30 V, 3 A, 700 kHz High-Efficiency, Constant On-Time Synchronous, Step-Down Converter

Features

- Low $R_{DS(ON)}$ for internal switches (top/bottom) 80 mΩ / 40 mΩ, 3.0 A
- 4.5 V to 30 V input voltage range
- Switching frequency: 700 kHz
- Feedback reference voltage: 0.6 V (typ.)
- Fixed frequency COT architecture achieves ultra fast transient response
- High-efficiency synchronous mode
- Internal soft-start limits the inrush current
- Overcurrent protection
- Output short-circuit protection with hiccup
- Thermal shutdown
- Operating temperature range: -40°C to 85°C

Applications

- Portable navigation devices
- Set-top boxes
- Portable TVs
- LCD TVs

Package Information

Part Number	Package	Body Size
DIO54312	TSOT23-6	1.65 mm × 2.95 mm

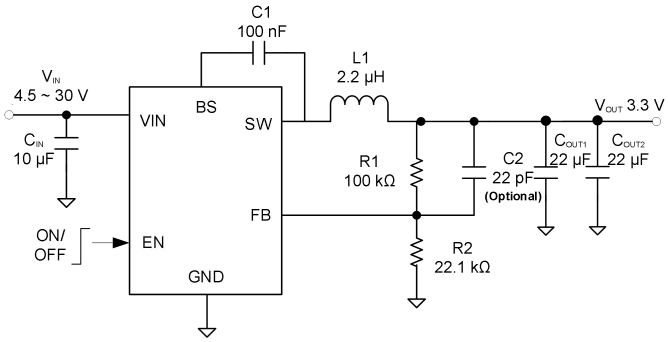
Description

The DIO54312 is a high-efficiency, high-frequency synchronous step-down DC-DC regulator IC capable of delivering up to 3 A output currents. The DIO54312 operates over a wide input voltage range from 4.5 V to 30 V and integrates the main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. The output voltage can be regulated to as low as 0.6 V.

The COT architecture with pseudo-fixed switching frequency operation provides a fast transient response and eases loop stabilization. The DIO54312 operates in pulse skip mode where the device maintains a high efficiency during light load operation. Protection features include overcurrent protection and thermal shutdown.

The DIO54312 requires a minimal number of readily-available, standard, external components and is available in a space-saving TSOT23-6 package.

Simplified Schematic



Ordering Information

Ordering Part No.	Top Marking	MSL	RoHS	T_A	Package	
DIO54312TST6	W412	3	Green	-40 to 85°C	TSOT23-6	Tape & Reel, 3000

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.

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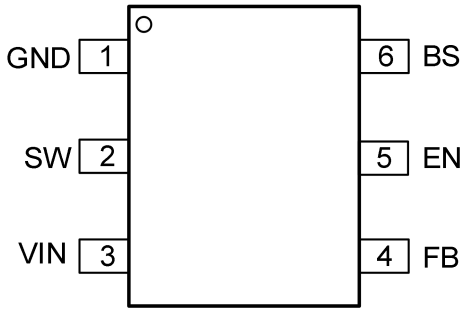


TSOT23-6 (Top view)

Pin No.	Name	Description
1	GND	Ground
2	SW	Inductor pin. Connect this pin to the switching node of inductor.
3	VIN	Power input
4	FB	Output feedback pin. Connect this pin to the center point of the output resistor divider (as shown in Block Diagram) to program the output voltage: V_{OUT} = 0.6 × (1 + R1/R2). Add optional C2 (10 pF ~ 47 pF) to speed up the transient response.
5	EN	This pin is the enable pin. Float the EN pin to enable. When the pin is floated, place a capacitor of 0.1 μF between the pin and GND to increase the interference resistance.
6	BS	Bootstrap. Connect a capacitor and a resistor between SW and BS pins to form a floating supply across the high-side switch driver. Recommend to use 0.1 μF BS capacitor.

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_{CC}	Supply voltage (V+ ~ V-)	-0.3 to 36	V
V_{EN}, V_{SW}	EN, SW voltage	-0.3 to V_{IN} + 0.3	V
V_{FB}	FB voltage	-0.3 to 6	V
V_{BS}	BS voltage	-0.3 to V_{SW} + 6	V
V_{SW}	SW (15 ns transient) voltage	-5 to 32	V
T_{STG}	Storage temperature range	-65 to 150	°C
T_J	Junction temperature range	150	°C
T_L	Lead temperature range	260	°C

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_{CC}	Supply voltage	4.5 to 30	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
HBM	ESDA/JEDEC JS-001	±2000	V
CDM	ESDA/JEDEC JS -002	±2000	V

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-ambient thermal resistance	87.9	°C/W
$R_{\theta JC}$	Junction-to-case thermal resistance	42.2	°C/W

6. Electrical Characteristics

The values are obtained under these conditions unless otherwise specified: V_{IN} = 12 V, V_{OUT} = 1.2 V, L = 2.2 μH, C_{OUT} = 47 μF, T_A = 25°C, I_{OUT} = 1 A.

