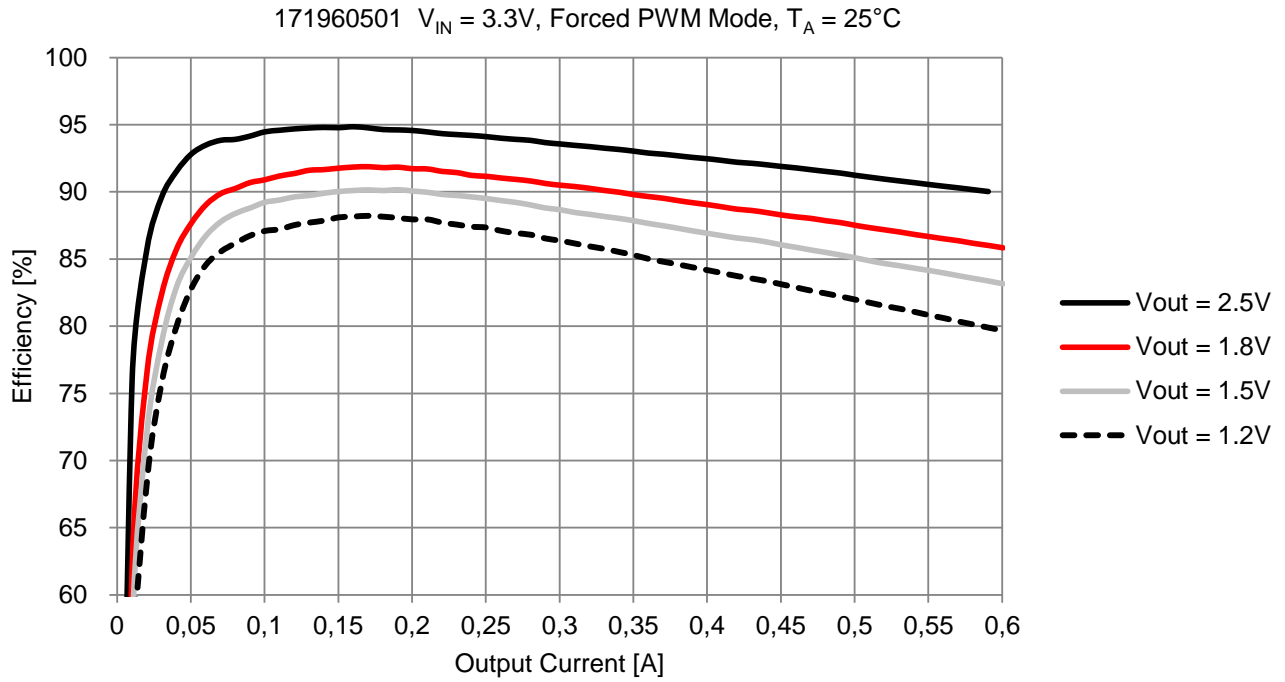


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EFFICIENCY



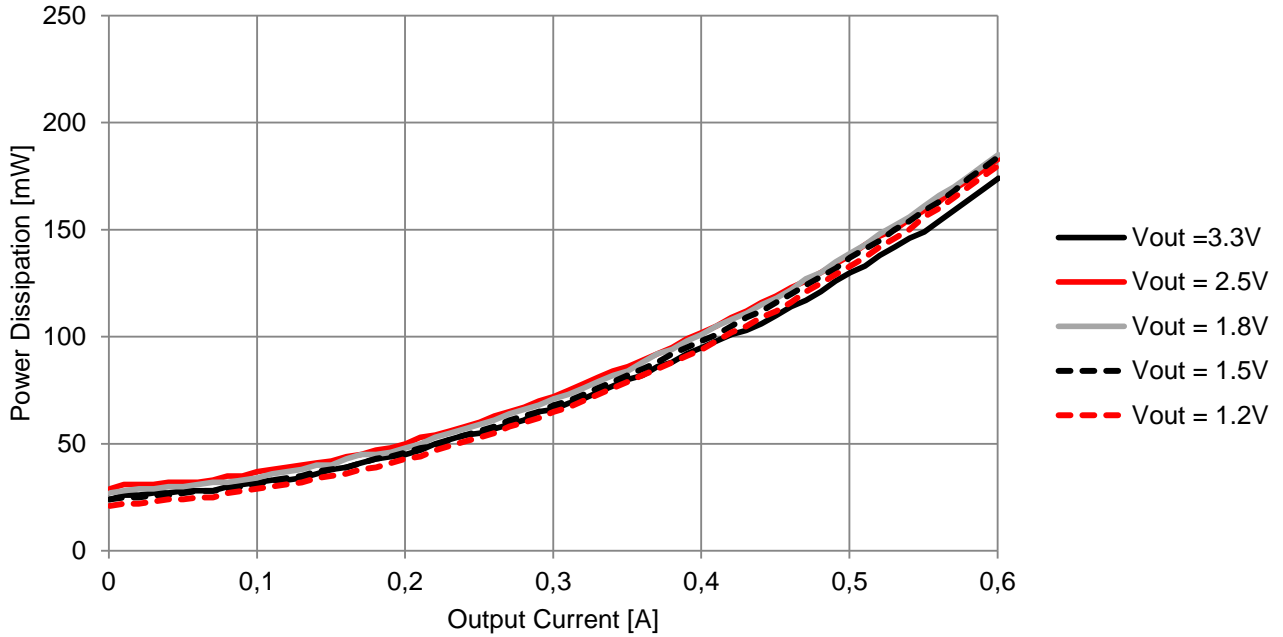
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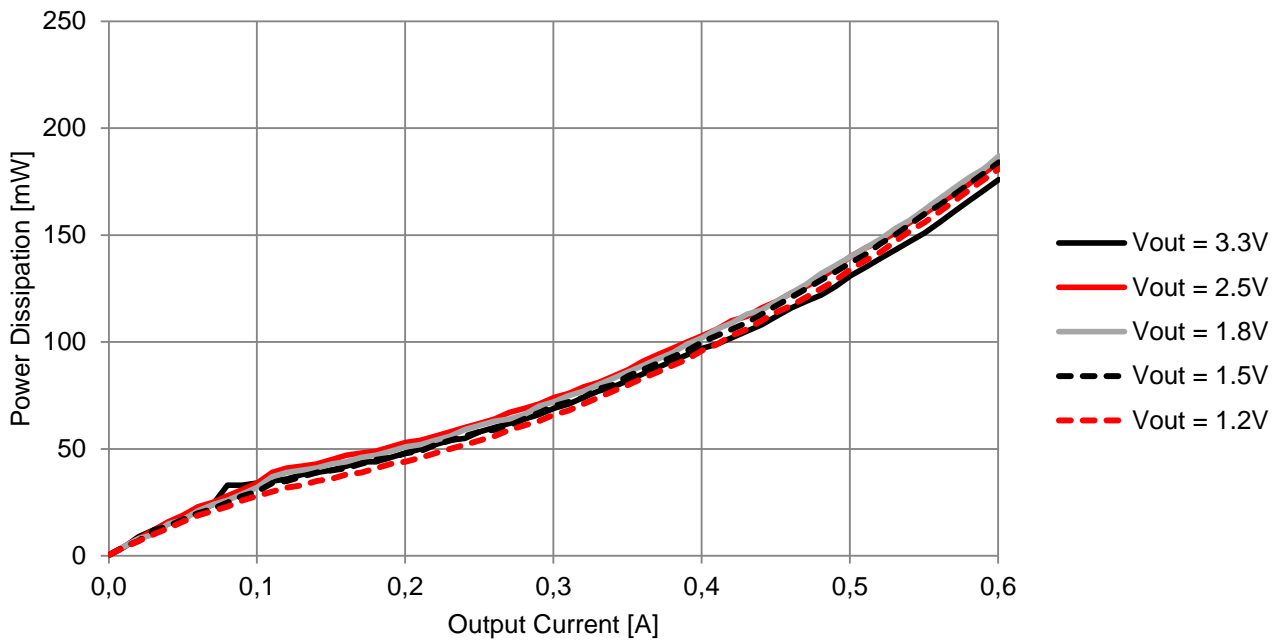


POWER DISSIPATION

171960501 $V_{IN} = 5V$, Forced PWM Mode, $T_A = 25^\circ C$



171960501 $V_{IN} = 5V$, PFM/PWM Mode, $T_A = 25^\circ C$



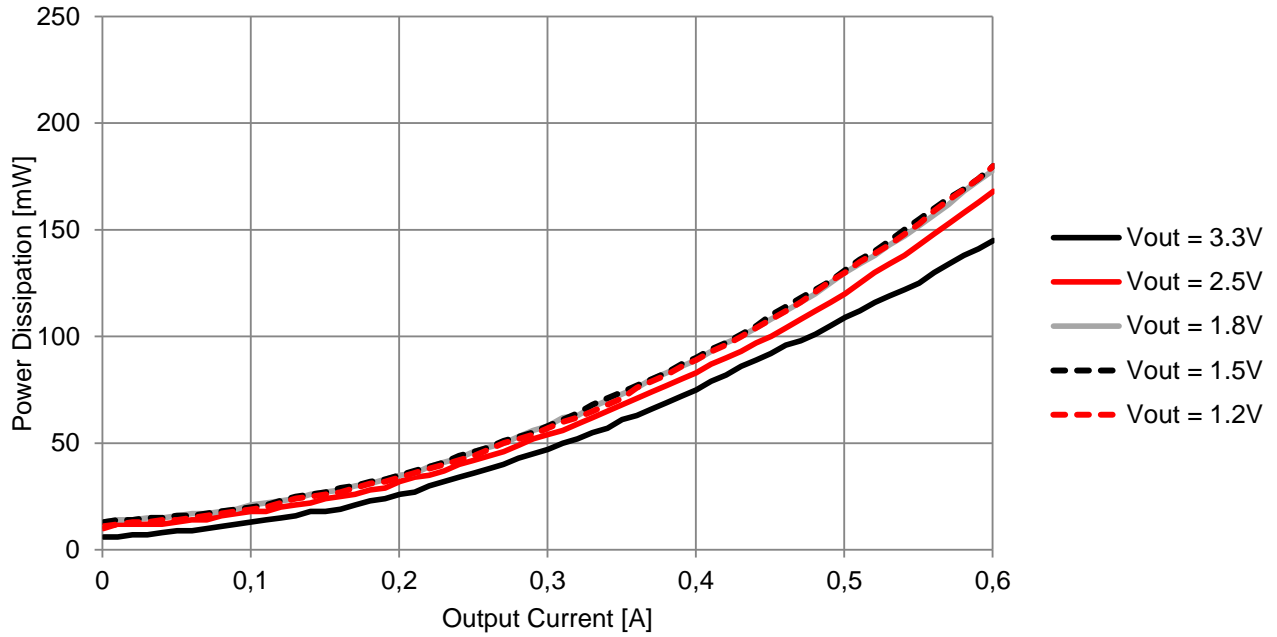
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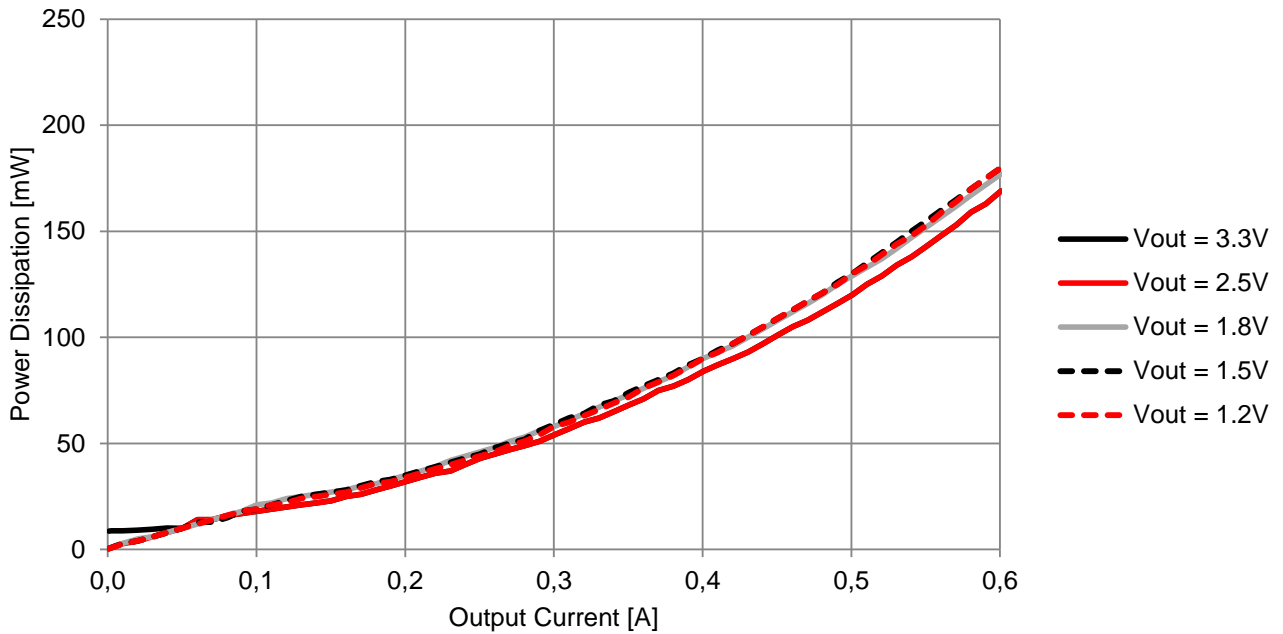


