

### 3.5V - 36V Input / 0.3A Output / 1V - 6V Output

#### DESCRIPTION

The VDMM 171930601 Magl<sup>3</sup>C power module provides a fully integrated DC-DC converter including the switching regulator IC with integrated MOSFETs, controller, compensation and shielded inductor in one package.

The 171930601 offers high efficiency and delivers up to 0.3A of output current. It operates with an input voltage from 3.5V to 36V and is designed for a small solution size.

The MicroModule maintains high efficiency throughout the output current range by automatically transitioning between operating modes based on the load demands.

The 171930601 is available in an LGA-8EP package (5 x 2.5 x 1.8mm).

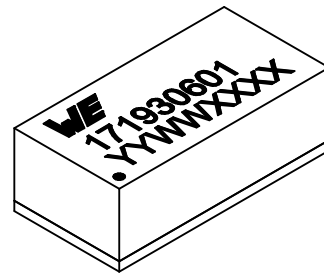
This module has integrated protection circuitry that guards against thermal overstress with thermal shutdown and protects against electrical damage using overcurrent, short-circuit and undervoltage protections.

#### FEATURES

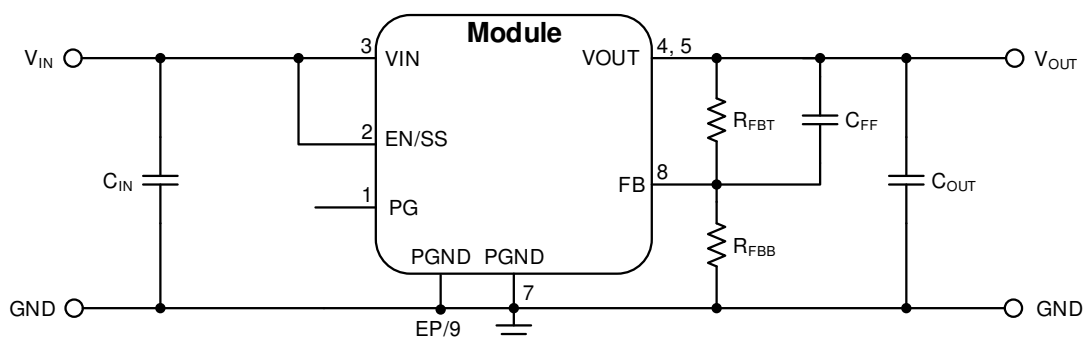
- Peak efficiency up to 87%
- Current capability up to 0.3A
- Input voltage range: 3.5V to 36V
- Output voltage range: 1V to 6V
- 12.5µA typical quiescent current
- Integrated shielded inductor
- Fixed switching frequency: 1.2MHz
- Current mode control
- Synchronous operation
- Undervoltage lockout
- Internal soft-start
- Adjustable soft-start
- Power good indicator
- Thermal shutdown
- Short-circuit protection
- Cycle-by-cycle current limit
- RoHS und REACH compliant
- Ambient temp. range: -40°C to 105°C
- No output current derating up to 85°C ambient temperature
- Operating junction temp. range: -40°C to 125°C
- Complies with EN55032 class B radiated and conducted emissions standards

#### TYPICAL APPLICATIONS

- Test and measurement
- Industrial control
- HVAC and building control
- Sensors



#### TYPICAL CIRCUIT DIAGRAM



## CONTENTS

<b>1</b>	<b>PINOUT</b> . . . . .	<b>4</b>
<b>2</b>	<b>ORDERING INFORMATION</b> . . . . .	<b>5</b>
<b>3</b>	<b>SALES INFORMATION</b> . . . . .	<b>5</b>
<b>4</b>	<b>ABSOLUTE MAXIMUM RATINGS</b> . . . . .	<b>6</b>
<b>5</b>	<b>OPERATING CONDITIONS</b> . . . . .	<b>6</b>
<b>6</b>	<b>THERMAL SPECIFICATIONS</b> . . . . .	<b>6</b>
<b>7</b>	<b>ELECTRICAL SPECIFICATIONS</b> . . . . .	<b>7</b>
<b>8</b>	<b>RoHS, REACH</b> . . . . .	<b>8</b>
<b>9</b>	<b>PACKAGE SPECIFICATIONS</b> . . . . .	<b>8</b>
<b>10</b>	<b>NOTES</b> . . . . .	<b>8</b>
<b>11</b>	<b>TYPICAL PERFORMANCE CURVES</b> . . . . .	<b>9</b>
11.1	EMI: Radiated and Conducted Emissions . . . . .	9
11.1.1	Test Setup . . . . .	9
11.1.2	Radiated and Conducted Emissions . . . . .	10
11.2	DC Performance Curves . . . . .	11
11.2.1	Efficiency 12Vin . . . . .	11
11.2.2	Efficiency 24Vin . . . . .	11
11.2.3	Thermal Derating 12Vin . . . . .	12
11.2.4	Thermal Derating 24Vin . . . . .	12
11.2.5	Operating Range . . . . .	13
11.2.6	Load Regulation . . . . .	14
11.2.7	Line Regulation . . . . .	14
<b>12</b>	<b>BLOCK DIAGRAM</b> . . . . .	<b>15</b>
<b>13</b>	<b>CIRCUIT DESCRIPTION</b> . . . . .	<b>15</b>
<b>14</b>	<b>DESIGN FLOW</b> . . . . .	<b>16</b>
14.1	<b>STEP 1</b> Setting The Output Voltage ( $V_{OUT}$ ) . . . . .	17
14.2	<b>STEP 2</b> Select The Input Capacitor ( $C_{IN}$ ) . . . . .	18
14.3	<b>STEP 3</b> Select The Output Capacitor ( $C_{OUT}$ ) . . . . .	18
14.4	<b>STEP 4</b> Select The Feed-Forward Capacitor ( $C_{FF}$ ) . . . . .	20
<b>15</b>	<b>MODES OF OPERATION</b> . . . . .	<b>21</b>
<b>16</b>	<b>OUTPUT VOLTAGE RIPPLE</b> . . . . .	<b>22</b>
<b>17</b>	<b>PROTECTION FEATURES</b> . . . . .	<b>23</b>
17.1	Over Current Protection (OCP) and Short Circuit Protection (SCP) . . . . .	23
17.2	Over Temperature Protection (OTP) . . . . .	24
17.3	Input Undervoltage Lockout (UVLO) . . . . .	24
17.4	Enable / Adjustable Soft-Start . . . . .	25
<b>18</b>	<b>DESIGN EXAMPLE</b> . . . . .	<b>26</b>
18.1	Layout . . . . .	26
18.2	Schematic . . . . .	27
18.3	Bill of Materials . . . . .	27



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<b>19 HANDLING RECOMMENDATIONS</b> . . . . .	<b>28</b>
19.1 Soldering Profile . . . . .	28
<b>20 PHYSICAL DIMENSIONS</b> . . . . .	<b>29</b>
20.1 Component . . . . .	29
20.2 Example Landpattern . . . . .	30
20.3 Packaging . . . . .	31
<b>21 DOCUMENT HISTORY</b> . . . . .	<b>33</b>
<b>22 LIST OF FIGURES</b> . . . . .	<b>34</b>
<b>23 LIST OF TABLES</b> . . . . .	<b>35</b>
<b>24 CAUTIONS AND WARNINGS</b> . . . . .	<b>36</b>
<b>25 IMPORTANT NOTES</b> . . . . .	<b>37</b>

## 1 PINOUT

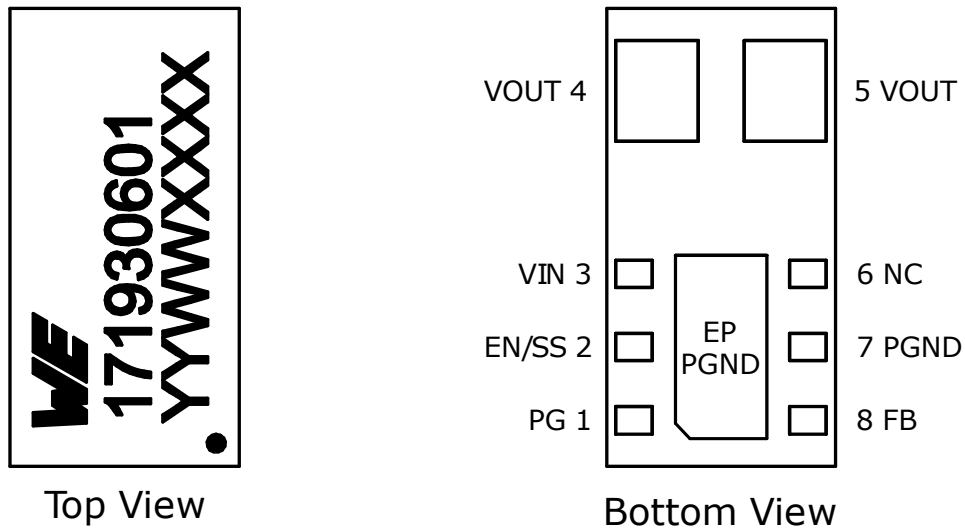


Figure 1: Pinout.

Table 1: Marking description.

MARKING	DESCRIPTION
WE	Logo
171930601	Order Code
.YYWWXXXX	Pin one indicator, year, week and lot number

Table 2: Pin description.

SYMBOL	NUMBER	TYPE	DESCRIPTION
PG	1	Output	Power good flag pin. This open drain output asserts low if the output voltage is lower than 90% or higher than 110% of the set value. A pull-up resistor of 100k $\Omega$ is recommended if this function is used.
EN/SS	2	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. An internal soft-start of 2ms has already been implemented in the MicroModule. For an external soft-start function, an external resistor ( $R_{SS}$ ) and capacitor ( $C_{SS}$ ) should be used.
VIN	3	Power	Input voltage pin. Place the input capacitor as close as possible to VIN and PGND.
VOUT	4, 5	Power	Output voltage pin. Place output capacitors as close as possible to VOUT and PGND. For thermal performance, use copper plane(s) at this pin.
NC	6		Pin is not internally electrically connected.
PGND	7	Power	Power ground pin. This pin must be connected to the ground plane and to the exposed pad for the best thermal performance.
FB	8	Input	Feedback pin. This pin must be connected to the external resistor divider (between VOUT and PGND) to adjust the output voltage. The trace between VOUT, FB and through the external resistor divider should be kept as short and near to the module as possible.
PGND	EP	Exposed Pad	Exposed pad. This pin is electrically connected internally to PGND. It is recommended to connect this pad to the ground plane for device heat dissipation.

## 2 ORDERING INFORMATION

Table 3: Ordering information.

ORDER CODE	SPECIFICATIONS	PACKAGE	PACKAGING UNIT
171930601	0.3A / 1V-6V Vout version	LGA-8EP	7" Reel (1000 pieces)
178930601	0.3A / 1V-6V Vout version	Eval Board	Box with 1 piece

## 3 SALES INFORMATION

Table 4: Package specifications.

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 <a href="http://www.we-online.com/powermodules">www.we-online.com/powermodules</a> Technical support: <a href="mailto:powermodules@we-online.com">powermodules@we-online.com</a>

#### 4 ABSOLUTE MAXIMUM RATINGS

**Caution:**

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

Table 5: Absolute maximum ratings.

SYMBOL	PARAMETER	LIMIT		UNIT
		MIN <sup>(1)</sup>	MAX <sup>(1)</sup>	
V <sub>IN</sub>	Input pin voltage	-0.3	40	V
V <sub>OUT</sub>	Output pin voltage	-0.3	40	V
FB	Feedback pin voltage	-0.3	6.2	V
EN	Enable pin voltage	-0.3	40	V
PG	Power good pin voltage	-0.3	6.2	V
I <sub>PG</sub>	Power Good Pin Current	—	8	mA
T <sub>storage</sub>	Assembled, non-operating storage temperature	-40	125	°C

#### 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 105°C.

Table 6: Operating conditions.

SYMBOL	PARAMETER	MIN <sup>(1)</sup>	TYP <sup>(3)</sup>	MAX <sup>(1)</sup>	UNIT
V <sub>IN</sub>	Input voltage	3.5	—	36	V
V <sub>OUT</sub>	Output voltage	1	—	6	V
T <sub>a</sub>	Ambient temperature range	-40	—	105 <sup>(2)</sup>	°C
T <sub>job</sub>	Junction temperature range	-40	—	125	°C
I <sub>out</sub>	Nominal output current	—	—	0.3 <sup>(4)</sup>	A

#### 6 THERMAL SPECIFICATIONS

**Caution:**

Typical values represent the statistically utmost probable values at the following conditions: V<sub>IN</sub> = 24V, V<sub>OUT</sub> = 5V, C<sub>IN</sub> = 4.7μF, C<sub>OUT</sub> = 47μF, T<sub>A</sub> = 25°C unless otherwise noted.

Table 7: Thermal specifications.

