171960501

MagI^{3}C Power Module

WPME-VDMM - Variable Step Down MicroModule

2.7V - 5.5V Input / 0.6A / 0.6V - 5.5V Output

DESCRIPTION

The VDMM 171960501 MagI^{3}C power module provides a fully integrated DC-DC power supply including the switching regulator IC with integrated MOSFETs, controller, 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 a small solution size.

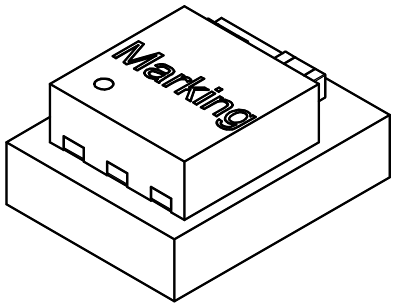
The selectable mode pin allows for the choice between high efficiency and low output voltage ripple at light load.

The 171960501 is available in an LGA-6EP package (3.2 x 2.5 x 1.6mm).

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

FEATURES

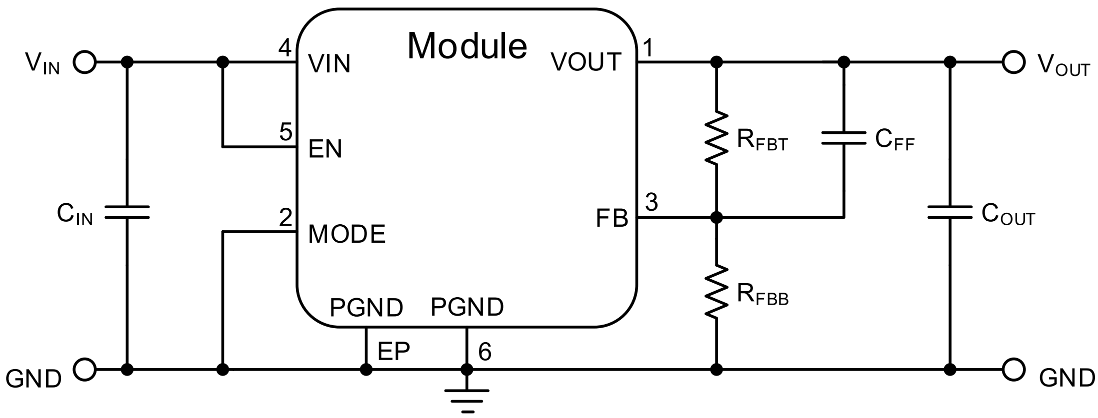
- Peak efficiency up to 97%
- Input voltage range: 2.7V to 5.5V
- Typical quiescent current: 60µA
- Output voltage range: 0.6V to 5.5V
- Current capability up to 0.6A
- Voltage mode control
- Synchronous operation
- Fixed switching frequency: 2.25MHz
- Selectable modes of operation
- Embedded soft-start
- Undervoltage lockout (UVLO)
- Cycle-by-cycle current limit
- Short-circuit protection
- Thermal shutdown
- Ambient temp. range: -40°C to 85°C
- Junction temp. range: -40°C to 125°C
- RoHS and REACH compliant
- Complies with EN55032 class B radiated emissions standard



TYPICAL APPLICATIONS

- 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

TYPICAL CIRCUIT DIAGRAM



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1 PINOUT

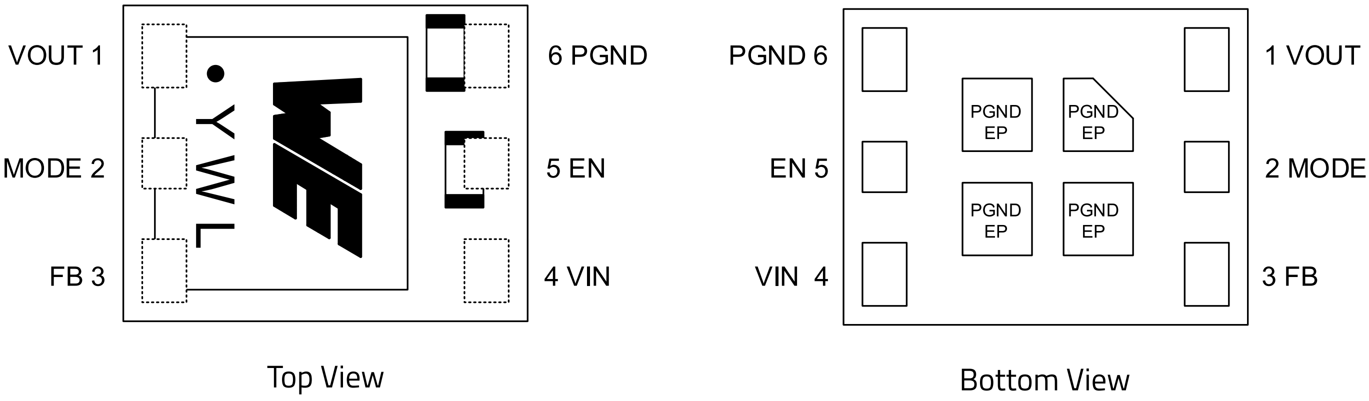


Figure 1: Pinout.

Table 1: Pin description.

SYMBOL	NUMBER	TYPE	DESCRIPTION
VOUT	1	Power	Output voltage. Place output capacitors as close as possible to VOUT and GND. For best thermal performance use a copper plane at this pin.
MODE	2	Input	Mode selection pin. Pulling this pin high will prevent PFM from engaging during light load conditions. Pulling this pin low will enable PFM operation during light load conditions. 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. Pulling this pin high enables the device, while pulling this pin low shuts down the device. This pin must not be left floating.
PGND	6	Power	Power ground pin. This pin must be connected to the ground plane and to the thermal pad.
PGND	EP	Exposed Pad	Exposed pad. The exposed pad is internally electrically connected to PGND. It is recommended to connect it to the ground plane for optimal device heat dissipation.

2 ORDERING INFORMATION

Table 2: Ordering information.

ORDER CODE	SPECIFICATIONS	PACKAGE	PACKAGING UNIT
171960501	0.6A / 0.6V-5.5V Vout version	LGA-6EP	7" Reel (2000 pieces)
178960501	0.6A / 0.6V-5.5V Vout version	Eval Board	Box with 1 piece

3 SALES INFORMATION

Table 3: Sales information.

SALES CONTACT
Würth Elektronik eiSos GmbH & Co. KG EMC and 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

4 ABSOLUTE MAXIMUM RATINGS

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

Table 4: Absolute maximum ratings.

SYMBOL	PARAMETER	LIMIT		UNIT
		MIN(1)	MAX(1)	
VIN	Input pin voltage	-0.3	6	V
VOUT	Output pin voltage	-0.3	V_{IN}	V
FB	Feedback pin voltage	-0.3	V_{IN}	V
EN	Enable pin voltage	-0.3	V_{IN}+0.3	V
MODE	Mode pin voltage	-0.3	V_{IN}	V
$T_{storage}$	Assembled, non-operating storage temperature	-40	125	°C
V_{esd}	ESD Voltage (HBM), VIN and VOUT vs. PGND according to EN61000-4-2(4)	-4	4	kV
V_{esd}	ESD Voltage (HBM), EN, MODE and FB vs. PGND according to EN61000-4-2(4)	-2	2	kV

5 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.

Table 5: Operating conditions.

SYMBOL	PARAMETER	MIN(1)	TYP(3)	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(2)	-40	—	85	°C
T_{jop}	Junction temperature range	-40	—	125	°C
I_{out}	Nominal output current(5)	—	—	0.6(2)	A

6 THERMAL SPECIFICATIONS

Table 6: Thermal specifications.

SYMBOL	PARAMETER	TYP(3)	UNIT
Θ_{JA}	Junction-to-ambient thermal resistance(2)	150	°C/W
T_{SD}	Thermal shutdown, rising	150	°C
	Thermal shutdown, hysteresis	20	°C

7 ELECTRICAL SPECIFICATIONS

Caution:
MIN and MAX limits are valid for the recommended ambient temperature range of -40 °C to 85 °C. Typical values represents statistically the utmost probable values at the following conditions: V_{IN} = 5V, V_{OUT} = 1.8V, C_{IN} = 10µF ceramic, C_{OUT} = 10µF ceramic, T_A = 25 °C unless otherwise noted.

Table 7: Electrical specifications part 1.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN(1)	TYP(3)	MAX(1)	UNIT
Output Current						
I_{OCP}	Overcurrent limit		—	2.4	—	A
Output Voltage						
V_{FB}	Reference voltage		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 bias current		-100	—	100	nA
V_{OUT}	Line regulation	V_{IN} = 2.7V to 5.5V, MODE = high	—	0.2	—	%
	Load regulation	0A ≤ I_{LOAD} ≤ 0.6A, MODE = high	—	0.5	—	%
	Output voltage ripple	V_{IN} = 3.6V, I_{OUT} = 0.6A, MODE = high	—	1	—	mV_{pp}
		V_{IN} = 3.6V, I_{OUT} = 50mA, MODE = low	—	30	—	mV_{pp}
Switching Frequency						
f_{SW}	Switching frequency	MODE = high	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	—	150	—	mV
V_{EN}	EN threshold	Enable logic high	2	—	—	V
		Enable logic low	0	—	0.3	V
I_{EN}	EN pin input current		-500	—	500	nA
Input Quiescent and Shutdown Current						
I_{SD}	Shutdown current	V_{EN} = 0V	—	0.1	1	µA
I_{IN}	No load input current	MODE = high, ENABLE = high, switching with no load	—	6	—	mA
		MODE = low, ENABLE = high, switching with no load	—	80	—	µA
I_Q	Quiescent current	MODE = low, ENABLE = high, no switching	—	60	—	µA
Soft-Start						
t_{SS}	Soft-start time	Rising edge to 90% of V_{OUT}	—	550	—	µs

Caution:
MIN and MAX limits are valid for the recommended ambient temperature range of -40 °C to 85 °C. Typical values represents statistically the utmost probable values at the following conditions: V_{IN} =5V, V_{OUT} = 1.8V, C_{IN} = 4.7µF ceramic, C_{OUT} = 10µF ceramic, T_A = 25 °C unless otherwise noted.

Table 8: Electrical specifications part 2.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN[(1)]	TYP[(3)]	MAX[(1)]	UNIT
Efficiency						
η	Efficiency	V_{OUT} = 3.3V, I_{OUT} = 275mA, MODE = low	—	93	—	%
		V_{IN} = 3.6V, V_{OUT} = 3.3V, I_{OUT} = 150mA, MODE = low	—	97	—	%
		V_{IN} = 3.3V, I_{OUT} = 150mA, MODE = low	—	93	—	%
Mode Selection						
V_{Mode}	Mode threshold	Mode logic high	V_{IN}-0.5	—	—	V
		Mode logic low	0	—	0.3	V
I_{Mode}	Mode current consumption	MODE = high	—	30	—	nA
		MODE = low	—	-40	—	nA
Output Capacitance						
C_{OUT}	External output capacitance		4.7	10	11[(6)]	µF

8 RoHS, REACH

Table 9: RoHS, REACH.

RoHS directive	COMPLIANT RoHS&REACH WÜRTH ELEKTRONIK	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).

9 PACKAGE SPECIFICATIONS

Table 10: Package specifications.

ITEM	PARAMETER	TYP(3)	UNIT
Lead finish	Silver-Paladium	—	—
Weight	—	0.047g	g

10 NOTES

(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) Measured without heatsink, still air. (0 - 20LFM / 0- 0.1m/s) on the 178960501 evaluation board, a 40 x 40mm two layer board, with 35µm (1 ounce) copper.

(3) Typical numbers are valid at 25°C ambient temperature and represent statistically the utmost probable values assuming a Gaussian distribution.

(4) The human body model is a 100pF capacitor discharged through a 1.5Ωk resistor into each pin. Test method is per JESD-22-114.

(5) Depending on ambient temperature; see THERMAL DERATING.

(6) If 11µF is to be used for the external output capacitance, it is recommended to use a 10µF capacitor (recommended Würth Elektronik part numbers 885012107014 or 885012107010) and a 1µF capacitor (recommended Würth Elektronik part numbers 885012106017 or 885012106010) in parallel; see APPLICATION RECOMMENDATION FOR HIGH CAPACITIVE LOADS.

11 TYPICAL PERFORMANCE CURVES

If not otherwise specified, the following conditions apply: V_{IN} = 5V, V_{OUT} = 3.3V, C_{IN} = 10µF X5R ceramic, C_{OUT} = 10µF X5R ceramic, C_{FF} = 22pF, T_A = 25°C.

11.1 Radiated Emissions EN55032 (CISPR-32) Class B Compliant

Measured with module on an Evaluation Board 178960501 in a Fully Anechoic Room (FAR) at 3m antenna distance.

