GigaDevice Semiconductor Inc.

GD30DC1301x
High Efficiency High Voltage 2A Step-down Regulator

Datasheet

Table of Contents

List of Figures

List of Tables

1 Features

- 4.5V to 18V Input Voltage Range
- Up to 2A Output Current
- 250μA Low I_Q
- Output to as low as 0.8V
- Low R_{DS_ON} for Internal Switches (High-side/Low-side) 110mΩ /60mΩ
- Switching Frequency 800kHz
- Pulse Frequency Mode at Light Load
- Cycle-by-Cycle Current Limit
- Internal Soft-start
- Hic-cup for Short Circuit Protection
- RoHS Compliant and Halogen Free
- Compact Package: SOT563/SOT23-6

2 Applications

- Security cameras
- Flat panels and monitors
- Set top boxes and media players
- General purpose

3 General description

The GD30DC1301x is a high efficiency synchronous step-down switching regulator. The device operates from an input voltage from 4.5V up to 18V. The main switch and synchronous switch are integrated in the device with very low R_{DS_ON} and capable of delivering up to 2A current.

The switching frequency is set at 800kHz to minimize output voltage ripple. Fault protections include under voltage lockout, cycle-by-cycle current limit and thermal shutdown.

The GD30DC1301x is available with space saving SOT563 and SOT23-6 package and requires minimal number of external components. Together with its low quiescent current, the GD30DC1301x is ideal for security cameras, flat panels and monitors, digital set top boxes etc.

4 Device overview

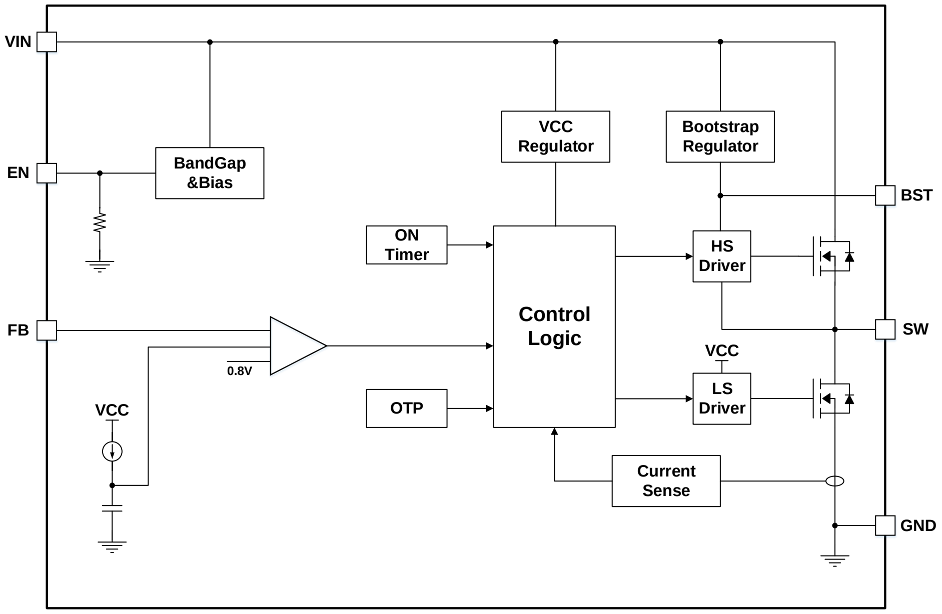
4.1 Device information

Table 4-1. Device information for GD30DC1301x

Part Number	Package	Function	Description
GD30DC1301x	SOT563/SOT23-6	Buck	High Efficiency High Voltage 2A Step-down Regulator