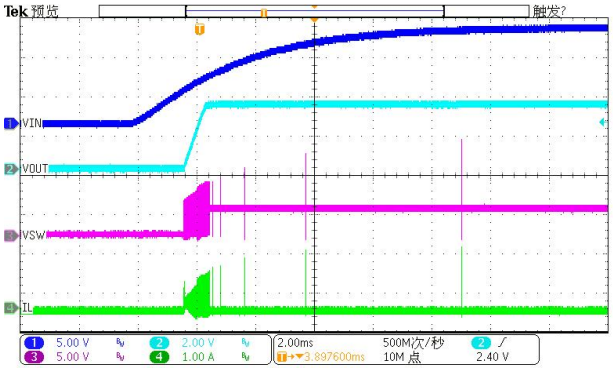
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{IN}	Input voltage range		4.5		30	V
I_Q	Quiescent current	I_{OUT} = 0, V_{FB} = V_{REF} × 105%		140		μA
I_{SHDN}	Shutdown current	EN = 0		10	15	μA
V_{REF}	Feedback reference voltage		0.588	0.6	0.612	V
I_{FB}	FB input current	V_{FB} = 3.3 V	-50		50	nA
$R_{DS(ON)}$(2)	Top FET R_{ON}			80		mΩ
$R_{DS(ON)}$(2)	Bottom FET R_{ON}			40		mΩ
I_{LIM}	Low side power FET current limit		3.0	4.0		A
V_{ENH}	EN rising threshold		1.5			V
V_{ENL}	EN falling threshold				0.4	V
V_{UVLO}	V_{IN} undervoltage unlock threshold, rising				4.45	V
	V_{IN} voltage hysteresis			0.4		V
f_{SW}	Switching frequency			700		kHz
	Min ON time			40		ns
	Min OFF time			180		ns
t_{SS}	Soft-start time			1		ms
T_{SD}	Thermal shutdown temperature			160		°C
T_{HYS}	Thermal shutdown hysteresis			20		°C

Note:

(1) Specifications subject to change without notice.

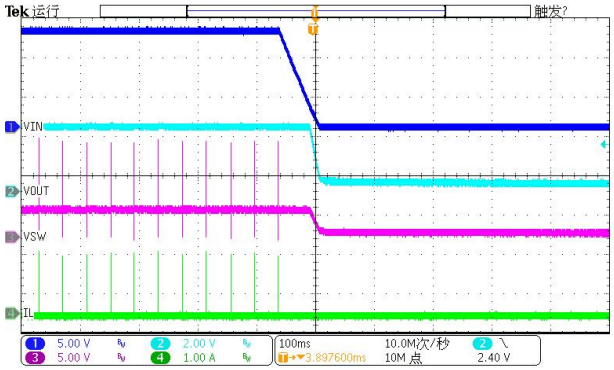
(2) Guaranteed by design.