11.1.1 Test Setup

Input wire length:

- Radiated Emission: 160cm (80cm Horizontal + 80cm Vertical)

Output wire length:

- Short wire (With Input Filter): Load directly on evaluation board

11.1.2 Radiated Emissions (Without Input Filter)

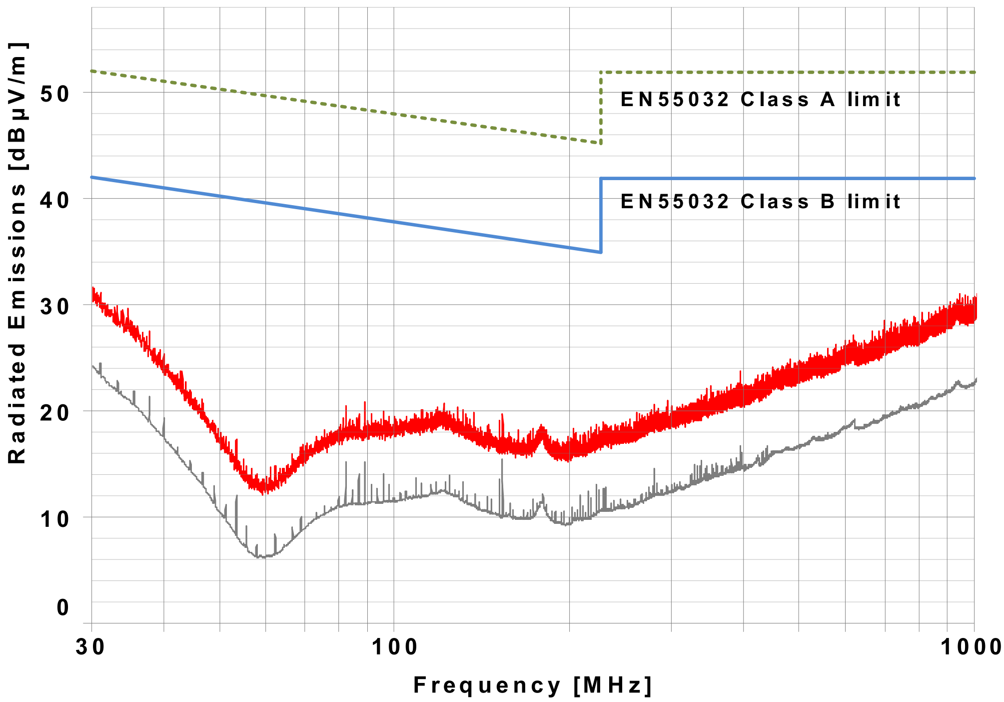


Figure 2: 171960501 radiated emissions (3m antenna distance) I_{LOAD} = 0.6A Without Input Filter

11.1.3 Radiated Emissions (With Input Filter)

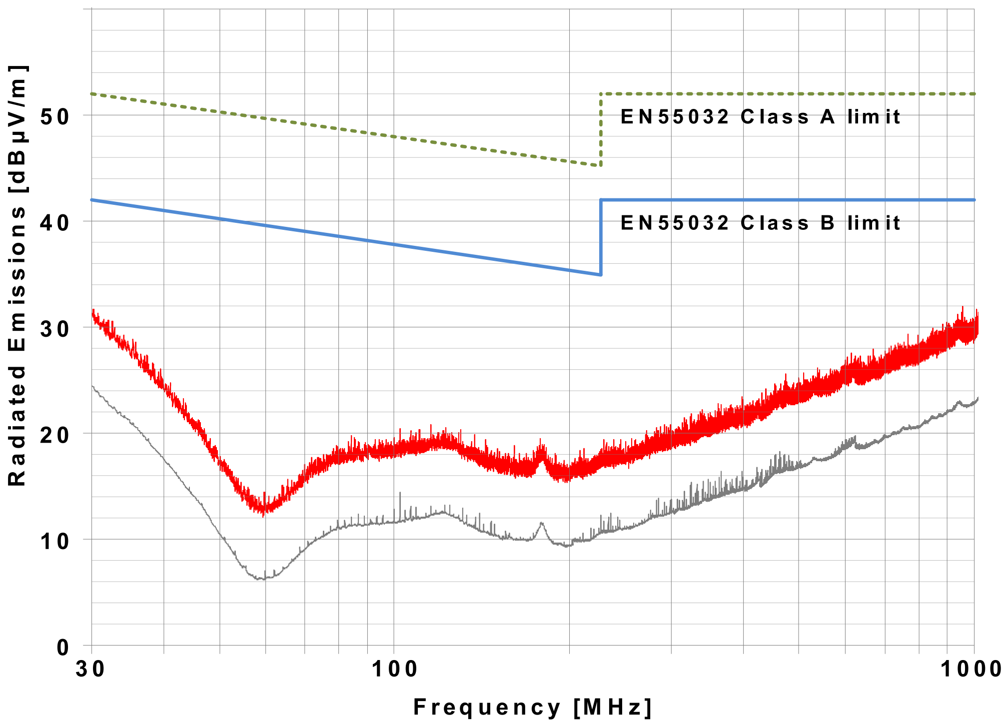


Figure 3: 171960501 radiated emissions (3m antenna distance) I_{LOAD} = 0.6A With Input Filter

The EMI behavior at the specified output current will be identical regardless of whether the MODE pin is pulled high or low.

11.2 DC Performance Curves

11.2.1 Efficiency 5V$_{IN}$ MODE = Low

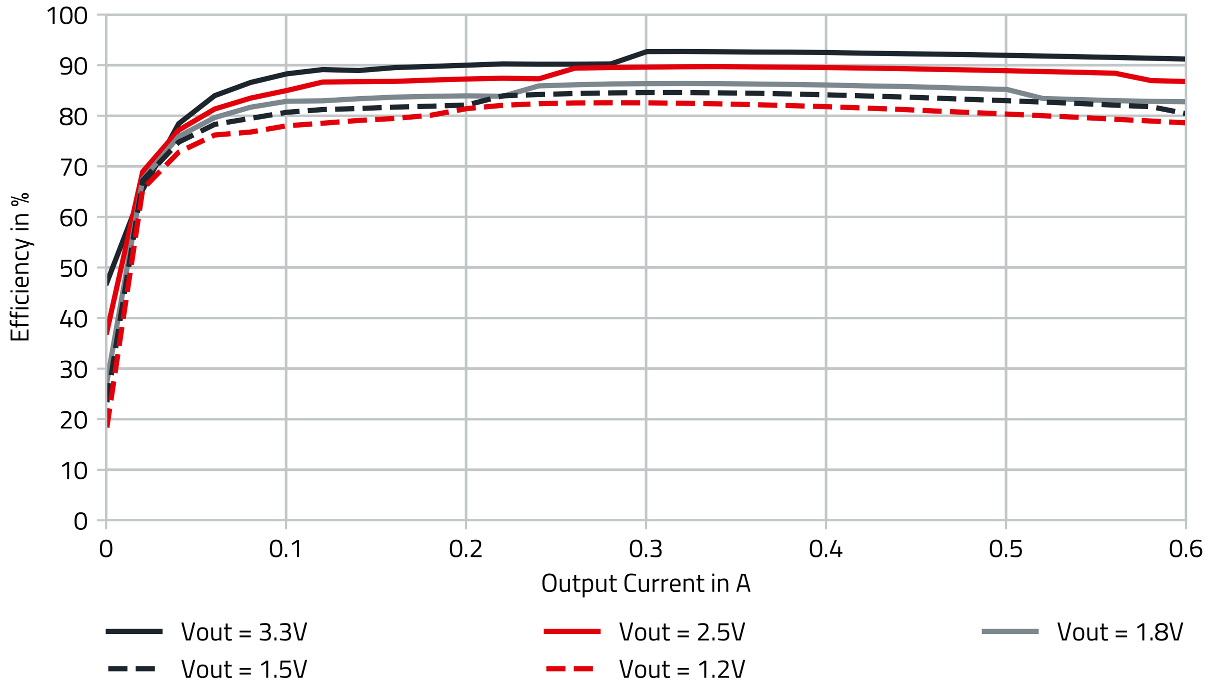


Figure 4: 171960501 efficiency V$_{IN}$ = 5V, MODE = low.

11.2.2 Efficiency 3.6V$_{IN}$ MODE = Low

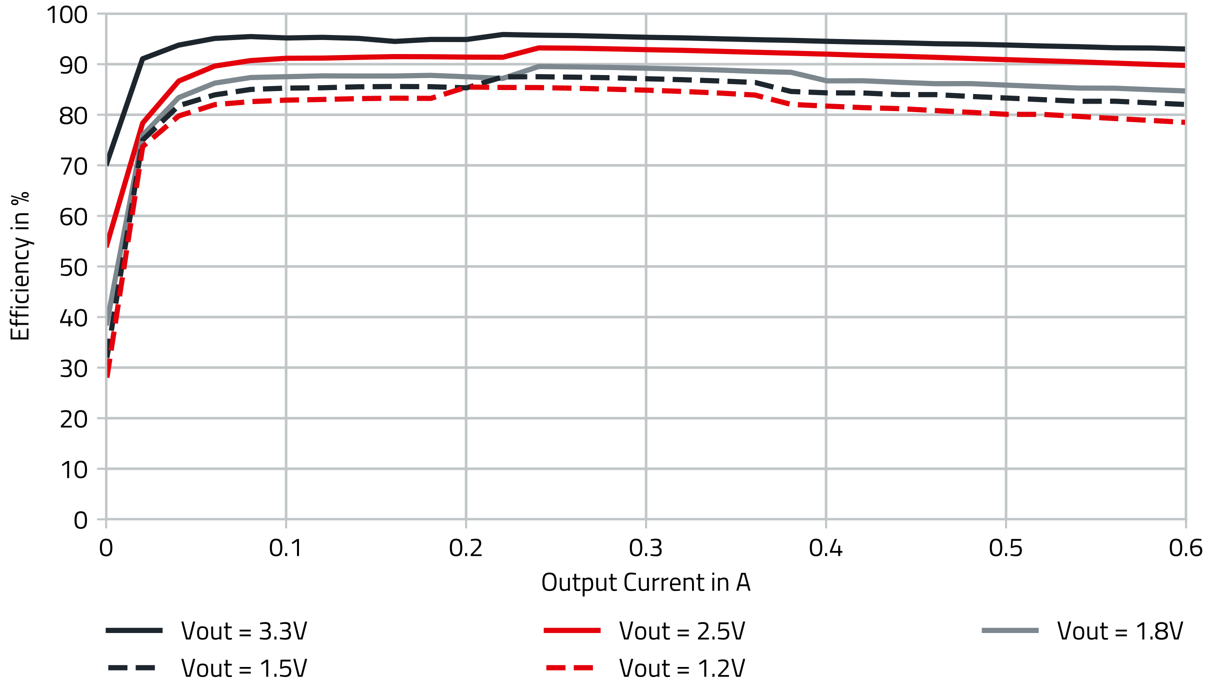


Figure 5: 171960501 efficiency V$_{IN}$ = 3.6V, MODE = low.

11.2.3 Efficiency 3.3V_{IN} MODE = Low

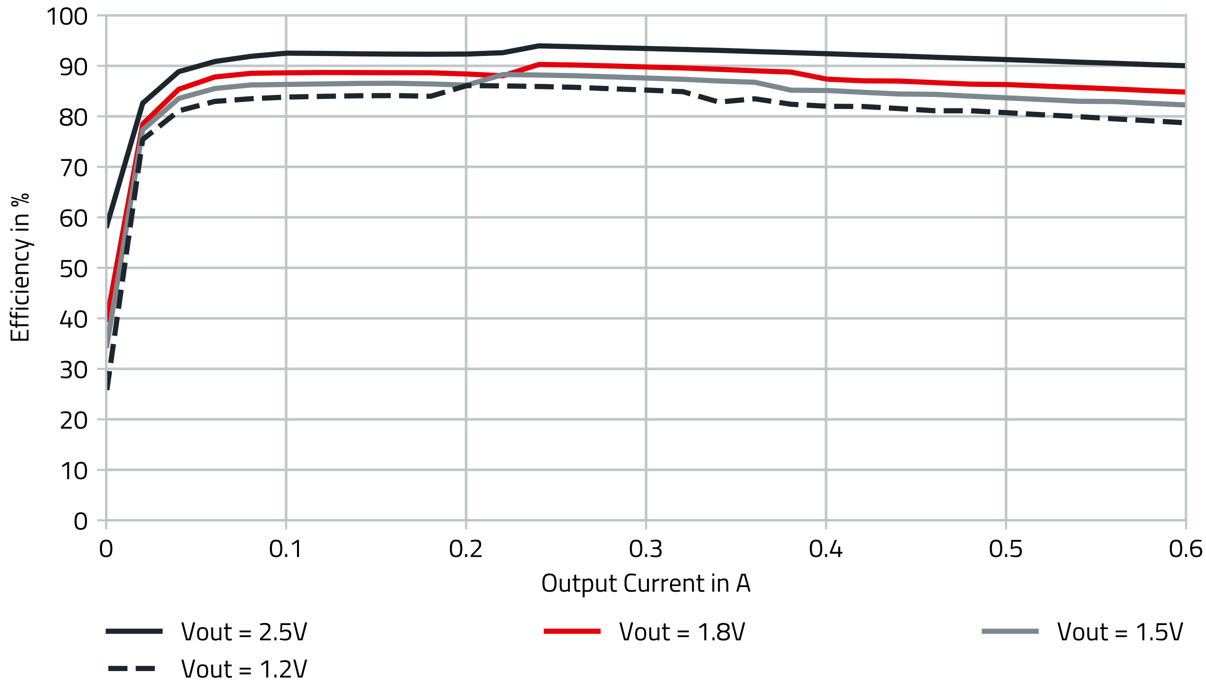


Figure 6: 171960501 efficiency V_{IN} = 3.3V, MODE = low.