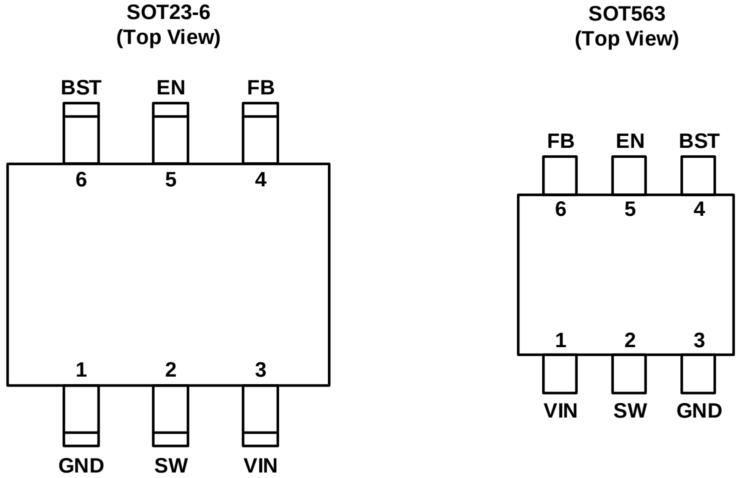
4.2 Block diagram

Figure 4-1 Block diagram for GD30DC1301x



4.3 Pinout and pin assignment

Figure 4-2 GD30DC1301x pinouts



4.4 Pin definitions

4.4.1 GD30DC1301x pin definitions

Table 4-2. GD30DC1301x pin definitions

Pin Name	Pins		Pin Type	Functions description
	SOT563	SOT23-6		
VIN	1	3	P	**Power supply voltage**. Operates from a 4.5V to 18V input rail. A decoupling capacitor is required to decouple the input.
SW	2	2	O	**Switch output**. Switch pin connected to the internal MOSFET switches and inductor terminal.
GND	3	1	G	**Power ground.**
BST	4	6	O	**Boostrap**. Connect a BST capacitor and a resistor between SW and BST to form a floating supply across the high-side switch driver.
EN	5	5	I	**Enable**. Pull high to enable the output.
FB	6	4	I	**Feedback**. Feedback pin for the internal control loop. Connect this pin to the external feedback divider.

Notes:

(1) Type: I = input, O = output, OD = open drain output, I/O = input or output, P = power, G = Ground.

5 Functional description

5.1 Operation mode

The GD30DC1301x is a synchronous switching DC/DC converter with constant on-time control. The adaptive on-time is so controlled by the input/output voltage that the IC operates at relative constant frequency, typically 800kHz. It is capable of delivering up to 2A for VIN between 4.5V and 18V. The output voltage can be as low as 0.8V.

5.1.1 Constant on-time control

Based on the VOUT/VIN ratio, a simple circuit sets the required on time for the high-side MOSFET. It makes the switching frequency relatively constant regardless of the variation of input voltage, output voltage, and load current. The relation between t_{ON} and V_{IN} and V_{OUT} is defined as following equation:

$$t_{ON} = \frac{V_{OUT}}{V_{IN}} * 1.25us$$

Excellent load transient response is achieved with a unique fast response constant on-time valley current mode. The switching frequency changes during load transition so that the output voltage comes back in regulation faster than a traditional fixed PWM control scheme. Internal loop compensation is integrated which simplifies the design process while minimizing the number of external components.

5.1.2 Enable

When the input voltage is greater than the under-voltage lockout (UVLO) threshold 4.0V(typical), the GD30DC1301x can be enabled by pulling EN higher than 1.2V(typical). Leaving EN floating or pulling it down to ground disables the GD30DC1301x. There is an internal 1MΩ resistor from EN to ground.

5.1.3 Soft start

After enabling the device, internal soft-start circuitry monotonically ramps up the output voltage which reaches nominal output voltage during a soft-start time of 2ms (typical). This avoids excessive inrush current and creates a smooth output voltage rise slope.

5.1.4 Light load operation

The GD30DC1301x automatically operates with pulse frequency modulation (PFM) at light load currents. As the output current decreases, the GD30DC1301x reduces the switching frequency to maintain high efficiency. When the inductor current reaches zero, the low-side MOSFET turns off. Then the output capacitors offer power for load and feedback resistors.

When FB voltage(V_{FB}) drops below the reference voltage, the high-side MOSFET is turned on. As the output current increases, the time period that the current modulator regulates becomes shorter, and the high-side MOSFET turns on more frequently. The switching frequency increases in turn. The output current reaches critical levels when the current modulator time is zero, and can be determined with the following equation:

$$I_{OUT} = \frac{(V_{IN} - V_{OUT}) * V_{OUT}}{2 * L * F_{SW} * V_{IN}}$$

5.1.5 Pre-Bias start-up

The GD30DC1301x is designed for monotonic start-up into pre-biased loads. If the output is pre-biased to a certain voltage during start-up, the BST voltage is refreshed and charged, and the voltage on the soft start is charged as well. If the BST voltage exceeds its rising threshold voltage, and the soft-start voltage exceeds the sensed output voltage at FB, the part works normally.

5.1.6 Bootstrap Charging

An external bootstrap capacitor can supplies the high-side MOSFET driver. This high-side driver has its own UVLO protection. The rising threshold is 2.2V(typical) and a hysteresis is 150mV(typical).VIN regulates the bootstrap capacitor voltage through a diode. The bootstrap regulator maintain a 4.5V(typical) voltage across BST-SW.