POWER DISSIPATION

171960501 $V_{IN} = 3.6V$, Forced PWM Mode, $T_A = 25^\circ C$



171960501 $V_{IN} = 3.6V$, PFM/PWM Mode, $T_A = 25^\circ C$



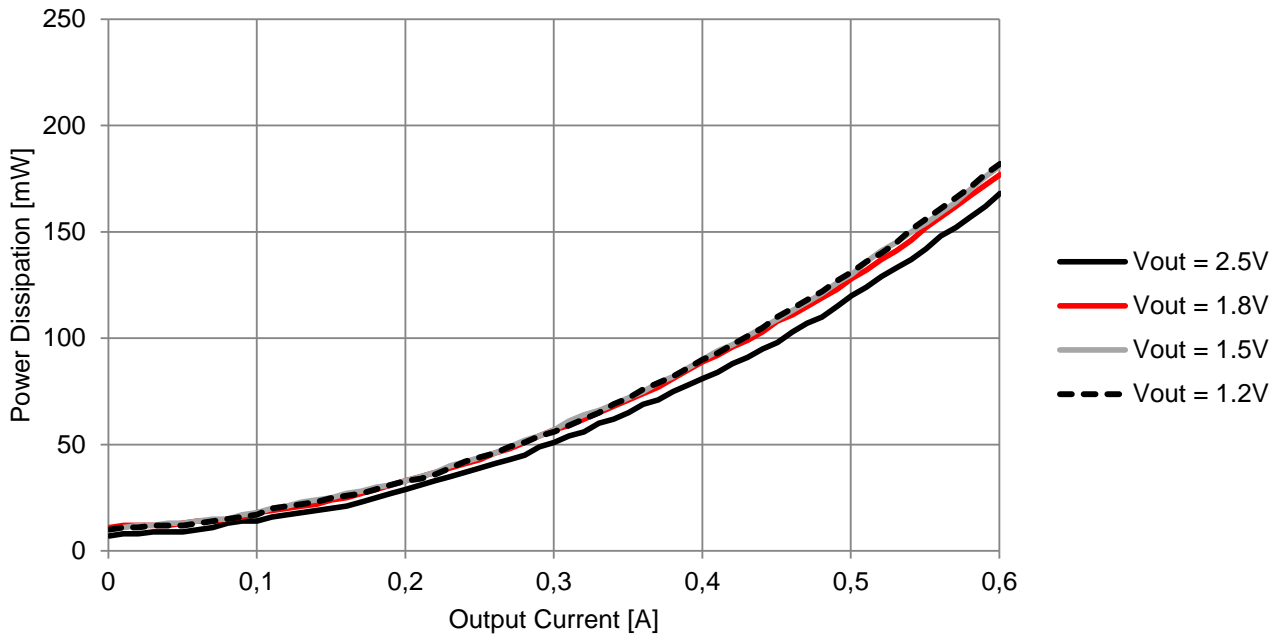
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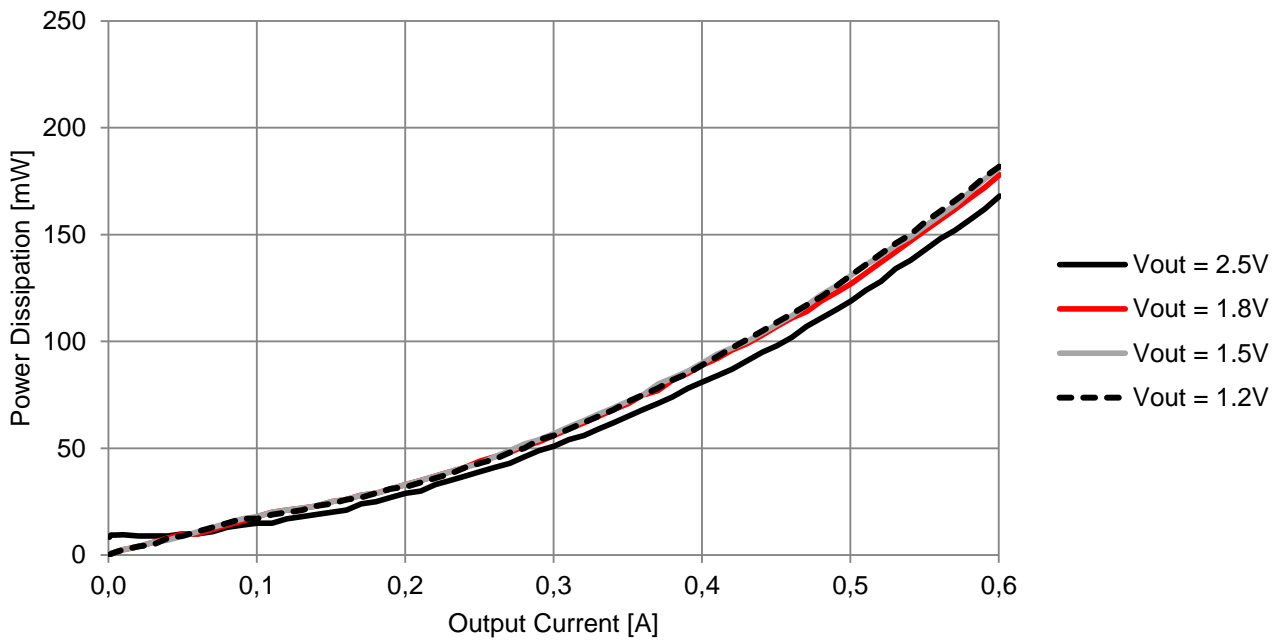


POWER DISSIPATION

171960501 $V_{IN} = 3.3V$, Forced PWM Mode, $T_A = 25^\circ C$



171960501 $V_{IN} = 3.3V$, PFM/PWM Mode, $T_A = 25^\circ C$



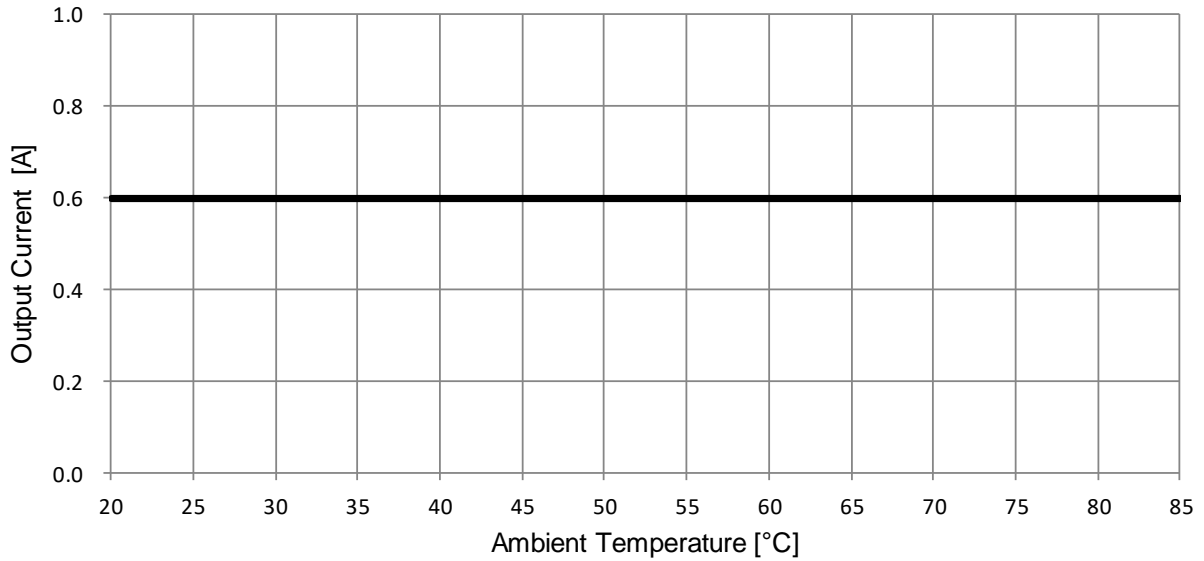
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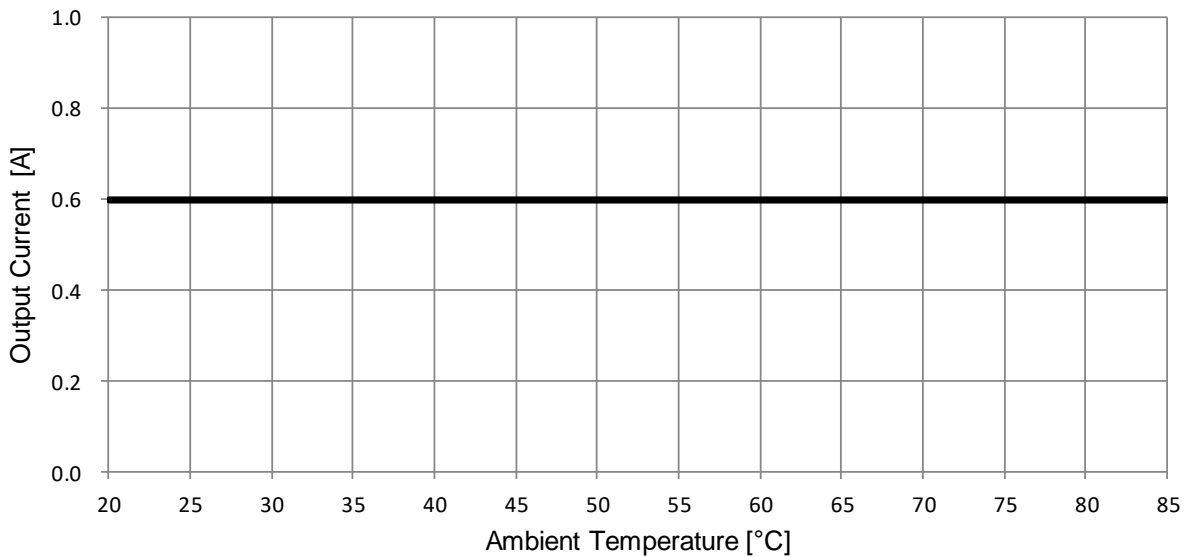