11.2.4 Efficiency 5V_{IN} MODE = High

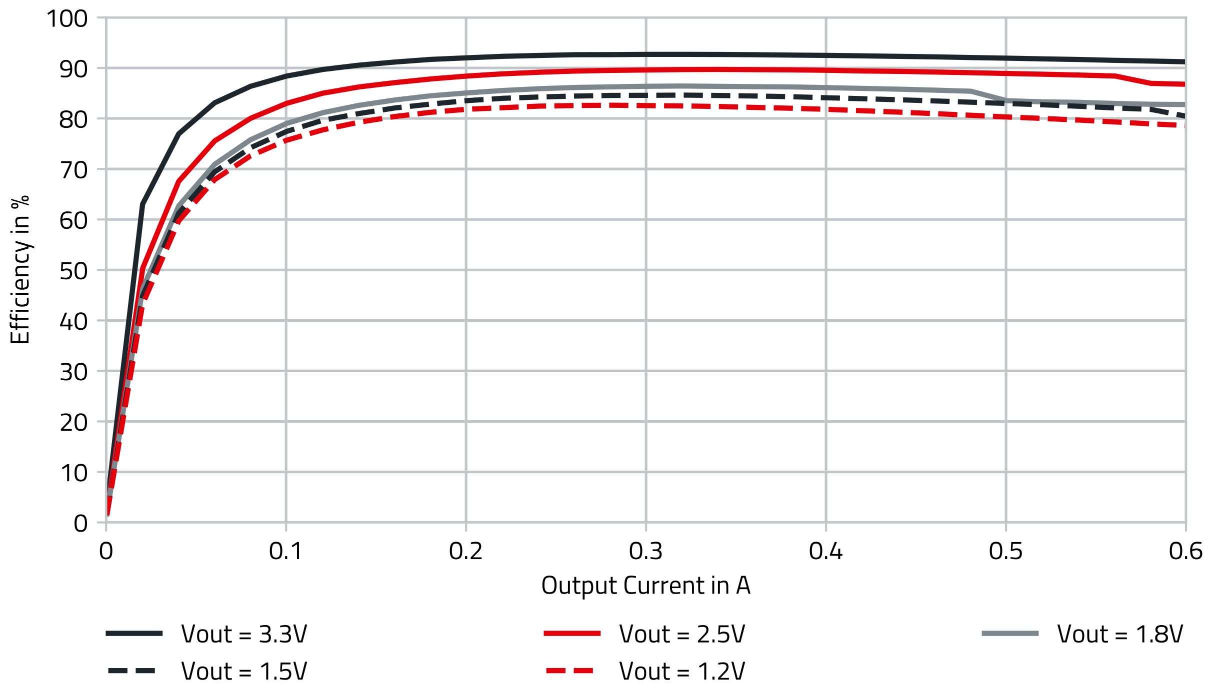


Figure 7: 171960501 efficiency V_{IN} = 5V, MODE = high.

11.2.5 Efficiency 3.6V_{IN} MODE = High

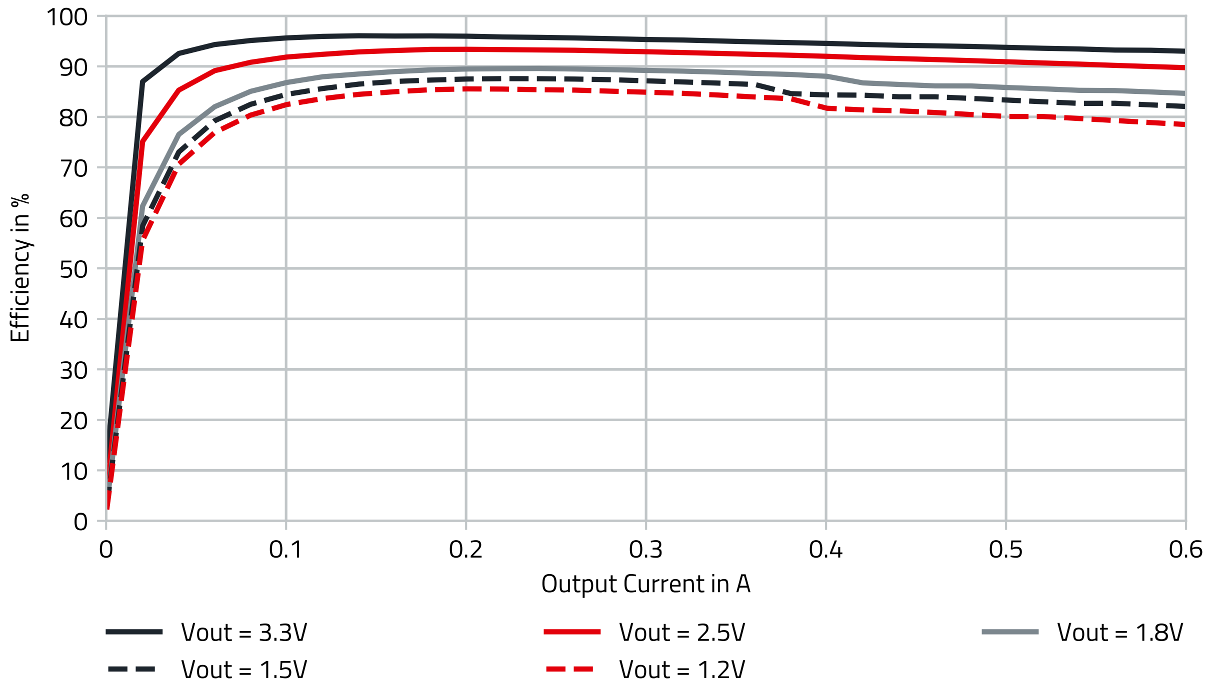


Figure 8: 171960501 efficiency V_{IN} = 3.6V, MODE = high.

11.2.6 Efficiency 3.3V_{IN} MODE = High

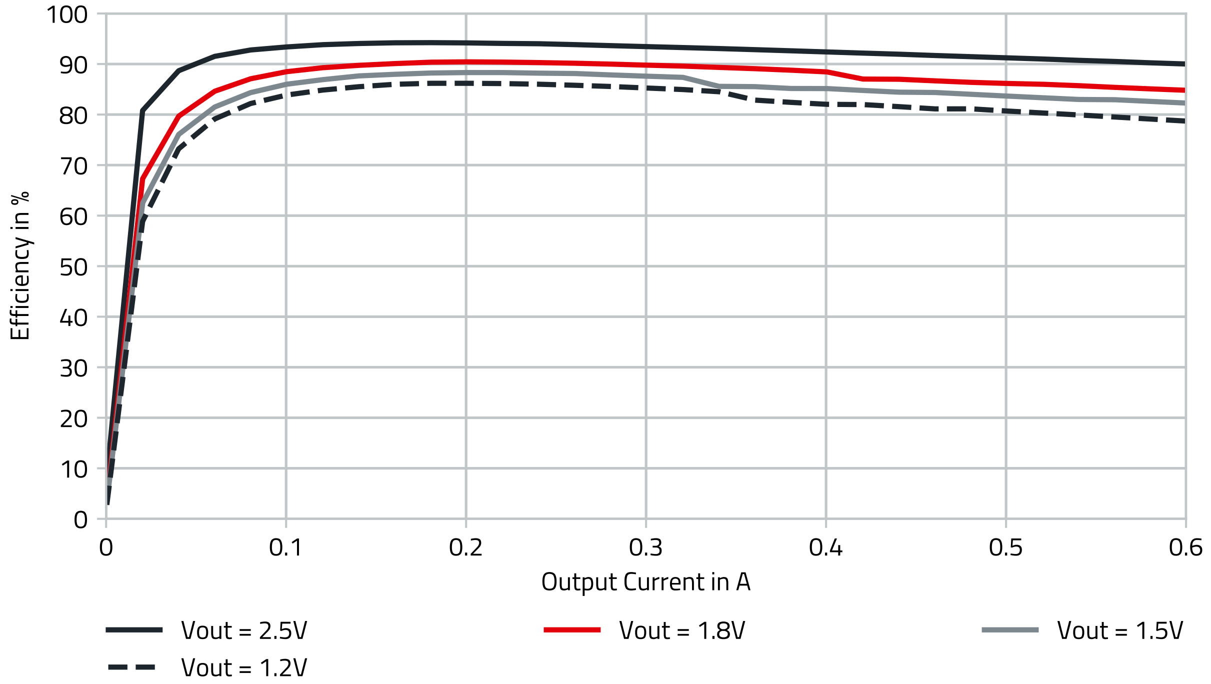


Figure 9: 171960501 efficiency V_{IN} = 3.3V, MODE = high.

