High-Efficiency 1.2 MHz, 3 A Output Synchronous, Step-Down Converter

Features

- Input voltage: 2.4 V to 5.5 V
- Output voltage: 0.6 V to V_{IN}
- 3 A continuous output current
- 0.6 V ±2% reference voltage
- 7 μA low quiescent current (pulse frequency modulation)
- 1.2 MHz switching frequency
- Programmable operation mode through EN
- Pulse width modulation regardless of output load
- Pulse frequency modulation (PFM)
- Low-dropout (LDO) mode
- Protection circuitry
  - Undervoltage lockout (UVLO)
  - Peak current limit
  - Valley current limit
  - Thermal shutdown

Applications

- 5 V distributed power bus supplies
- White goods and small home appliances
- FPGA, DSP, and ASIC supplies
- Network video cameras
- Wireless routers
- Consumer electronics
- General purpose point of load

Package Information

Part Number	Package	Body Size
DIO61302	SOT563	1.6 mm × 1.2 mm

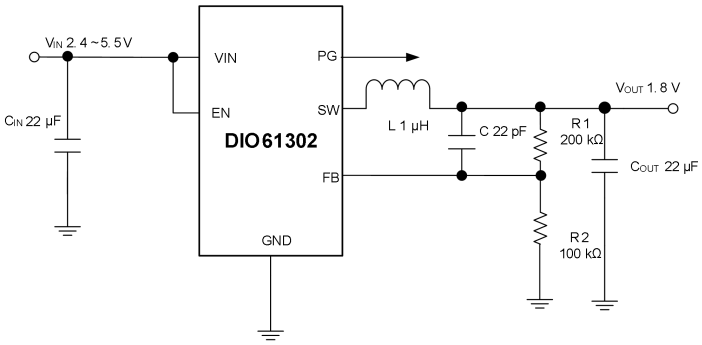
Description

The DIO61302 is a high-efficiency, 1.2 MHz synchronous step-down DC-DC regulator IC capable of delivering an up to 3 A output current. The device provides high-efficiency step-down DC-DC conversion with an 80 mΩ high-side power MOSFET and a 50 mΩ low-side power MOSFET.

To achieve fast transient response, easy loop stabilization, and low output voltage ripple, the DIO61302 minimizes the external component count by adopting constant on-time (COT) control.

The DIO61302 operates over a wide input voltage ranging from 2.4 V to 5.5 V and integrate with a main switch and a synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. Low output voltage ripple and small external inductor and capacitor sizes are achieved with a 1.2 MHz switching frequency.

Simplified Schematic



Ordering Information

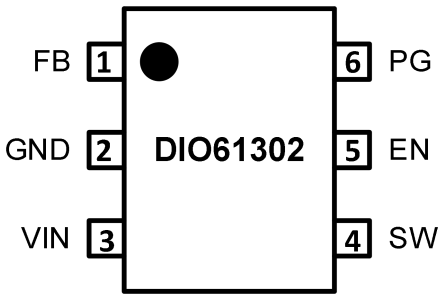
Part Number	Top Marking	MSL	RoHS	T_A	Package	
DIO61302SH3	W3B	3	Green	-40 to 85°C	SOT563	Tape & Reel, 5000

If you encounter any issue in the process of using the device, please contact our customer service at marketing@dioo.com or phone us at (+86)-21-62116882. If you have any improvement suggestions regarding the datasheet, we encourage you to contact our technical writing team at docs@dioo.com. Your feedback is invaluable for us to provide a better user experience.

Table of Contents

List of Figures

1. Pin Assignment and Functions



SOT563 (Top view)

Pin No.	Pin Name	Description
1	FB	Feedback sensing terminal for the output voltage. Connect this pin to the resistive divider of the output.
2	GND	Power ground.
3	VIN	Power input. VIN supplies the power to the IC as well as power MOSFETs of the step-down converter. Drive VIN with a 2.4 V to 5.5 V power source. Bypass VIN to GND with a suitably large capacitor to eliminate noise caused by the switching of the IC.
4	SW	Power switching output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load.
5	EN	Enable input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator and low to turn it off. EN is used to program the operation mode (PFM or PWM).
6	PG	Power-good. Open-drain power-good output that is pulled to GND when the output voltage is out of its regulation limits or during soft-start.

2. Absolute Maximum Ratings

Exceeding the maximum ratings listed under Absolute Maximum Ratings when designing is likely to damage the device permanently. Do not design to the maximum limits because long-time exposure to them might impact the device's reliability. The ratings are obtained over an operating free-air temperature range unless otherwise specified.

Symbol	Parameter	Rating	Unit
V_{IN}	Supply voltage (V+ – V-)	-0.3 to 6.0	V
V_{FB}	FB voltage	-0.3 to (V_{IN} + 0.6)	V
V_{EN}	Enable voltage	-0.3 to (V_{IN} + 0.6)	V
V_{PG}	Power-good pin voltage	-0.3 to 6.0	V
P_D	Power dissipation, T_A = 25°C	1	W
T_{STG}	Storage temperature range	-65 to 150	°C
T_J	Junction temperature range	150	°C
T_L	Lead temperature range	260	°C
	Dynamic LX voltage in 50 ns duration	VIN + 3 to GND - 4	V

3. Recommended Operating Conditions

Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. The ratings are obtained over an operating free-air temperature range unless otherwise specified.

Symbol	Parameter	Rating	Unit
V_{IN}	Supply voltage	2.4 to 5.5	V
T_J	Junction temperature range	-40 to 125	°C
T_A	Ambient temperature range	-40 to 85	°C

4. ESD Ratings

When a statically-charged person or object touches an electrostatic discharge sensitive device, the electrostatic charge might be drained through sensitive circuitry in the device. If the electrostatic discharge possesses sufficient energy, damage might occur to the device due to localized overheating.

Model	Condition	Value	Unit
ESD	HBM, JEDEC:JS-001	±2000	V
	CDM, JEDEC:JS-002	±2000	

5. Thermal Considerations

The thermal resistance determines the heat insulation property of a material. The higher the thermal resistance is, the lower the heat loss. Accumulation of heat energy degrades the performance of semiconductor components.