7. Typical Performance Characteristic



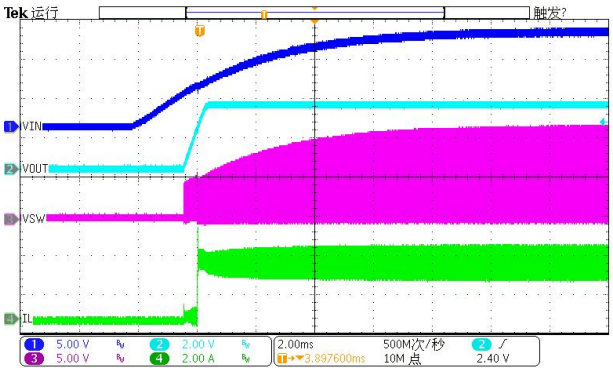
V_{IN} = 12 V, V_{OUT} = 3.3 V, No Load

Figure 1. Start up from V_{IN}



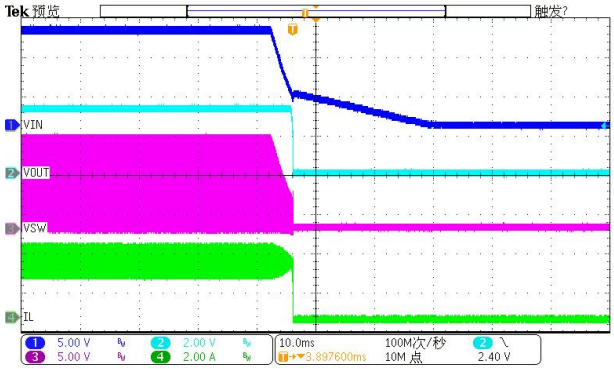
V_{IN} = 12 V, V_{OUT} = 3.3 V, No Load

Figure 2. Shut down from V_{IN}



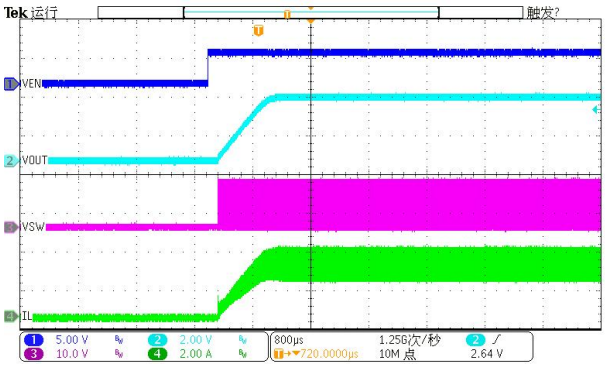
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 3 A

Figure 3. Start up from V_{IN}



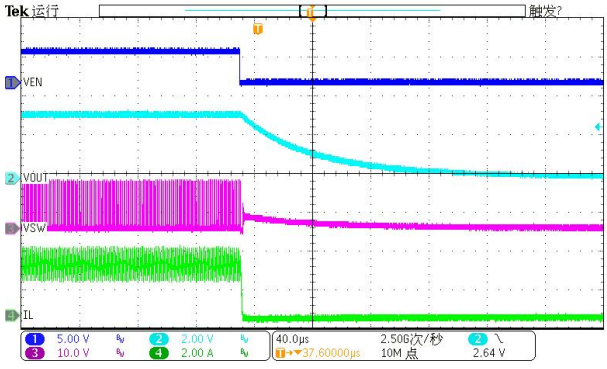
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 3 A

Figure 4. Shut down from V_{IN}



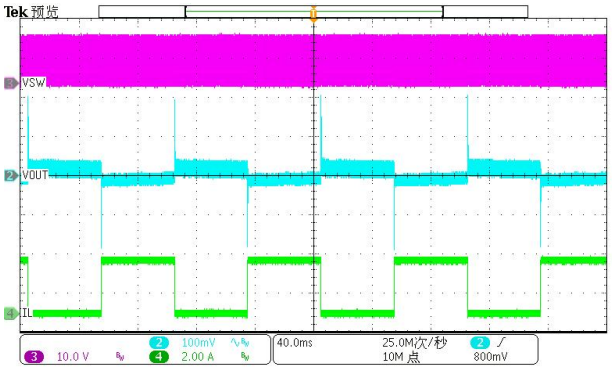
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 1.1 Ω

Figure 5. Start up from enable



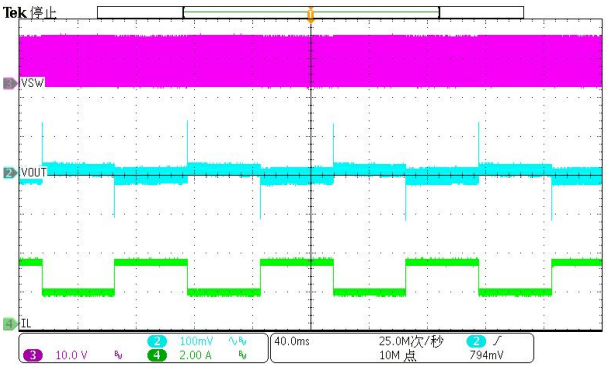
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 1.1 Ω

Figure 6. Shut down from enable



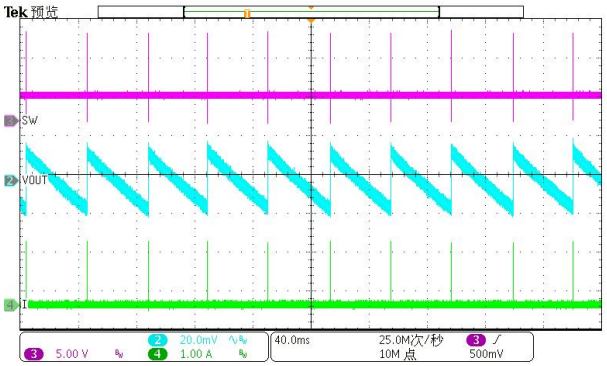
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 10 mA ~ 3 A