11.2.7 Thermal Derating 3.3V_{OUT}

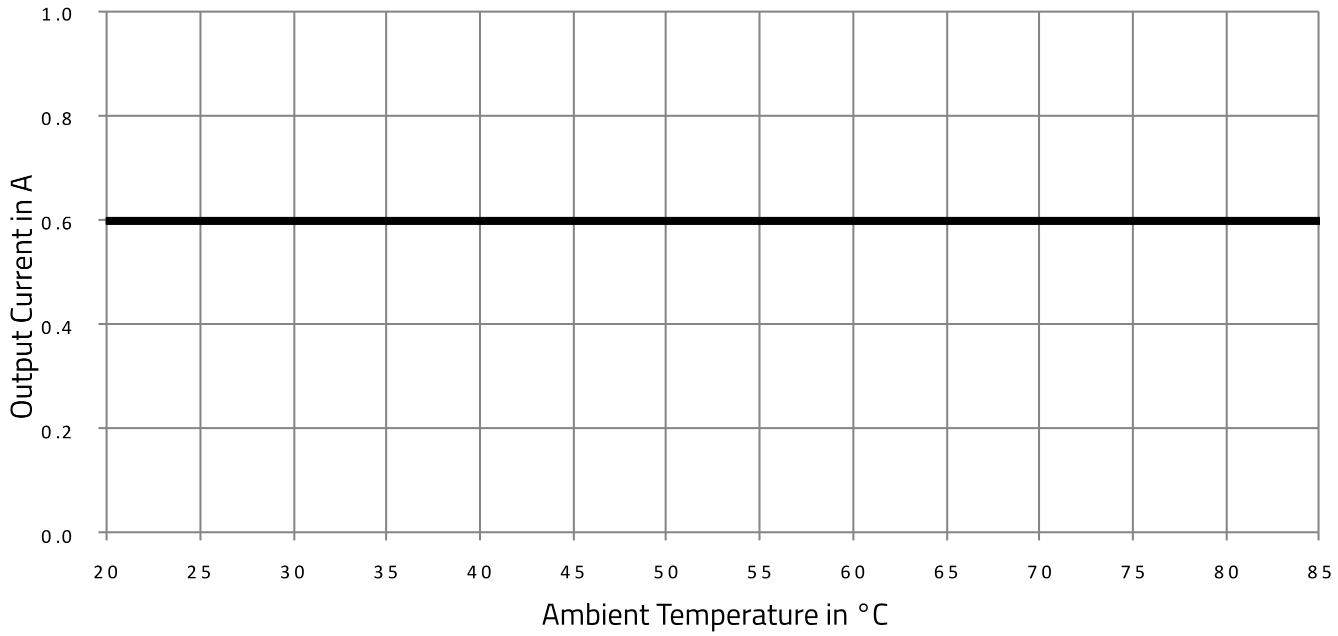


Figure 10: 171960501 output current thermal derating V_{IN} = 5V, V_{OUT} = 3.3V

11.2.8 Thermal Derating 1.8V_{OUT}

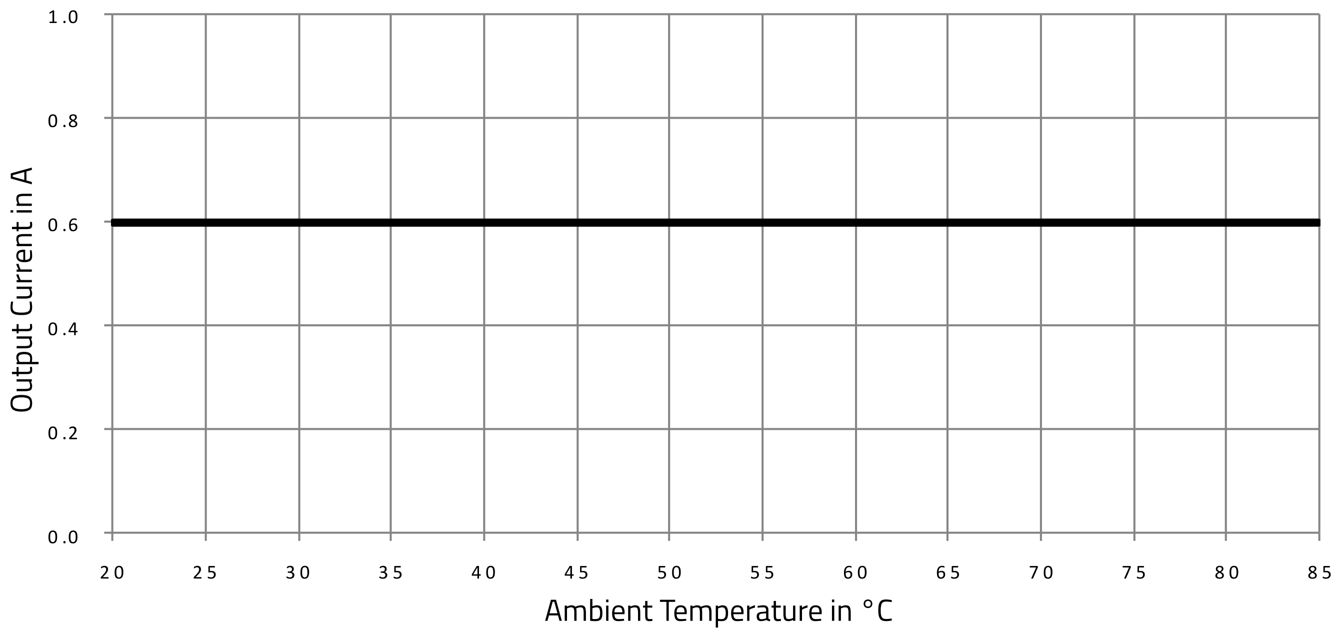


Figure 11: 171960501 output current thermal derating V_{IN} = 3.6V, V_{OUT} = 1.8V

Note: Both thermal derating graphs were measured on the 178960501 Evaluation Board (40 x 40mm two layer board, with 35µm (1 ounce) copper). Please see T_A limits in OPERATING CONDITIONS.

11.2.9 Load Regulation

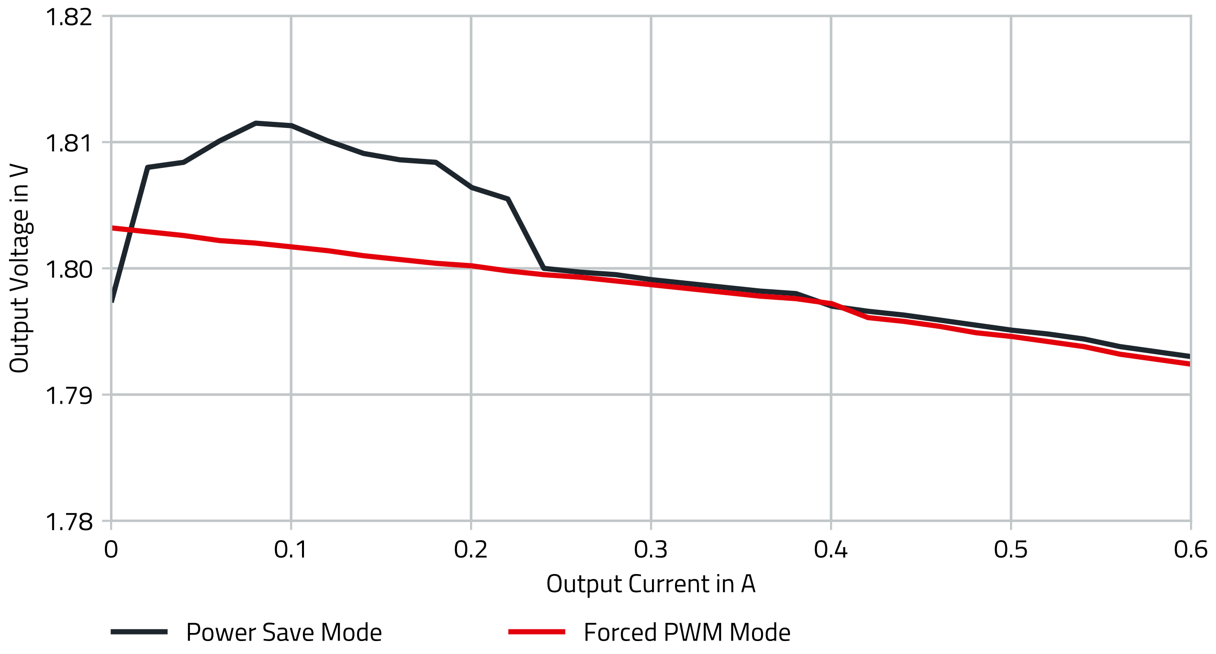


Figure 12: 171960501 load regulation V_{IN} = 3.6V, V_{OUT} = 1.8V.

11.2.10 Line Regulation

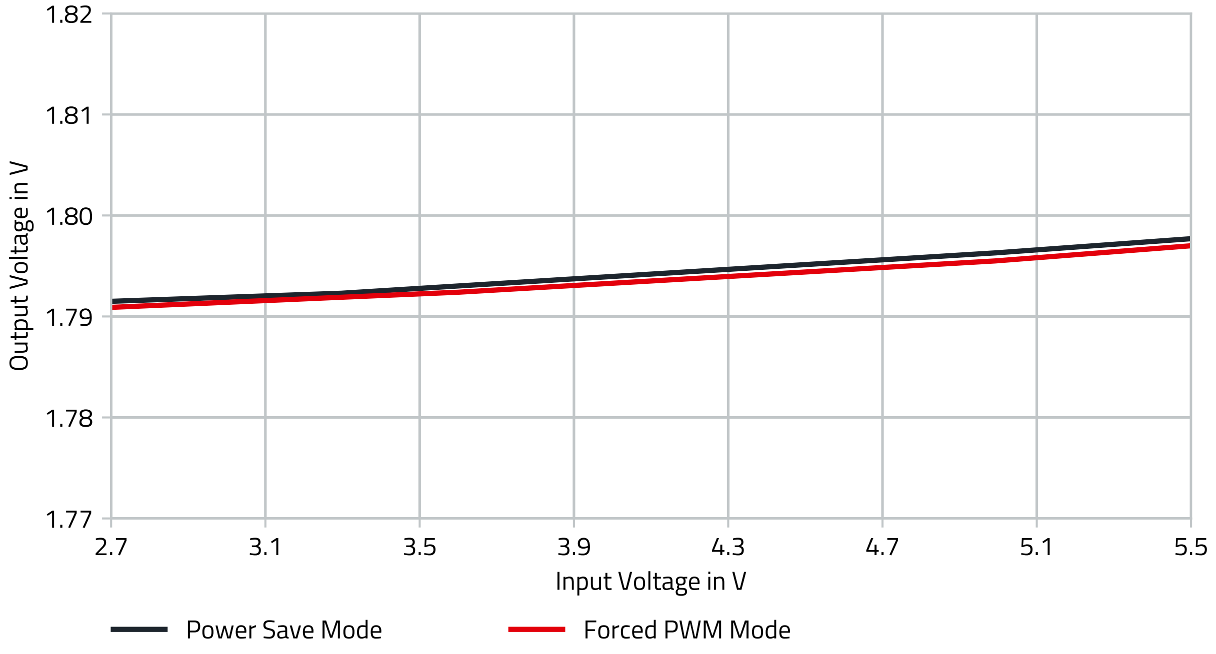


Figure 13: 171960501 line regulation V_{OUT} = 1.8V, I_{OUT} = 0.6A.

12 BLOCK DIAGRAM

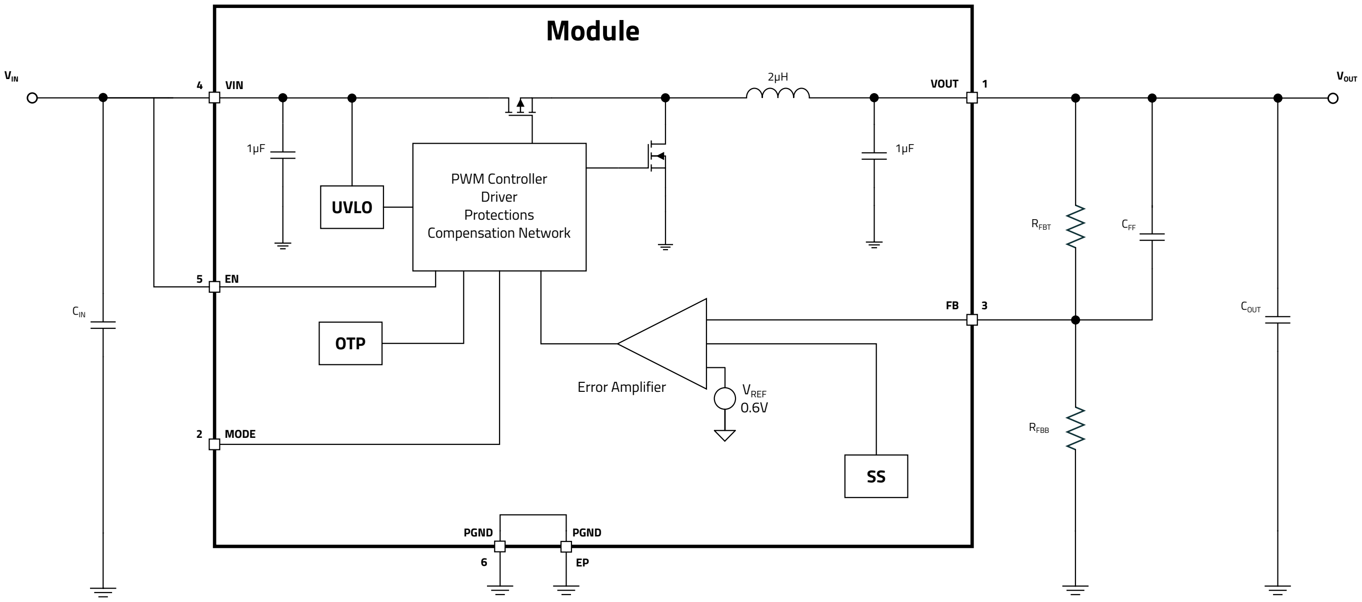


Figure 14: 171960501 block diagram.

13 CIRCUIT DESCRIPTION

The MagI³C power module 171960501 is a synchronous step down regulator with integrated MOSFETs, control circuitry and 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 power module. 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 MODE pin is pulled high the switching frequency always remains constant at 2.25MHz.

14 DESIGN FLOW

The following simple steps will show how to select the external components to design the 171960501 into an application.

Essential Steps

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

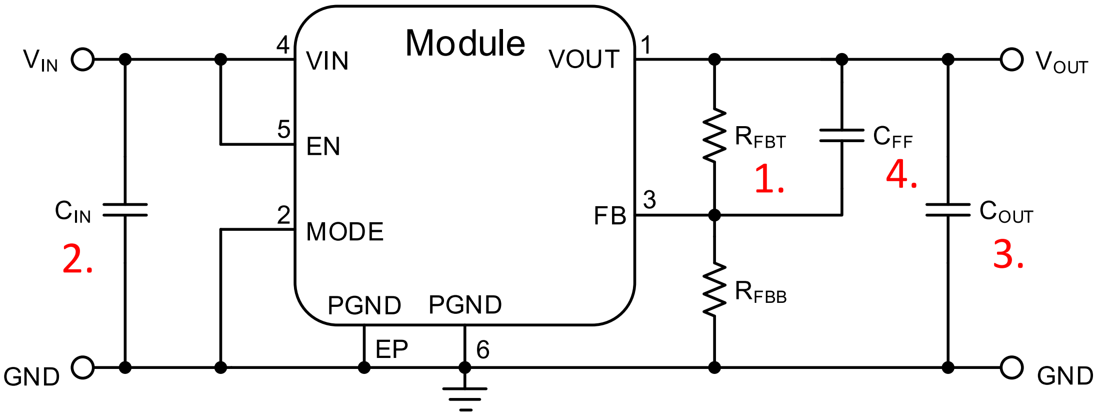


Figure 15: Design flow schematic.

14.1 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 bottom resistor of the divider is provided to the FB pin and compared with an internal reference voltage of 0.6V (V_{REF}). The output voltage adjustment range is from 0.6V to 5.5V. The output voltage can be calculated according to the following formula:

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

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.