5.1.7 Under voltage lockout

To avoid mis-operation of the device at low input voltages, the GD30DC1301x shuts down at voltages lower than 4V(typical) with hysteresis 300mV(typical).

5.1.8 Over current protection

The GD30DC1301x has a 4A(typical) valley current limit control. While the low-side MOSFET is turned on, the conduction current is monitored by the internal circuitry. During over current protection(OCP) mode, the inductor valley current is exceeded the low-side source current limit, the high-side MOSFET does not turn on and the low-side MOSFET stays on for the next cycle. The high-side MOSFET turns on again when the inductor valley current is below the low-side sourcing current-limit at the start of a cycle.

5.1.9 Short circuit protection

The GD30DC1301x enters short-circuit protection mode when it reaches the current limit and attempts to recover with hiccup mode. In this process, the GD30DC1301x disables the output power stage, discharges the soft-start capacitor, and then attempts to soft-start again automatically. If the short-circuit condition remains after the soft-start ends, the GD30DC1301x repeats this cycle until the short-circuit disappears and the output rises back to regulation level, the hiccup time typically 6ms.

5.1.10 Thermal shutdown

The GD30DC1301x enters thermal shutdown once the junction temperature exceeds 160°C (typical). Once the device temperature falls below the threshold with hysteresis 20°C(typical), the device returns to normal operation automatically.

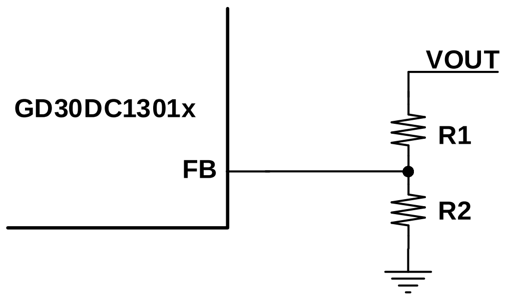
6 Application information

6.1 Setting up the output

An external resistor divider is used to set output voltage. By selecting R1 and R2, the output voltage is programmed to the desired value. When the output voltage is regulated, the typical voltage at the FB pin is V_{FB} = 0.8V.

$$V_{OUT} = V_{FB} * (1 + \frac{R_1}{R_2})$$

Figure 6-1 Feedback resistor divider



6.2 Input capacitor selection

The input current to the step-down converter is discontinuous and therefore requires a capacitor to supply AC current to the step-down converter while maintaining the DC input voltage. For best performance, use low ESR capacitors. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 22µF capacitor is sufficient.

The input capacitor requires an adequate ripple current rating since it absorbs the input switching current. For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current.

6.3 Output capacitor selection

The output capacitor (C3、C4) stabilizes the DC output voltage. Ceramic capacitors are recommended. Use low ESR capacitors to limit the output voltage ripple. Estimate the output voltage ripple with the following equation:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{SW} \times C_{OUT}}\right)$$

Where L_1 is the inductor value, and C_{OUT} is the output capacitor and R_{ESR} is the equivalent series resistance (ESR) value of C_{OUT}.

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance.

6.4 Inductor selection

The inductor selection trade-offs among size, cost, efficiency, and transient response requirements. Generally, three key inductor parameters are specified for operation with the device: inductance value (L), inductor saturation current (I_{SAT}), and DC resistance (DCR).

A good compromise between size and loss is to choose the peak-to-peak ripple current equals to 20% to 40% of the IC rated current. The switching frequency, input voltage, output voltage, and selected inductor ripple current determines the inductor value as follows:

$$L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{V_{IN} \times F_{SW} \times \Delta I_L}$$

Once an inductor value is chosen, the ripple current(ΔI_L) is calculated to determine the required peak inductor current.

$$\Delta I_L = \frac{V_{OUT}}{F_{SW} \times L}\left(1 - \frac{V_{OUT}}{V_{IN}}\right) \text{ and } I_{L(peak)} = I_{OUT(max)} + \frac{\Delta I_L}{2}$$

7 Electrical characteristics

7.1 Absolute maximum ratings

The maximum ratings are the limits to which the device can be subjected without permanently damaging the device. Note that the device is not guaranteed to operate properly at the maximum ratings. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.