Symbol	Metric	Value	Unit
$R_{\theta JA}$	Junction-to-air thermal resistance	140	°C/W
$R_{\theta JC}$	Junction-to-case thermal resistance	34	

6. Electrical Characteristics

V_{IN} = 3.6 V, V_{OUT} = 0.9 V, L = 1 μH, C_{OUT} = 2 × 22 μF, T_A = 25°C, I_{MAX} = 1 A, unless otherwise specified.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{IN}	Input voltage range		2.4		5.5	V
I_Q	Quiescent current	I_{OUT} = 0, V_{FB} = V_{REF} × 105%		7		μA
I_{SHDN}	Shutdown current	EN = 0		0.1	1	μA
V_{REF}	Feedback reference voltage		0.588	0.6	0.612	V
I_{FB}	FB input current	V_{FB} = V_{IN}	-50		50	nA
$R_{DS(ON)}$, P	PFET R_{ON}	V_{IN} = 5 V, I_{OUT} = 100 mA		80		mΩ
$R_{DS(ON)}$, N	NFET R_{ON}	V_{IN} = 5 V, I_{OUT} = 100 mA		50		mΩ
I_{LIM}	PFET current limit		3.5			A
V_{ENH}	EN rising threshold		0.825			V
V_{ENL}	EN falling threshold				0.4	V
V_{UVLO}	Input UVLO threshold				2.4	V
V_{HYS}	UVLO hysteresis			0.15		V
R_{DSC}	Output discharge switch on resistance			50		Ω
f_{OSC}	Oscillator frequency	I_{OUT} = 1 A		1.2		MHz
	PG rising delay time(1)			50		μs
	PG falling delay time(1)			30		μs
V_{FB,UV_R}	Undervoltage PG rising threshold			0.58		V
V_{FB,UV_F}	Undervoltage PG falling threshold			0.55		V
V_{FB,OV_R}	Overvoltage PG rising threshold			0.63		V
V_{FB,OV_F}	Overvoltage PG falling threshold			0.72		V
	Min on-time			70		ns
	Max duty-cycle		100			%
t_{SS}	Soft-start time			1.2		ms
T_{SD}	Thermal shutdown temperature			150		°C

Note:

(1) Guaranteed by design.

(2) Specifications subject to change without notice.

7. Typical Performance Characteristic

T_A = 25°C, V_{IN} = 5 V, V_{OUT} = 1.8 V, C_{IN} = C_{OUT} = 22 µF, L = 1 µH, unless otherwise specified.