Table 11: Output voltage selection.

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

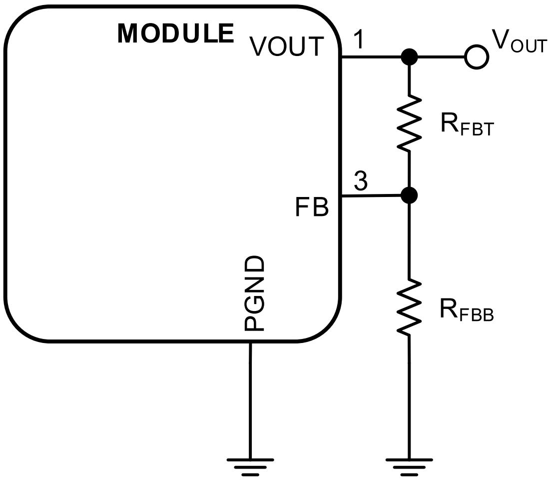


Figure 16: Output voltage schematic.

14.2 STEP 2 Select The Input Capacitor (C_{IN})

An input capacitor of 1µF is integrated inside the 171960501 MagI³C power module, ensuring excellent EMI performance and helping protect against possible voltage transients. An additional external input capacitance is required 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 power module it is recommended to use an MLCC (multi-layer ceramic capacitor) of 10µF. Attention must be paid to the voltage, frequency, and temperature deratings as well as the thermal class of the selected capacitor. The Würth Elektronik part number 885012107014 has been experimentally verified to work with this power module.

14.3 STEP 3 Select The 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 power module. An external MLCC of 10µF is recommended for all application conditions. Attention must be paid to the voltage, frequency, and temperature deratings as well as the thermal class of the selected capacitor. The Würth Elektronik part number 885012107014 has been experimentally verified to work with this power module. Attention must be paid to the external output capacitor limitations describedy in the ELECTRICAL SPECIFICATIONS.

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

$$V_{\text{OUT ripple}} = \Delta I_{\text{L}} \cdot ESR + \Delta I_{\text{L}} \cdot \left(\frac{1}{8 \cdot f_{\text{SW}} \cdot C_{\text{OUT}}}\right) \tag{2}$$

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

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

14.4 STEP 4 Select The Feed-Forward Capacitor (C_{FF})

The 171960501 MagI³C power module allows for the selection of a feed forward capacitor, C_{FF}, providing a trade-off between response time and efficiency while also affecting the transition current threshold between PFM and PWM 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 higher value of current needed to leave PFM operation.

A C_{FF} of 22pF has been evaluated experimentally as a value with suitable efficiency and transient characteristics for most applications. The Würth Elektronik part number 885012005009 has been experimentally verified to work with this power module.

The pictures below show the transient behavior of the 171960501 in response to a load transition from 0A to 0.6A using the recommended C_{FF} = 22pF, as well as other values of C_{FF}.

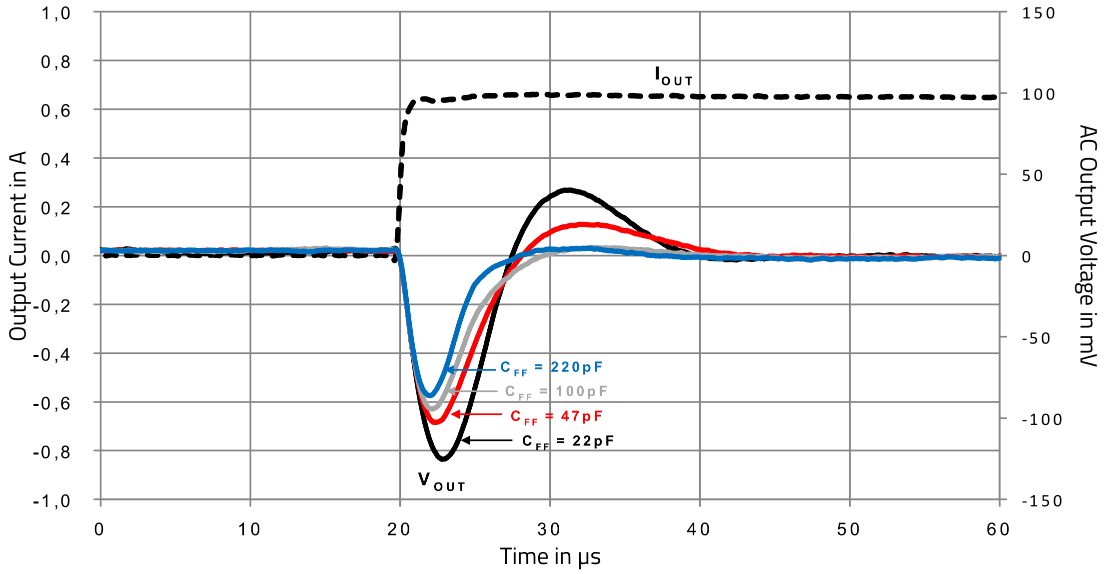


Figure 17: 171960501 load transient V_{IN} = 3.6V, V_{OUT} = 1.8V from 0A to 0.6A, MODE = high.

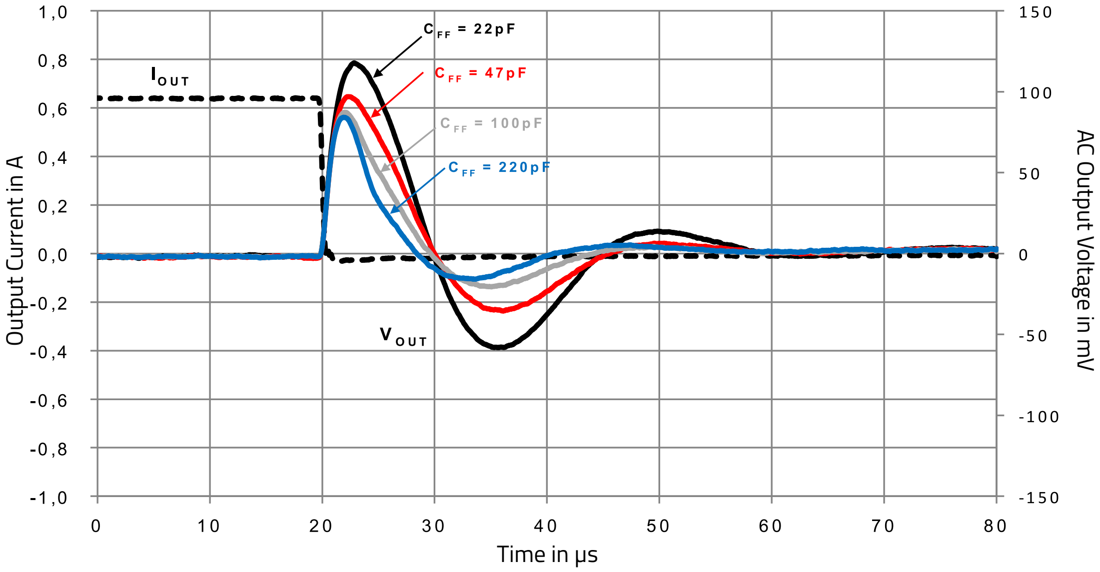


Figure 18: 171960501 load transient V_{IN} = 3.6V, V_{OUT} = 1.8V from 0.6A to 0A, MODE = high.

These behaviors are valid only for the specified conditions and must be verified in the real application.

The C_{FF} value only affects the efficiency during light load conditions when the MODE pin is pulled low.

As explained in the section MODES OF OPERATION, during light load conditions with the MODE pin pulled low 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.

Increasing C_{FF} will cause the power module to burst more often, resulting in a decrease in light load efficiency.

While the recommended C_{FF} value of 22pF will work for most applications, the user can adjust the performance of the power module based on their application by trading between light load efficiency and transient response. This customization tailors the behavior of the power module to the application's needs. Any deviations from the recommended values and components should be thoroughly evaluated by the customer to ensure the device operates properly.

15 MODES OF OPERATION

The MODE pin of the 171960501 can be pulled either high or low to alter the light load performance of the power module based on the application requirements.
When pulled high, PWM operation will be forced throughout the entire load current range. When pulled low, PFM operation will occur during light load conditions.
The power module will operate in one of three modes, depending on the operating conditions.

15.1 Pulse Width Modulation (PWM) Operation

The power module operates at a fixed switching frequency of 2.25MHz where the duty cycle (D) is determined by the following equation:

$$D = \frac{V_{\text{OUT}}}{V_{\text{IN}}} \tag{4}$$

The on-time is determined by the duty cycle and the switching frequency as follows:

$$t_{\text{ON}} = \frac{D}{f_{\text{SW}}} \tag{5}$$

The on and off-times can be related to the switching frequency as follows:

$$\frac{1}{f_{\text{SW}}} = t_{\text{ON}} + t_{\text{OFF}} \tag{6}$$

15.2 100% Duty Cycle Operation

When the input voltage approaches the output voltage and the duty cycle approaches 100%, the power module will leave the high side MOSFET on continuously and the output voltage will be limited by the input voltage. Further decreases of input voltage will result in a corresponding decrease in output voltage.

15.3 Pulse Frequency Modulation (PFM) Operation

If the MODE pin is pulled low PFM operation is initiated when the power module enters discontinuous mode. A burst of switching cycles increases the output voltage above the set value followed by a period of dead time where the output current is only delivered by the output capacitor. This results in slightly increased output voltage ripple in exchange for significantly increased conversion efficiency.
The frequency of the bursts depends on the load and is significantly lower than the default switching frequency. As the output current demand increase the bursts become more frequent until the module automatically transitions out of PFM operation.
The burst frequency is a function of input voltage, output voltage, output current, C_{FF}, and C_{OUT}. Changing any of these parameters will alter the device's behavior during PFM operation.

16 OUTPUT VOLTAGE RIPPLE

The output voltage ripple is influenced by the condition applied to the MODE pin and the output current drawn from the module. If the MODE pin is pulled high and the duty cycle is below 76%, the ripple is very low and it always has the same frequency as the internal oscillator (2.25MHz typ.). If MODE is pulled low and either the load current is low enough or the duty cycle is high enough then the output voltage ripple will be higher and the frequency lower than the nominal switching frequency (see pictures below).

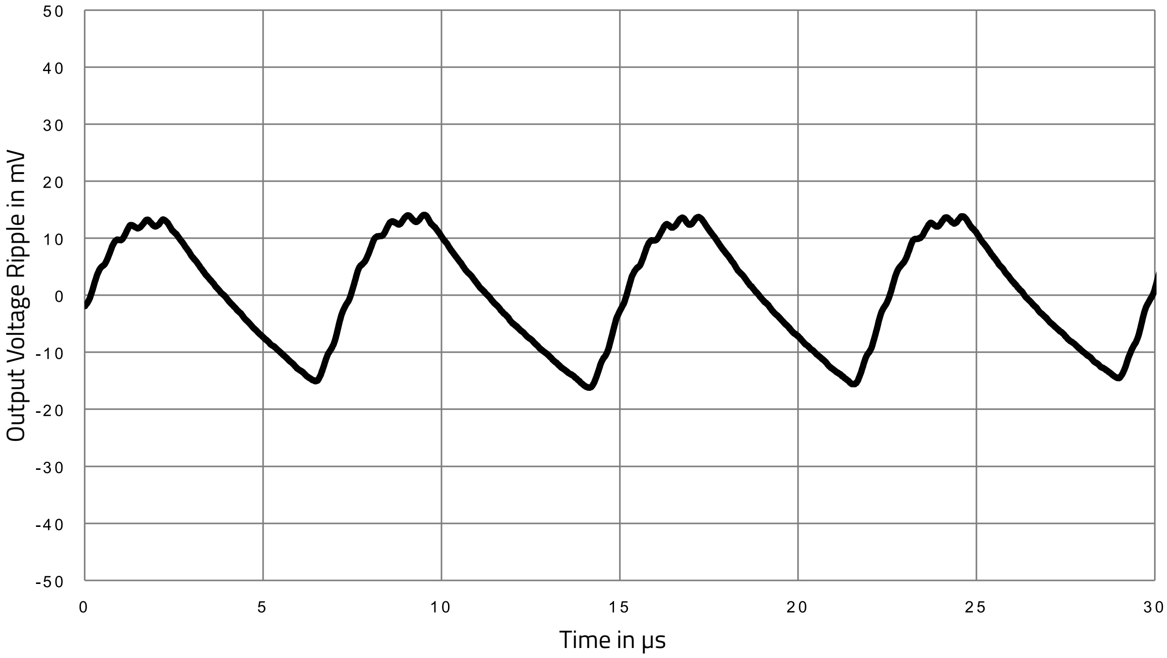


Figure 19: 171960501 output voltage ripple V_{IN} = 3.6V, V_{OUT} = 1.8V, I_{OUT} = 0.1A, C_{OUT} = 10µF, MODE = low.