SYMBOL	PARAMETER	TYP <sup>(3)</sup>	UNIT
Θ <sub>JA</sub>	Junction-to-ambient thermal resistance <sup>(4)</sup>	55	K/W
Θ <sub>JC</sub>	Junction-to-case (top) thermal resistance <sup>(4)</sup>	40	K/W
T <sub>SD</sub>	Thermal shutdown, rising	155	°C
	Thermal shutdown, hysteresis	25	°C

## 7 ELECTRICAL SPECIFICATIONS

### Caution:


MIN and MAX limits are valid for the recommended ambient temperature range of  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$ . Typical values represents statistically the utmost probable values at the following conditions:  $V_{\text{IN}} = 24\text{V}$ ,  $V_{\text{OUT}} = 5\text{V}$ ,  $C_{\text{IN}} = 4.7\mu\text{F}$  ceramic,  $C_{\text{OUT}} = 47\mu\text{F}$  ceramic,  $T_{\text{A}} = 25^{\circ}\text{C}$  unless otherwise noted.

Table 8: Electrical specifications part 1.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN <sup>(1)</sup>	TYP <sup>(3)</sup>	MAX <sup>(1)</sup>	UNIT
<b>OUTPUT VOLTAGE</b>						
$V_{\text{FB}}$	Reference voltage		0.739	0.75	0.761	V
$I_{\text{FB}}$	Feedback input bias current		-0.1	—	0.1	nA
$V_{\text{OUT}}$	Line regulation	$V_{\text{IN}} = 8\text{V to } 36\text{V}$ , $I_{\text{OUT}} = 0.3\text{A}$	—	0.06	—	%
	Load regulation	$0.03\text{A} \leq I_{\text{LOAD}} \leq 0.3\text{A}$	—	1.35	—	%
	Output voltage ripple	$I_{\text{OUT}} = 0.03\text{A}$ , 20MHz BWL	—	10	—	mV <sub>pp</sub>
$I_{\text{OUT}} = 0.3\text{A}$ , 20MHz BWL		—	7	—	mV <sub>pp</sub>	
<b>OUTPUT CURRENT</b>						
$I_{\text{OUT}}$	Output current		—	—	0.3	A
$I_{\text{CL-HS}}$	High side switch current limit		1	1.3	—	A
<b>SWITCHING FREQUENCY</b>						
$f_{\text{SW}}$	Switching frequency		—	1.2	—	MHz
<b>ENABLE AND UNDERVOLTAGE LOCKOUT</b>						
$V_{\text{UVLO}}$	$V_{\text{IN}}$ undervoltage threshold	$V_{\text{IN}}$ increasing	2.7	2.8	2.9	V
		$V_{\text{IN}}$ decreasing	2.6	2.7	2.8	V
$V_{\text{EN/SS}}$	EN/SS threshold	Enable logic high	2.5	—	36	V
		Enable logic low	—	—	0.3	V
$I_{\text{EN/SS}}$	EN/SS pin input current	$V_{\text{IN}} = 36\text{V}$ , Enable = high	—	0.1	0.3	$\mu\text{A}$
		$V_{\text{IN}} = 36\text{V}$ , Enable = low	-0.1	—	0.1	$\mu\text{A}$
<b>SOFT-START</b>						
$t_{\text{SS}}$	Soft-start time	$T_{\text{A}} = 25^{\circ}\text{C}$ (rising edge to 95% of $V_{\text{OUT}}$ )	—	2	—	ms
<b>EFFICIENCY</b>						
$\eta$	Efficiency	$V_{\text{IN}} = 5\text{V}$ , $V_{\text{OUT}} = 3.3\text{V}$ , $I_{\text{OUT}} = 0.3\text{A}$	—	87	—	%
		$V_{\text{IN}} = 12\text{V}$ , $V_{\text{OUT}} = 5\text{V}$ , $I_{\text{OUT}} = 0.3\text{A}$	—	87	—	%
		$V_{\text{IN}} = 24\text{V}$ , $V_{\text{OUT}} = 5\text{V}$ , $I_{\text{OUT}} = 0.3\text{A}$	—	83	—	%
<b>INPUT QUIESCENT AND SHUTDOWN CURRENT</b>						
$I_{\text{SD}}$	Shutdown current	$V_{\text{IN}} = 12\text{V}$ , $V_{\text{EN}} = \text{low}$	—	1.7	—	$\mu\text{A}$
		$V_{\text{IN}} = 24\text{V}$ , $V_{\text{EN}} = \text{low}$	—	2.8	—	$\mu\text{A}$
$I_{\text{IN-NL}}$	No load input current	$V_{\text{OUT}} = 3.3\text{V}$	—	15.3	—	$\mu\text{A}$
$I_{\text{Q}}$	Quiescent current	$V_{\text{IN}} = 12\text{V}$ , Enable = high	—	12.5	—	$\mu\text{A}$
		$V_{\text{IN}} = 24\text{V}$ , Enable = high	—	13.5	—	$\mu\text{A}$
<b>OUTPUT CAPACITANCE</b>						
$C_{\text{OUT\_MAX}}$	Output capacitance	These values are absolute. Practical capacitor values need to have derating aspects considered.	20	47	150	$\mu\text{F}$

## 8 RoHS, REACH

Table 9: 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).

## 9 PACKAGE SPECIFICATIONS

Table 10: Package specifications.

ITEM	PARAMETER	TYP <sup>(3)</sup>	UNIT
Mold Compound	UL94V-0	—	—
Weight	—	0.04341	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) Depending on heat sink desing, number of PCB layers, copper thickness and air flow.
- (3) Typical numbers are valid at 25°C ambient temperature and represent statistically the utmost probable values assuming a Gaussian distribution.
- (4) Measured on the 178930601 evaluation board, a 80 x 80mm two layer board with 35µm (1 ounce) copper.



## 11 TYPICAL PERFORMANCE CURVES

If not otherwise specified, the following conditions apply:  $V_{IN} = 24V$ ,  $C_{IN} = 4.7\mu F$  X7R 50V ceramic,  $C_{OUT} = 47\mu F$  X5R ceramic,  $C_{FF} = 220pF$ ,  $T_{AMB} = 25^{\circ}C$ .

### 11.1 Radiated and Conducted Emissions EN55032 (CISPR-32) Class B Compliance

The 171930601 MicroModule is tested with a standard EMC configuration (1m wire between the module and the load) to give more realistic information about implementation in applications. The test setup is based on CISPR16 with the limit values from CISPR-32. Measured with module on an evaluation board 178930601 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)
- Conducted Emissions: 80cm

Output wire length:

- Long wire (with input filter): 1m

### 11.1.2 Radiated and Conducted Emissions

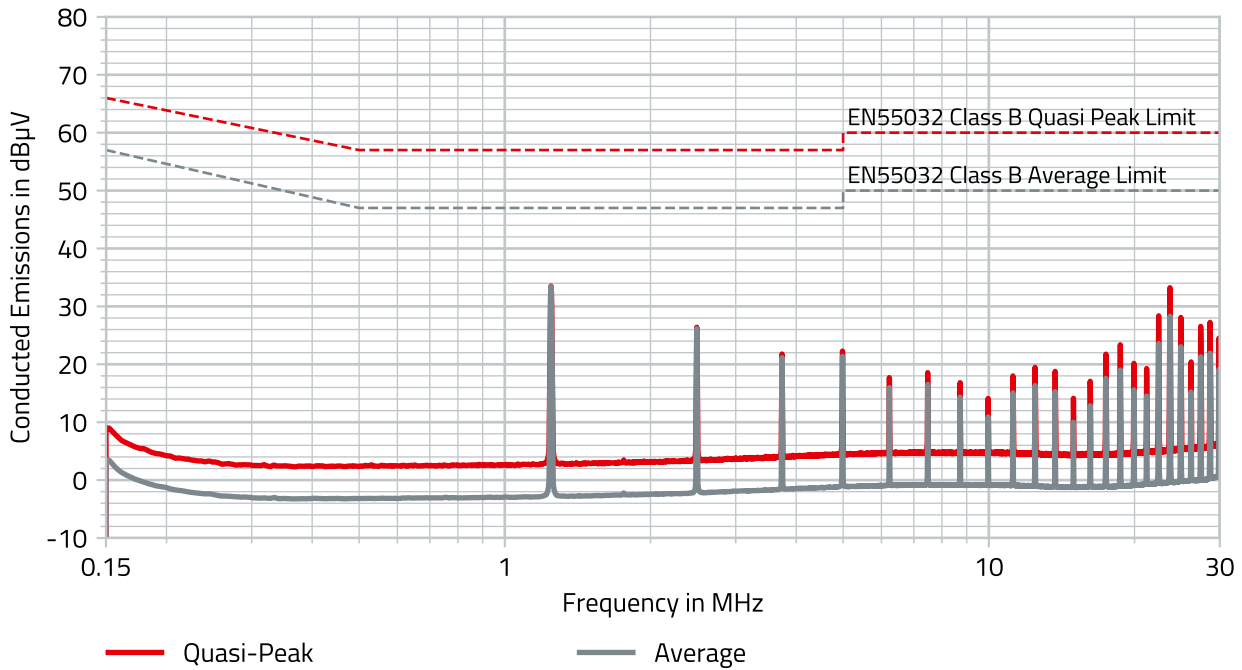


Figure 2: 171930601 conducted emissions (3m antenna distance)  $V_{IN} = 24V$ ,  $V_{OUT} = 5V$ ,  $I_{LOAD} = 0.3A$  with input filter  $C_F = 4.7\mu F$ ,  $L_F = 1\mu H$ .

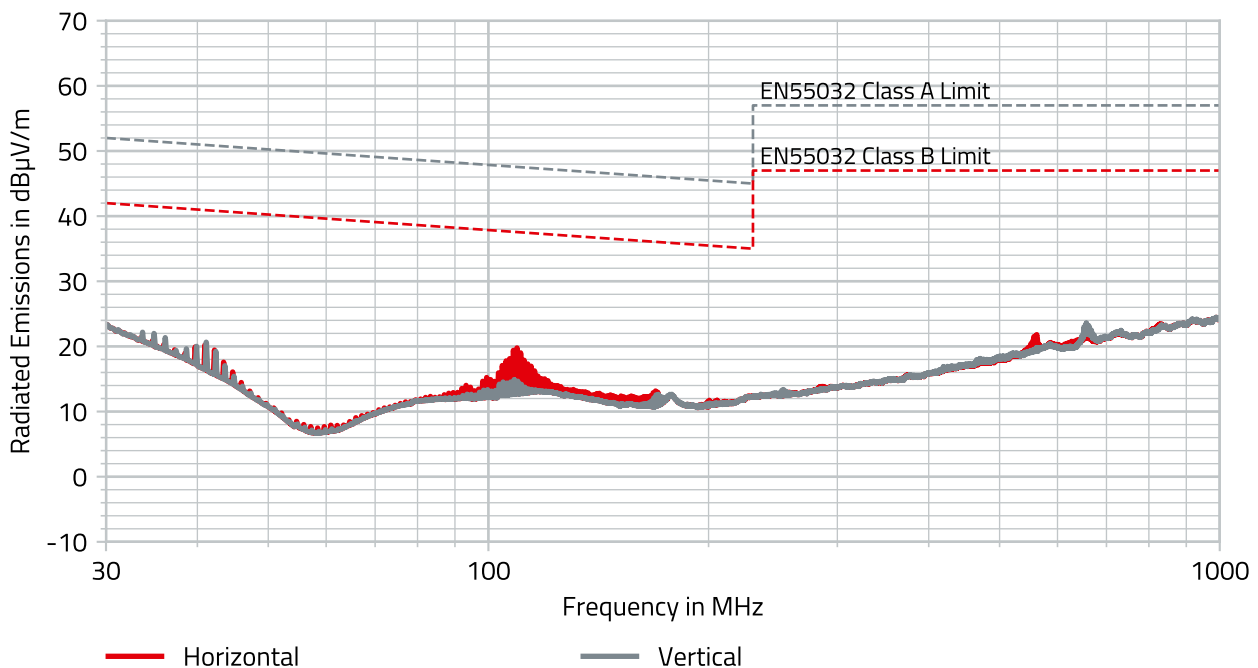


Figure 3: 171930601 radiated emissions (3m antenna distance)  $V_{IN} = 24V$ ,  $V_{OUT} = 5V$ ,  $I_{LOAD} = 0.3A$  with input filter  $C_F = 4.7\mu F$ ,  $L_F = 1\mu H$ .