Figure 7. Load transient



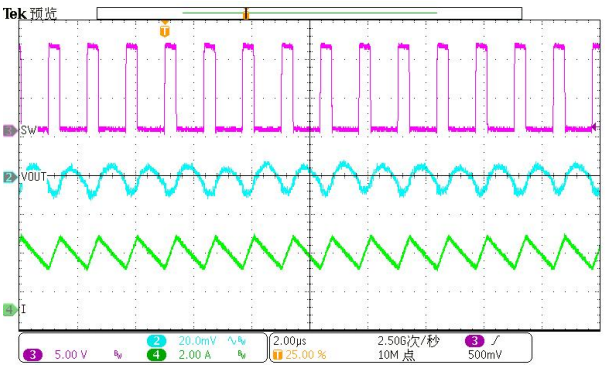
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 1.5 ~ 3 A

Figure 8. Load transient



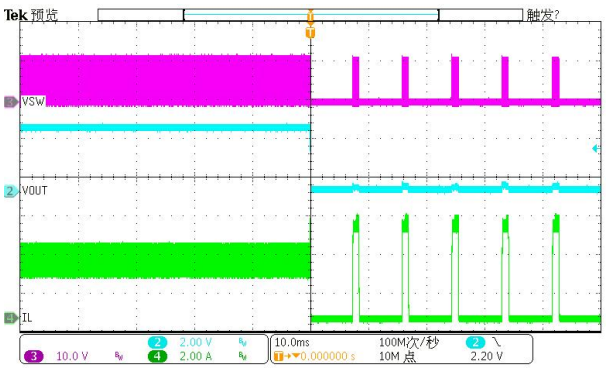
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 0 A

Figure 9. Ripple



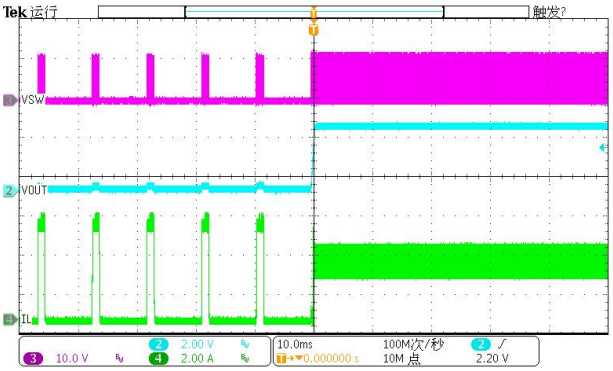
V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 3 A