OUTPUT CURRENT DERATING

171960501 Current Thermal Derating
 $V_{in} = 5V, V_{out} = 3.3V, \text{PFMPWM Mode}$



171960501 Current Thermal Derating
 $V_{in} = 3.6V, V_{out} = 1.8V, \text{PFMPWM Mode}$



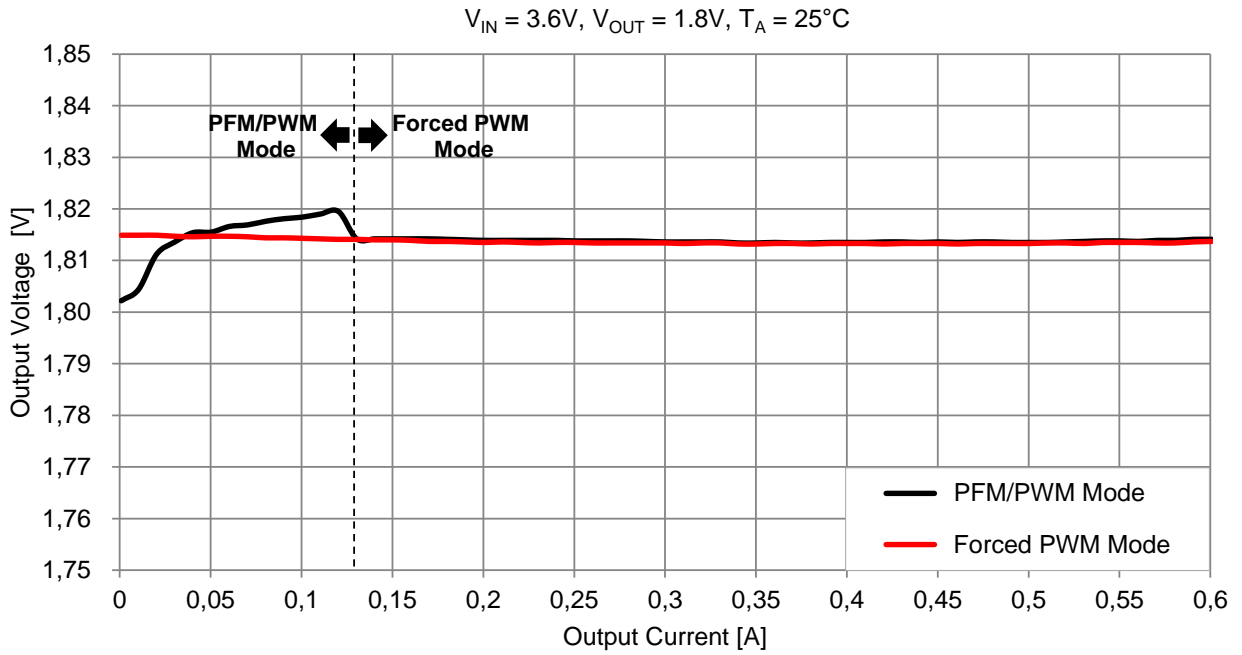
Note : see T_A limits in [Operating Conditions](#) on page 4.

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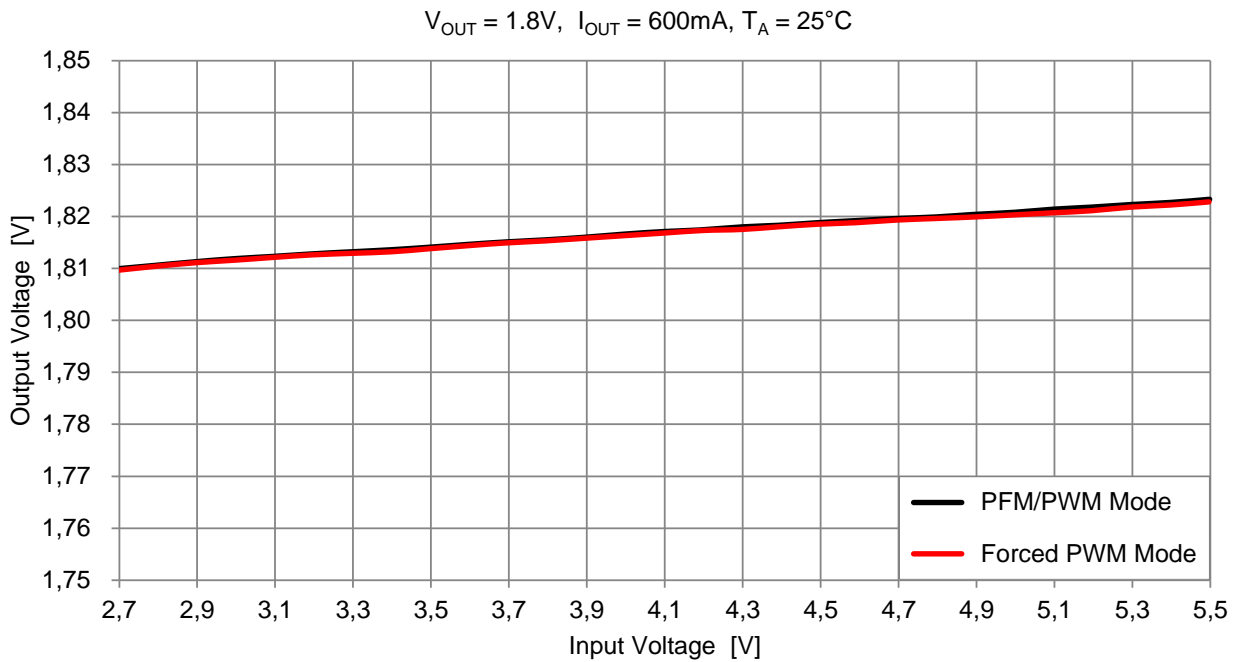
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LOAD REGULATION



LINE REGULATION

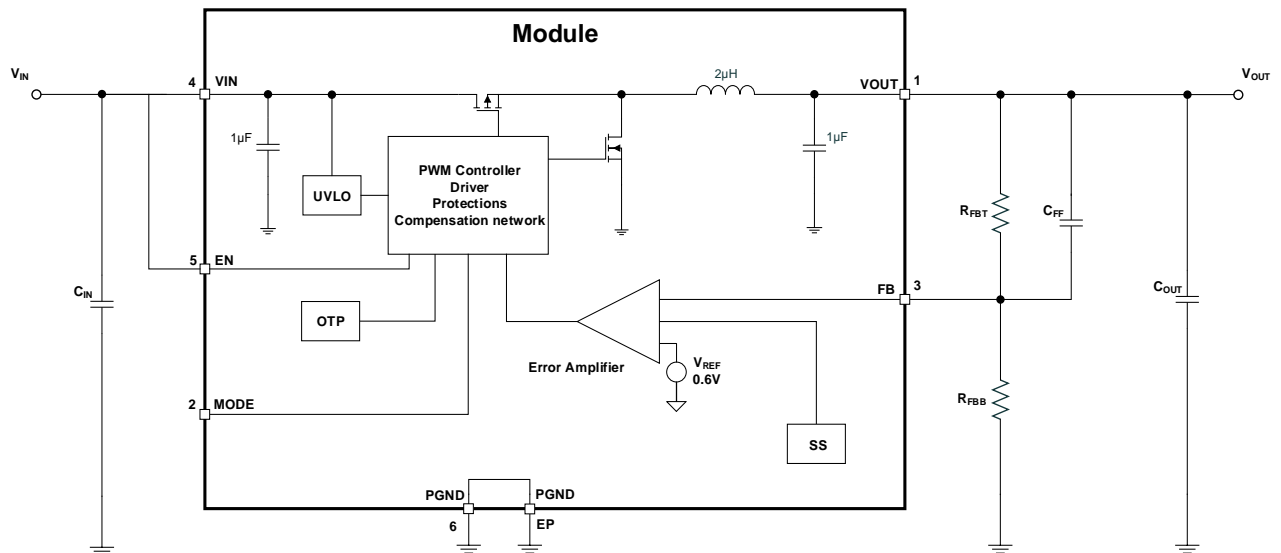


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BLOCK DIAGRAM



CIRCUIT DESCRIPTION

The MagI³C MicroModule 171960501 is a synchronous step down regulator with integrated MOSFETs and a power inductor. The control scheme is based on a Voltage Mode (VM) regulation loop.

Through the external resistor divider, a voltage proportional to V_{OUT} is fed to the FB pin of the MicroModule. This voltage is then compared with an internal 0.6V reference voltage. The signal resulting from this comparison is then used to drive the two power MOSFETs in accordance with the status of the MODE pin. When the Forced PWM mode is selected the switching frequency always remains constant at 2.25 MHz.

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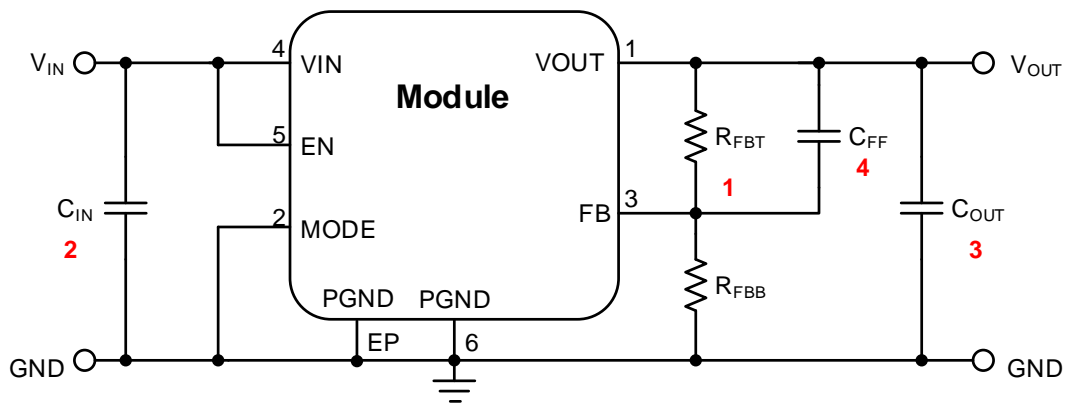


DESIGN FLOW

The next four simple steps will show how to select the external components to design the 171960501 application.

Essential Steps

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



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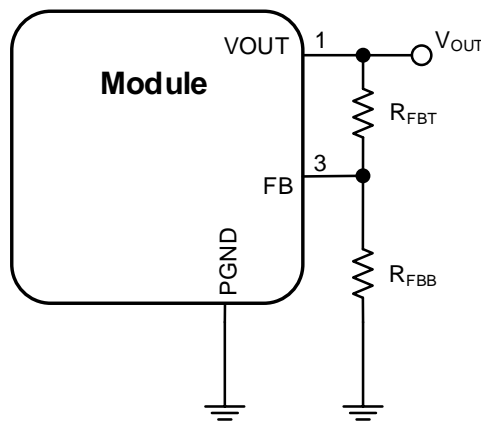
Step 1 Setting the output voltage (V_{OUT})

The output voltage is selected with an external resistor divider between V_{OUT} and GND (see circuit below). The voltage across the lower resistor of the divider is provided to the FB pin. The output voltage adjustment range is from 0.6V to 5.5V. The output voltage can be calculated according to the following formula:

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

One resistor must be chosen and then the other resistor can be calculated. For example, if R_{FBT} = 100kΩ then the resistance value of the lower resistor in the feedback network is indicated in the table below for common output voltages.