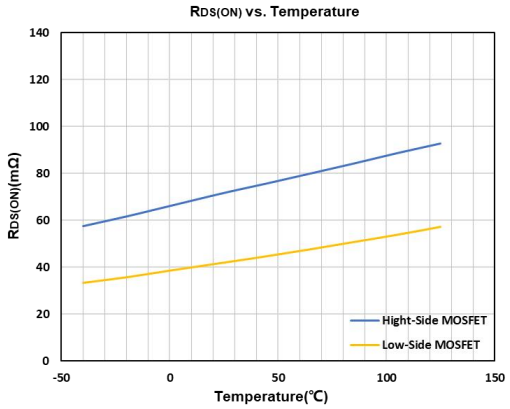


Figure 1. $R_{DS(ON)}$ vs. Temperature

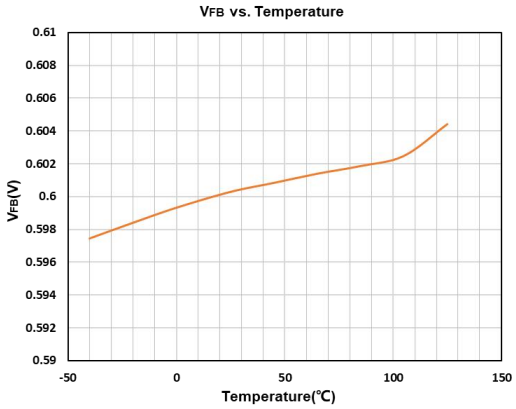


Figure 2. V_{FB} vs. Temperature

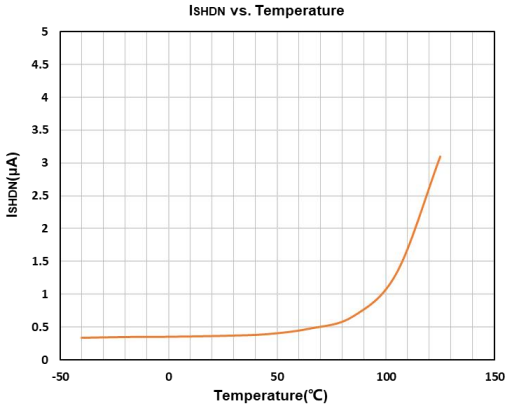


Figure 3. I_{SHDN} vs. Temperature

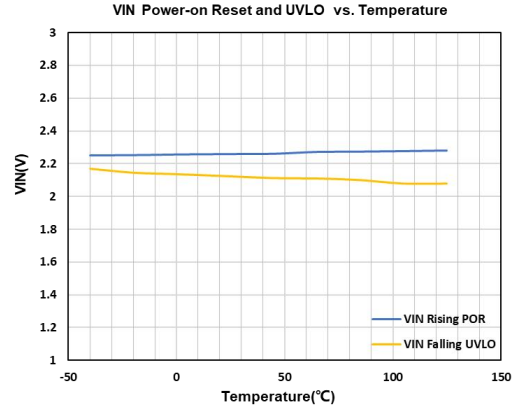


Figure 4. VIN Power-on reset and UVLO vs. Temperature

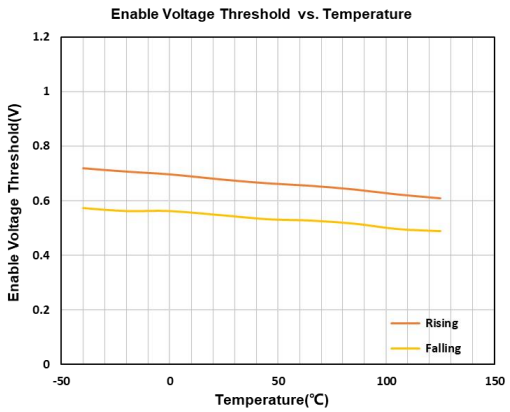


Figure 5. Enable voltage threshold vs. Temperature

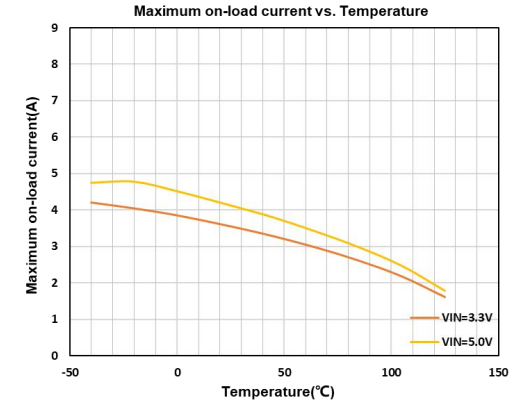


Figure 6. Maximum on-load current vs. Temperature

T_A = 25°C, V_{IN} = 5 V, V_{OUT} = 1.8 V, C_{IN} = C_{OUT} = 22 µF, L = 1 µH, PFM, unless otherwise specified.