## 11.2 DC PERFORMANCE CURVES

### 11.2.1 Efficiency 12V<sub>IN</sub>

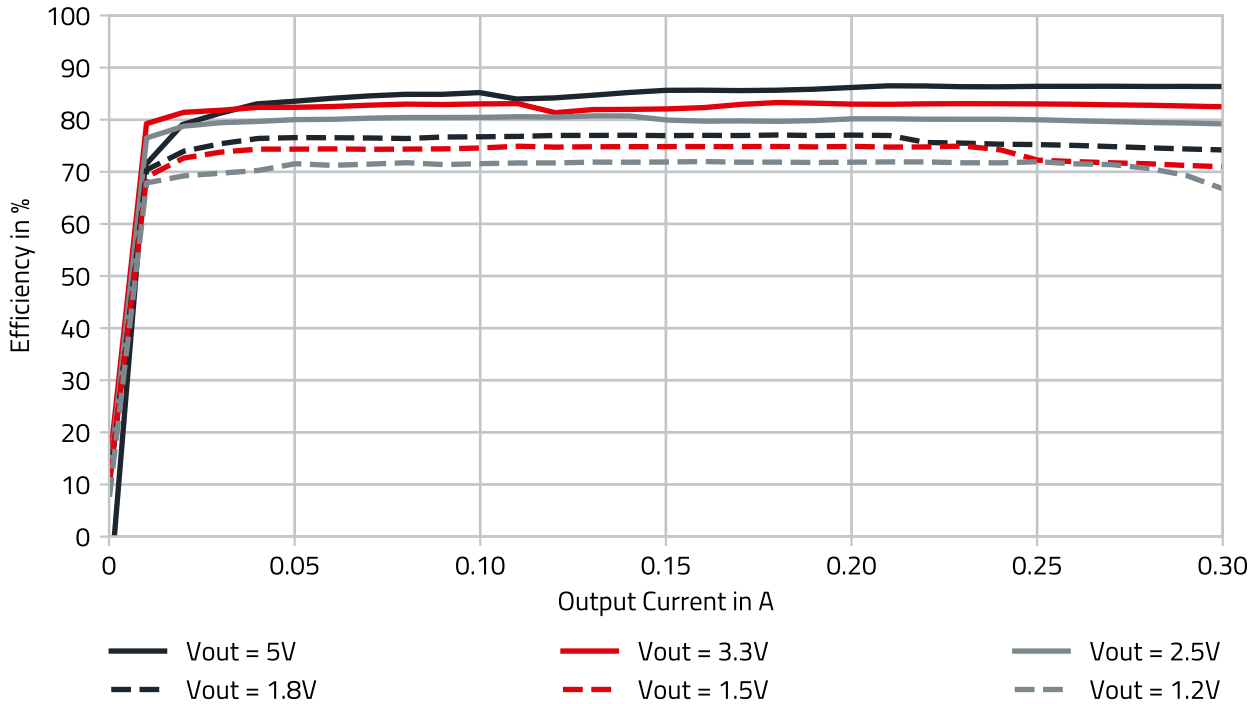


Figure 4: 171930601 efficiency V<sub>IN</sub> = 12V, T<sub>A</sub> = 25°C.

### 11.2.2 Efficiency 24V<sub>IN</sub>

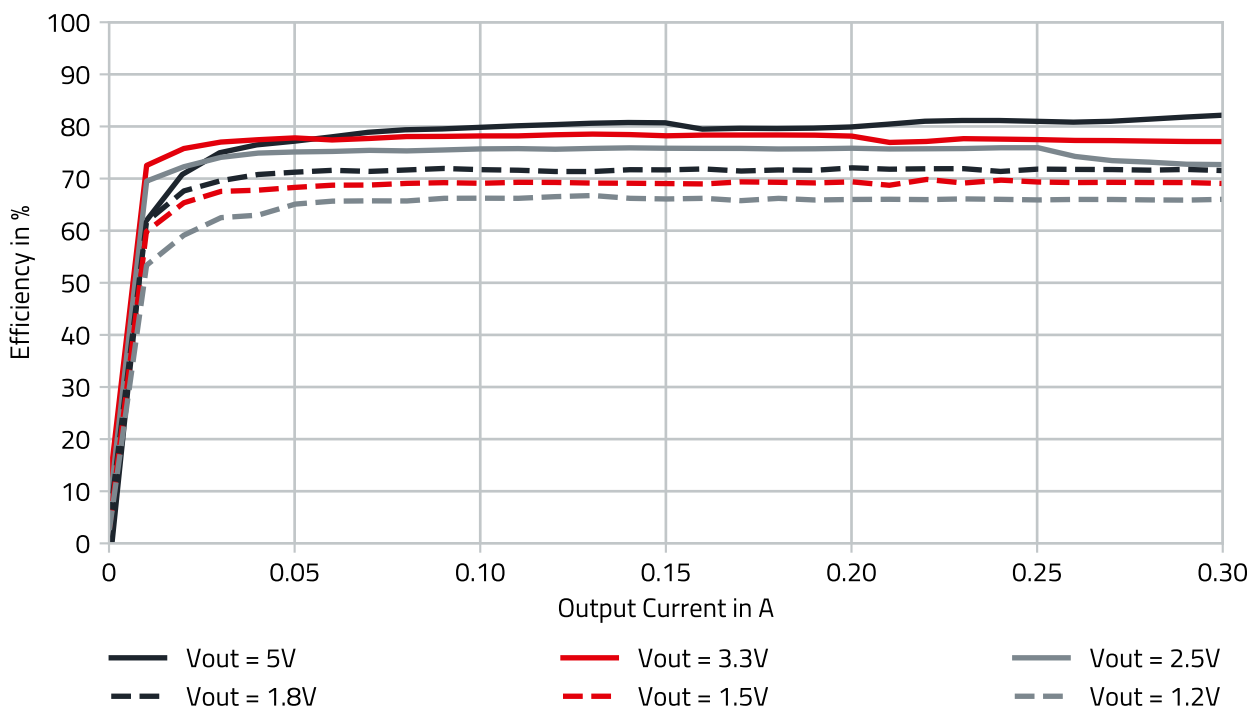


Figure 5: 171930601 efficiency V<sub>IN</sub> = 24V, T<sub>A</sub> = 25°C.

### 11.2.3 Thermal Derating 12V<sub>IN</sub>

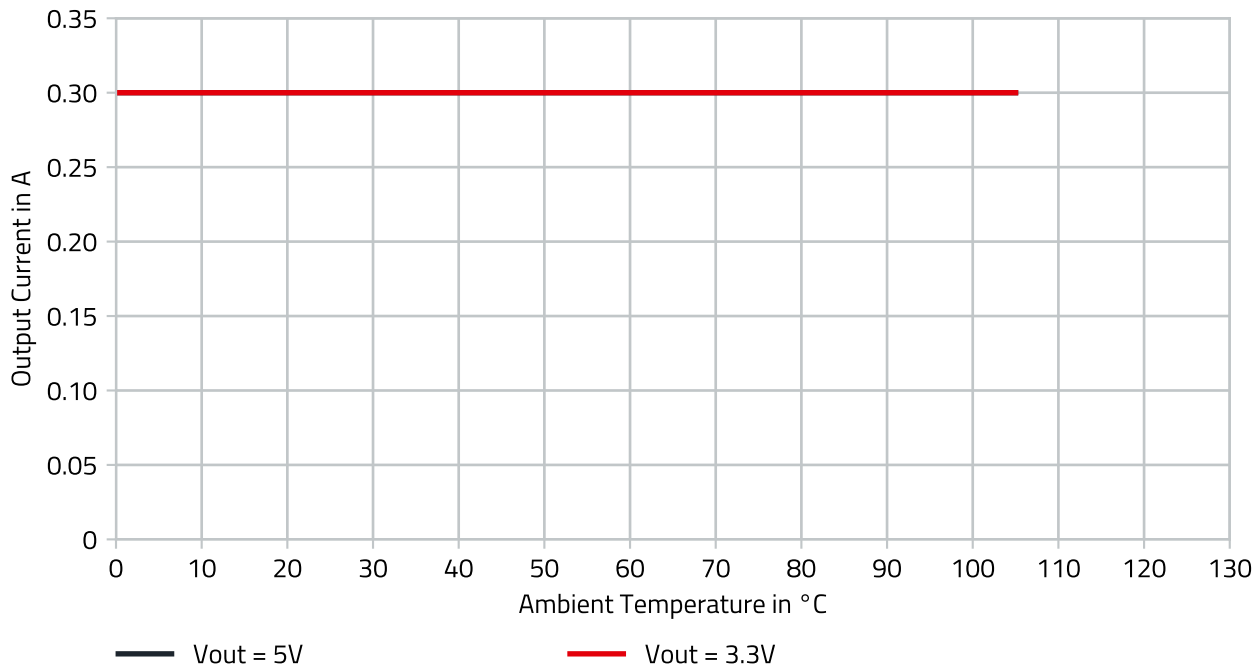


Figure 6: 171930601 output current thermal derating  $V_{IN} = 12V$ ,  $\Theta_{JA} = 55 K/W$ .

### 11.2.4 Thermal Derating 24V<sub>IN</sub>

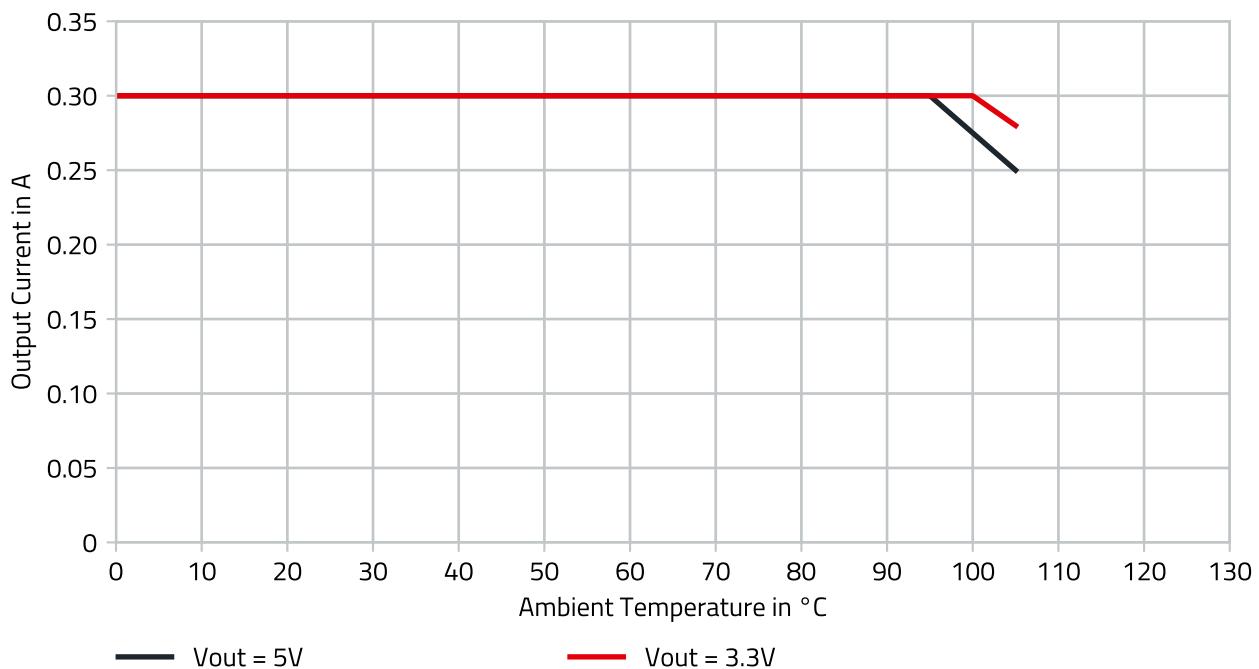


Figure 7: 171930601 output current thermal derating  $V_{IN} = 24V$ ,  $\Theta_{JA} = 55 K/W$ .

Note: Both thermal derating graphs were measured on the 178930601 Evaluation Board (80 x 80mm two layer board with 35 $\mu$ m (1 ounce) copper). Please see  $T_A$  limits in [OPERATING CONDITIONS](#).

### 11.2.5 Operating Range

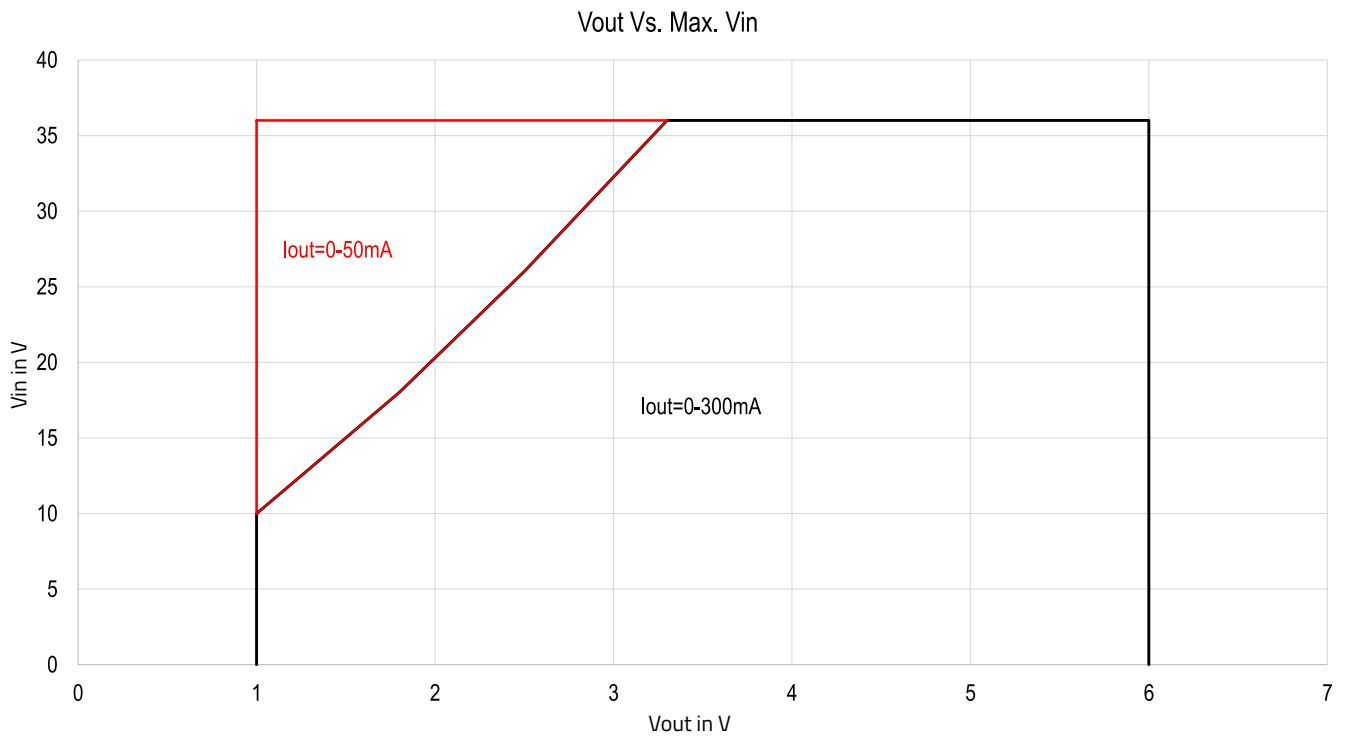


Figure 8: 171930601 output voltage vs. maximum input voltage.