Figure 10. Ripple



V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 3 A

Figure 11. Short-circuit protection



V_{IN} = 12 V, V_{OUT} = 3.3 V, Load = 3 A

Figure 12. Short-circuit recovery

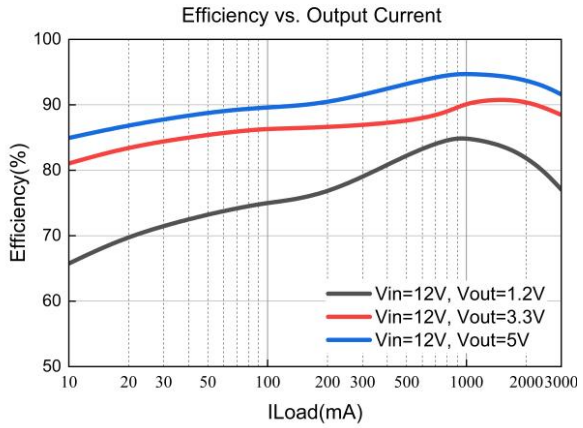


Figure 13. Effiency vs. Output current

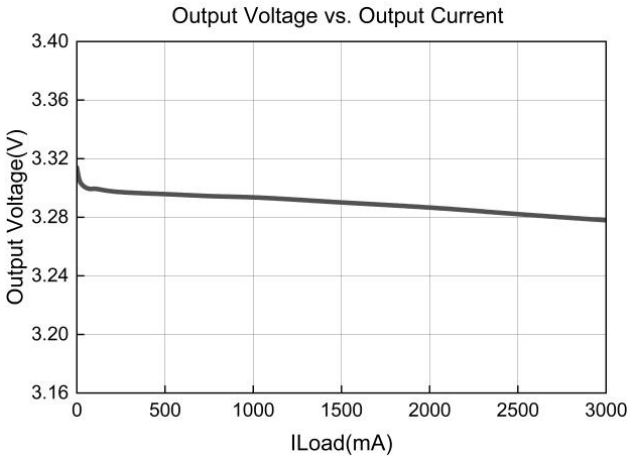


Figure 14. Output voltage vs. Output current

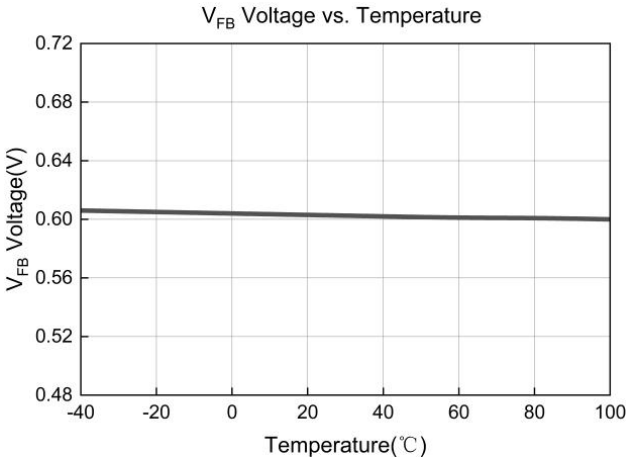


Figure 15. V_{FB} vs. Temperature

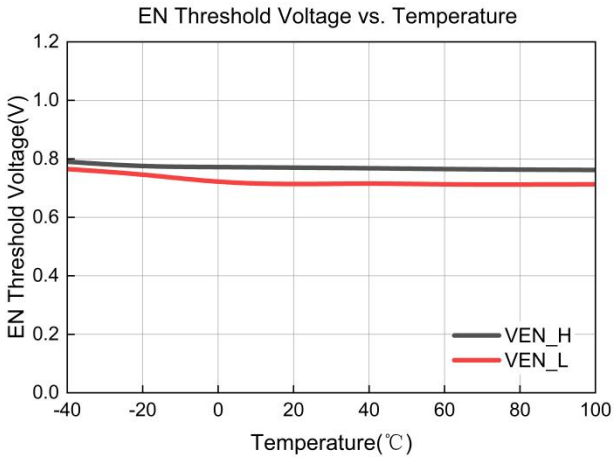


Figure 16. EN threshold vs. Temperature

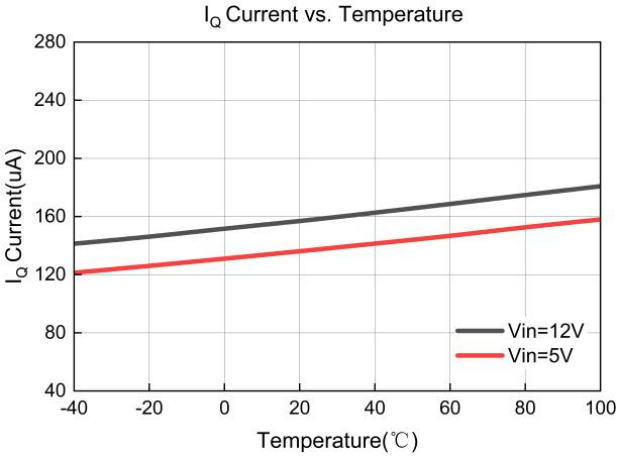
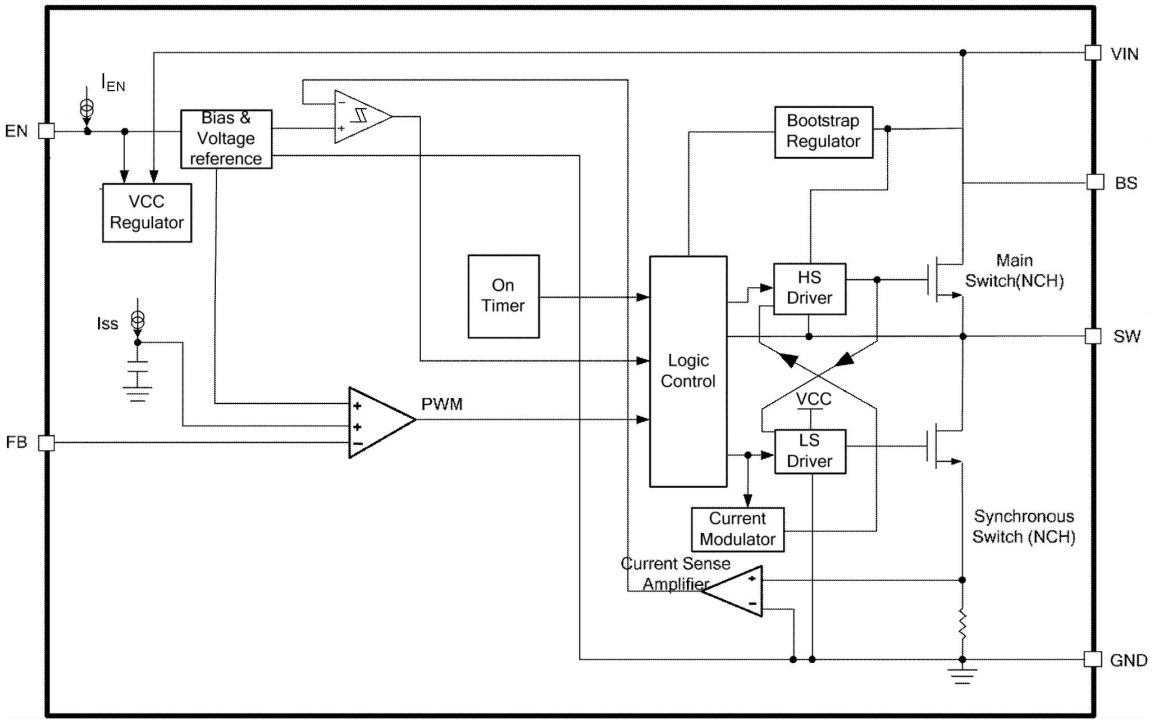