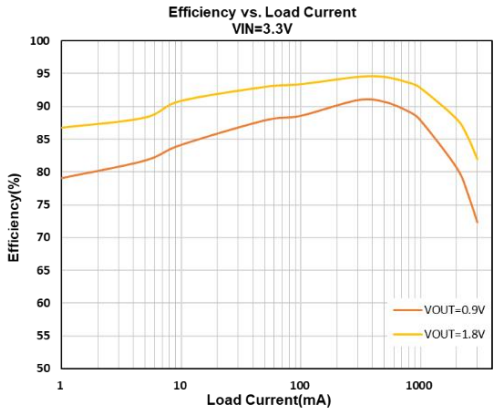


Figure 7. Efficiency vs. Output current, V_{IN} = 3.3 V

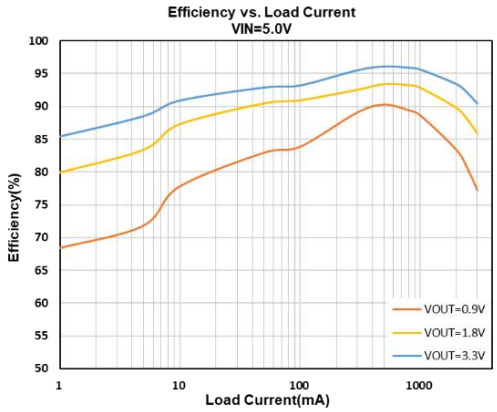


Figure 8. Efficiency vs. Output current, V_{IN} = 5.0 V

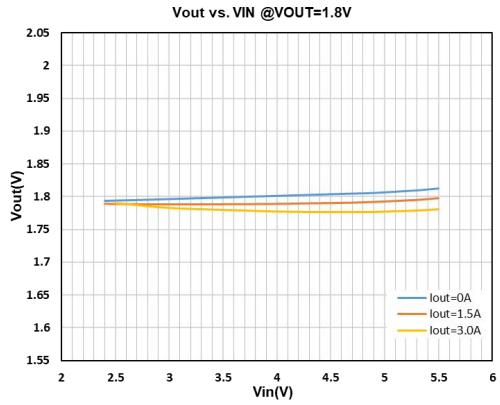


Figure 9. Line regulation

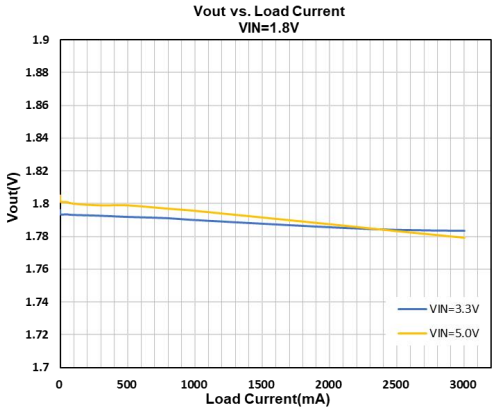


Figure 10. Load regulation

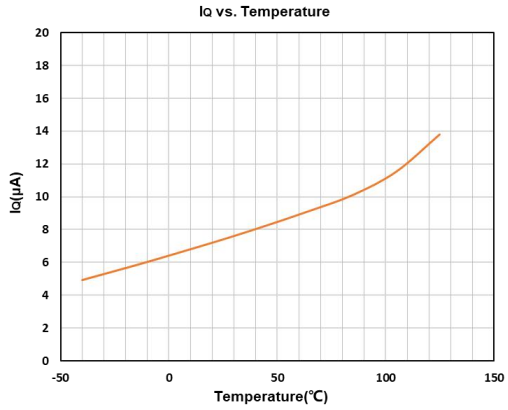


Figure 11. I_Q vs. Temperature

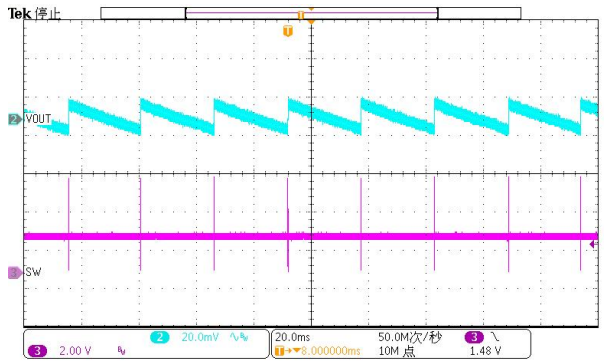


Figure 12. Output voltage ripple, I_{OUT} = 0 A

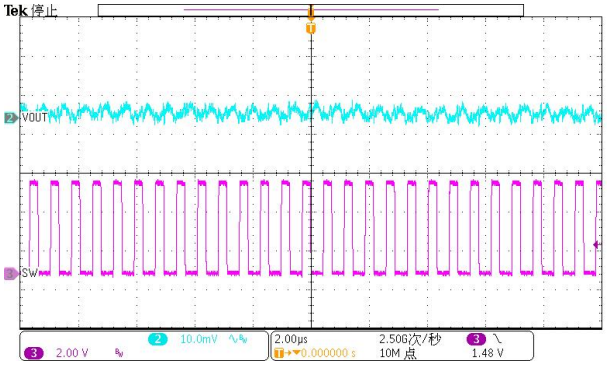


Figure 13. Output voltage ripple, I_{OUT} = 3 A

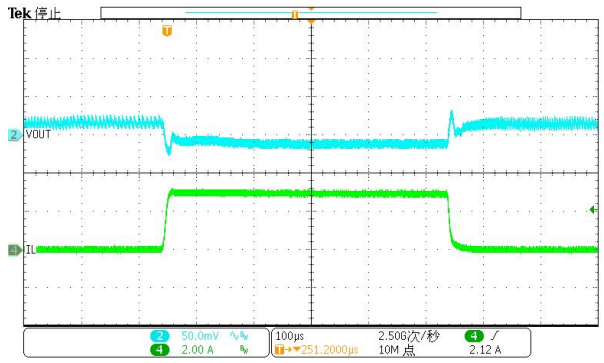


Figure 14. Load transient, I_{OUT} = 1 mA to 3000 mA to 1 mA

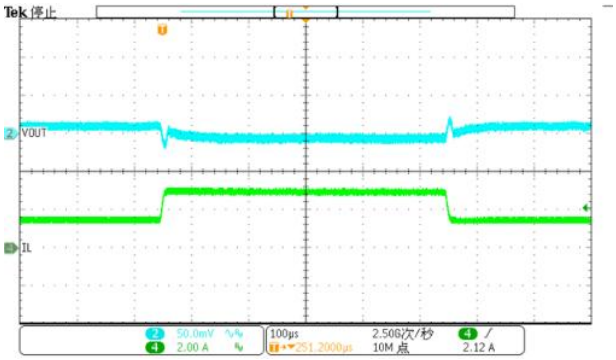


Figure 15. Load transient, I_{OUT} = 1.5 A to 3 A to 1.5 A

T_A = 25°C, V_{IN} = 5 V, V_{OUT} = 1.8 V, C_{IN} = C_{OUT} = 22 µF, L = 1 µH, PWM, unless otherwise specified.