11.2.6 LOAD REGULATION

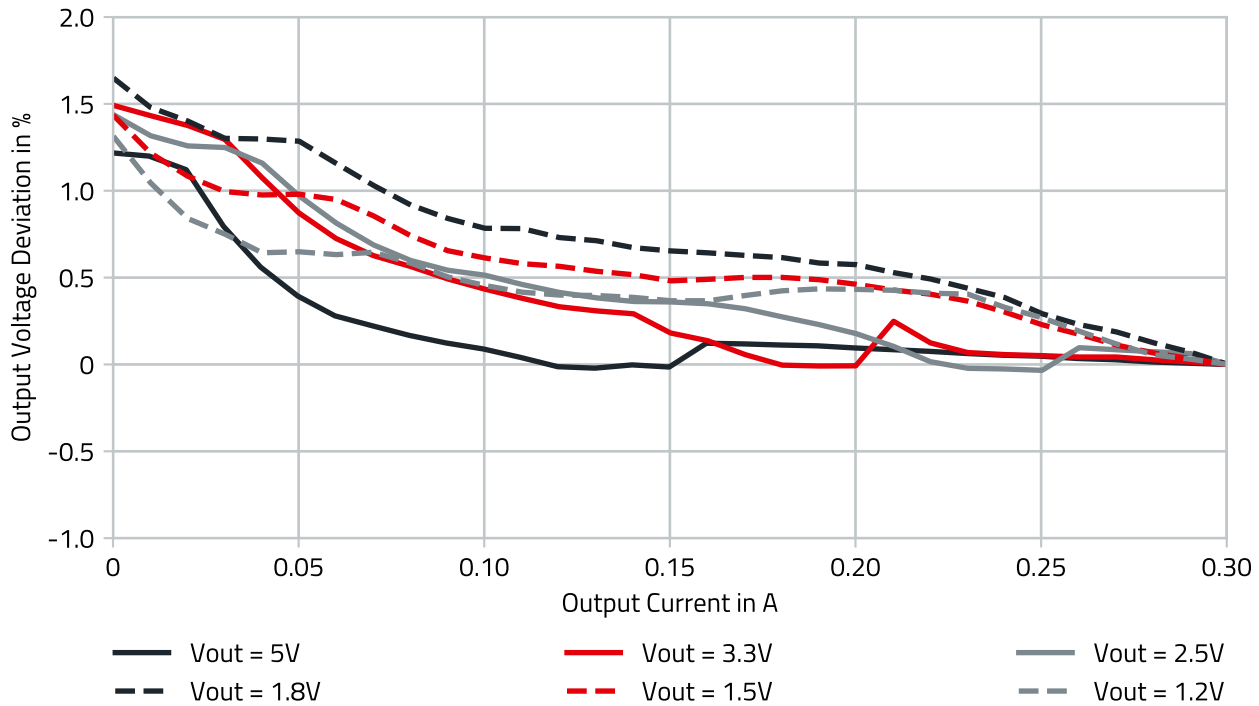


Figure 9: 171930601 load regulation  $V_{IN} = 24V$ ,  $V_{OUT} = 3.3V$ ,  $T_A = 25^\circ C$ .

11.2.7 LINE REGULATION

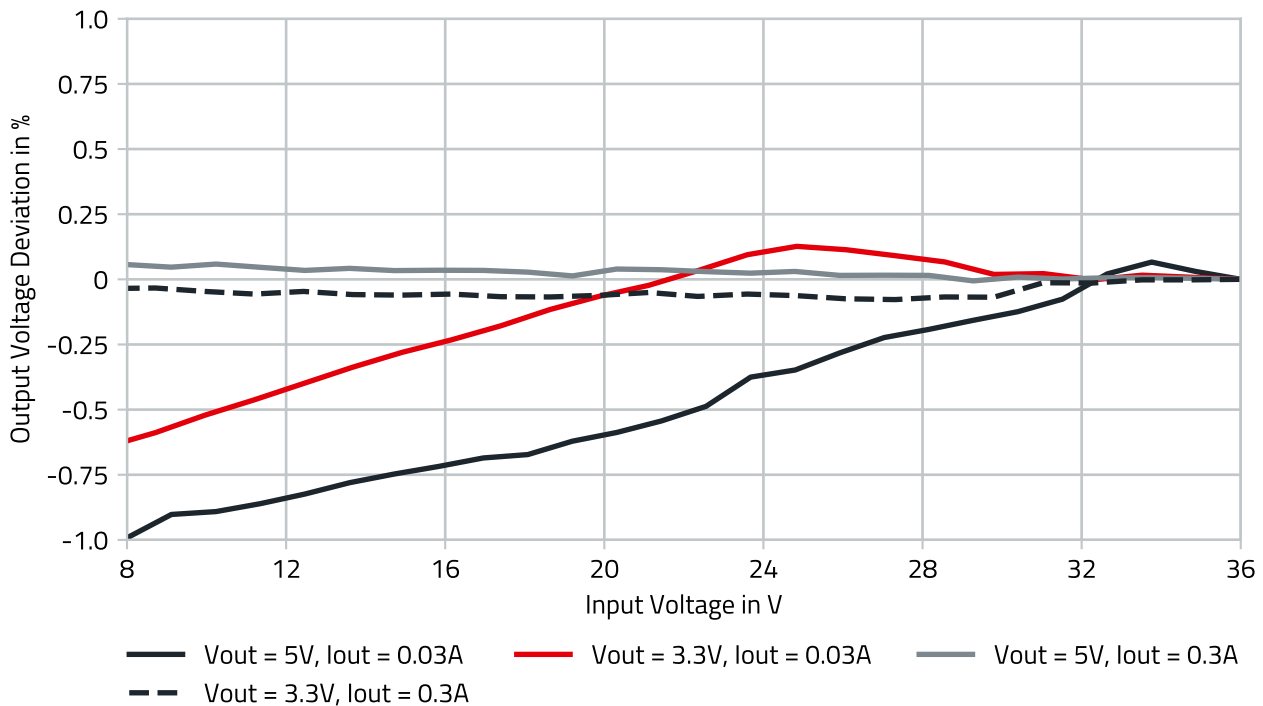


Figure 10: 171930601 line regulation  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 0.3A$ ,  $T_A = 25^\circ C$ .

## 12 BLOCK DIAGRAM

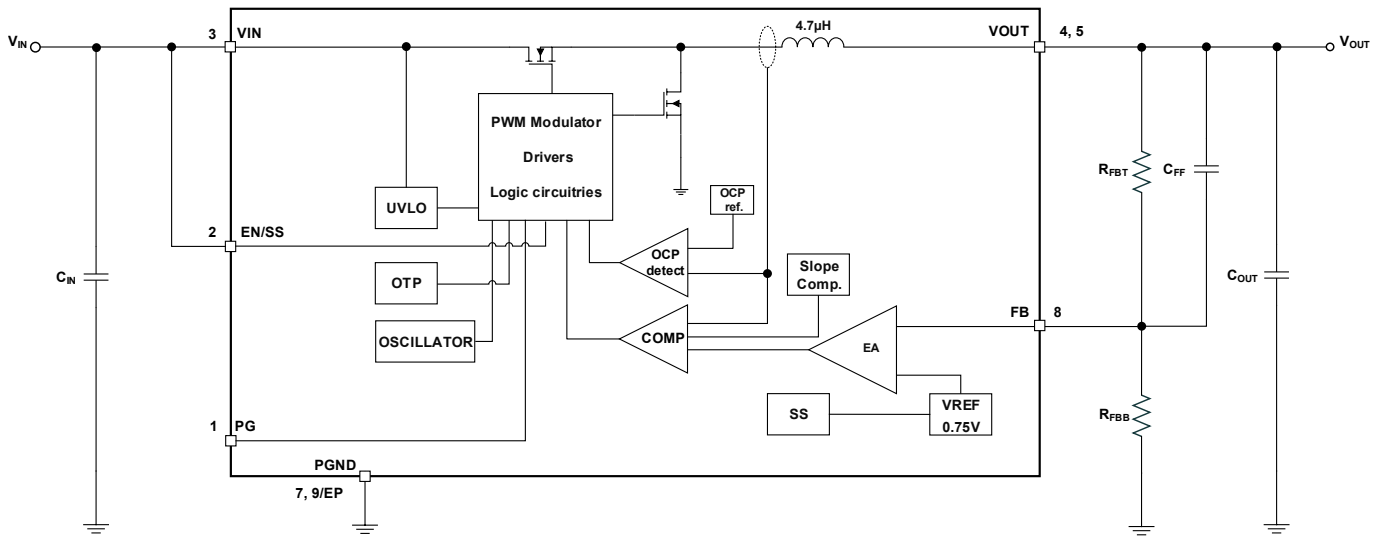


Figure 11: 171930601 block diagram.

## 13 CIRCUIT DESCRIPTION

The MagI<sup>3</sup>C 171930601 MicroModule is a fully integrated DC-DC power supply including the switching regulator with integrated MOSFETs, controller and compensation, as well as the shielded inductor in one package. The control scheme is based on a current mode (CM) regulation loop.

The  $V_{OUT}$  of the regulator is divided by the feedback resistor network  $R_{FBT}$  and  $R_{FBB}$  and fed into the FB pin. The error amplifier compares this signal with the internal 0.75V reference. The error signal is amplified and controls the on-time of a fixed frequency pulse width generator. This signal drives the power MOSFETs.

The current mode architecture features a constant frequency during load steps. Only the on-time is modulated. It is internally compensated and stable with low ESR output capacitors and requires no external compensation network.

This architecture supports fast transient response and very small output voltage ripples ( $< 10mV_{p-p}$ ) are achieved.

## 14 DESIGN FLOW

The next four simple steps will show how to select the external components to design the 171930601 into an application.

### Essential Steps

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

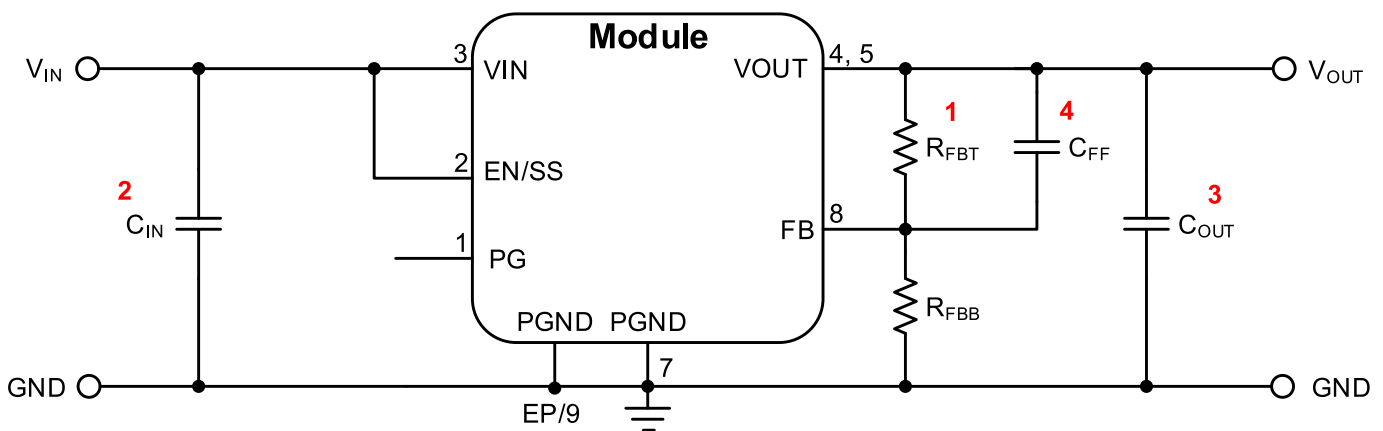


Figure 12: Design flow schematic.



### 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 lower resistor of the divider is output voltage adjustment range is from 1V to 6V. The output voltage can be calculated according to the following formula:

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

One resistor must be chosen and then the other resistor can be calculated. For example, if  $R_{FBT} = 64.9\text{k}\Omega$  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 with  $R_{FBT} = 64.9\text{k}\Omega$ .