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



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Step 2 Select input capacitor (C_{IN})

An input capacitor of 1µF is integrated inside the 171960501 MagI³C MicroModule, ensuring good EMI performance and helping protect against possible voltage transients. Additional input capacitance is required externally to provide the high input pulse current. The external input capacitor must be placed as close as possible to the VIN and PGND pins. For this MagI³C MicroModule it is recommended to use an MLCC (Mutli Layer Ceramic Capacitor) of 10µF. Attention must be paid to the voltage and temperature deratings of the selected capacitor. The Würth Elektronik part numbers 885012107010 and 885012107014 have been experimentally verified to work with this MicroModule.

Step 3 Select output capacitor (C_{OUT})

The output capacitor should be selected in order to minimize the output voltage ripple and to provide a stable voltage at the output. It also affects the loop stability. An output capacitor of 1µF is integrated inside the 171960501 MagI³C MicroModule. An external MLCC of 10µF is recommended for all application conditions. Attention must be paid to the voltage and temperature deratings of the selected capacitor. The Würth Elektronik part numbers 885012107010 and 885012107014 have been experimentally verified to work with this MicroModule.

In general, the output voltage ripple can be calculated using the following equation:

$$V_{\text{OUT ripple}} = \Delta I_L \cdot \text{ESR} + \Delta I_L \cdot \frac{1}{8 \cdot f_{\text{SW}} \cdot C_{\text{OUT}}} \quad (2)$$

where ΔI_L is the inductor current ripple and can be calculated with the following equation:

$$\Delta I_L = \frac{V_{\text{OUT}} \cdot (V_{\text{IN}} - V_{\text{OUT}})}{f_{\text{SW}} \cdot L \cdot V_{\text{IN}}} \quad (3)$$

Example

In the section [OUTPUT VOLTAGE RIPPLE](#) on page 27 a ripple measurement is shown under the following conditions:

$$V_{\text{IN}} = 3.6\text{V}$$

$$V_{\text{OUT}} = 1.8\text{V}$$

$$L = 2\mu\text{H (internally fixed)}$$

$$f_{\text{SW}} = 2.25\text{MHz (internally fixed)}$$

$$C_{\text{OUT}} = 10\mu\text{F X5R 0805 10V (external, Würth Elektronik, part number 885012107010)} + 1\mu\text{F (internal)} = 11\mu\text{F}$$

Assuming a reduction of the capacitance of about 40% due to the frequency and voltage deratings, a remaining capacitance of around 10µF can be considered. Another assumption can be done for the ESR, which can be considered lower than 5mΩ. Using equations (2) and (3), the expected ripple is $V_{\text{OUT ripple}} \leq 2\text{mV}$, which matches the results obtained with the measurement.

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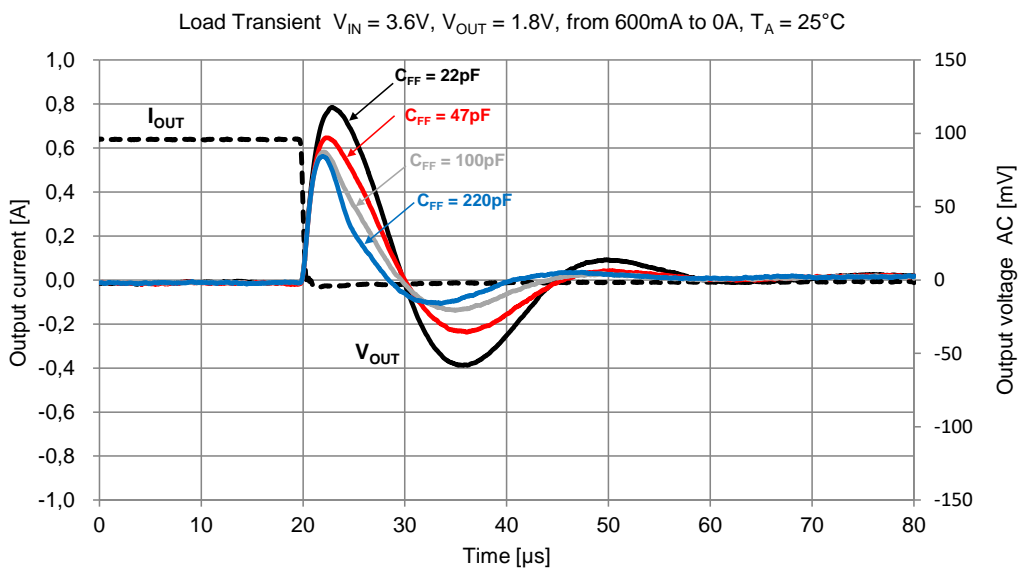
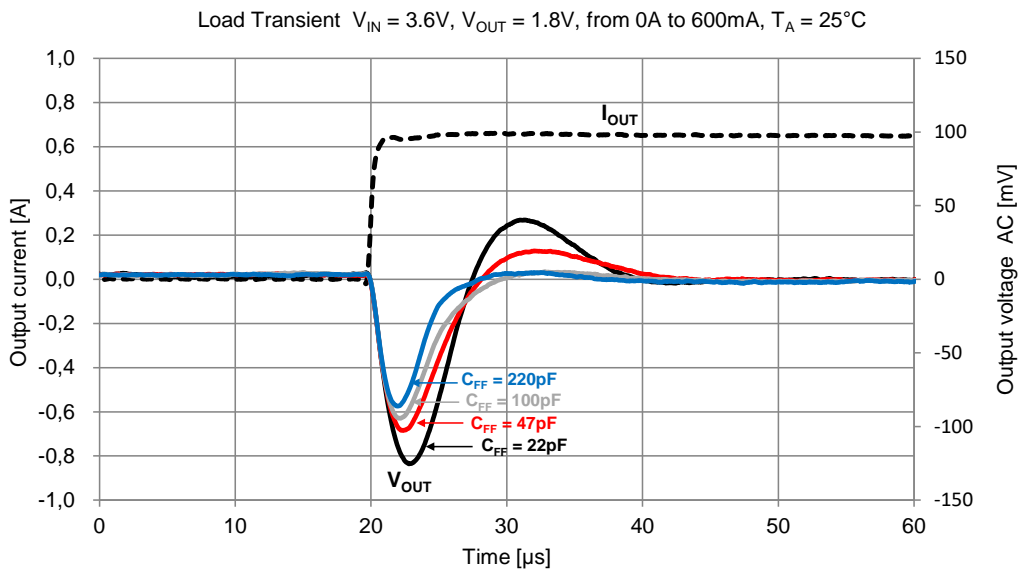


Step 4 Select the feed-forward capacitor (C_{FF})

For the 171960501 MagI³C MicroModule allows for the adjustment of a feed forward capacitor, C_{FF}, providing a trade-off between response time and efficiency while also affecting the transition current threshold between the PFM and PWM modes of operation. A lower value of C_{FF} will increase the light load conversion efficiency while slowing down the response time and increasing the overshoot and undershoot. Increasing the C_{FF} value will decrease the response time and the overshoot and undershoot while decreasing light load conversion efficiency. Increasing the value of C_{FF} results in a higher output current required to transition from PFM mode to PWM mode.

22pF has been evaluated experimentally as a value with suitable efficiency and transient characteristics for most applications.

The pictures below show the transient behavior of the 171960501 in response to a load transition from 0A to 600mA using the recommended C_{FF} of 22pF, as well as other values of C_{FF}.



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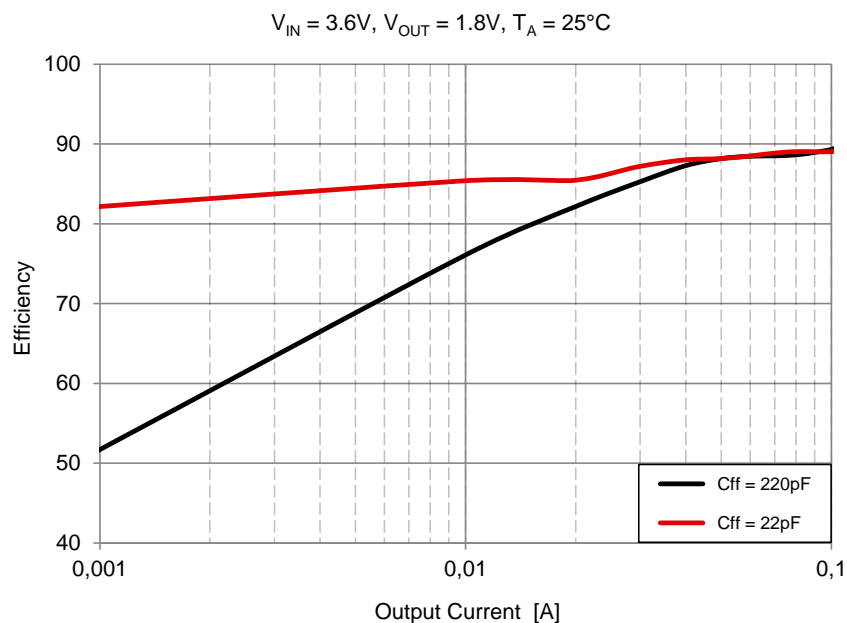
The graphs above show behavior that is valid only for this test under the specified conditions and must be verified in the real application.

The C_{FF} value only affects the efficiency during light load conditions.

As explained in the section [LIGHT LOAD OPERATION](#) on page 25, under light load operation and PFM/PWM Mode, the device does not continuously switch, instead delivering energy to the load in bursts. The frequency between bursts is influenced by various parameters including the C_{FF} value. The [LIGHT LOAD OPERATION](#) section provides a more in-depth explanation of the additional parameters which affect the behavior in this area of operation.

Increasing C_{FF} will cause the MicroModule to burst more often (shown in the two images above) resulting in a decrease in light load efficiency as depicted in the diagram below.

A trade-off between load step response and efficiency should be considered while selecting the most suitable value for C_{FF} .



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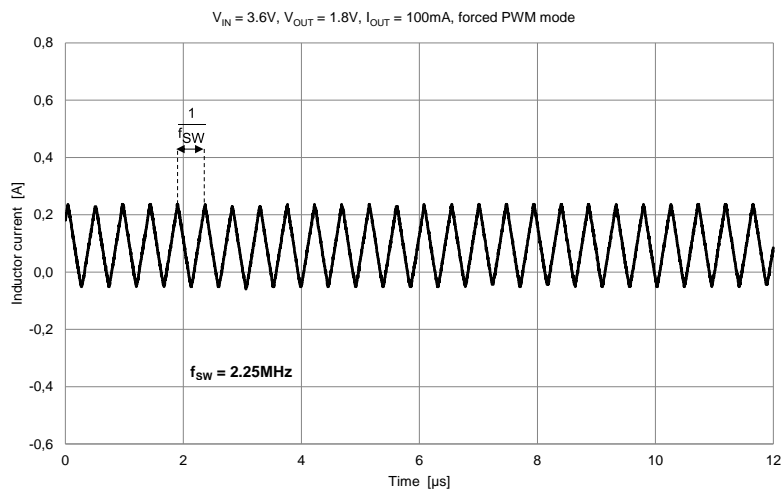


LIGHT LOAD OPERATION

Under light load conditions the 171960501 behaves differently according to the MODE pin setting.