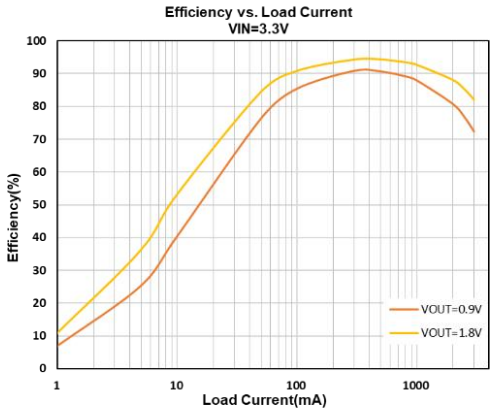


Figure 16. Efficiency vs. Output current, V_{IN} = 3.3 V

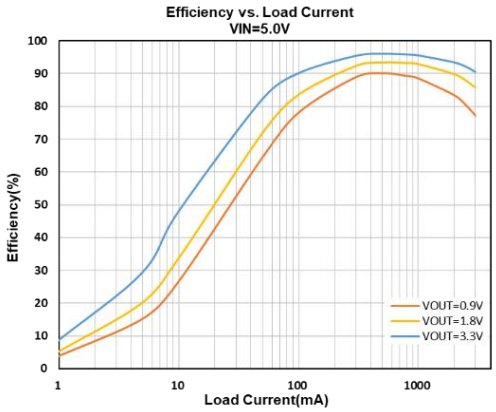


Figure 17. Efficiency vs. Output current, V_{IN} = 5.0 V

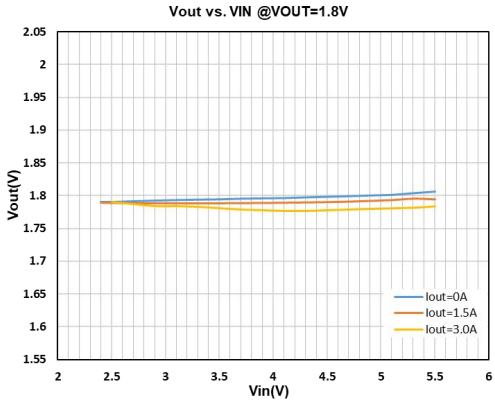


Figure 18. Line regulation

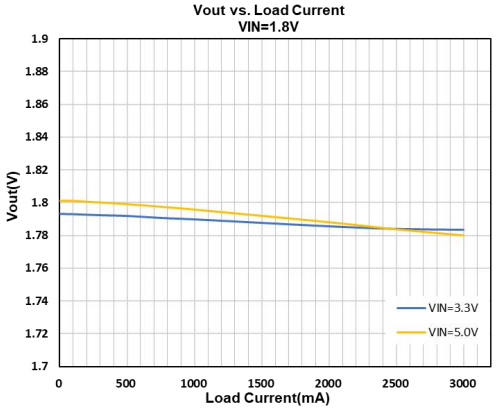


Figure 19. Load regulation

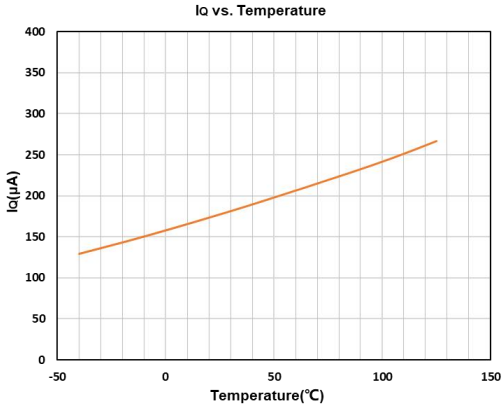


Figure 20. I_Q vs. Temperature

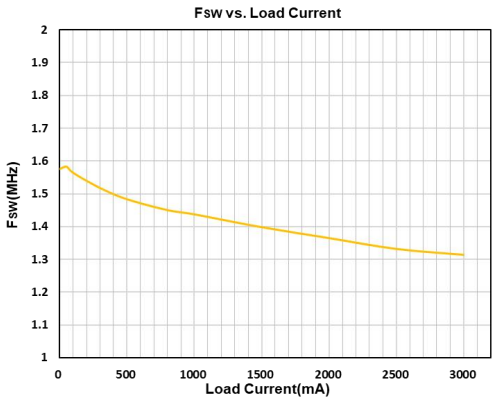


Figure 21. f_{SW} vs. Load

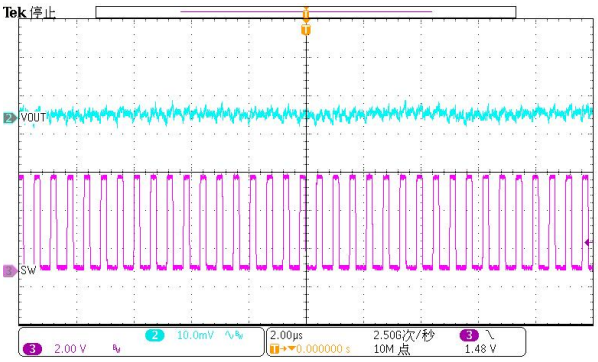


Figure 22. Output voltage ripple, I_{OUT} = 0 A

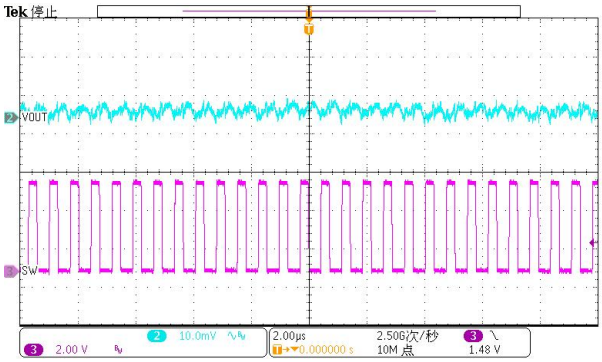


Figure 23. Output voltage ripple, I_{OUT} = 3 A

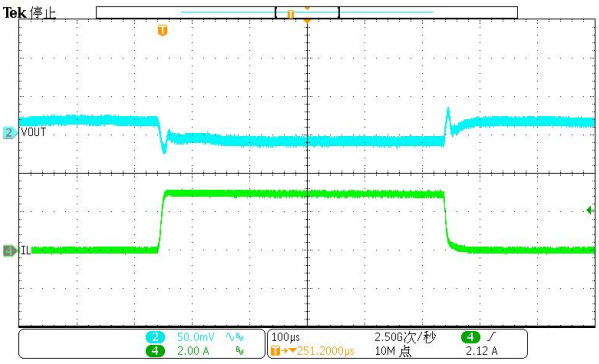


Figure 24. Load transient, I_{OUT} = 1 mA to 3000 mA to 1 mA

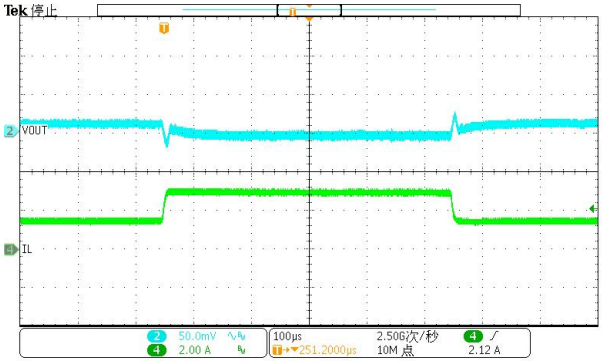


Figure 25. Load transient, I_{OUT} = 1.5 A to 3 A to 1.5 A

T_A = 25°C, V_{IN} = 5 V, V_{OUT} = 1.8 V, C_{IN} = C_{OUT} = 22 µF, L = 1 µH, unless otherwise specified.