$V_{OUT}$ [V]	1.2	1.5	1.8	2.5	3.3	5.0	6.0
$R_{FBB}$ (E96) [ $\text{k}\Omega$ ]	107	64.9	46.4	27.4	19.1	11.3	9.3

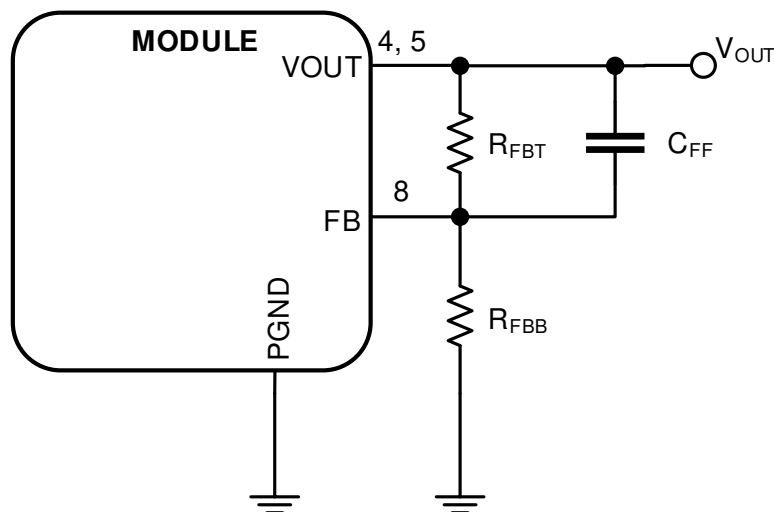


Figure 13: Output voltage schematic.

## 14.2 STEP 2 Select The Input Capacitor (C<sub>IN</sub>)

An external input capacitor 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 Magi<sup>3</sup>C MicroModule, it is recommended to use an MLCC (multi-layer ceramic capacitor) with 4.7µF. Attention must be paid to the voltage, frequency, temperature derating and thermal class of the selected capacitor.

## 14.3 STEP 3 Select The Output Capacitor (C<sub>OUT</sub>)

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 external MLCC of 47µF is recommended for all application conditions. Attention must be paid to the voltage, frequency, temperature derating and thermal class of the selected capacitor.

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

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

where  $\Delta I_L$  is the inductor current ripple and can be calculated with the following equation:

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

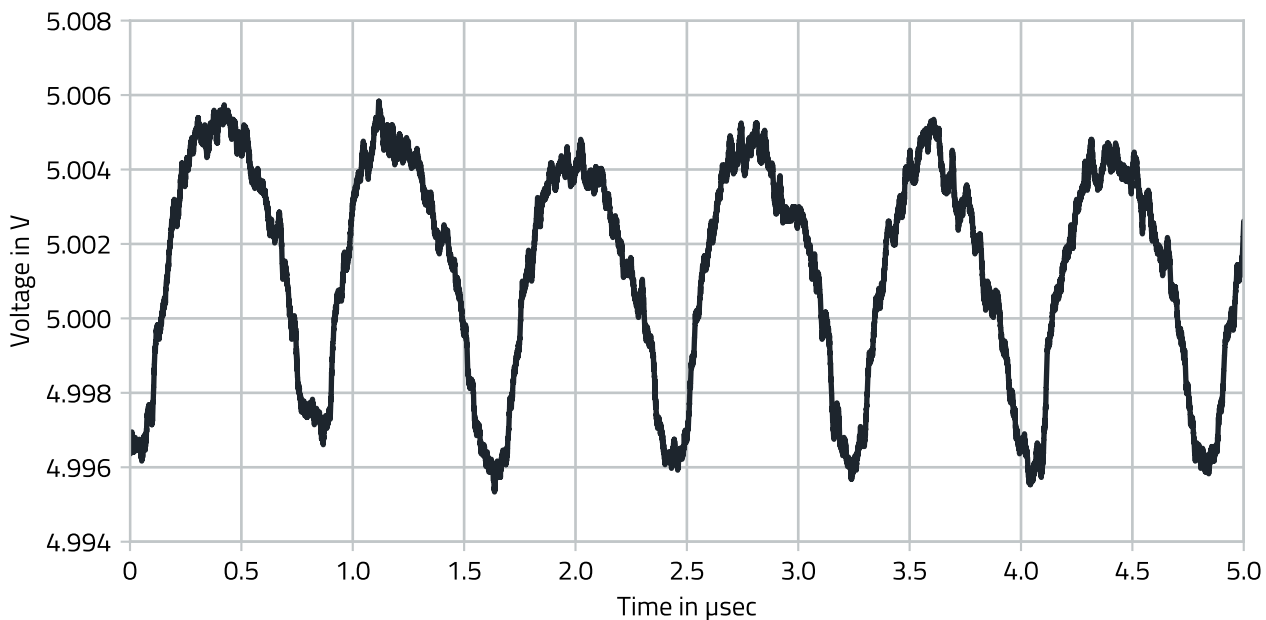


Figure 14: 171930601 output voltage ripple  $V_{\text{IN}} = 24\text{V}$ ,  $V_{\text{SV}}$ ,  $I_{\text{OUT}} = 0.3\text{A}$ ,  $C_{\text{OUT}} = 33\mu\text{F}$ .

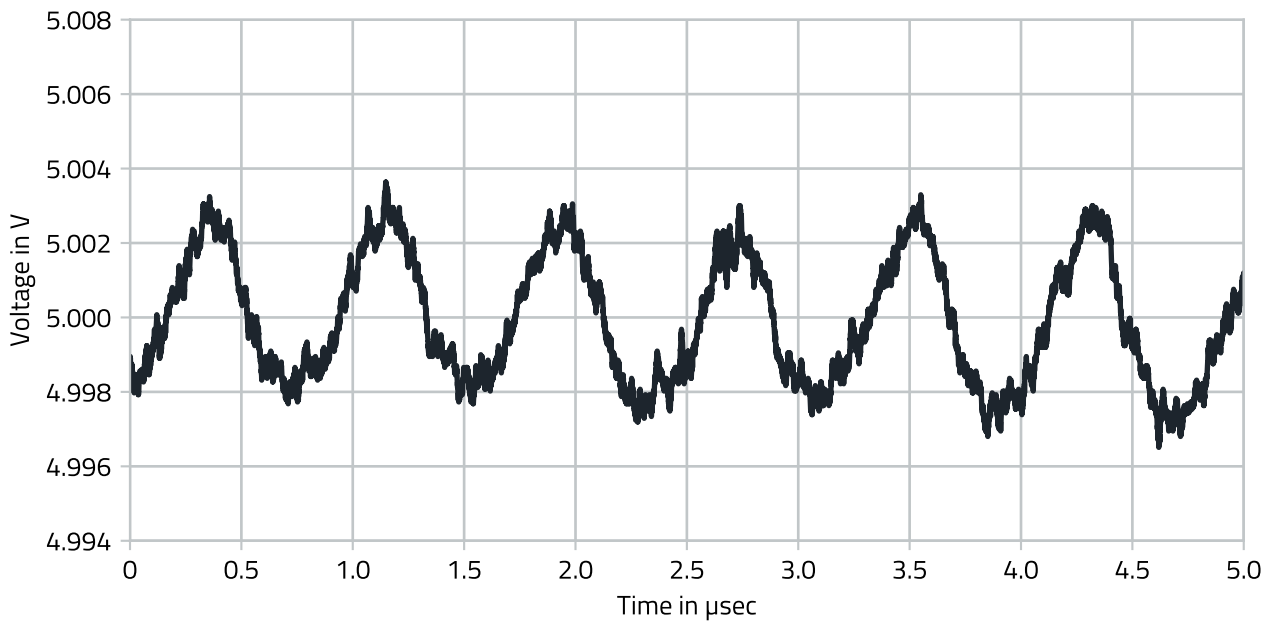


Figure 15: 171930601 output voltage ripple  $V_{IN} = 24V$ ,  $V_{5V}$ ,  $I_{OUT} = 0.3A$ ,  $C_{OUT} = 68\mu F$ .

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

The 171930601 Magi<sup>3</sup>C MicroModule allows for the selection of a feed forward capacitor,  $C_{FF}$ . To maintain the same transient response for different  $C_{FF}$  values, the top feedback resistor  $R_{FBT}$  should also be adjusted. The integrated inductor has a value of 4.7 $\mu$ H. The equation used to determine  $C_{FF}$  and  $R_{FBT}$  is as follows:

$$C_{FF} = \frac{\sqrt{C_{OUT} \cdot L}}{R_{FBT}} \quad (4)$$

A  $C_{FF}$  of 220pF has been evaluated experimentally as a value with suitable efficiency and transient characteristics for most applications.

The figures below show the transient behavior of the 171930601 in response to a load transition from 0A to 0.3A using the recommended  $C_{FF} = 220$ pF, as well as other values of  $C_{FF}$ .

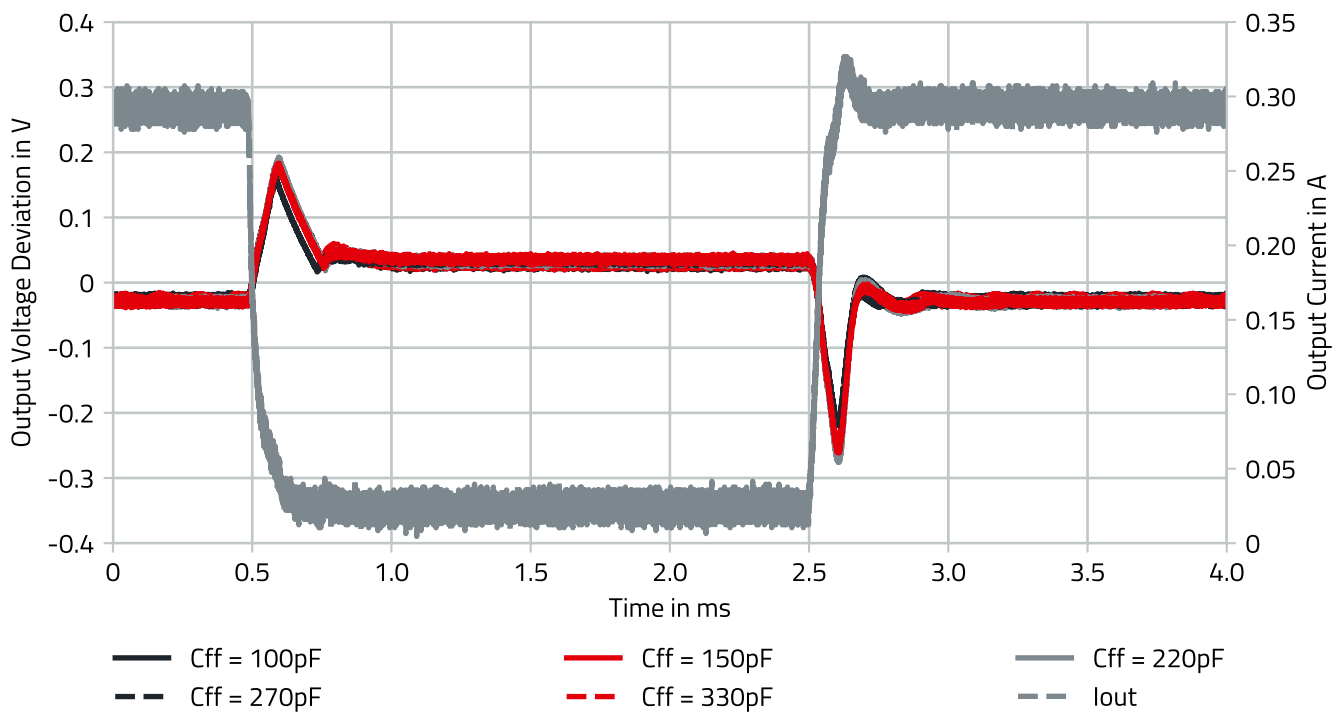


Figure 16: 171930601 load transient  $V_{IN} = 24$ V,  $V_{OUT} = 5$ V from 0.03A to 0.3A,  $T_A = 25^\circ$ C.

This behavior is valid only for this test under the specified conditions and must be verified in the real application. The recommended  $C_{FF}$  value of 220pF will work for most applications.

## 15 MODES OF OPERATION

The 171930601 MicroModule has two different modes of operation and the transition takes place automatically depending on the load current value. Under light load conditions, the module operates in PFM mode where the MicroModule runs at a lower switching frequency to reduce the current consumption, which leads to achieving a higher efficiency. The PFM control is achieved by creating a single pulse to turn on the high side switch while monitoring the inductor current. The high side switch is kept on until the inductor current hits a preset value ( $I_{PFM}$ ).

After reaching  $I_{PFM}$ , the high side switch is turned off and the low side switch turns on. The inductor current decreases until it reaches zero. When the inductor current reaches zero, both switches are turned off (idle time) and the output capacitor solely supplies the load with energy. While the energy is supplied to the load, the output voltage starts to drop. The MicroModule monitors the output voltage ripple value and when it hits a certain limit, while the two switches are off, another pulse is initiated and the cycle repeats. When the load current increases, the idle time decreases and the switching frequency increases until the nominal switching frequency is reached and the MicroModule goes to the PWM mode.

## 16 OUTPUT VOLTAGE RIPPLE

If the module is working PWM mode, the ripple is very low and it always has the same frequency as the internal oscillator (1.2). If the load current is low enough to be in the PFM mode of operation then the output voltage ripple will be higher and the frequency lower than the nominal switching frequency (see figures below).