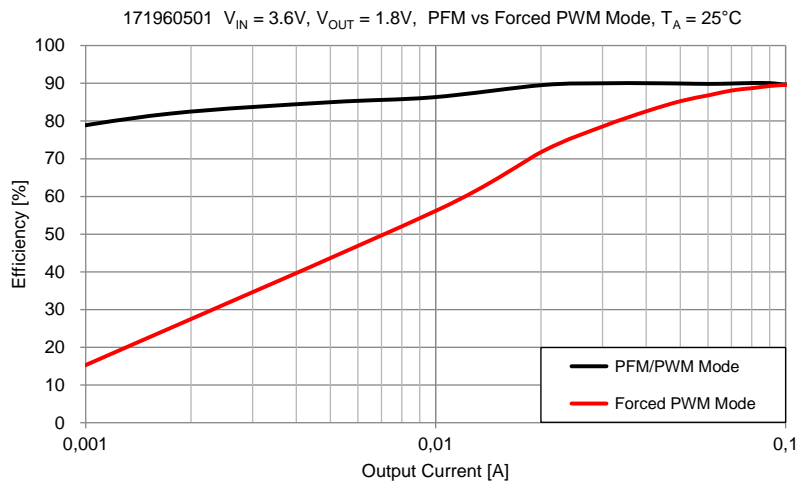
Forced PWM mode

Pulling the MODE pin high selects the forced PWM mode. In this mode the device constantly functions in PWM mode, switching at the default 2.25 MHz fixed switching frequency, independently of the load (see figure below). This mode of operation eases the filtering requirements to help with noise sensitive applications.



PFM/PWM mode

Setting the MODE pin low selects the PFM/PWM mode. This mode achieves a much higher efficiency at light loads (normally below 100mA), as shown in the picture below.



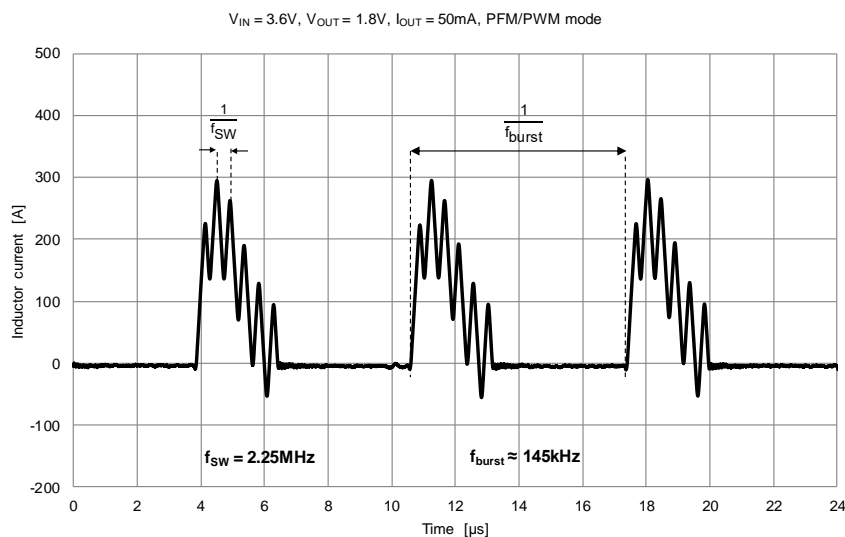
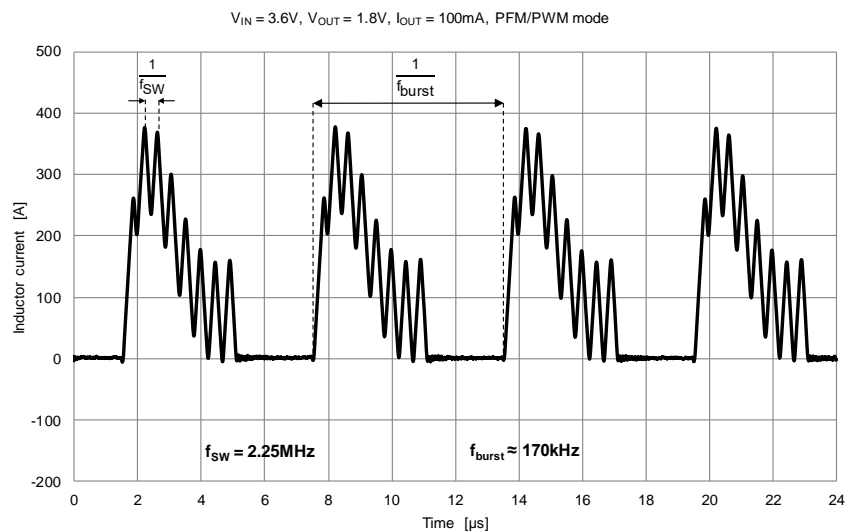
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In PFM/PWM mode the energy is delivered in bursts to the load (see figure below). Within each burst the device switches at the default switching frequency and the energy is delivered to both the load and the output capacitor. Between two bursts, the device does not switch (the load demand is supported by the output capacitor) and the current consumption is significantly reduced, leading to higher efficiency compared to the forced PWM mode. The frequency of the bursts (f_{burst}) depends on the load and it is much lower than the default switching frequency (see picture below at two different load conditions). When the load current is above 100mA, the transition from the PFM mode to the PWM mode takes place automatically.



Please consider that the burst frequency f_{burst} can differ from the example measurements above depending on several parameters (e.g. C_{OUT} , C_{FF}).

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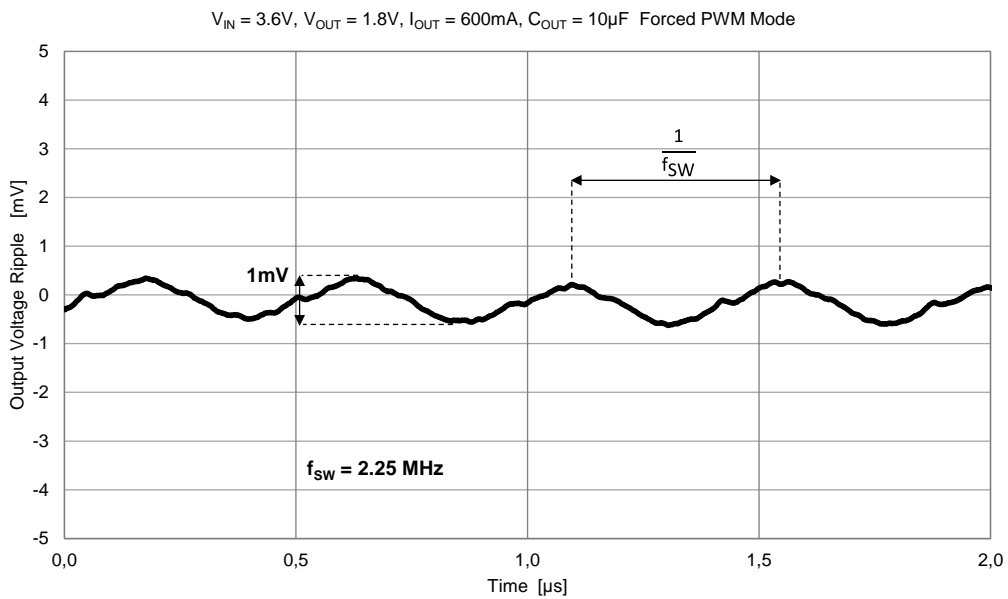
MagI³C[®] Power Module
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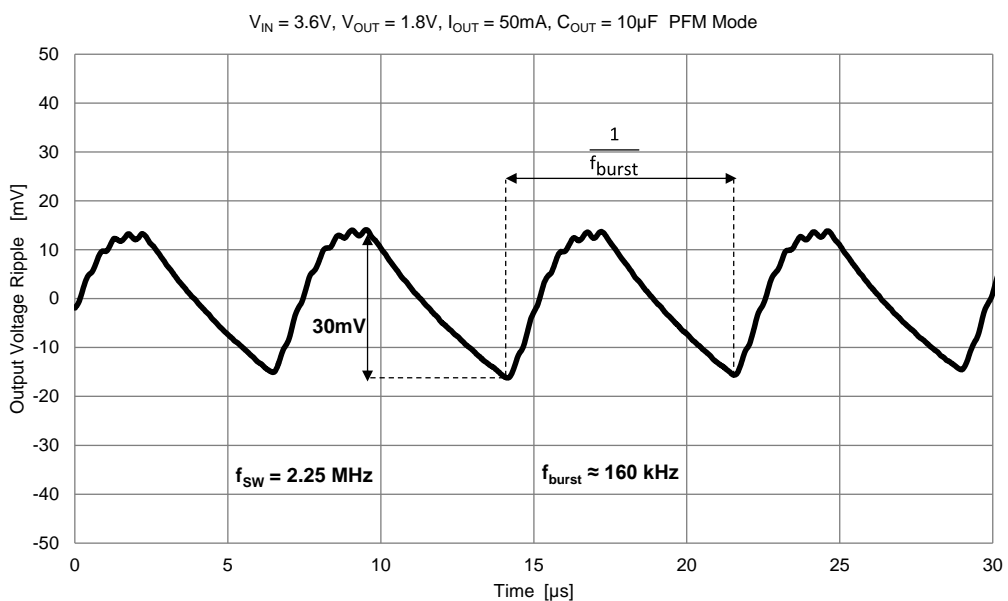
OUTPUT VOLTAGE RIPPLE

The output voltage ripple is dependent on the selection of the MODE pin and the value of the output current. If the forced PWM mode is selected, the ripple is very low and it always has the same frequency as the internal oscillator (2.25 MHz). If the PFM/PWM mode is selected, the output voltage ripple is higher and the frequency is lower than the nominal switching frequency (see pictures below).

Ripple in forced PWM mode



Ripple in PFM/PWM mode



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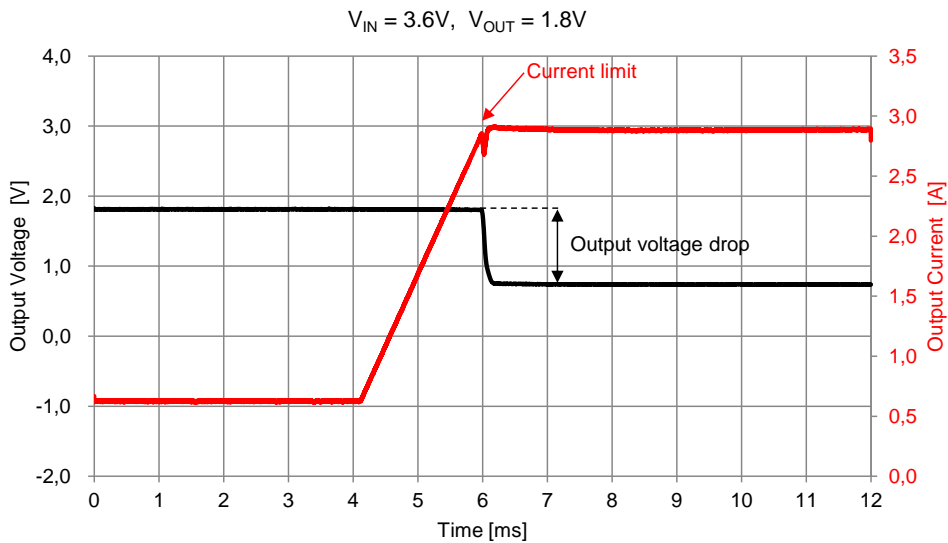
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PROTECTIVE FEATURES

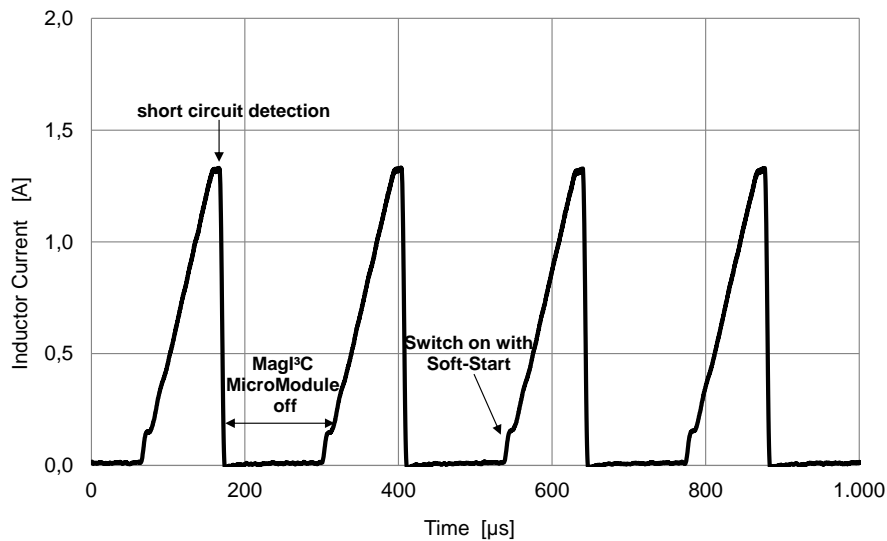
Overcurrent protection (OCP)

For protection against load faults, the MagI³C MicroModule incorporates cycle-by-cycle current limiting (see I_{OCP} in “Electrical Specification” on page 5). During an overcurrent condition the output current is limited and the output voltage drops (see figure below). When the overcurrent condition is removed, the output voltage returns to the nominal voltage.