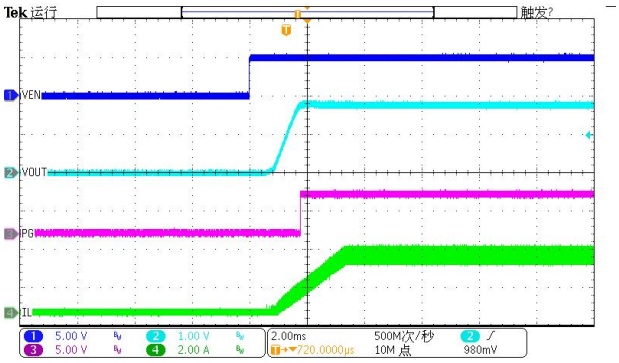


Figure 26. Startup using EN, I_{OUT} = 3 A

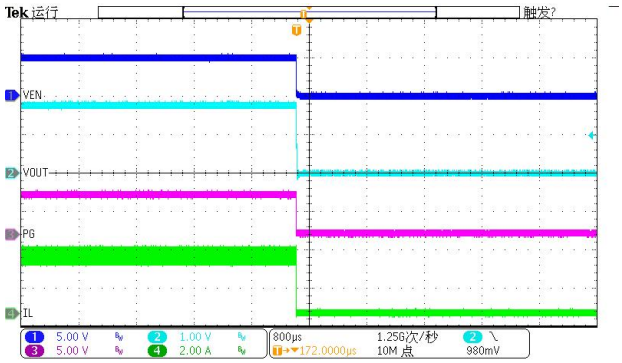


Figure 27. Shutdown using EN, I_{OUT} = 3 A

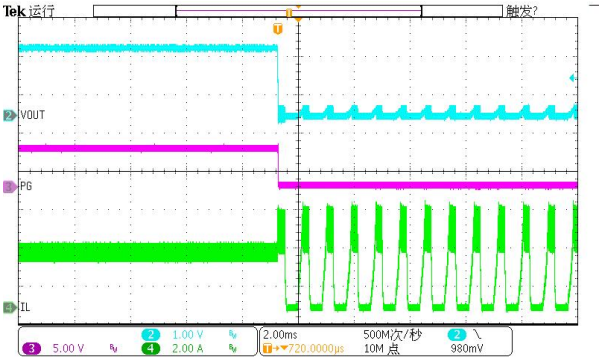


Figure 28. Output short protection, I_{OUT} = 3 A

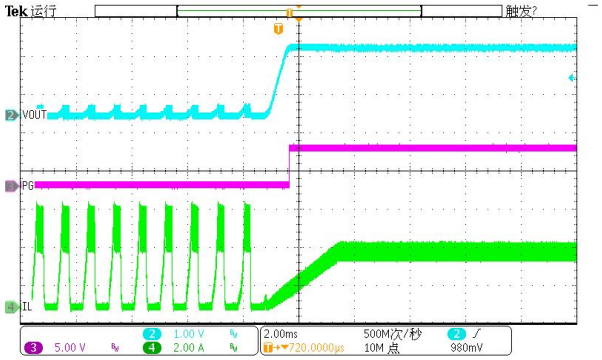
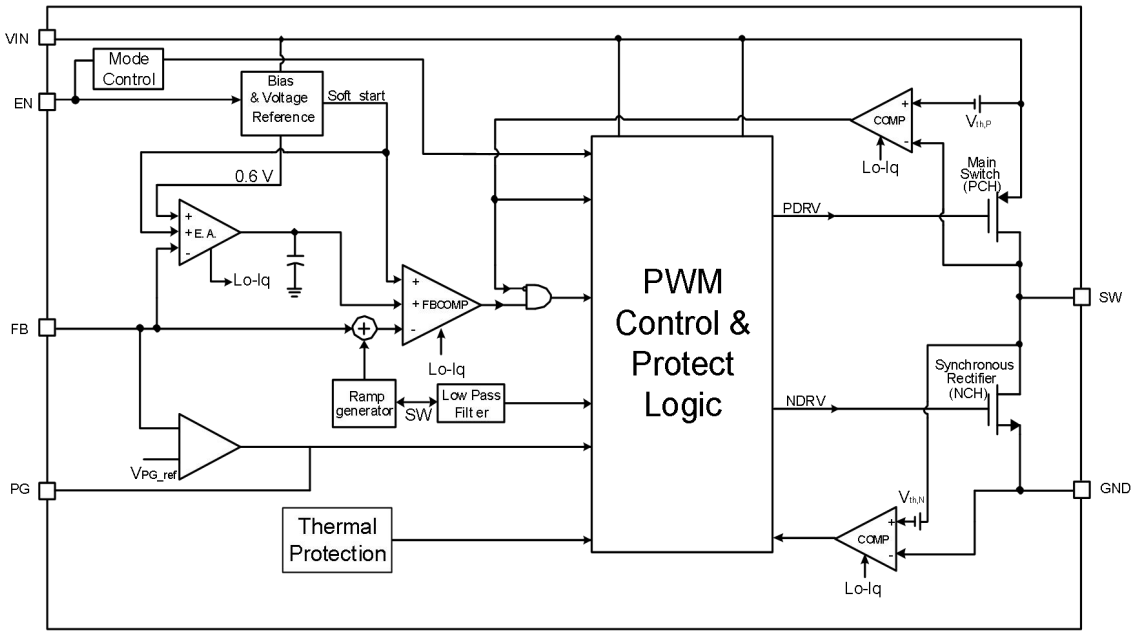


Figure 29. Output short recovery, I_{OUT} = 3 A

8. Block Diagram



9. Application Information

Important notice: Validation and testing are the most reliable ways to confirm system functionality. The application information is not part of the specification and is for reference purposes only.