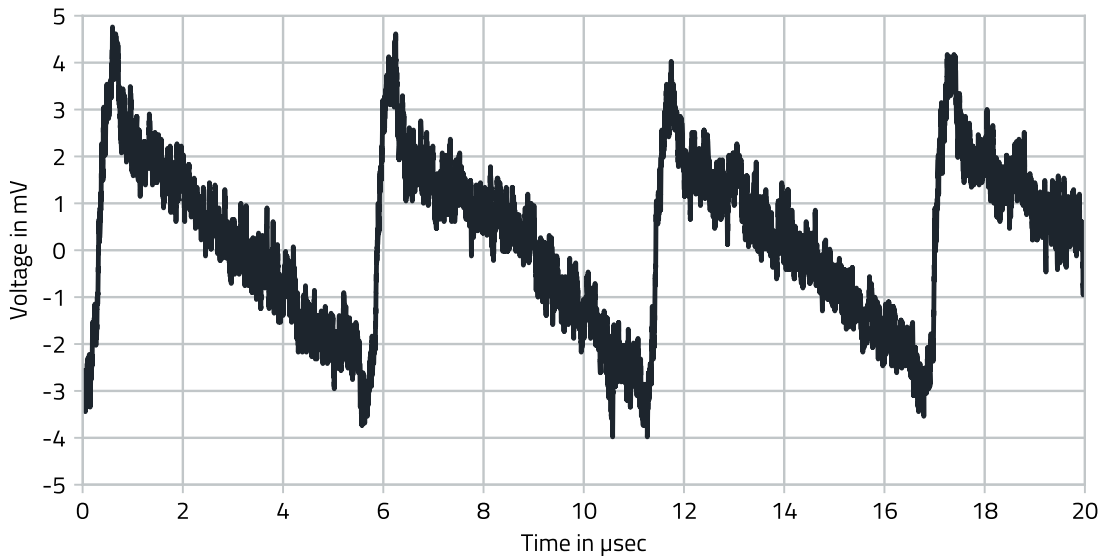


Figure 17: 171930601 output voltage ripple  $V_{IN} = 24V$ ,  $V_{OUT} = 5V$ ,  $I_{OUT} = 0.03A$ .

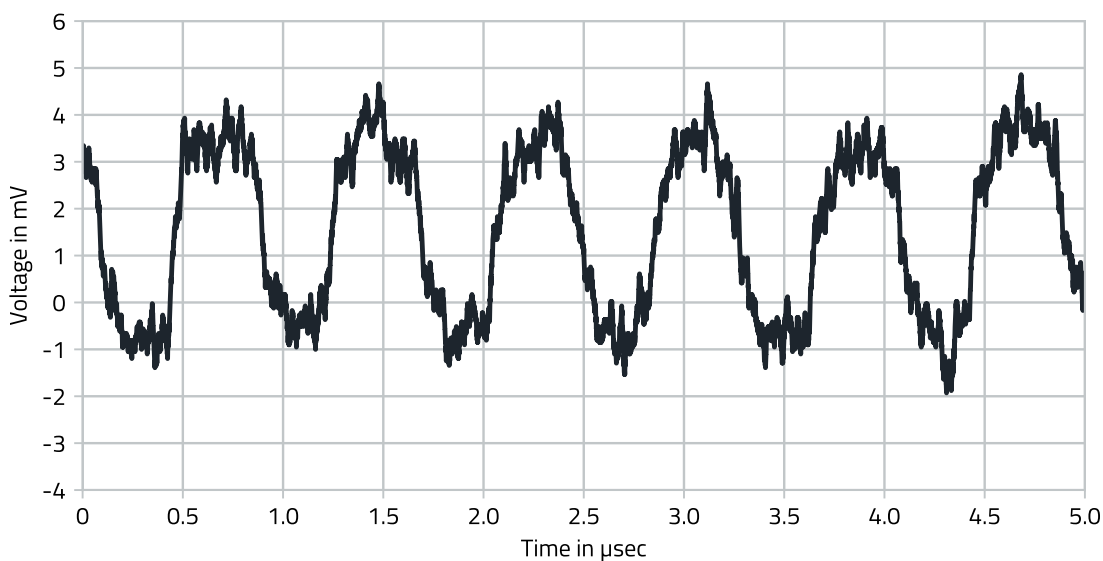


Figure 18: 171930601 output voltage ripple  $V_{IN} = 24V$ ,  $V_{OUT} = 5V$ ,  $I_{OUT} = 0.3A$ .

## 17 PROTECTION FEATURES

### 17.1 Over Current Protection (OCP) and Short Circuit Protection (SCP)

The overcurrent and short circuit protections are implemented using a cycle-by-cycle scheme. The high-side switch current is sensed and when the current exceeds the high side limit value (1.3A typ.), the high-side switch is turned off and the low-side switch is turned on, until the current hits the low-side switch limit value (1A typ.). When the low-side switch limit is reached, the high side switch is turned on again and the cycle repeats itself. In addition, a frequency foldback circuit is enabled to reduce the high- and low-side current limits, further reducing the rms current and heat dissipation through the MicroModule. The figures below shows the operation of the converter under OCP and SCP conditions.

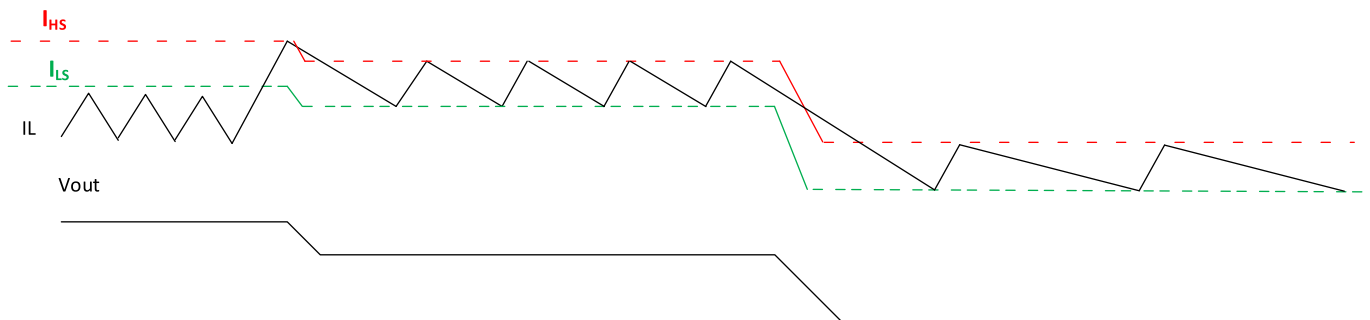


Figure 19: 171930601 inductor current and frequency foldback.

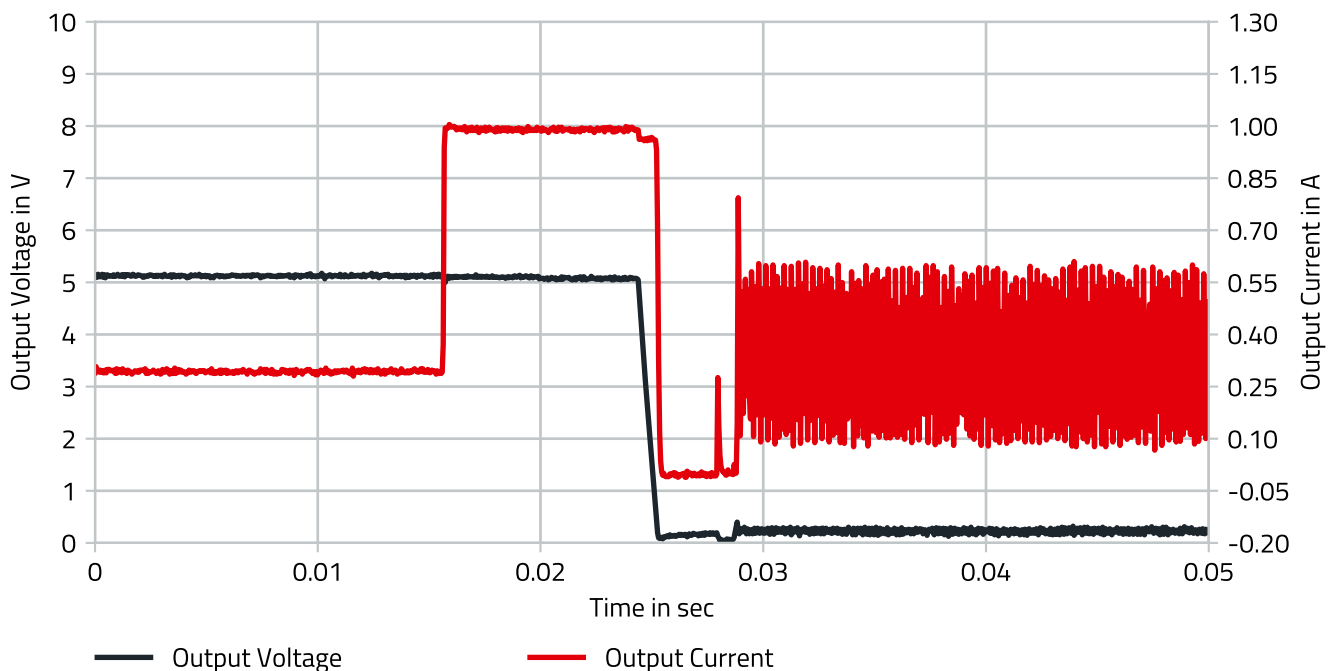


Figure 20: 171930601 OCP  $V_{IN} = 24V$ ,  $V_{OUT} = 5V$ .

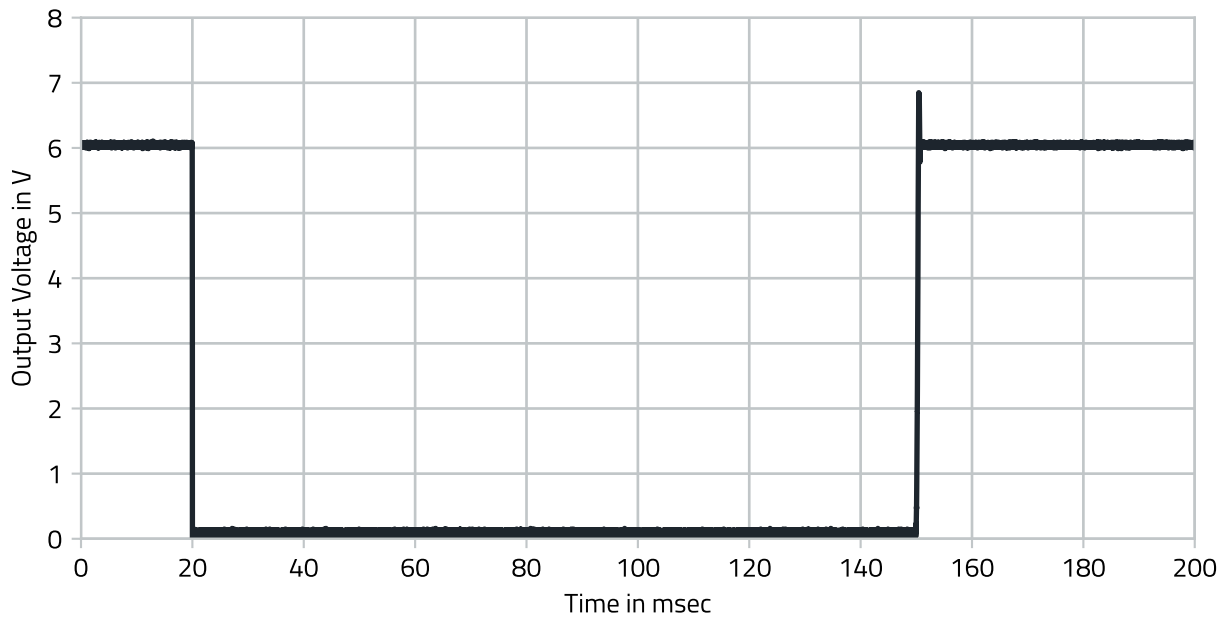


Figure 21: 171930601 SCP  $V_{IN} = 24V$ ,  $V_{OUT} = 5V$ , short circuit condition.

Note that an output voltage overshoot is expected upon the return to normal operation after an overcurrent or short circuit fault. This is due to the soft-start functionality only activating when the module first turns on.

### 17.2 Over Temperature Protection (OTP)

Thermal protection helps prevent catastrophic failures due to accidental device overheating. The junction temperature of the 171930601 MagI<sup>3</sup>C 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 160°C (typ). Under the thermal shutdown condition both MOSFETs remain off causing  $V_{OUT}$  to drop. When the junction temperature falls below 150°C the internal soft-start is released,  $V_{OUT}$  rises smoothly, and normal operation resumes.

### 17.3 Input 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 SPECIFICATION](#).



#### 17.4 Enable / Adjustable Soft-Start

The 171930601 Magl<sup>3</sup>C MicroModule combines the enable and soft-start functions into a single pin and is enabled by setting the pin EN/SS high. Enabling the device achieves a 2ms soft-start time. After setting EN/SS 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.