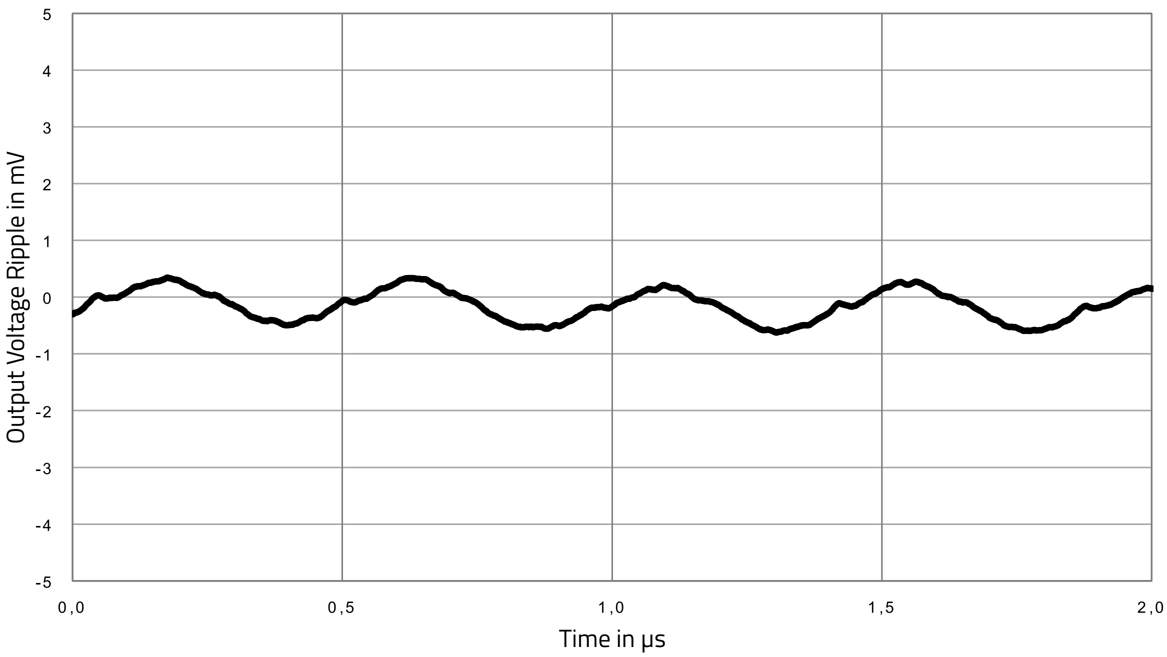


Figure 20: 171960501 output voltage ripple V_{IN} = 3.6V, V_{OUT} = 1.8V, I_{OUT} = 0.1A, C_{OUT} = 10µF, forced PWM mode.

17 PROTECTION FEATURES

17.1 Overcurrent Protection (OCP)

For protection against load faults, the 171960501 MagI³C power module incorporates a current limit (see I_{OCP} in ELECTRICAL SPECIFICATIONS). 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.

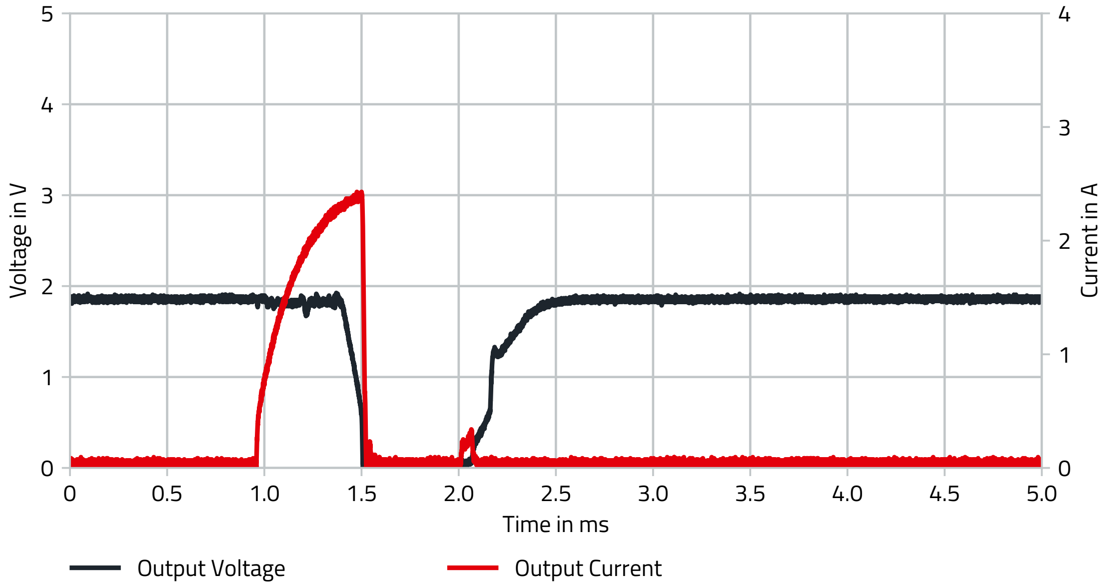


Figure 21: 171960501 overcurrent protection V_{IN} = 3.6V, V_{OUT} = 1.8V.

17.2 Short Circuit Protection (SCP)

When the 171960501 MagI³C power module experiences a short circuit condition at the output it enters a hiccup mode. The power module 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 condition is not cleared, these cycles will continue to repeat (see figure below).

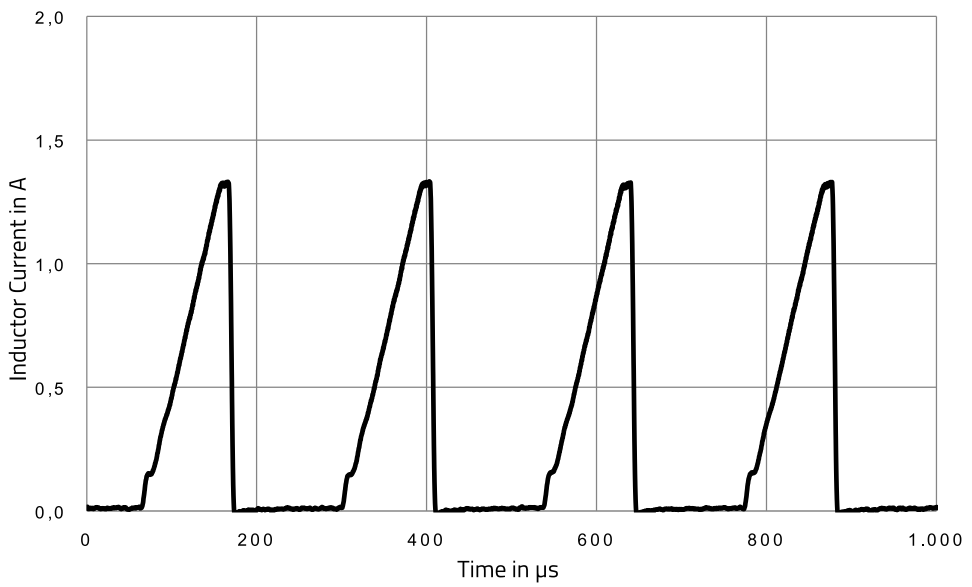


Figure 22: 171960501 short circuit protection V_{IN} = 3.6V, V_{OUT} = 1.8V, short circuit condition.

17.3 Over Temperature Protection (OTP)

Thermal protection helps prevent catastrophic failures due to accidental device overheating. The junction temperature of the 171960501 MagI³C power module 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 the hysteretic value, the internal soft-start is engaged, V_{OUT} rises smoothly, and normal operation resumes.

17.4 Undervoltage Lockout (UVLO)

The device incorporates input undervoltage lockout (UVLO) to protect from unexpected behavior at input voltages below the recommended values. The thresholds of the UVLO are indicated in the ELECTRICAL SPECIFICATIONS.

17.5 Soft-Start

The 171960501 MagI³C power module implements an internal soft-start in order to limit the inrush current and avoid output voltage overshoot during start-up.

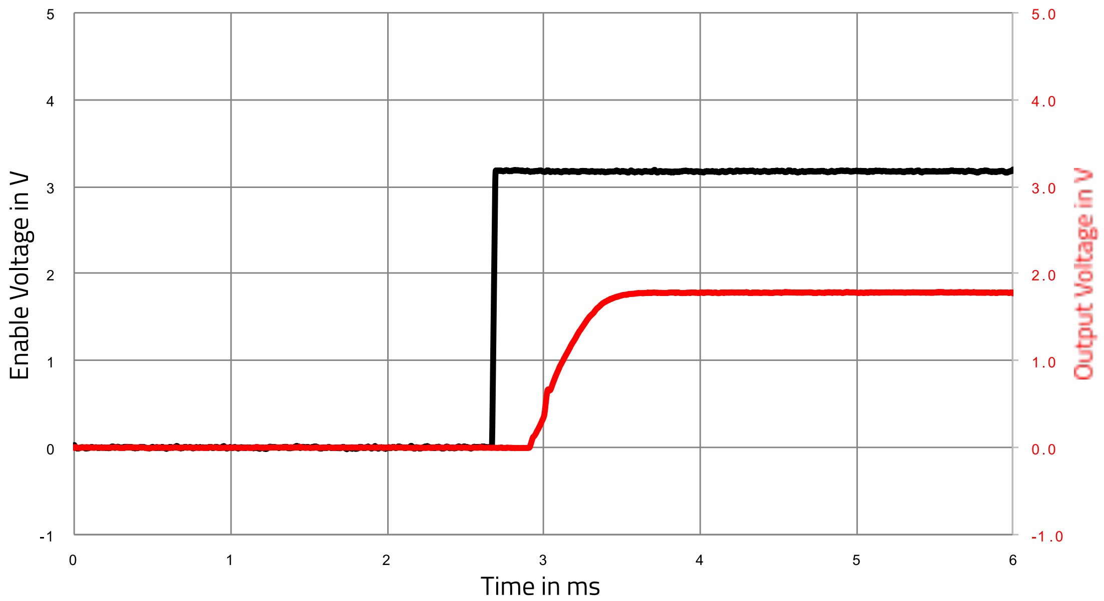


Figure 23: 171960501 soft-start V_{IN} = 3.6V, V_{OUT} = 1.8V

17.6 Enable

The 171960501 MagI³C power module is enabled by setting the pin EN high. After setting EN high the module prepares for operation. Once prepared, the module begins switching and the internal soft-start regulates the output voltage rise until the desired output voltage is met allowing normal operation to take place.

18 APPLICATION RECOMMENDATION FOR HIGH CAPACITIVE LOADS

There are applications, such as FPGAs and 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 module may decrease. This will result in undesired oscillations at the output of the power module.

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 power module and recommended external circuitry (i.e. feedback network, 10µF input capacitor and recommended output capacitor of 10µF) and the second system contains any additional capacitance beyond the recommended 10µF. An output filter with a 4.7µH inductor is required in between the first and the second system. This output filter separates the power module system from the higher capacitive load, keeping the phase and gain margin of the control loop of the power module within the intended frequency range.

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

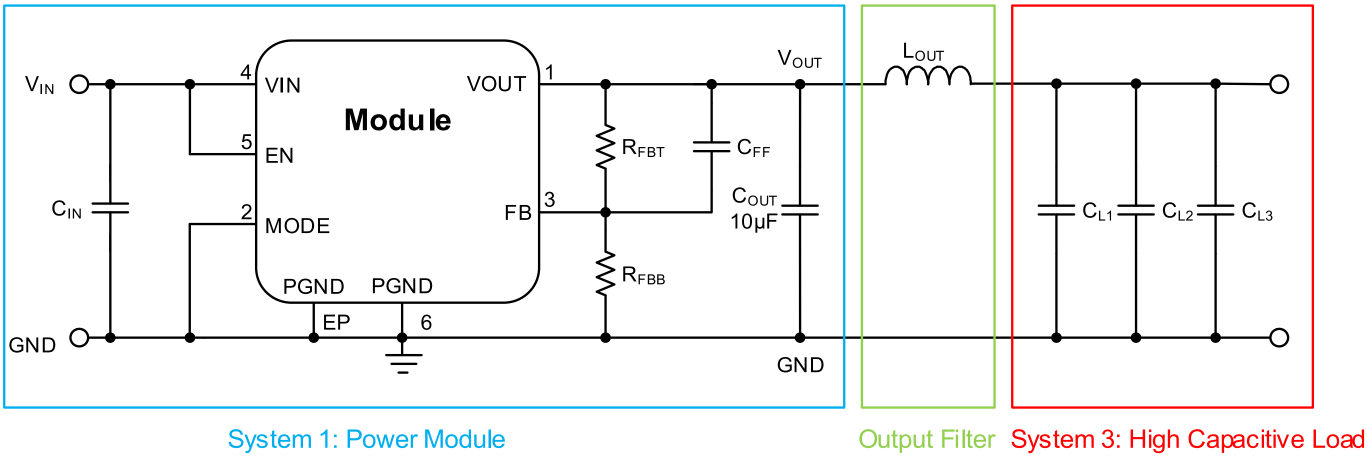


Figure 24: 171960501 application implementation with high capacitive loading.