Figure 17. I_Q vs. Temperature

8. Block Diagram



9. Function Description

9.1. Enable and undervoltage lockout

The EN pin electrically controls the device. The device begins the operation when the EN pin voltage exceeds the threshold voltage. If the EN pin voltage is pulled below the threshold voltage, the regulator stops switching and enters the low-quiescent (I_Q) state.

With the internal pull-up current source in the EN pin, users can float the EN pin to enable the device. Users can interface with the EN pin by using open-drain or open-collector output logic.

The device implements internal undervoltage-lockout (UVLO) circuitry on the VIN pin. In case of a VIN pin voltage below the internal UVLO threshold, the device is disabled. The internal VIN UVLO threshold has a hysteresis of 400 mV.

9.2. Overcurrent protection (OCP) and short-circuit protection (SCP)

The DIO54312 has a valley current limit control. During LS-FET ON state, the inductor current is monitored. When the sensed inductor current hits the valley current limit, the LS limit comparator (shown in Block Diagram) turns over, the device enters over-current protection mode, and HS-FET will wait until the valley current limit disappears to turn on again. Meanwhile, the output voltage drops until V_{FB} is below the undervoltage (UV) threshold (typically 55% below the reference). As soon as UV is triggered, the DIO54312 enters hiccup mode and periodically restart the part. During overcurrent protection, the device tries to recover from overcurrent fault with hiccup mode, which means the chip will disable output power stage, discharge soft-start and then automatically try to operate the soft-start again. If the overcurrent condition still holds after the soft-start ends, the device repeats this operation cycle until overcurrent conditions disappear and then output rises back to regulation level. So the OCP is non-latch protection.

9.3 Thermal shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 160°C, it shuts down the whole chip. When the temperature falls below its lower threshold (typically 140°C), the chip is enabled again.

10. 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.

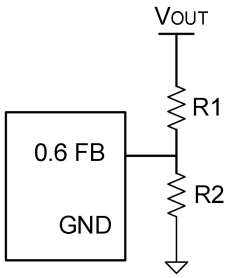
The DIO54312 is a synchronous buck regulator IC that integrates the COT control, and top and bottom switches on the same die to minimize the switching transition loss and conduction loss. With ultra-low $R_{DS(ON)}$ power switches and proprietary COT control, this regulator IC can achieve the highest efficiency and the highest switch frequency simultaneously to minimize the external inductor and capacitor size, thus achieving the minimum solution footprint.

Because of the high integration in the DIO54312 IC, the application circuit based on this regulator IC is rather simple. Only input capacitor C_{IN}, output capacitor C_{OUT}, output inductor L and feedback resistors (R1 and R2) need to be selected for the targeted applications specifications.