Adjustable soft-start permits the regulator to slowly ramp to its steady state operating point after being enabled, thereby reducing inrush current from the input supply and slowing the output voltage rise time to prevent overshoot. Upon turn-on, after all UVLO conditions have been passed, an internal circuit slowly ramps the EN/SS input to implement the internal soft-start. If the preset soft-start time is enough for the application, the EN/SS should be set to high. Longer soft-start periods are achieved by adding an external capacitor and a resistor to this pin as shown in the figure below:

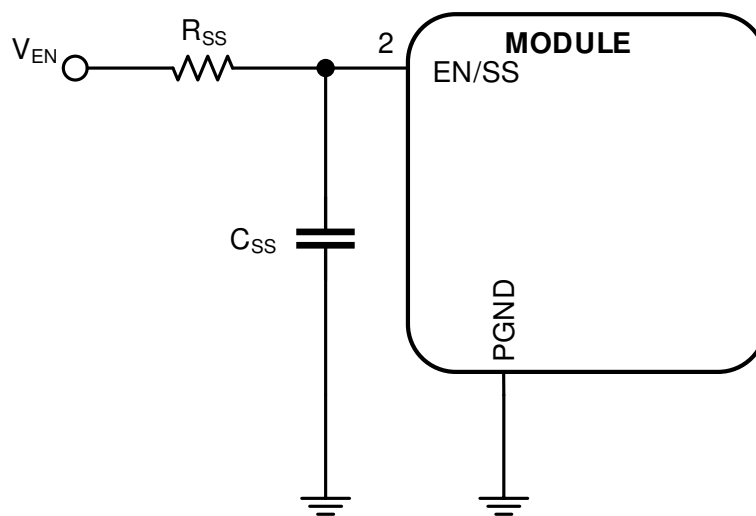


Figure 22: 171930601 external soft-start schematic.

The following equation can be used to set the soft-start time:

$$T_{SS} = C_{SS} \cdot R_{SS} \cdot \ln\left(\frac{V_{EN}}{V_{EN} - 1.45}\right) \quad (5)$$

## 18 DESIGN EXAMPLE

The design example shows a possible solution for 24V to 5V with a max. I<sub>out</sub> of 0.3A. All of the necessary components to fulfill the requirements of the CISPR 32 EMI conducted- and radiated-emissions tests are included in the design example. It passes the conducted emissions class B with 0.8m input and 1m output lines and passes the radiated emissions class B in a FAR at 3m measurement distance with 0.8m horizontal, 0.8m vertical input and 1m horizontal output lines. In the final application, filter components may be omitted depending on the requirements.

### 18.1 Layout

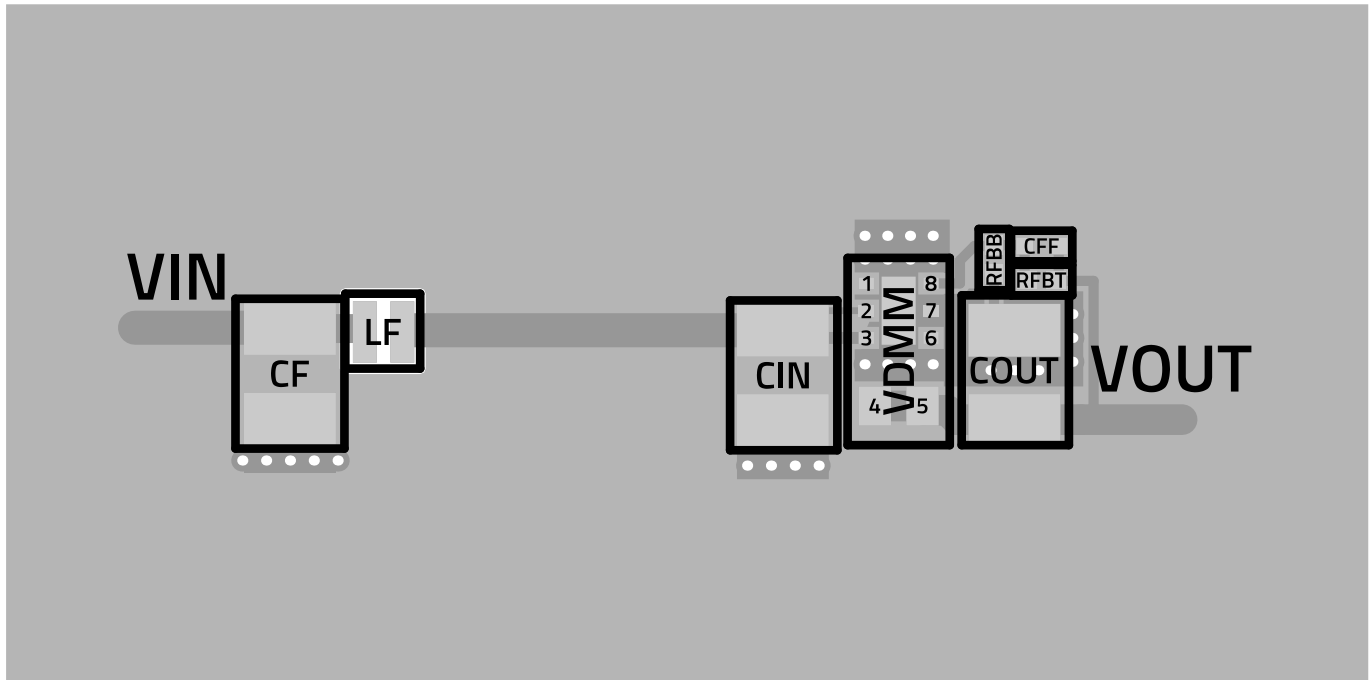


Figure 23: 171930601 layout recommendation.

The picture above shows a possible layout for the 171930601 MagI<sup>3</sup>C MicroModule. Nevertheless, some recommendations should be followed when designing the layout:

1. The input and output capacitors should be placed as close as possible to the VIN and VOUT pins of the device.
2. The feedback resistor divider should be placed as close as possible to the FB pin.
3. Avoid placing vias in any of the pads for the module the small size of the pads, significant amounts of solder can be pulled through the vias during heating, resulting in incomplete connections between the module and board.
4. The ambient temperature of this design example is limited to 85°C due to the X5R output capacitor. For usage above 85°C, two X7R 22µF (885012209006) capacitors are recommended to replace the single X5R capacitor.
5. To avoid direct coupling of the DC/DC converter's E- and H-fields into connectors, filter components and cables, the module must be placed as far away from these components as possible.

## 18.2 Schematic

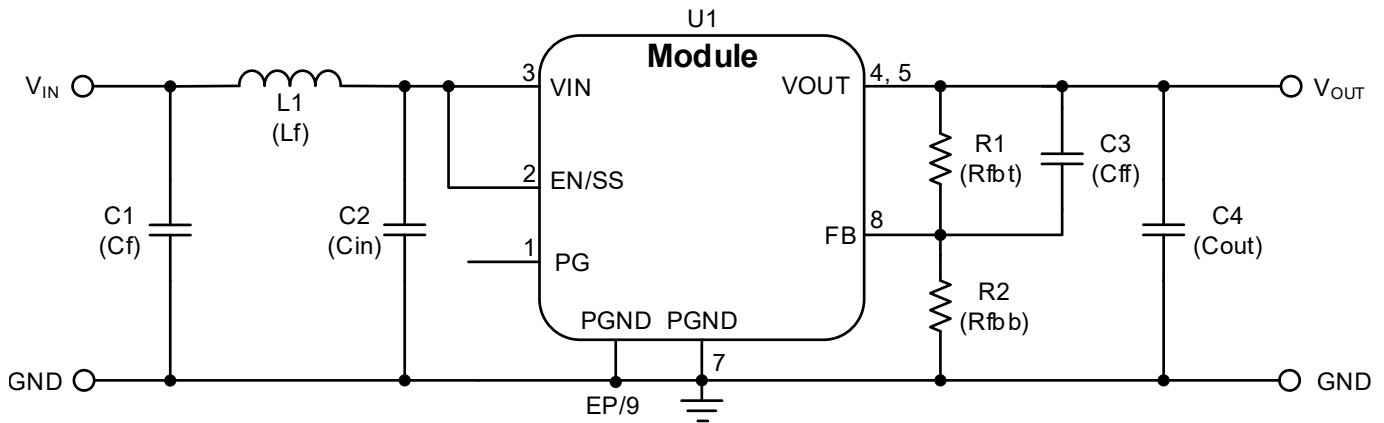


Figure 24: 171930601 design example schematic.

## 18.3 Bill of Materials

Table 12: 171930601 design example bill of materials.

Designator	Description	Function	Quantity	Order Code	Manufacturer
U1	Magi <sup>3</sup> C MicroModule	Power supply	1	171930601	WE
L <sub>1</sub>	Filter inductor, 1μH, MAPI family, I <sub>SAT</sub> = 3.4A, I <sub>R</sub> = 1.4A	Input filter	1	74438313010	WE
C <sub>1</sub> , C <sub>2</sub>	Ceramic chip capacitor 4.7μF, 50V, X7R, 1210	Input filter	1	885012209048	WE
C <sub>3</sub>	Ceramic chip capacitor 220pF, 10V, NPO, 0402	Electrical performance	1	885012005015	WE
C <sub>4</sub>	Ceramic chip capacitor 47μF, 16V, X5R, 0805	Output filter	1	885012109011	WE
R <sub>1</sub>	64.9kΩ	Electrical performance	1	—	—
R <sub>2</sub>	11.3kΩ for V <sub>OUT</sub> = 5V	Electrical performance	1	—	—

## 19 HANDLING RECOMMENDATIONS

1. The power module is classified as MSL3 (JEDEC Moisture Sensitivity Level 3) and requires special handling due to moisture sensitivity (JEDEC J-STD033D).
2. The parts are delivered in a sealed bag (Moisture Barrier Bag = 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 hour (7 days) of floor life. Once this time has been exceeded, bake parts prior to soldering per JEDEC J-STD033D recommendation.
5. Maximum number of solder cycles is two.
6. For minimum risk, solder the module in the last solder cycle of the PCB production.
7. For soldering process please consider lead material copper (Cu) and lead finish tin (Sn).
8. It is recommended to use a standard SAC Alloy such as SAC 305, type 3 or higher.
9. The profile below is valid for convection reflow only.
10. Other soldering methods (e.g. vapor phase) are not verified and have to be validated by the customer at their own risk.

### 19.1 SOLDERING PROFILE

Table 13: Reflow solder 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 $T_L$	$t_L$	60-190 seconds
Classification temperature	$T_C$	260°C
Peak package body temperature	$T_P$	$T_P \leq T_C$
Time within 5°C of actual peak temperature	$t_p$	$t_p \leq 20$ 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.

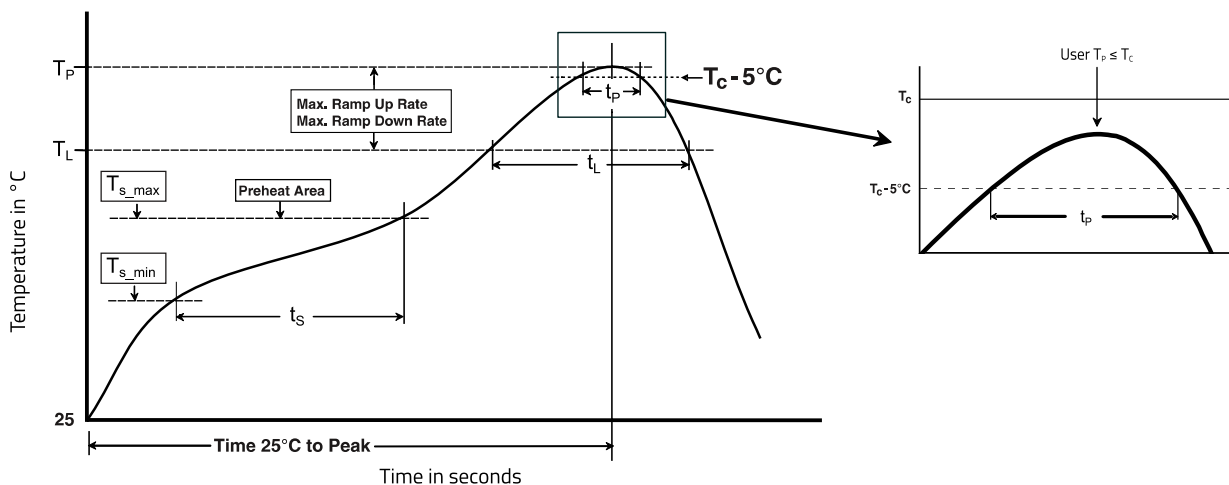
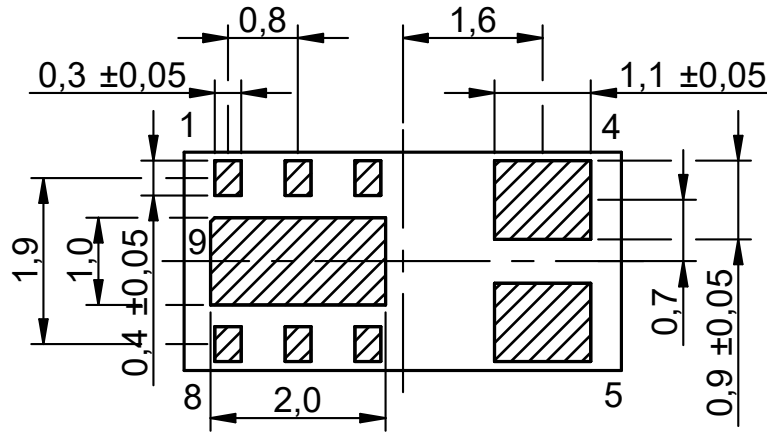


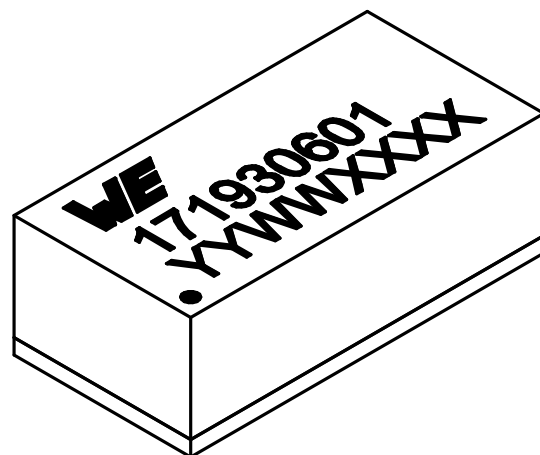
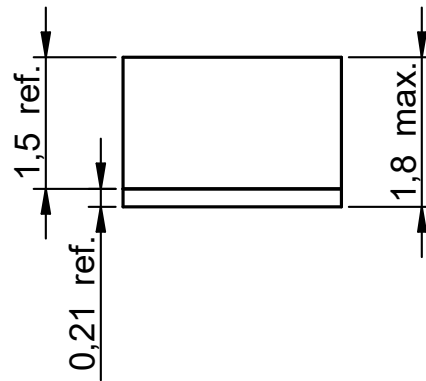
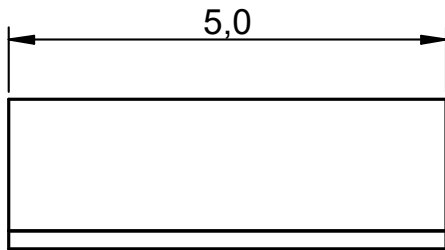
Figure 25: Solder profile.