Table 7-1 Absolute maximum ratings

Symbol	Parameter	Min	Max	Unit
V_{VIN}	Power supply pin	−0.3	20	V
V_{EN}	Enable pin	−0.3	6	V
V_{BST}	Boostrap voltage	−0.3	25	V
	V_{BST} -V_{SW}	−0.3	6.5	V
V_{SW}	Switching node voltage	−0.3	20	V
	10ns Transient	−3	22	V
V_{FB}	FB pin voltage	−0.3	6.5	V
Thermal characteristics				
T_J	Operating junction temperature	−40	150	°C
T_{stg}	Storage temperature	−65	150	°C
P_{max}	Maximum power dissipation @T_A=25°C		0.7	W

7.2 Recommended operation conditions

Table 7-2 Recommended operation conditions

Symbol	Parameter	Min	Typ	Max	Unit
V_{VIN}	Power supply pin	4.5		18	V
V_{IO}	I/O pin voltage (EN,FB)	2.5		5.5	V
Thermal characteristics					
T_A	Operating ambient temperature	−40		85	°C
T_J	Operating junction temperature	−40		125	°C

7.3 Electrical sensitivity

The device is strained in order to determine its performance in terms of electrical sensitivity. Electrostatic discharges (ESD) are applied directly to the pins of the sample.

Table 7-3 Electrostatic Discharge and Latch-up characteristics

Symbol	Parameter	Conditions	Value	Unit
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	T_A = 25 °C; JS-001-2017	±2000	V
$V_{ESD(CDM)}$	Electrostatic discharge voltage (charge device model)	T_A = 25 °C; JS-002-2018	±500	V

7.4 Power supplies voltages and currents

Table 7-4 Power supplies voltages and currents

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_Q	Quiescent current	V_{VIN} = 12V, No switching, T_J =25°C		250	300	μA
I_{SHDN}	Shutdown current	EN=0, VIN=12V		3	10	μA
T_{ON_DLY}	Turn-on delay time	V_{VIN} > V_{UVLO} to SW start		0.5		ms
T_{SS}	Soft-start period			2		ms
V_{UVLO}	VIN under voltage lockout	VIN voltage rising		4		V
V_{UVLO_HYS}	VIN under voltage lockout hysteresis	VIN rising to falling threshold		120		mV

7.5 EN characteristics

Table 7-5 EN characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{ENH}	EN logic high voltage			1.23		V
V_{HYS}	EN logic hysteresis			140		mV
R_{EN}	EN pull down resistor			1		MΩ

7.6 Switching regulator characteristics

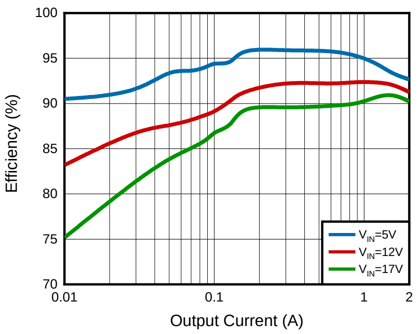
Table 7-6 Switching regulator characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{FB}	Feedback voltage	VIN=4.5 to 18V, T_J =25°C	0.792	0.8	0.808	V
	FB voltage over all temperature	T_J =−20 to 125°C	0.780		0.820	V
I_{FB}	FB leakage current				100	nA
R_{NMOS}	Main NMOS switch	V_{IN}=5V, T_J =25°C		110		mΩ

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R_{NMOS}	Synchronous NMOS switch	V_{IN}=5V, T_J =25°C		60		mΩ
f_{SW}	Switching frequency	VFB = 0.75V	600	800	1000	kHz
I_{SW}	Switch node leakage current	V_{EN} = 0V, V_{IN} = 12V, V_{SW} = 0V and 12V, T_J = 25°C			10	µA
I_{NMOS}	NMOS vally current limit	sourcing		4		A
I_{ZCD}	Zero cross detection	V_{OUT} = 3.3V, L_O = 2.2µH, I_{OUT} = 0A		20		mA
t_{ON_min}	Minimum on-time			50		ns
t_{OFF_min}	Minimum off-time			180		ns
T_{OT}	Thermal shutdown temperature	Die temperature, T_J		160		°C
T_{HYS}	Thermal hysteresis	Die temperature, T_J		20		°C

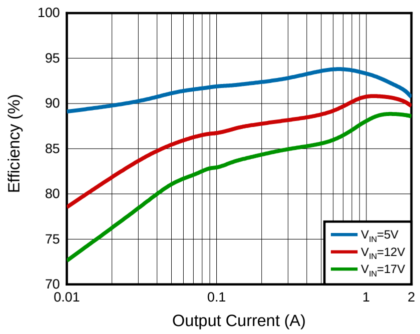
7.7 Typical characteristics

V_{IN} = 12V, V_{OUT} = 3.3V, L = 2.2μH, T_A=+25°C, unless otherwise noted.