10.1. 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 10 kΩ and 1 MΩ is highly recommended for both resistors. If V_{OUT} is 3.3 V, R1 = 100 kΩ is chosen, then R2 is 22.1 kΩ.

$$R2 = \frac{0.6V}{V_{OUT} - 0.6V} R1 \quad (1)$$



10.2. Input capacitor C_{IN}

This ripple current through input capacitor is calculated from Equation (2).

$$I_{CIN\_RMS} = I_{OUT} \times \sqrt{D(1-D)} \quad (2)$$

This formula has a maximum at V_{IN} = 2 V_{OUT} condition, where I_{CIN_RMS} = I_{OUT}/2. This simple worst-case condition is commonly used for the DC/DC design.

To minimize the potential noise problem, place a typical X5R or better grade ceramic capacitor really close to the IN and GND pins. Carefully minimize the loop area formed by C_{IN}, and IN/GND pins. In this case, a 10 µF low ESR ceramic capacitor is recommended.

10.3. 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, it is recommended to use X5R or better grade ceramic capacitor greater than 22 μF capacitance.

10.4. Output inductor L

There are several considerations in choosing this inductor.

1) Choose the inductance to provide the desired ripple current. It is suggested to choose the ripple current to be about 40% of the maximum output current. The inductance is calculated from Equation (3).

$$L = \frac{V_{OUT}(1 - V_{OUT}/V_{IN,MAX})}{f_{SW} \times I_{OUT,MAX} \times 40\%} \quad (3)$$

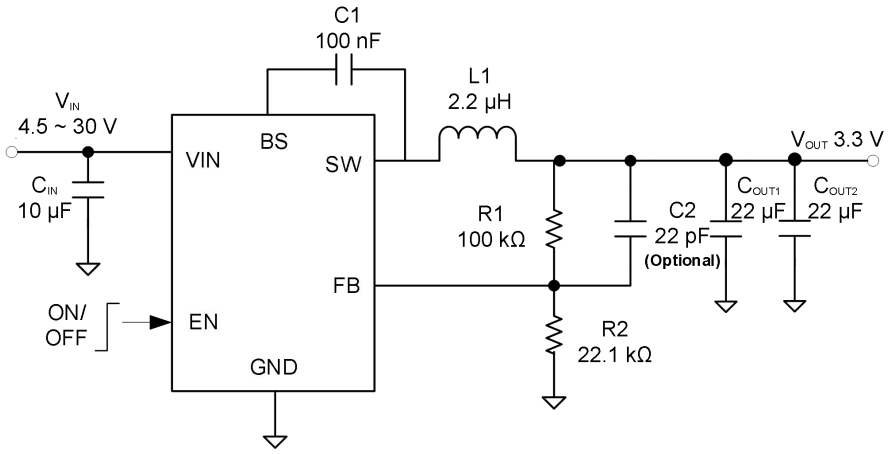
where f_{SW} is the switching frequency and $I_{OUT,MAX}$ is the maximum load current. The DIO54312 regulator IC is quite tolerant of different ripple current amplitudes. Consequently, the final choice of inductance can be slightly off the calculation value without significantly impacting the performance.

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

$$I_{SAT,MIN} > I_{OUT,MAX} + \frac{V_{OUT}(1 - V_{OUT}/V_{IN,MAX})}{2 \times f_{SW} \times L} \quad (4)$$

3) The DCR of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement. It is desirable to choose an inductor with DCR < 50 mΩ to achieve a good overall efficiency.

10.5. Application examples



11. Layout Guidelines

The layout design of the DIO54312 regulator is relatively simple. For the best efficiency and minimum noise problems, we should place the following components close to the IC: C_{IN}, L, R1, and R2.

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

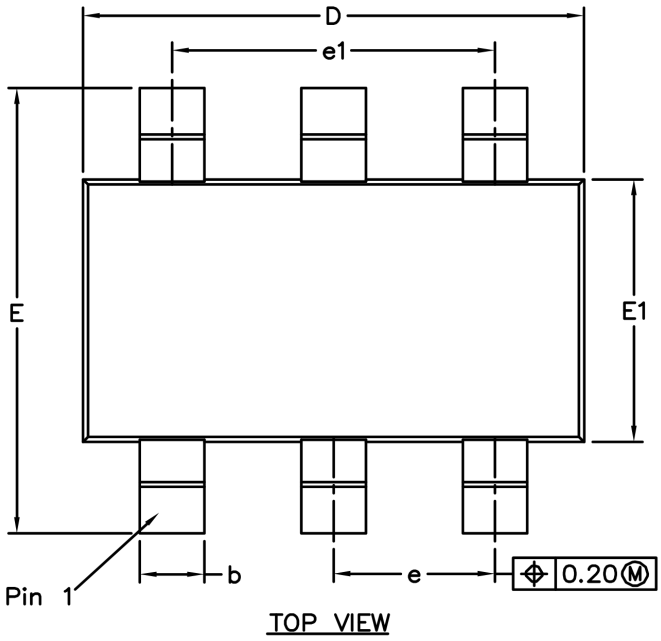
2) Place C_{IN} close to pins IN and GND. Minimize the loop area formed by C_{IN} and GND.