20 PHYSICAL DIMENSIONS

20.1 COMPONENT



Bottom view



All dimensions in mm  
Tolerances  $\pm 0.1$ mm unless otherwise indicated

Figure 26: 171930601 component dimensions.



20.3 PACKAGING

Reel in mm

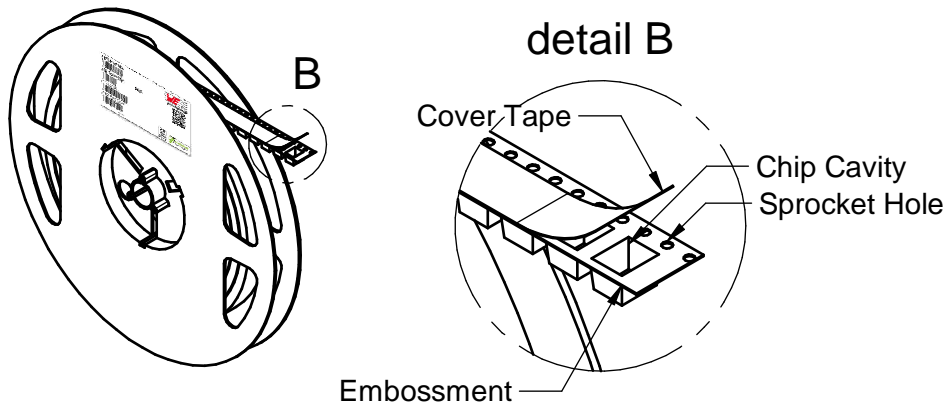
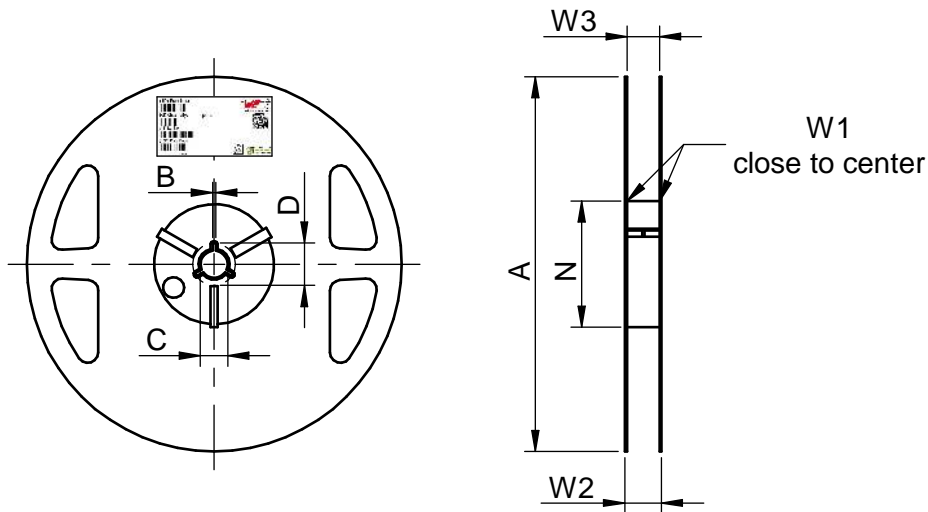


Figure 28: 171930601 reel dimensions.

Table 14: Reel dimensions.

A	B	C	D	N	W1	W2	W3	W3	Material
±1.0	±0.5	±0.5	Min.	±0.5	±1.5	±1.0	Min.	Max.	
178.00	2.50	13.00	12.50	60.00	13.2	16.00	12.20	15.00	Polystyrene

Tape in mm

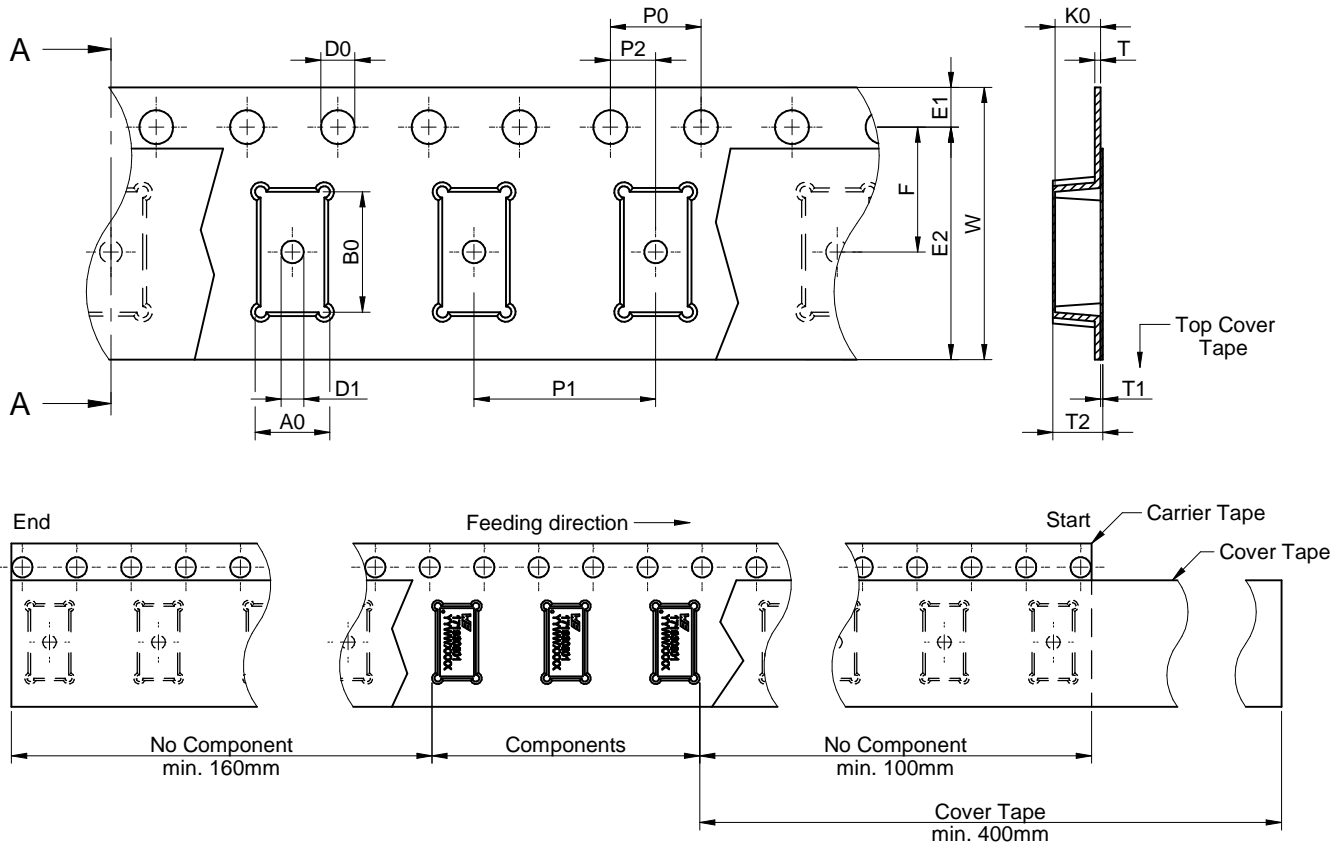


Figure 29: 171930601 tape dimensions.

Table 15: Tape dimensions.

Tape Type	A0	B0	W	T	T1	T2	K0	P0	P1	P2	D0	D1	E1	E2	F
	±0.1	±0.1	±0.3	±0.05	±0.01		±0.1	±0.1	±0.1	±0.05	Max.	Min.	±0.1	Min.	±0.05
2a	2.8	5.3	12	0.3	0.05	2.005	2.0	4	8	2	1.6	1.0	1.75	10.25	5.5

Tape material is polystyrene.



## 21 DOCUMENT HISTORY

Table 16: Document history.

Revision	Date	Description	Comment
1.0	November 2021	Initial data sheet release	
1.1	December 2021	Minor formatting change	Updated format and updated front page
1.2	April 2022	Minor changes	<ol style="list-style-type: none"> <li>1. Updated document font style</li> <li>2. Corrected output voltage values in output voltage selection table in Design Flow</li> <li>3. Updated Filter Suggestion for Conducted EMI section</li> </ol>
2.0	July 2023	PCN	The recommended reflow solder profile in the Handling Recommendations section of the data sheet has been updated. The formatting of the document has been updated.

## 22 LIST OF FIGURES

1	Pinout. . . . .	4
2	Conducted emissions with input filter. . . . .	10
3	Radiated emissions with input filter. . . . .	10
4	Efficiency $V_{IN} = 12V$ , $T_A = 25^\circ C$ . . . . .	11
5	Efficiency $V_{IN} = 24V$ , $T_A = 25^\circ C$ . . . . .	11
6	Output current thermal derating $V_{IN} = 12V$ , $\Theta_{JA} = 55 K/W$ . . . . .	12
7	Output current thermal derating $V_{IN} = 24V$ , $\Theta_{JA} = 55 K/W$ . . . . .	12
8	Output voltage vs. maximum input voltage . . . . .	13
9	Load regulation $V_{IN} = 24V$ , $V_{OUT} = 3.3V$ , $T_A = 25^\circ C$ . . . . .	14
10	Line regulation $V_{OUT} = 3.3V$ , $I_{OUT} = 0.3A$ , $T_A = 25^\circ C$ . . . . .	14
11	Block diagram. . . . .	15
12	Design flow schematic. . . . .	16
13	Output voltage schematic. . . . .	17
14	Output voltage ripple $V_{IN} = 24V$ , $V_{5V}$ , $I_{OUT} = 0.3A$ , $C_{OUT} = 33\mu F$ . . . . .	18
15	Output voltage ripple $V_{IN} = 24V$ , $V_{5V}$ , $I_{OUT} = 0.3A$ , $C_{OUT} = 68\mu F$ . . . . .	19
16	Load transient from 0.03A to 0.3A. . . . .	20
17	Output voltage ripple $V_{IN} = 24V$ , $V_{OUT} = 5V$ , $I_{OUT} = 0.03A$ . . . . .	22
18	Output voltage ripple $V_{IN} = 24V$ , $V_{OUT} = 5V$ , $I_{OUT} = 0.3A$ . . . . .	22
19	Inductor current and frequency foldback. . . . .	23
20	OCP $V_{IN} = 24V$ , $V_{OUT} = 5V$ . . . . .	23
21	SCP $V_{IN} = 24V$ , $V_{OUT} = 5V$ , short circuit condition. . . . .	24
22	External soft-start schematic. . . . .	25
23	Layout recommendation. . . . .	26
24	Design example schematic. . . . .	27
25	Solder profile. . . . .	28
26	Component dimensions. . . . .	29
27	Landpattern dimensions. . . . .	30
28	Reel dimensions. . . . .	31
29	Tape dimensions. . . . .	32

**23 LIST OF TABLES**

1	Marking description. . . . .	4
2	Pin description. . . . .	4
3	Ordering information. . . . .	5
4	Package specifications. . . . .	5
5	Absolute maximum ratings. . . . .	6
6	Operating conditions. . . . .	6
7	Thermal specifications. . . . .	6
8	Electrical specifications part 1. . . . .	7
9	RoHS, REACH. . . . .	8
10	Package specifications. . . . .	8
11	Output voltage selection with $R_{FBT} = 64.9k\Omega$ . . . . .	17
12	Design example bill of materials. . . . .	27
13	Reflow solder profile. . . . .	28
14	Reel dimensions. . . . .	31
15	Tape dimensions. . . . .	32
16	Document history. . . . .	33

## 24 CAUTIONS AND WARNINGS

The following conditions apply to all goods within the product series of MagI<sup>3</sup>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.

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