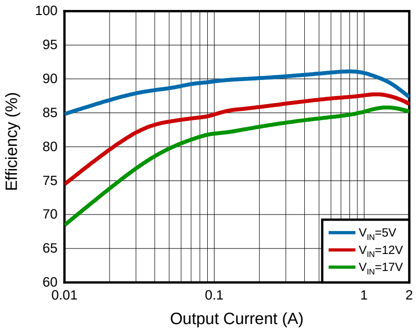
Vout = 3.3V

Efficiency vs. Output Current



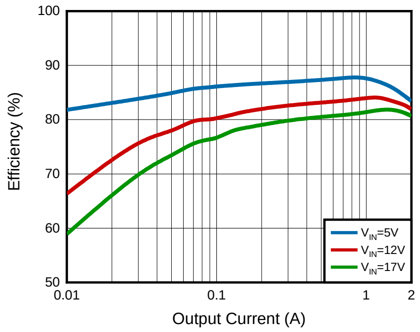
Vout = 2.5V

Efficiency vs. Output Current



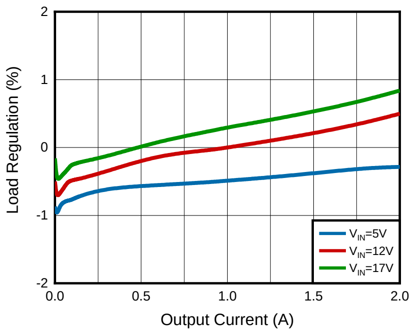
Vout = 1.8V

Efficiency vs. Output Current

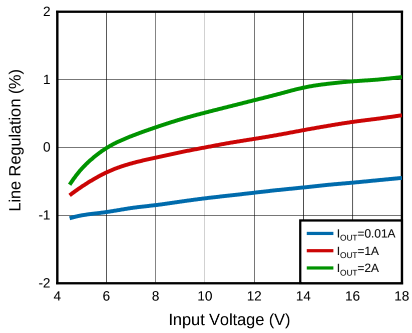


Vout = 1.2V

Efficiency vs. Output Current



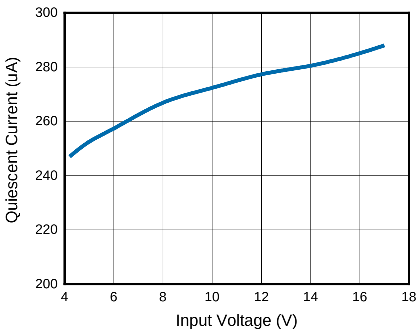
Load Regulation vs. Output Current



Line Regulation vs. Input Voltage

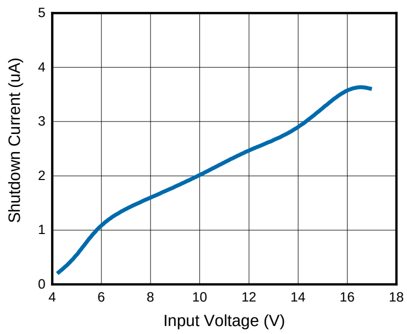
Typical Characteristic(continued)

VIN = 12V, VOUT = 3.3V, L = 2.2μH, T_A=+25°C, unless otherwise noted.



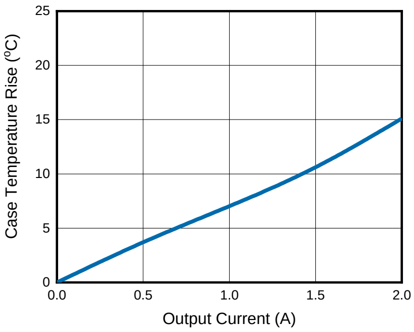
V_{EN}=2V, V_{FB}=0.85V

Quiescent Current vs. Input Voltage



V_{EN}=0V

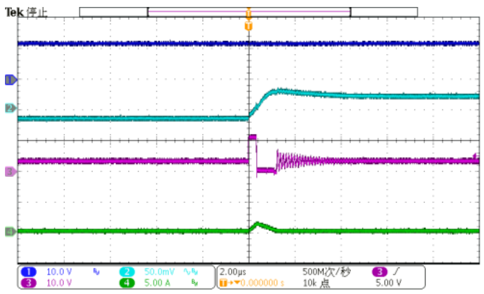
Shutdown Current vs. Input Voltage



Case Temperature Rise vs. Output Current

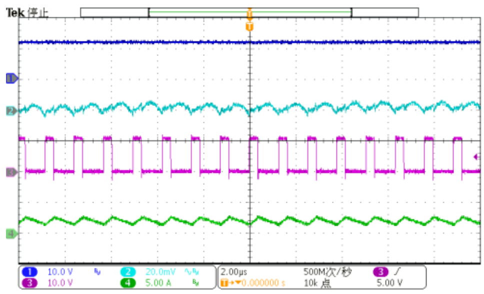
Typical Characteristic(continued)

VIN = 12V, VOUT = 3.3V, L = 2.2μH, T_A=+25°C, unless otherwise noted.