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 drawn from the power module. 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 171960501.

19 DESIGN EXAMPLE

19.1 Layout

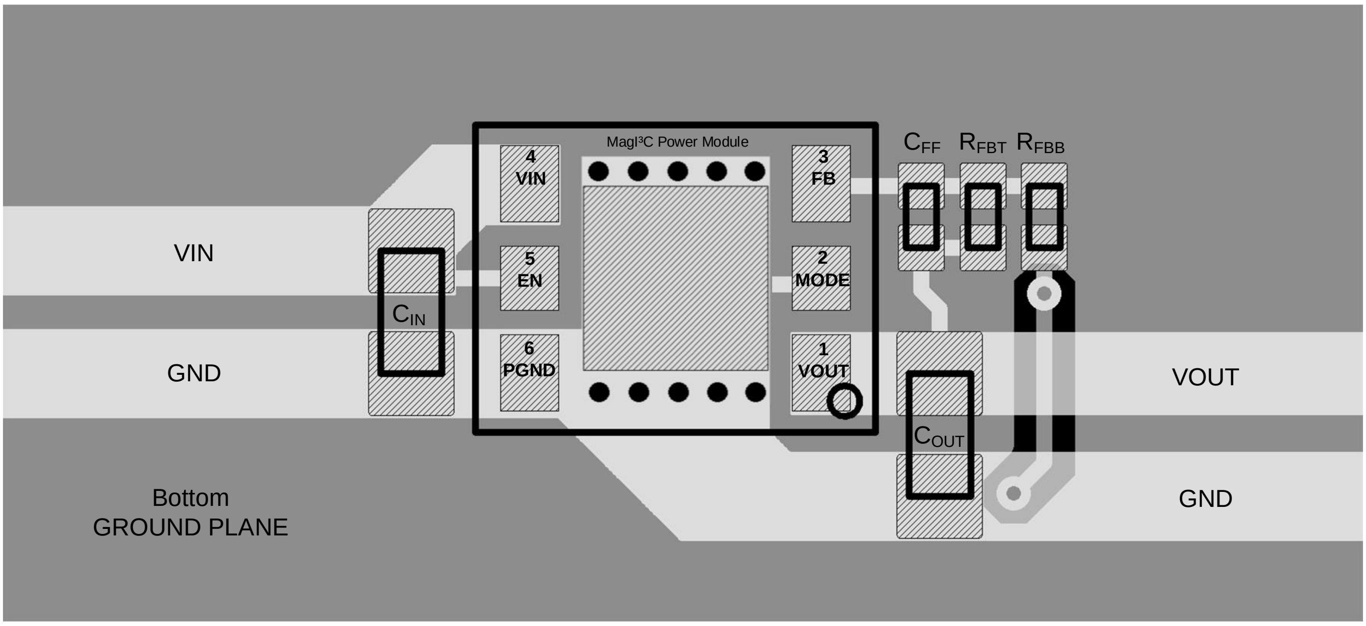


Figure 25: 171960501 layout recommendation.

The picture above shows a possible layout for the 171960501 MagI³C power module. Nevertheless, some recommendations should be followed when designing the layout:

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).

19.2 Schematic

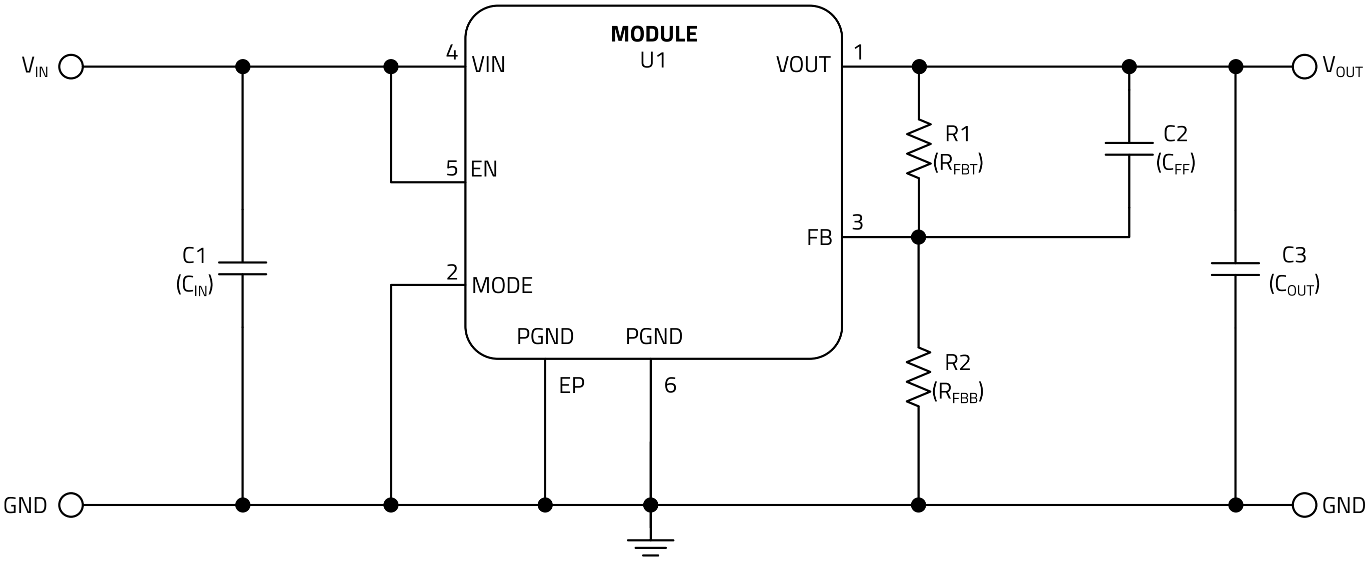


Figure 26: 171960501 design example schematic.

19.3 Bill of Materials

Table 12: 171960501 bill of materials.

Designator	Description	Quantity	Order Code	Manufacturer
U1	MagI³C power module	1	171960501	WE
C1, C3	Ceramic chip capacitor 10µF/16V X5R, 0805	2	885012107014	WE
C2	Ceramic chip capacitor 22pF/25V NP0, 0603	1	885012005009	WE
R1	100kΩ	1		
R2	49.9kΩ for V_{OUT} = 1.8V	1		

20 HANDLING RECOMMENDATIONS

1. The power module is classified as MSL1 (JEDEC Moisture Sensitivity Level 1) according to JEDEC J-STD033.
2. The components should be sealed and stored in a controlled environment prior to soldering or other use.
3. If the components are to be baked prior to soldering, the baking must be performed with the components in an inert gas such as nitrogen or argon.
4. Maximum numbers of reflow cycles is two.
5. For minimum risk, solder the module in the last reflow cycle of the PCB production.
6. Please consider that the leads are finished with AgPd.
7. For solder paste use a standard SAC Alloy such as SAC 305, type 3 or higher.
8. The profile below is valid for convection reflow only.
9. Other soldering methods (e.g. vapor phase) are not verified and have to be validated by the customer at their own risk

21 SOLDERING PROFILE

Table 13: Reflow soldering profile.

Profile Feature	Symbol	Value
Preheat temperature minimum	T_{s_min}	150 °C
Preheat temperature maximum	T_{s_max}	180 °C
Preheat time from T_{s_min} to T_{s_max}	t_s	60-90 seconds
Liquidous temperature	T_L	217 °C
Time maintained above T_L	t_L	60-90 seconds
Classification temperature	T_C	240 °C
Peak package body temperature	T_P	$T_P \leq T_C$
Time within T_C - 5 °C and T_C	t_P	$t_P \leq$ 20 seconds
Ramp-up Rate (T_L to T_p)		3 °C/second maximum
Ramp-down rate (T_p to T_L)		3 °C/second maximum
Time 25 °C to peak temperature		8 minutes maximum

Please refer to JEDEC J-STD020E for further information pertaining to reflow soldering of electronic components.

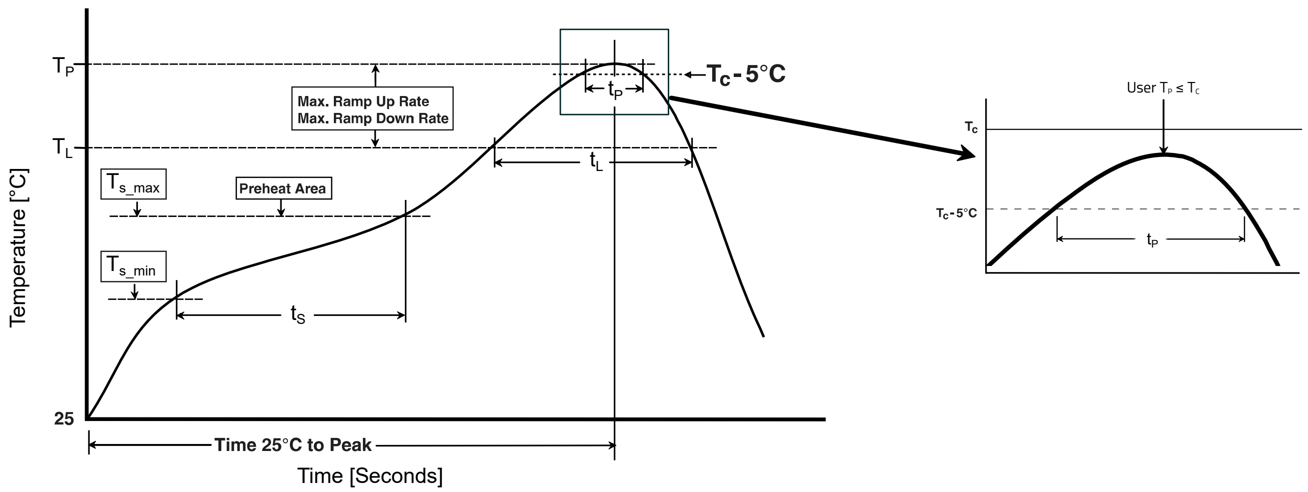


Figure 27: Soldering profile.