Short-circuit protection (SCP)

When the MagI³C MicroModule experiences a short-circuit condition, it enters a hiccup mode. The MagI³C MicroModule reduces the current limit threshold to around 1.5A (typ.) and switches off when this threshold is reached. After that it stays off for a few hundred microseconds and then switches on again with a soft-start. As long as the short-circuit is not cleared, these cycles will continue to repeat (see figure below).



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Over temperature protection (OTP)

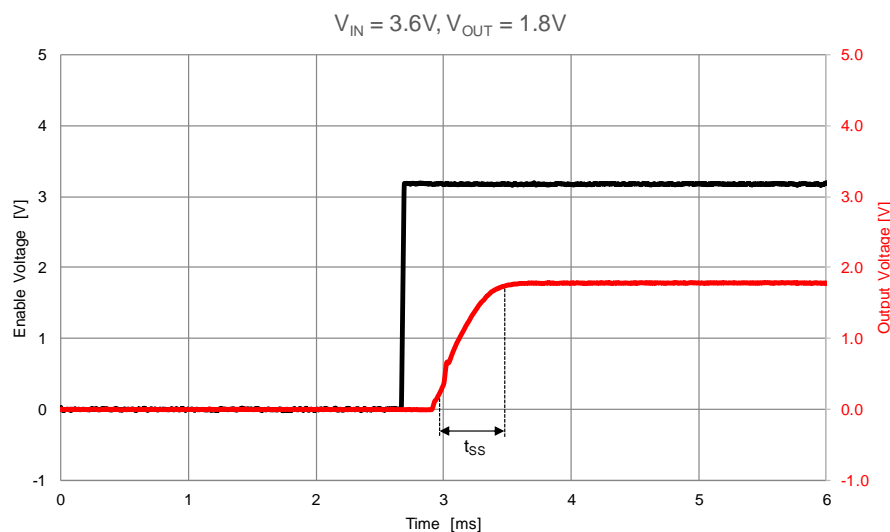
Thermal protection helps prevent catastrophic failures due to accidental device overheating. The junction temperature of the MagI³C MicroModule should not be allowed to exceed its maximum ratings. Thermal protection is implemented by an internal thermal shutdown circuit, which activates when the junction temperature reaches 150°C (typ). Under the thermal shutdown condition both MOSFETs remain off causing V_{OUT} to drop. When the junction temperature falls below 130°C the internal soft-start is released, V_{OUT} rises smoothly, and normal operation resumes.

Input undervoltage lockout

The device incorporates undervoltage lockout (UVLO) to protect unexpected behavior at input voltages below the recommended values. The thresholds of the UVLO are indicated in the [Electrical Specifications](#) on page 5.

Soft-Start

The 171960501 implements an internal soft-start in order to limit the inrush current and avoid output voltage overshoot during start-up. The typical duration of the soft-start is around 550µs, as can be seen in the graph below.



Enable

The 171960501 MagI³C MicroModule is enabled by connecting the EN pin to V_{in} or a similar voltage. The output voltage starts to increase after the internal circuitry of the MicroModule is ready for operation. The soft start time, typically 550µs, indicates the time difference between when the input voltage turns the MicroModule on and when the output voltage reaches the present value.

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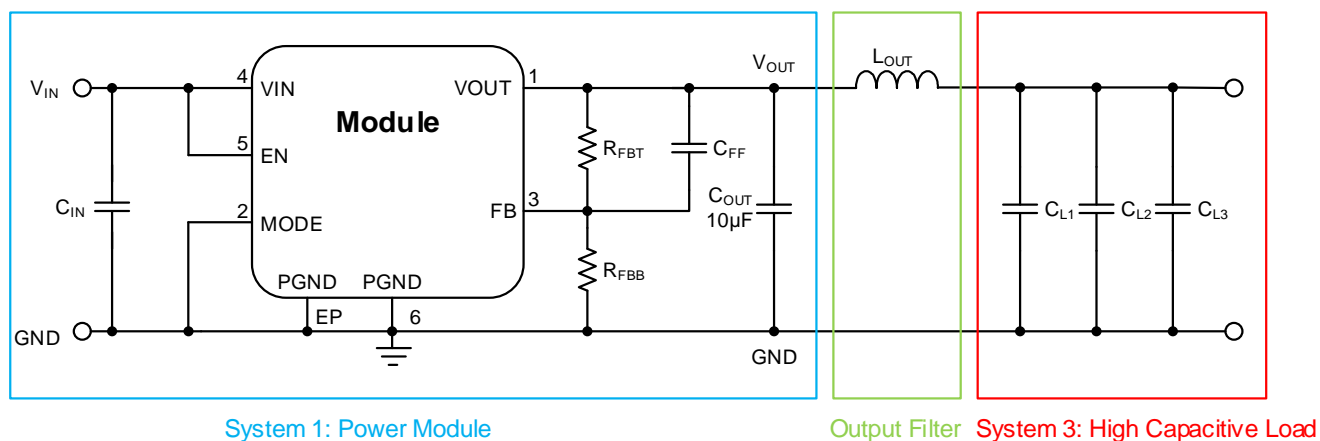


APPLICATION RECOMMENDATION FOR HIGH CAPACITIVE LOAD

There are applications, such as FPGAs or some microcontrollers, which require a high capacitance value at their input. If more capacitance than the recommended absolute maximum capacitance is used, the phase and gain margin of the control loop of the power MicroModule may decrease. This will result in undesired oscillations at the output of the power MicroModule.

In order to maintain stable operation regardless of the increased capacitance value, the converter and surrounding circuitry can be divided into two different systems decoupled by an output filter. The first system contains the MicroModule and recommended external circuitry (i.e. feedback network, 10 μ F input capacitor and recommend output capacitor of 10 μ F) and the second system contains any additional capacitance beyond the recommended value of 10 μ F. An output filter with a 4.7 μ H inductor is required in between the first and the second system. This output filter separates the MicroModule power system from a higher capacitive load, keeping the phase and gain margin of the control loop of the power MicroModule within the intended frequency range.

The following diagram shows how an application with high capacitive load can be designed taking advantage of the decoupling output filter described in the previous paragraph.



Due to the DCR of the inductor used in the decoupling output filter, the nominal value of the output voltage may decrease depending on the output current. To compensate for this and return the output voltage set point to the desired value, the resistor feedback network can be tuned by either increasing the upper resistor or decreasing the lower resistor.

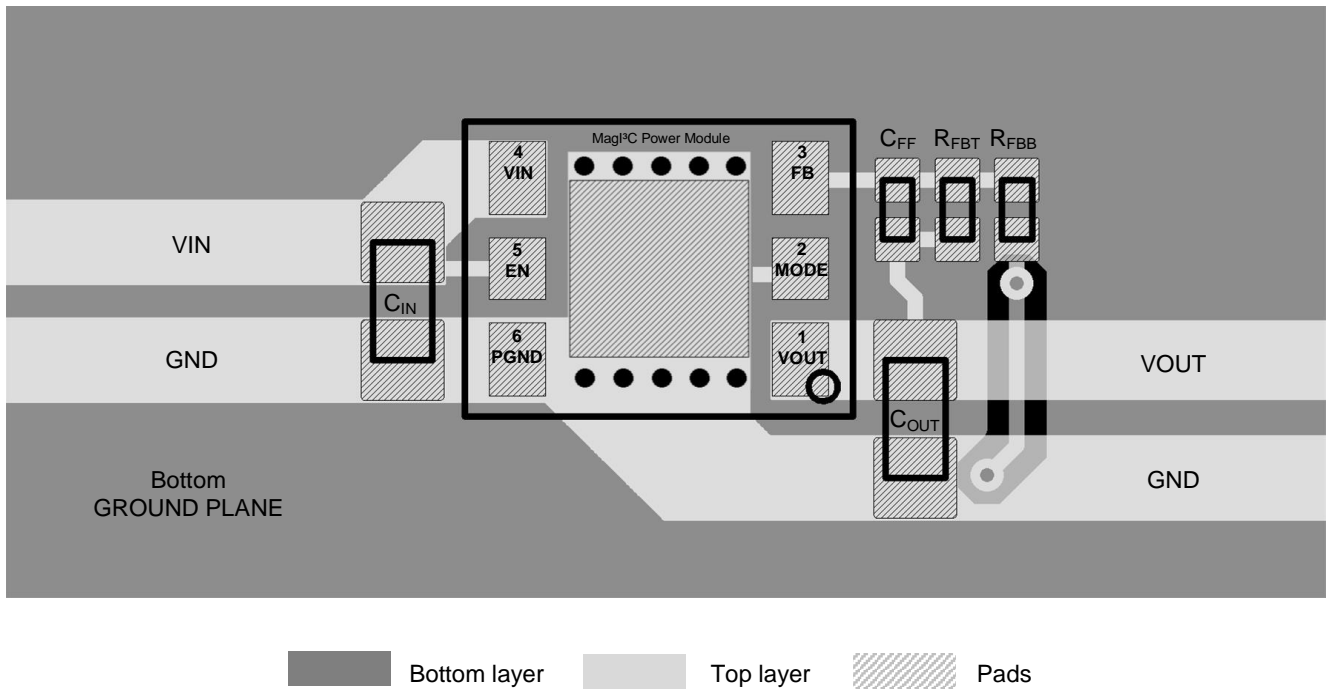
The specific inductor for the decoupling output filter can be chosen based on the application requirements. Various design aspects such as inductor package size and DCR can be balanced to achieve the best results for the given application. The WE-PMI family of inductors offers small case sizes with minimal DCR, providing an excellent choice for a decoupling inductor if high capacitive loads must be powered by the MicroModule.