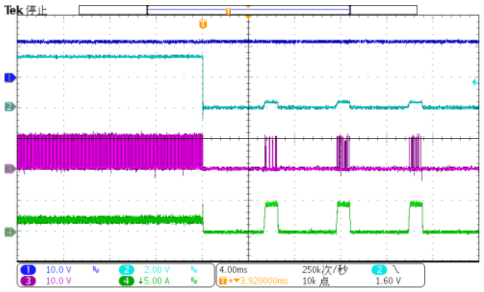
CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 0A

Output Ripple



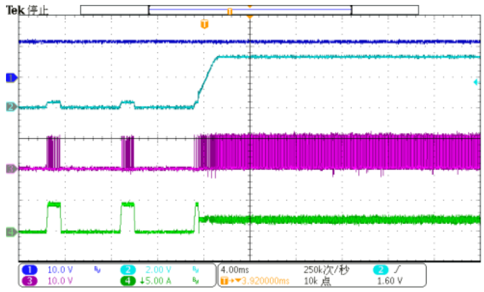
CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 2A

Output Ripple



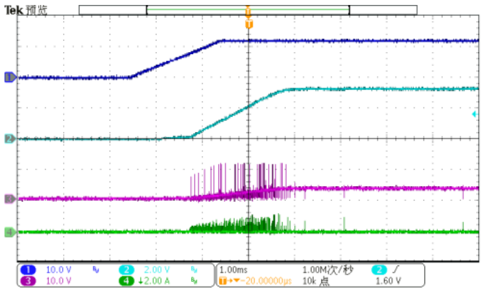
CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL

Short Circuit Entry



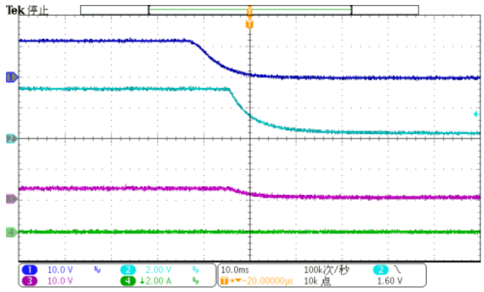
CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL

Short Circuit Recovery



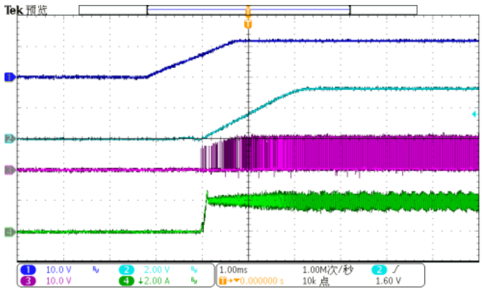
CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 0A

VIN Power Up



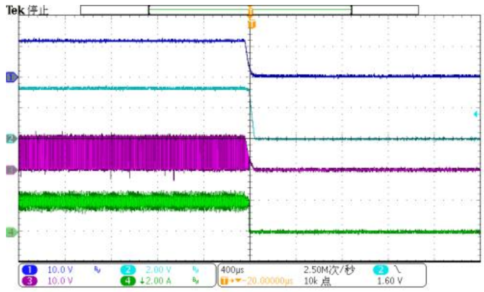
CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 0A

VIN Shut Down



CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 2A

VIN Power Up

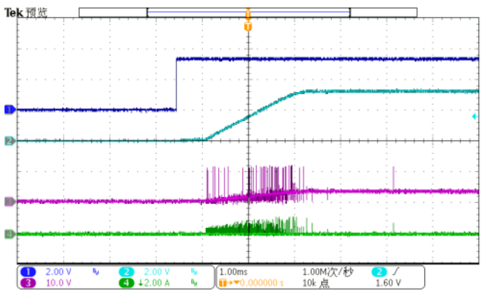


CH1 = V_{IN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 2A

VIN Shut Down

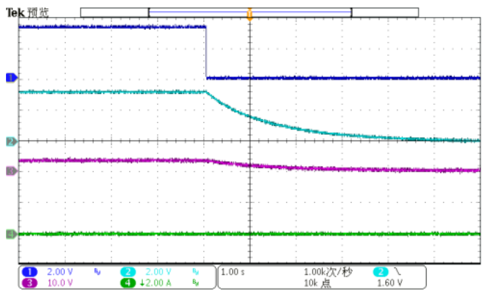
Typical Characteristic(continued)

VIN = 12V, VOUT = 3.3V, L = 2.2uH, T_A=+25°C, unless otherwise noted.