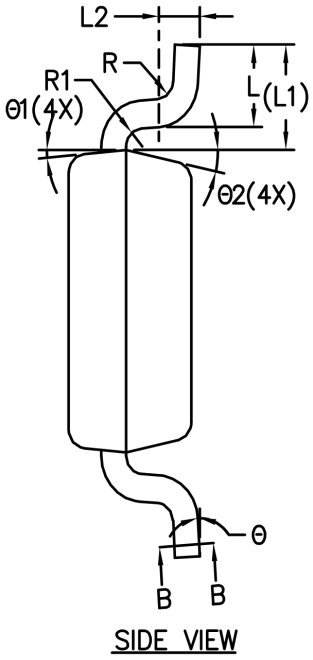
3) Minimize the PCB copper area associated with the SW pin to avoid the potential noise problem.

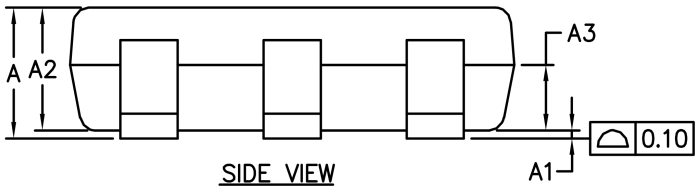
4) Avoid placing the components R1 and R2, and the trace connected to the FB pin adjacent to the SW net on the PCB layout to prevent the noise problem.

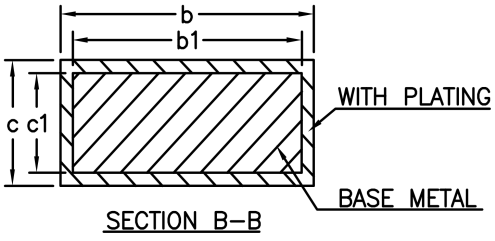
5) If the system chip interfacing with the EN pin has a high impedance state at shutdown mode and the IN pin is connected directly to a power source such as a Li-ion battery, add a pull-down 1 MΩ resistor between the EN and GND pins to prevent the noise from falsely turning on the regulator at shutdown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

12. Physical Dimensions: TSOT23-6

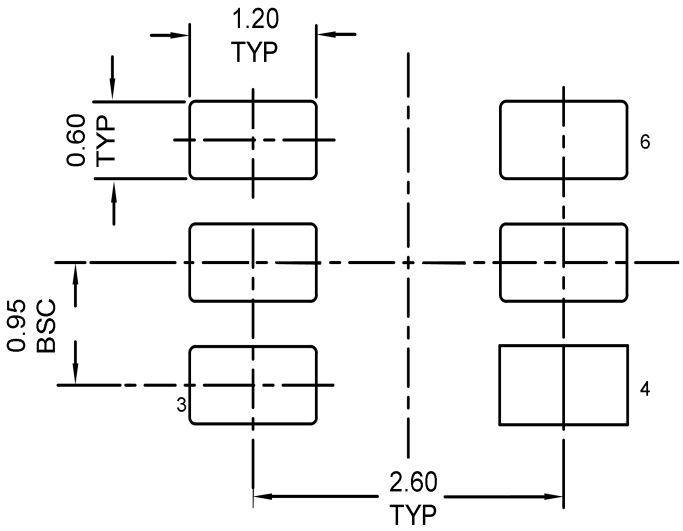








Common Dimensions (Units of measure = Millimeter)			
Symbol	**Min**	**Nom**	**Max**
A	-	-	0.90
A1	0	-	0.15
A2	0.65	0.75	0.85
A3	0.35	0.40	0.45
b	0.36	-	0.50
b1	0.36	0.38	0.45
c	0.14	-	0.20
c1	0.14	0.15	0.16
D	2.85	2.95	3.05
E	2.60	2.80	3.00
E1	1.60	1.65	1.70
e	0.90	0.95	1.00
e1	1.80	1.90	2.00
L	0.30	0.45	0.60
L1	0.575 REF		
L2	0.25 BSC		
R	-	-	0.25
R1	-	-	0.25
θ	0°	-	8°
θ1	3°	5°	7°
θ2	10°	12°	14°



RECOMMENDED LAND PATTERN

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