9.1. Application examples

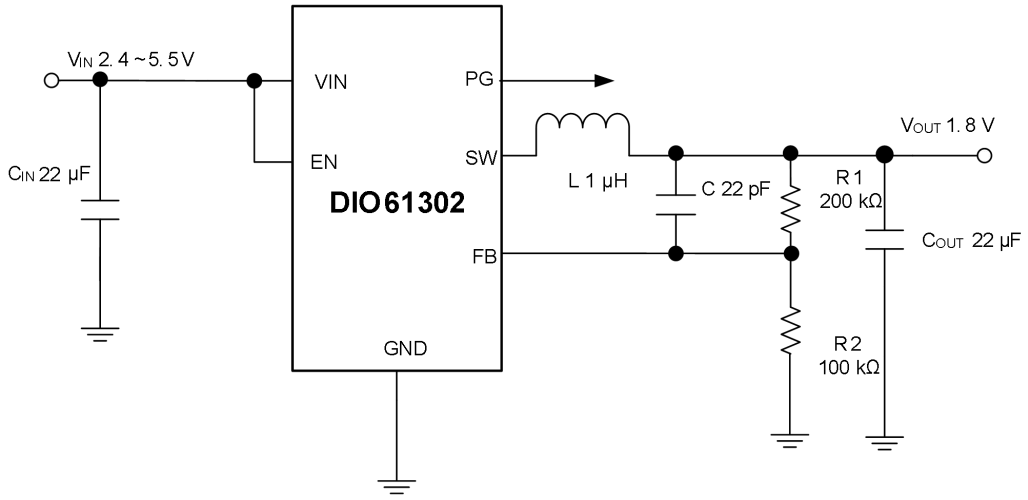


Figure 30. Typical application

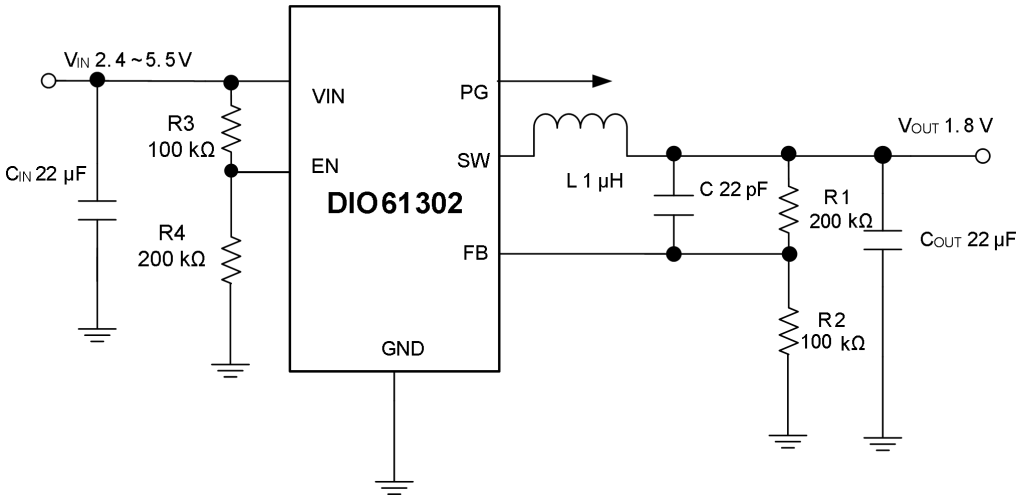


Figure 31. Typical application for forced PWM operation

9.2. Pulse width modulation (PWM) operation

The device will operate in continuous conduction mode (CCM) when the output current is high. In CCM operation, the switching frequency is fairly constant. This is called pulse-width modulation (PWM) mode. The PWM operation is based on an adaptive constant on-time (COT) control with stabilized switching frequency. The on-time is inversely proportional to the input voltage and directly proportional to the output voltage. It is calculated by Equation (1):

$$t_{ON} = \frac{V_{OUT}}{V_{IN} \times f_{SW}} \quad (1)$$

The off-time duration is t_{OFF} and starts after the on-time expires. The off-time expires when the feedback voltage decreases below the reference voltage, which then triggers the on-time duration to start again.

9.3. Pulse frequency modulation (PFM) operation

Under light load conditions, the DIO61302 enters pulse frequency modulation (PFM) to maintain high efficiency. Meanwhile, the device works continuously in discontinuous conduction mode (DCM). This happens when the output current becomes smaller than half of the ripple current of the inductor. The device operates now with a fixed on-time and the switching frequency further decreases proportionally to the load current. It can be calculated from Equation (2):

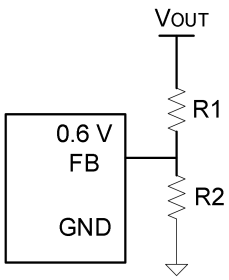
$$f_{PFM} = \frac{2 \times I_{OUT}}{t^2_{ON} \times \frac{V_{IN}}{V_{OUT}} \times [\frac{V_{IN} - V_{OUT}}{L}]} \quad (2)$$

In PFM, the output voltage rises slightly above the nominal target, which can be minimized by using larger output capacitance. At duty cycles larger than 90%, the device may not enter PFM and can only maintain output regulation in PWM mode.

9.4. Feedback resistor dividers R1 and R2

Choose R1 and R2 to program the proper output voltage. To minimize the power consumption under light loads, choose large resistance values for both R1 and R2. A value of between 100 kΩ and 1 MΩ is highly recommended for both resistors. If R1 is 120 kΩ, then R2 can be calculated from Equation (3).

$$R_2 = (\frac{0.6}{V_{OUT} - 0.6}) \times R_1 \quad (3)$$



9.5. Output voltage V_{OUT}

The DIO61302 has adjustable output voltages, starting from 0.6 V, using an external resistive divider. The resistor values of the feedback network are selected based on a design trade-off between efficiency and output voltage accuracy. There is less current consumption in the feedback network for high resistor values, which improves efficiency at light loads. However, values too high cause the device to be more susceptible to noise affecting its output voltage accuracy. R2 can be determined by Equation (4):

$$R_2 = \frac{0.6 \times R_1}{V_{OUT} - 0.6} \quad (4)$$

9.6. Input capacitor C_{IN}

With the maximum load current at 3 A, the maximum ripple current through input capacitor is about 1.5 A. A typical X7R or a better grade ceramic capacitor with 6 V rating and greater than 10 μF capacitance can handle this ripple current well. To minimize the potential noise problem, place this ceramic capacitor really close to the VIN and GND pins. Carefully minimize the loop area formed by C_{IN} and VIN/GND pins.

9.7. Output capacitor C_{OUT}

The output capacitor is selected to handle the output ripple noise requirements. Both steady state ripple and transient requirements must be taken into consideration when selecting this capacitor. For the best performance, use a X5R or a better grade ceramic capacitor with 6 V rating and greater than 10 μF capacitance.

9.8. Output inductor L

There are several considerations in choosing this inductor.

(1) To provide the desired ripple current, choose the ripple current to be about 40% of the maximum output current. The inductance is calculated from Equation (5).

$$L = \frac{V_{OUT} \times \left(1 - \frac{V_{OUT}}{V_{IN,MAX}}\right)}{f_{SW} \times I_{OUT,MAX} \times 40\%} \quad (5)$$

where f_{SW} is the switching frequency and $I_{OUT,MAX}$ is the maximum load current. The DIO61302 regulator IC is quite tolerant of different ripple current amplitudes. Consequently, the final choice of inductance can be slightly off the calculation value without significantly impacting the performance.

(2) The saturation current rating of the inductor must be greater than the peak inductor current under full load conditions.

$$I_{SAT,MIN} > I_{OUT,MAX} + \frac{V_{OUT} \times \left(1 - \frac{V_{OUT}}{V_{IN,MAX}}\right)}{2 \times f_{SW} \times L} \quad (6)$$

(3) The DC resistance (DCR) of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement. Choose an inductor with a DCR lower than 50 mΩ to achieve a good overall efficiency.

9.9. Load transient considerations

The DIO61302 needs a 22 pF ceramic capacitor in parallel with R1 to further speed up the load transient responses for applications with large load transient step requirements.