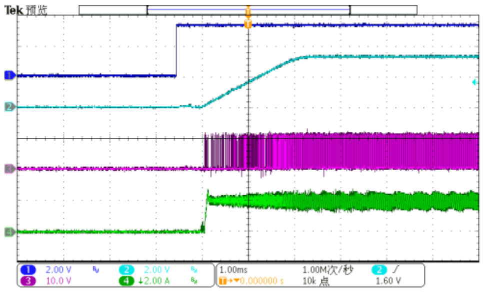
CH1 = V_{EN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 0A

EN Power Up



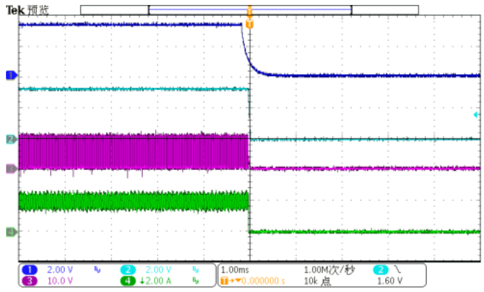
CH1 = V_{EN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 0A

EN Shut Down



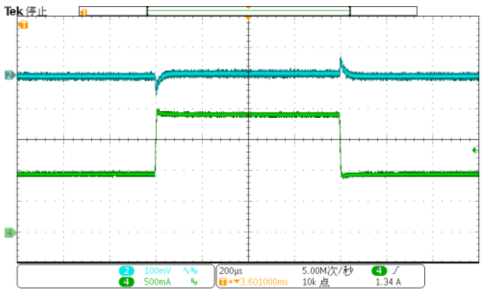
CH1 = V_{EN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 2A

EN Power Up



CH1 = V_{EN}, CH2 = V_{OUT}, CH3 = SW, CH4 = IL, I_O = 2A

EN Shut Down



CH2 = V_{OUT}, CH4 = I_O

I_O = 1A to 2A, 2.5A/us

Load Transient Response

8 Typical application circuit

Figure 8-1 Typical GD30DC1301x application circuit.

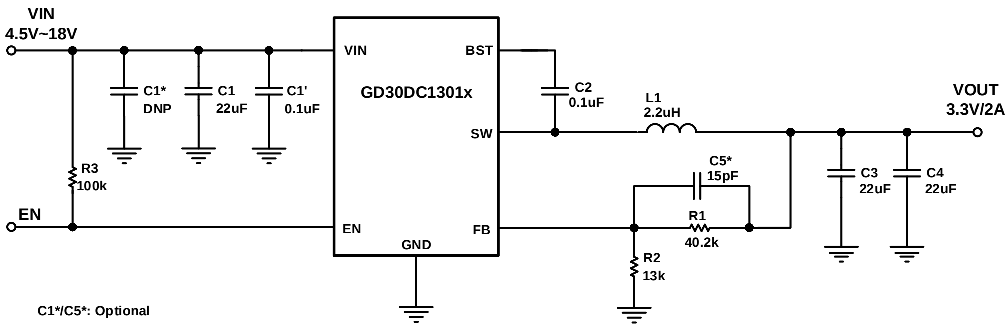


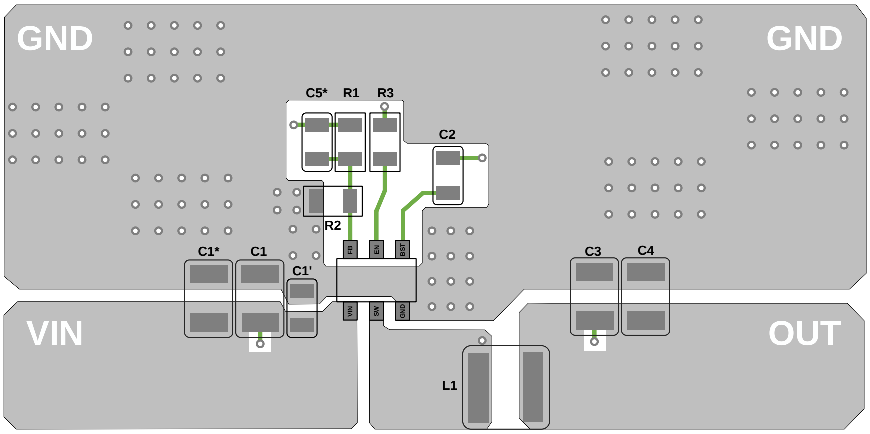
Table 8-1 Components parameter recommend