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LAYOUT RECOMMENDATION



The picture above shows a possible layout for the 171960501 MagI³C MicroModule. Nevertheless some recommendation should be followed when a layout is designed:

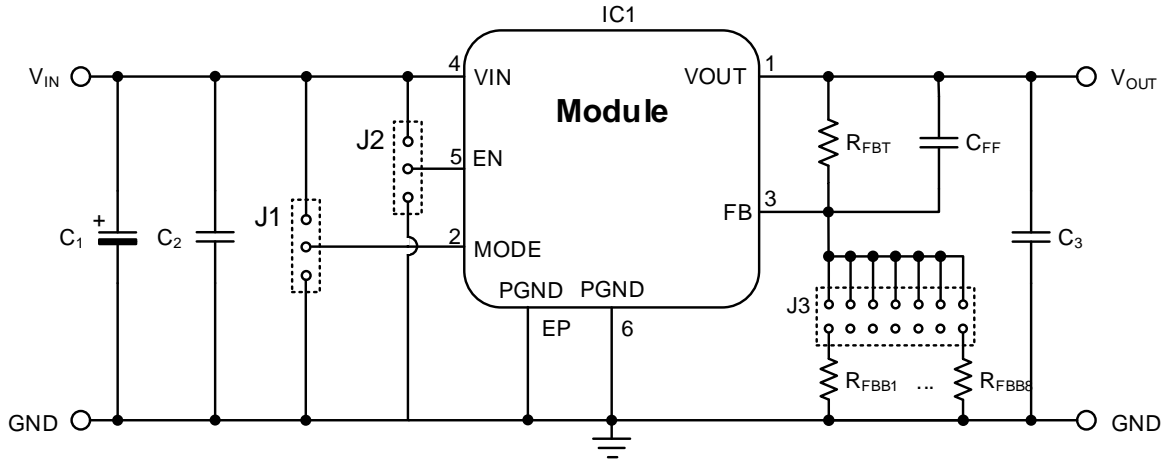
1. The exposed pad should be connected to the bottom copper layer of the circuit board with sufficient vias to optimize the heat dissipation during operation. The above example uses 10 vias each with a drill diameter of 200µm. Ensure that nearby vias are either plugged or covered in solder mask to ensure the best solderability.
2. The input and output capacitors should be placed as close as possible to the VIN, VOUT and PGND pins of the device.
3. The feedback resistor divider should be placed as close as possible to the VOUT and FB pins.
4. Pins 5 and 2 (EN and MODE respectively) must always be connected to either VIN or PGND and cannot be left floating (an example is shown in the layout depicted above, where EN and MODE pins are connected to VIN and PGND, respectively).

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EVALUATION BOARD SCHEMATIC



Operational Requirements

The additional aluminum polymer capacitor C1 is only for evaluation board protection purposes. It is mounted as the termination of the supply line and provides a slight damping of possible oscillations of the series resonance circuit represented by the inductance of the supply line and the input capacitance. It is not essential for operation.

Bill of Material

Designator	Description	Quantity	Order Code	Manufacturer
IC1	MagI ³ C MicroModule	1	171960501	Würth Elektronik
C ₁	Aluminum Polymer Capacitor 220µF/10V	1	875105244013	Würth Elektronik
C ₂ , C ₃	Ceramic chip capacitor 10µF/16V X5R, 0805	2	885012107014	Würth Elektronik
	Ceramic chip capacitor 10µF/10V X5R, 0805 (*)		885012107010	Würth Elektronik
C _{FF}	Ceramic chip capacitor 22pF/25V NP0/COG 0603	1	885012005009	Würth Elektronik
R _{FBT}	100 kΩ	1		
R _{FBB}	open for V _{OUT} = 0.6V			
	150 kΩ for V _{OUT} = 1.0V	1		
	100 kΩ for V _{OUT} = 1.2V	1		
	66.5 kΩ for V _{OUT} = 1.5V	1		
	49.9 kΩ for V _{OUT} = 1.8V	1		
	31.6 kΩ for V _{OUT} = 2.5V	1		
	22.1 kΩ for V _{OUT} = 3.3V	1		
	To be soldered for adjustable output voltage $R_{FBB} = \frac{R_{FBT}}{\frac{V_{OUT}}{V_{FB}} - 1}$			
J1, J2	Pin header	2	61300311121	Würth Elektronik
J3	Pin header	1	61301621121	Würth Elektronik

(*) alternative recommended part

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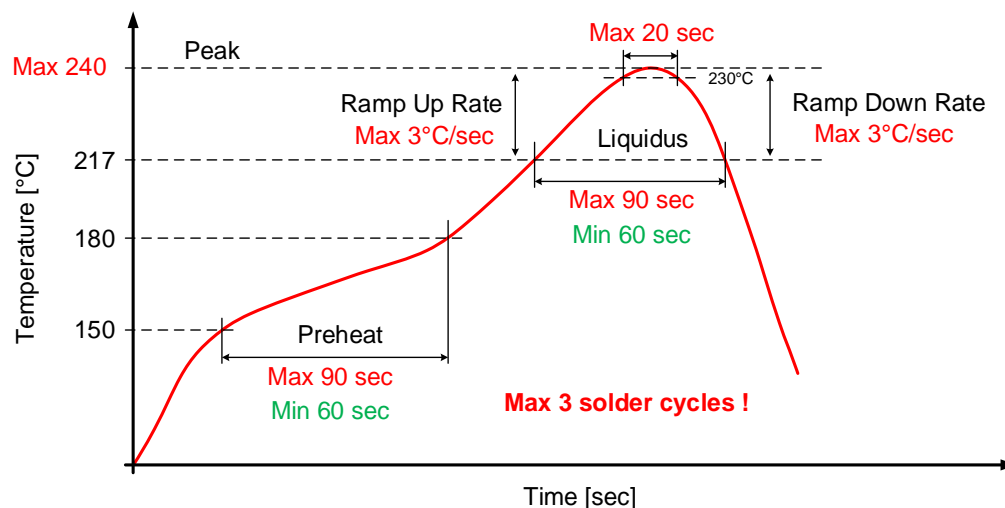


HANDLING RECOMMENDATIONS

1. The power MicroModule is classified as MSL3 (JEDEC Moisture Sensitivity Level 3) and requires special handling due to moisture sensitivity (JEDEC J-STD033).
2. The parts are delivered in a sealed bag (Moisture Barrier Bags = MBB) and should be processed within one year.
3. When opening the moisture barrier bag check the Humidity Indicator Card (HIC) for color status. Bake parts prior to soldering in case indicator color has changed according to the notes on the card.
4. Parts must be processed after 168 hours (7 days) of floor life. Once this time has been exceeded, bake parts prior to soldering per JEDEC J-STD033 recommendation.

SOLDER PROFILE

1. Only Pb-Free assembly is recommended according to JEDEC J-STD020.
2. Measure the peak reflow temperature of the MagI³C MicroModule in the middle of the packaged IC on top.
3. Ensure that the peak reflow temperature does not exceed $235^{\circ}\text{C} \pm 5^{\circ}\text{C}$ as per JEDEC J-STD020.
4. The reflow time period during peak temperature of $235^{\circ}\text{C} \pm 5^{\circ}\text{C}$ must not exceed 20 seconds.
5. Reflow time above liquidus (217°C) must not exceed 90 seconds.
6. Maximum ramp up rate is 3°C per second.
7. Maximum ramp down rate is 3°C per second.
8. Reflow time from room (25°C) to peak must not exceed 8 minutes as per JEDEC J-STD020.
9. **Maximum number of allowed reflow cycles is three.**
10. **For minimum risk, solder the MicroModule in the last reflow cycle of the PCB production.**
11. For soldering process please consider lead material copper (Cu) and lead finish tin (Sn).
12. For solder paste use a SAC 305 alloy (Sn 96.5 / Ag 3.0 / Cu 0.5) type 3 or higher.
13. The profile shown below is valid for convection reflow only.
14. Other soldering methods (e.g.vapor phase) are not verified and have to be validated by the customer at their own risk.

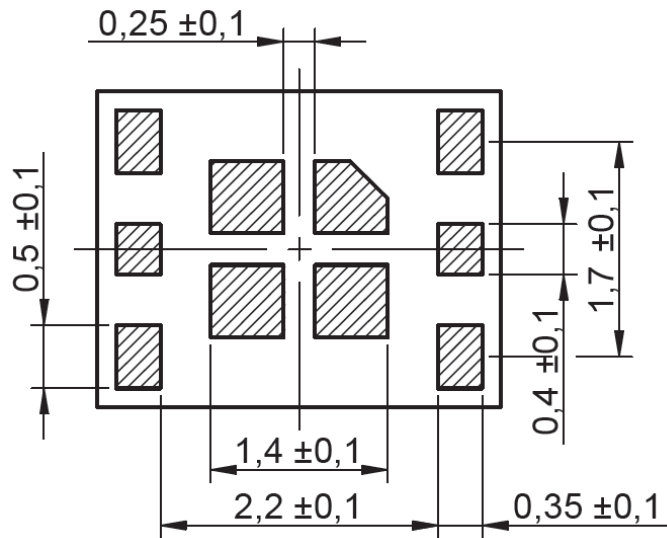


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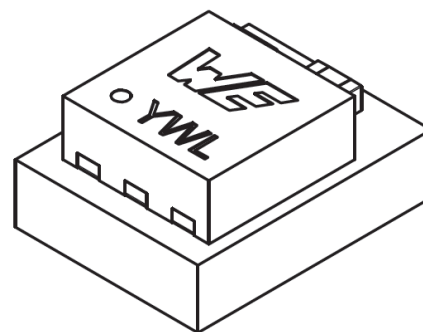
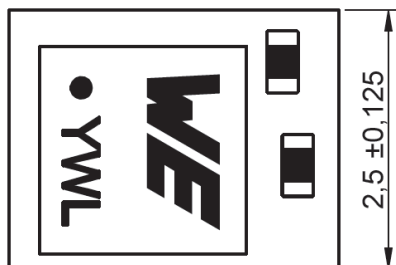
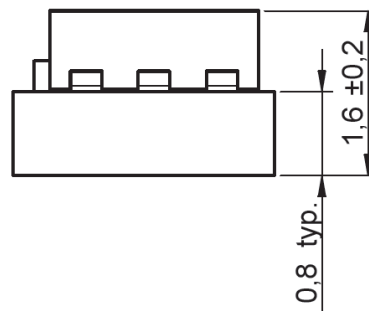
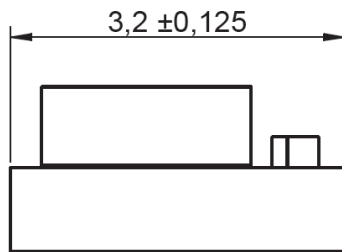
Magl³C[®] Power Module
VDMM – Variable Step Down MicroModule