9.10. Enable

When disabled, the device shutdown supply current is only 0.1 μA. When applying a voltage greater than the EN logic high threshold (typically 0.65 V, rising), the DIO61302 enables all functions and the device initiates the soft-start phase. The DIO61302 has a built-in 1.2 ms soft-start time to prevent output voltage overshoot and inrush current. When the EN voltage falls below its logic low threshold (typically 0.58 V, falling), the device operation is disabled and the 50 Ω active discharge is enabled to discharge the output voltage to ground.

The device operates in PFM when a logic high voltage is applied to the EN pin greater than (V_{IN} - 200) mV. Tying the EN pin to the VIN pin is sufficient to achieve this threshold condition.

The device operates in PWM regardless of the output load when a logic high voltage is applied to the EN pin less than (V_{IN} - 200) mV. In order to reach this threshold condition, an external resistive divider is required to create a difference in voltage between the VIN and EN pins.

9.11. Power-good (PG) indicator

The PG pin of DIO61302 is actively held low during the soft-start period until the output voltage reaches 95% of its target value. When the output voltage is outside of its regulation by ±10%, PG pulls low until the output returns within 5% of its set value. The PG rising edge transition is delayed by 50 μs.

9.12. Undervoltage lockout (UVLO)

Undervoltage lockout protects the IC from insufficient input voltages. The DIO61302 is disabled if the input voltage falls below 2.1 V. In this UVLO event, both the high-side and low-side power MOSFETs turn off.

9.13. Switch current limit and short-circuit protection

The protection function prevents the device from drawing excessive current in case of externally-caused overcurrent or short-circuit conditions. If the current limit threshold is reached, the device delivers its maximum output current. Detecting this condition for 32 switching cycles, the device turns off the high-side MOSFET for about 300 μs and then restarts again with a soft-start cycle. As long as the overload condition is present, the device hiccups that way, limiting the output power.

9.14. Thermal shutdown (T_{SD})

If the junction temperature of the device reaches the thermal shutdown limit of 150°C, the DIO61302 shuts down both high-side and low-side power MOSFETs. When the junction temperature reduces to the required level (130°C typical), the device initiates a normal power-up cycle with a soft-start.

10. Layout Design

The layout design of the DIO61302 regulator is relatively simple. For the best efficiency and minimum noise problems, place four components close to the IC: C_{IN}, L, R1, and R2.

(1) Maximize the PCB copper area connected to GND pin to achieve the best thermal and noise performance. If the board space allows, a ground plane is highly desirable.

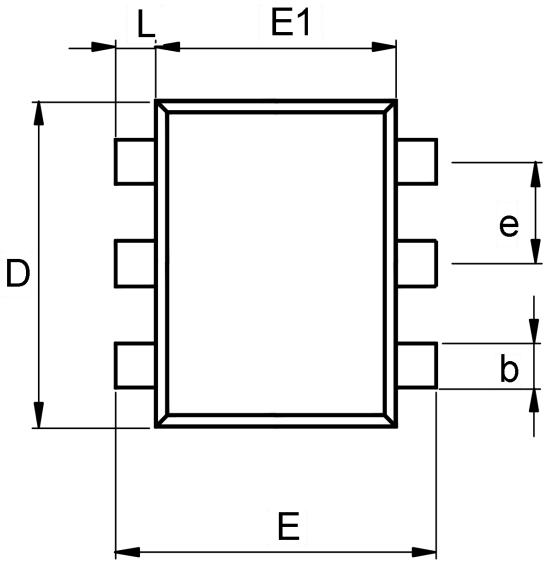
(2) Place C_{IN} close to IN and GND pins. Minimize the loop area formed by C_{IN} and GND.

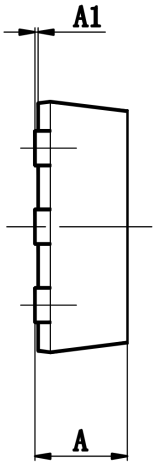
(3) Minimize the PCB copper area associated with the SW pin to avoid the potential noise problem.

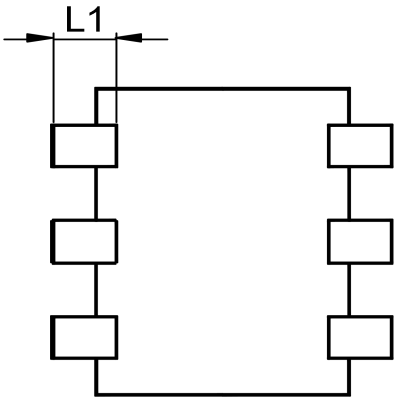
(4) Avoid placing the components R1 and R2 and the trace connected to the FB pin adjacent to the SW net on the PCB layout to prevent the noise problem.

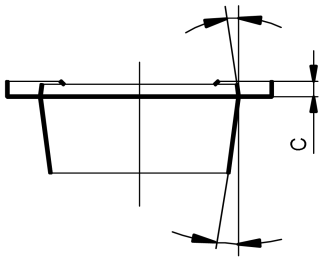
(5) If the system chip interfaced with the EN pin has a high impedance state at shutdown mode and the IN pin is connected directly to a power source such as a Li-Ion battery, it is desirable to add a pull-down 1 MΩ resistor between the EN and GND pins to prevent the noise from falsely turning on the regulator at shutdown mode.

11. Physical Dimensions: SOT563









Common Dimensions (Units of measure = Millimeter)		
Symbol	**Min**	**Max**
A	0.525	0.600
A1	0.000	0.050
e	0.450	0.550
c	0.090	0.160
D	1.500	1.700
b	0.170	0.270
E1	1.100	1.300
E	1.500	1.700
L	0.100	0.300
L1	0.200	0.400
θ	7° REF	

Disclaimer

This specification and information contained herein are provided on an “AS IS” basis and WITH ALL FAULTS. All product specifications, statements, information, and data (collectively, the “Information”) in this datasheet or made available on the website of www.dioo.com are subject to change without notice. The customer is responsible for checking and verifying the extent to which the Information contained in this publication is applicable to his/her application. All Information given herein is believed to be accurate and reliable, but it is presented without guarantee, warranty, or responsibility of any kind, express or implied.