22 PHYSICAL DIMENSIONS

22.1 Component

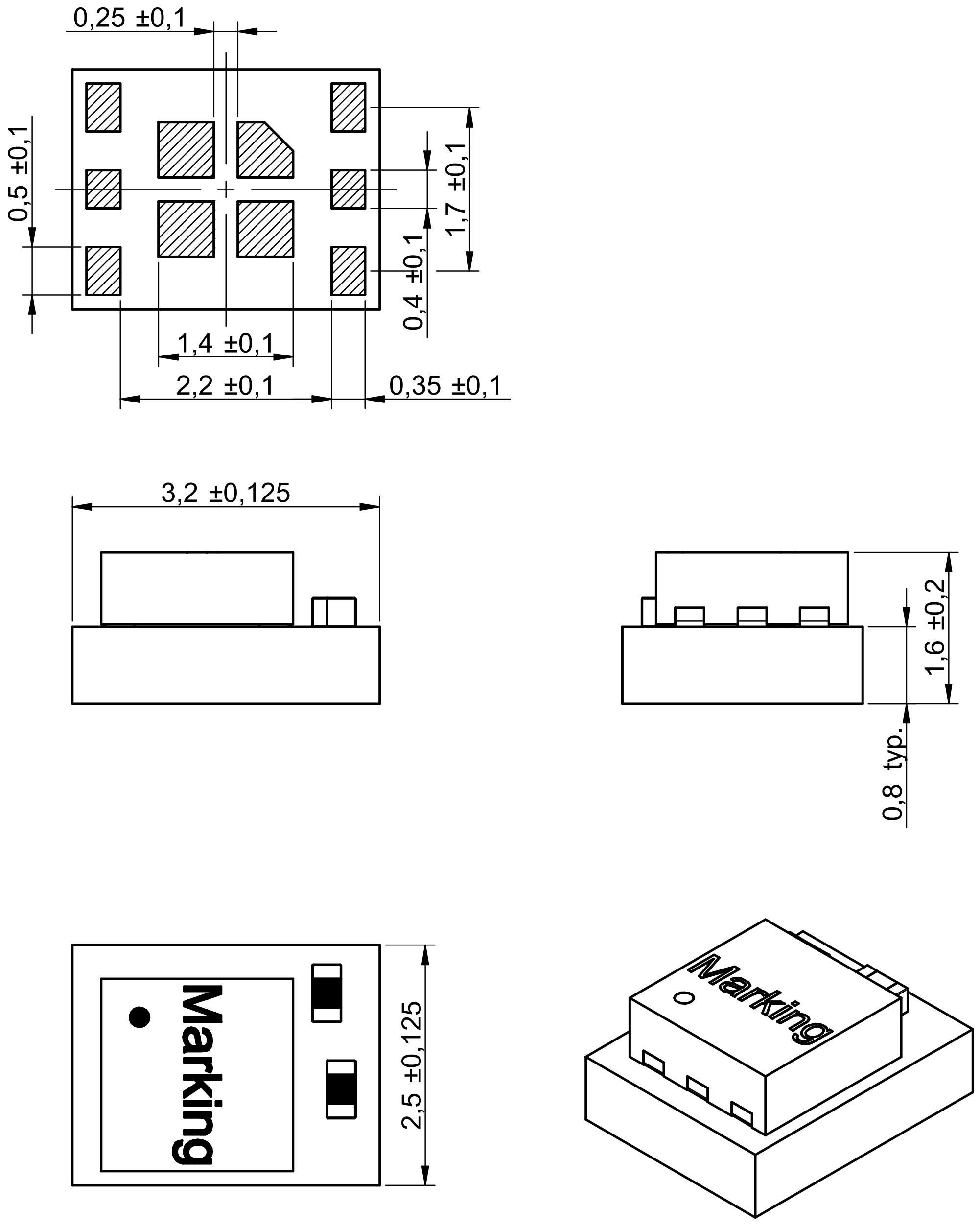
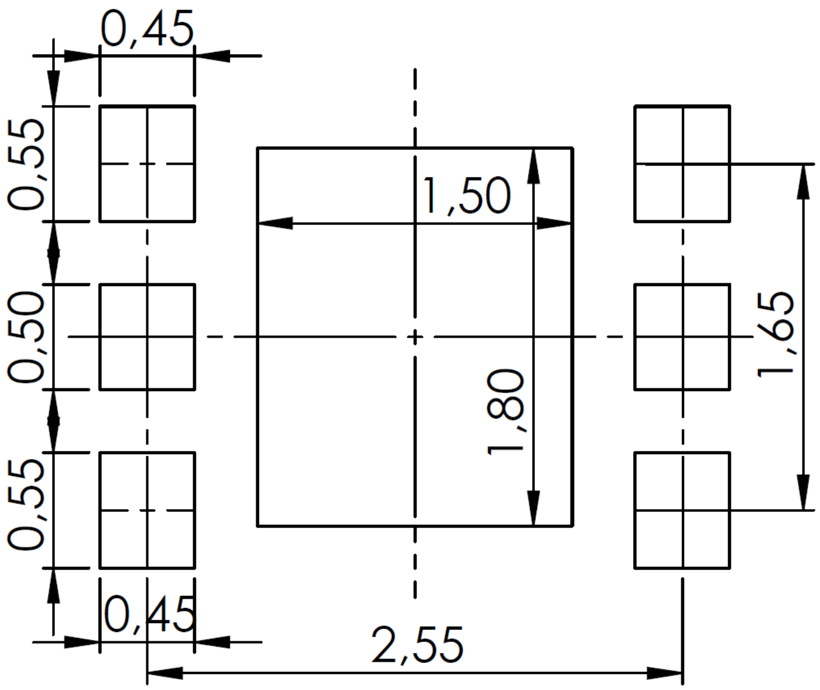


Figure 28: 171960501 module dimensions.

All dimensions in mm
Tolerances ±0,1mm unless otherwise specified

22.2 Example Landpattern



All dimensions in mm

Figure 29: 171960501 example landpattern.

All dimensions in mm
Stencil thickness of 100µm

22.3 Packaging

Reel in mm

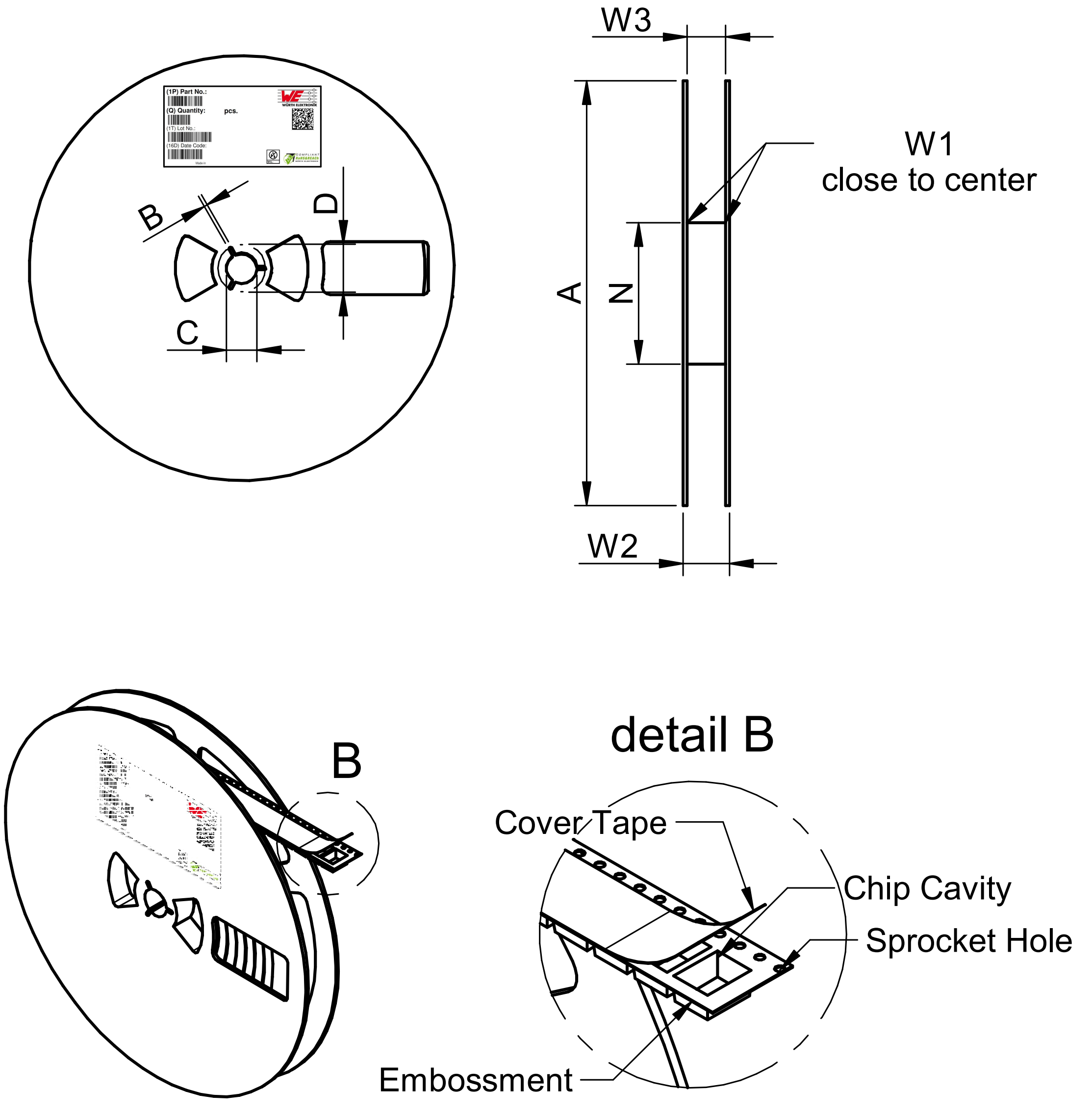
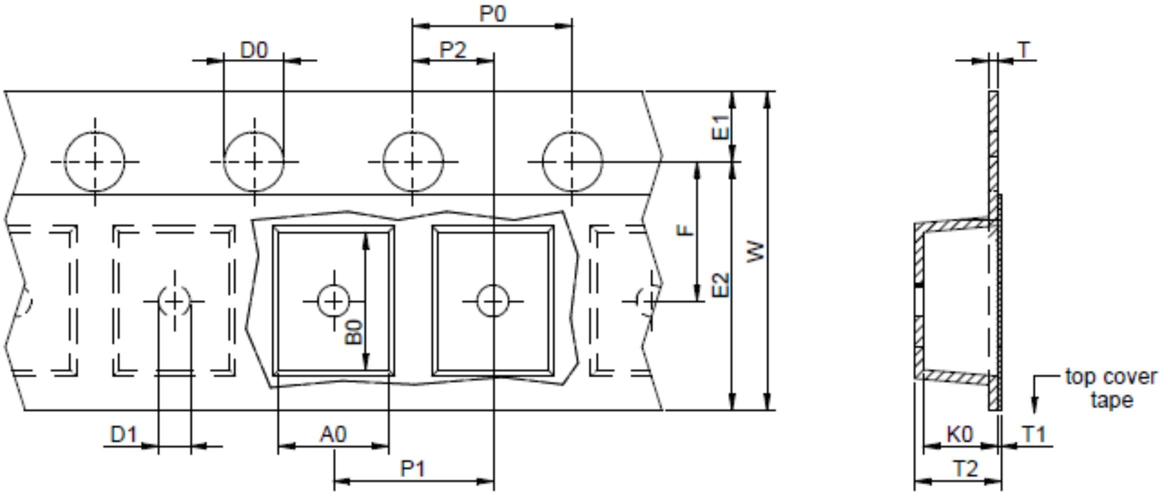


Figure 30: 171960501 reel dimensions.

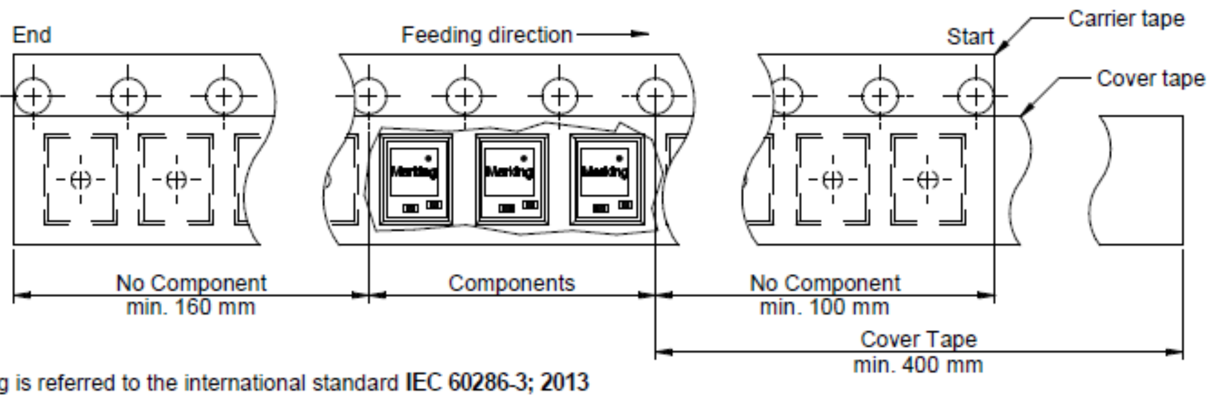
Table 14: Reel dimensions.

A	B	C	D	N	W1	W2	W3	Material
typ.	min.	±0.8	min.	min.	±1.5	max.	min.	
178.00	1.50	13.00	20.20	50.00	8.40	14.40	7.90	Polystyrene

Tape in 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 1206	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	3000



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

Figure 31: 171960501 tape dimensions.

Tape material is polystyrene.

23 DOCUMENT HISTORY

Table 15: Document history part 1.

Revision	Date	Description	Comment
1.0	July 2019	Initial data sheet release	
2.0	November 2021	PCN	Würth Elektronik has defined the maximum allowable output capacitance that can be used at the output of the power module. 1. The minimum and maximum storage temperature. 2. The junction to ambient thermal resistance. 3. The layout recommendation to improve readability and recommended practices. 4. The solder handling instructions (no change to actual profile). 5. The package information. 6. The evaluation board bill of material to reflect the evaluation board. 7. The cautions and warnings of the data sheet. 8. The format of the data sheet to improve readability of the document.
2.1	March 2022	Minor formatting change	Changed output voltage and feedback resistor table format in Step 1 of the Design Flow section.
3.0	May 2022	PCN	1. The maximum absolute rating maximum limit for VOUT, EN, FB and MODE. 2. The parameter description for the MODE absolute maximum rating. 3. The quiescent current values in the electrical specifictions. 4. The date for the release of version 2.0 in the document history.

Table 16: Document history part 2.

Revision	Date	Description	Comment
4.0	September 2024	PCN	Würth Elektronik has updated or corrected: 1. Line and load regulation units. 2. Input current values. 3. Modes of operation. 4. Overcurrent graph. 5. Handling recommendations. 6. MSL level. 7. Number of allowed solder cycles. 8. Component storage and baking instructions. 9. Lead finish information. 10. Storage temperature range.

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26 CAUTIONS AND WARNINGS

The following conditions apply to all goods within the product series of MagI^{3}C 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.
- The responsibility for the applicability of customer specific products and use in a particular customer design is always within the authority of the customer. All technical specifications for standard products do also apply for customer specific products
- 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.
- 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.

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.

27 IMPORTANT NOTES

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.

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.

Best Care and Attention

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

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.

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.

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.

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.

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.