PHYSICAL DIMENSIONS



Bottom view
 All dimensions in mm



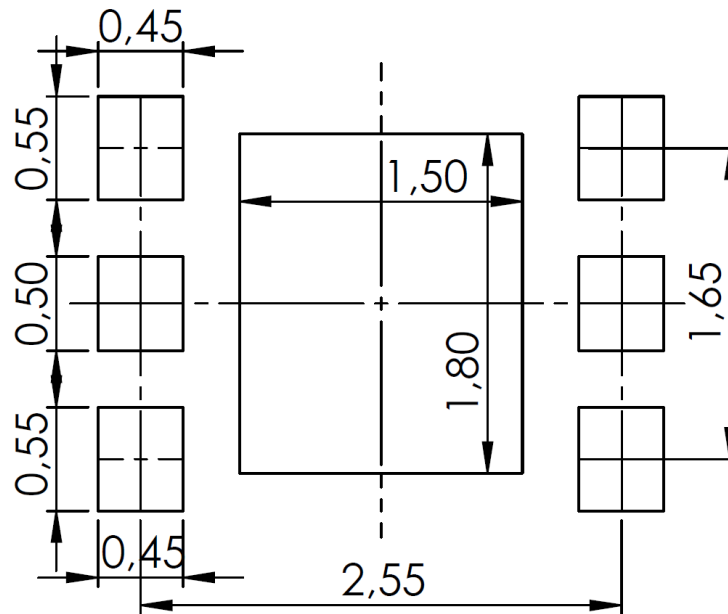
All dimensions in mm

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EXAMPLE FOOTPRINT DESIGN



All dimensions in mm

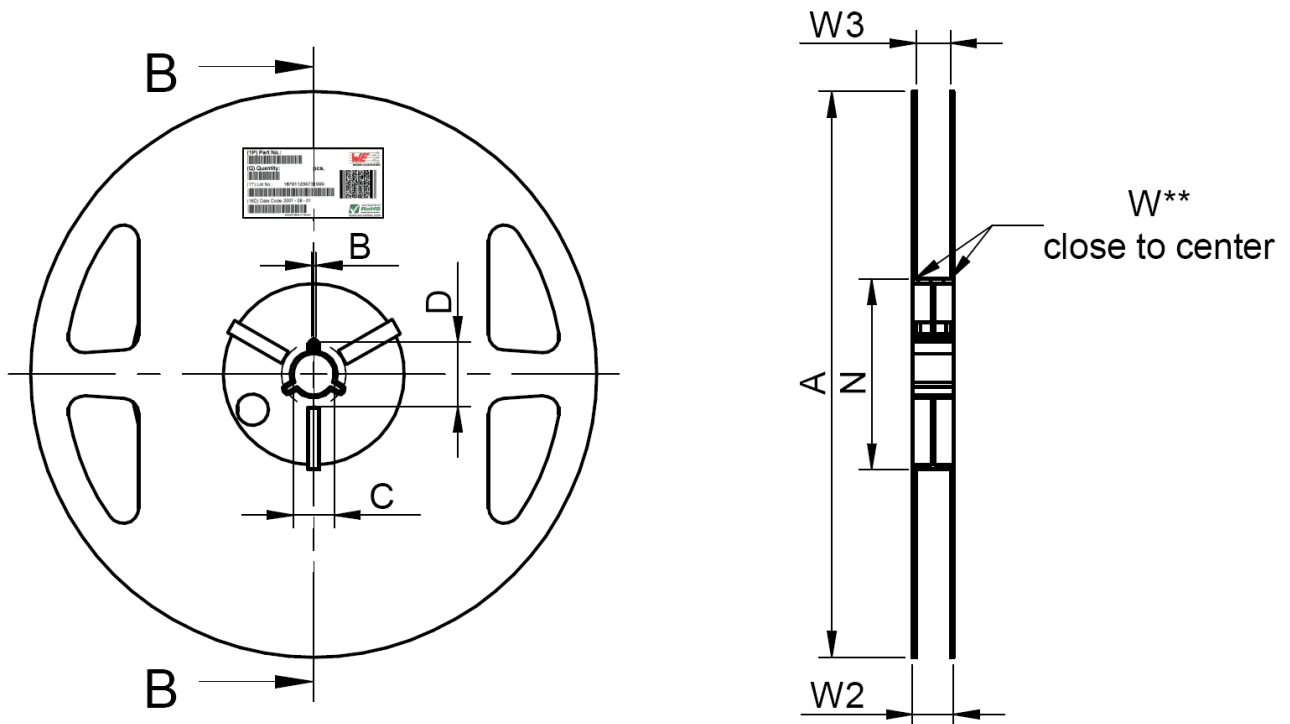
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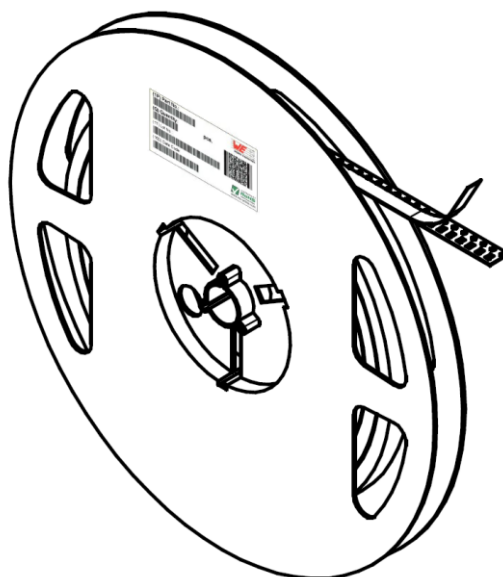


PACKAGING

Reel (mm)



		A	B	C	D	N	W1	W2	W3
tolerance		typ.	min.	± 0,8	min.	min.	+ 1,5	max.	min.
Tape width	8 mm	178,00	1,50	13,00	20,20	50,00	8,40	14,40	7,90

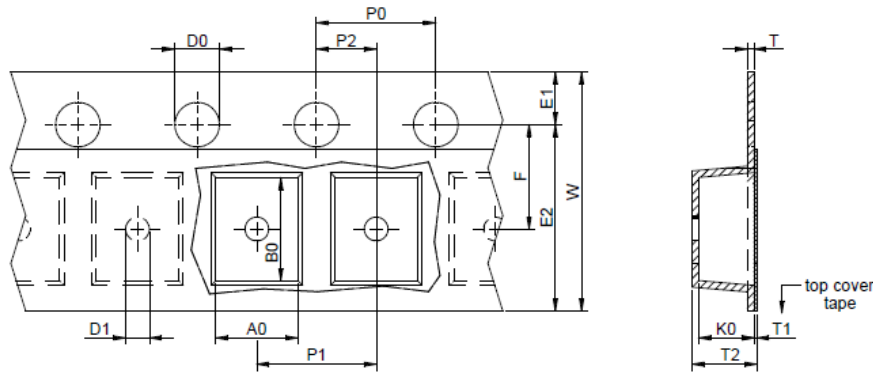


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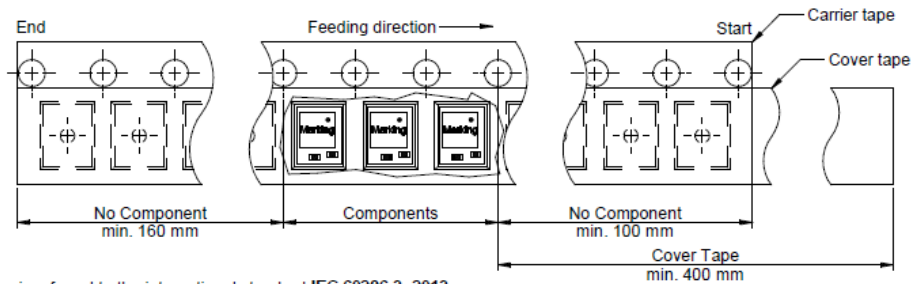
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Tape (mm)



	A0	B0	W	P1	T	T1	T2	D0	E1	E2	F	P0	P2	Tape	Packaging Unit	
tolerance	±0.1	±0.1	±0.1	±0.1	±0.05	max.	typ.	±0.1	±0.1	min.	±0.1	±0.1	±0.05			
size	1210	2.75	3.45	8.00	4.00	0.22	0.10	2.20	1.50	1.75	6.25	3.50	4.00	2.00	Polystyrene	2000



Packaging is referred to the international standard IEC 60286-3; 2013

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**DOCUMENT HISTORY**

Revision	Date	Description	Comment
1.0	November 2017	Data sheet release	
2.0	January 2019	Data sheet update	Marking, electrical specifications, and diagrams updated; legal disclaimer added.
3.0	April 2020	Data sheet update	Updated descriptions and output capacitance information

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CAUTIONS AND WARNINGS

The following conditions apply to all goods within the product series of MagI³C of Würth Elektronik eiSos GmbH & Co. KG:

General:

- All recommendations according to the general technical specifications of the data-sheet have to be complied with.
- The usage and operation of the product within ambient conditions which probably alloy or harm the component surface has to be avoided.
- Electronic components that will be used in safety-critical or high-reliability applications, should be pre-evaluated by the customer.
- The component is designed and manufactured to be used within the datasheet specified values. If the usage and operation conditions specified in the datasheet are not met, the component may be damaged or dissolved.
- Do not drop or impact the components as material of the body, pins or termination may flake apart.
- Würth Elektronik products are qualified according to international standards, which are listed in each product reliability report. Würth Elektronik does not warrant any customer qualified product characteristics beyond Würth Elektronik's specifications, for its validity and sustainability over time.
- The responsibility for the applicability of the customer specific products and use in a particular customer design is always within the authority of the customer. All technical specifications for standard products also apply to customer specific products.
- Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Würth Elektronik eiSos GmbH & Co. KG components in its applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos GmbH & Co. KG. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Customer will fully indemnify Würth Elektronik eiSos and its representatives against any damages arising out of the use of any Würth Elektronik eiSos GmbH & Co. KG components in safety-critical applications.

Product specific:

Follow all instructions mentioned in the datasheet, especially:

- The solder profile has to comply with the technical reflow or wave soldering specification, otherwise this will void the warranty.
- All products are supposed to be used before the end of the period of 12 months based on the product date-code.
- Violation of the technical product specifications such as exceeding the absolute maximum ratings will void the warranty.
- It is also recommended to return the body to the original moisture proof bag and reseal the moisture proof bag again.
- ESD prevention methods need to be followed for manual handling and processing by machinery.
- Residual washing varnish agent that is used during the production to clean the application might change the characteristics of the body, pins or termination. The washing varnish agent could have a negative effect on the long term function of the product.
- Direct mechanical impact to the product shall be prevented as the material of the body, pins or termination could flake or in the worst case it could break. As these devices are sensitive to electrostatic discharge customer shall follow proper IC Handling Procedures.

DISCLAIMER

This electronic component has been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use.

Moreover Würth Elektronik eiSos GmbH & Co KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc.. Würth Elektronik eiSos GmbH & Co KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component which is used in electrical circuits that require high safety and reliability functions or performance.

These cautions and warnings comply with the state of the scientific and technical knowledge and are believed to be accurate and reliable. However, no responsibility is assumed for inaccuracies or incompleteness.

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IMPORTANT NOTES

The following conditions apply to all goods within the product range of Würth Elektronik eiSos GmbH & Co. KG:

1. General Customer Responsibility

Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact it is up to the customer to evaluate, where appropriate to investigate and decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not. Accordingly, the customer is cautioned to verify that the datasheet is current before placing orders.

2. Customer Responsibility related to Specific, in particular Safety-Relevant Applications

It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. In certain customer applications requiring a very high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component.

3. Best Care and Attention

Any product-specific notes, warnings and cautions must be strictly observed. Any disregard will result in the loss of warranty.

4. Customer Support for Product Specifications

Some products within the product range may contain substances which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case the field sales engineer or the internal sales person in charge should be contacted who will be happy to support in this matter.

5. Product R&D

Due to constant product improvement product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard we inform about minor and major changes. In case of further queries regarding the PCN, the field sales engineer or the internal sales person in charge should be contacted. The basic responsibility of the customer as per Section 1 and 2 remains unaffected.

6. Product Life Cycle

Due to technical progress and economical evaluation we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this we cannot guarantee that all products within our product range will always be available. Therefore it needs to be verified with the field sales engineer or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

7. Property Rights

All the rights for contractual products produced by Würth Elektronik eiSos GmbH & Co. KG on the basis of ideas, development contracts as well as models or templates that are subject to copyright, patent or commercial protection supplied to the customer will remain with Würth Elektronik eiSos GmbH & Co. KG. Würth Elektronik eiSos GmbH & Co. KG does not warrant or represent that any license, either expressed or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, application, or process in which Würth Elektronik eiSos GmbH & Co. KG components or services are used.

8. General Terms and Conditions

Unless otherwise agreed in individual contracts, all orders are subject to the current version of the "General Terms and Conditions of Würth Elektronik eiSos Group", last version available at www.we-online.com.