VOUT	C1	C3/C4	R1	R2	L1
5.0V	22uF	22uF	40.2KΩ(1%)	7.68KΩ(1%)	3.3uH
3.3V	22uF	22uF	40.2KΩ(1%)	13KΩ(1%)	2.2uH
2.5V	22uF	22uF	40.2KΩ(1%)	19.1KΩ(1%)	2.2uH
1.8V	22uF	22uF	40.2KΩ(1%)	32.4KΩ(1%)	1.5uH
1.5V	22uF	22uF	40.2KΩ(1%)	45.3KΩ(1%)	1.5uH
1.2V	22uF	22uF	40.2KΩ(1%)	82KΩ(1%)	1.0uH

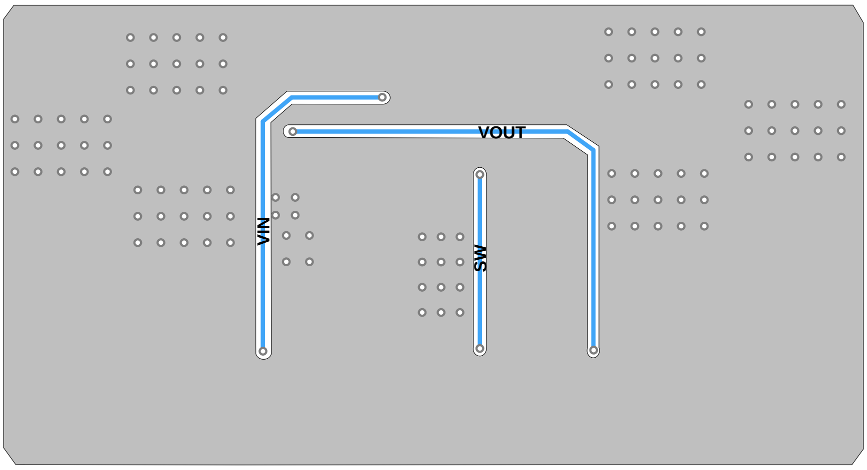
9 Layout guideline

Figure 9-1 Typical GD30DC1301x layout guideline

Efficient PCB layout is critical for stable operation. For the high-frequency switching converter, a poor layout design can result in poor line or load regulation and stability issues. For best results, follow the guidelines below.



TOP Layer



BOTTOM Layer

Notes:

1) Place the high-current paths (GND, IN, and SW) very close to the device with short, direct, and wide traces.
2) Place the input capacitor as close to IN and GND as possible.
3) Place the external feedback resistors next to FB.
4) Keep the switching node SW short and away from the feedback network.
5) Keep the VOUT sense line as short as possible or keep it away from the power inductor.

10 Package information

10.1 SOT563 package outline dimensions

Figure 10-1 SOT563 package outline

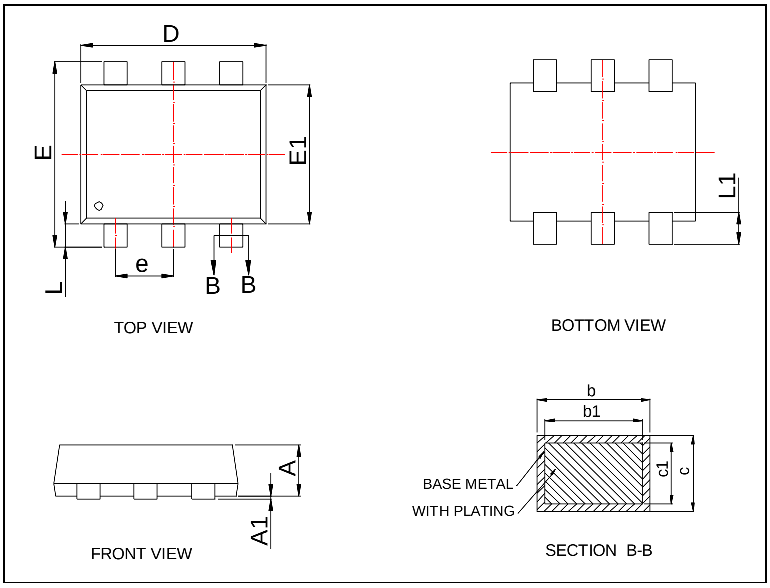
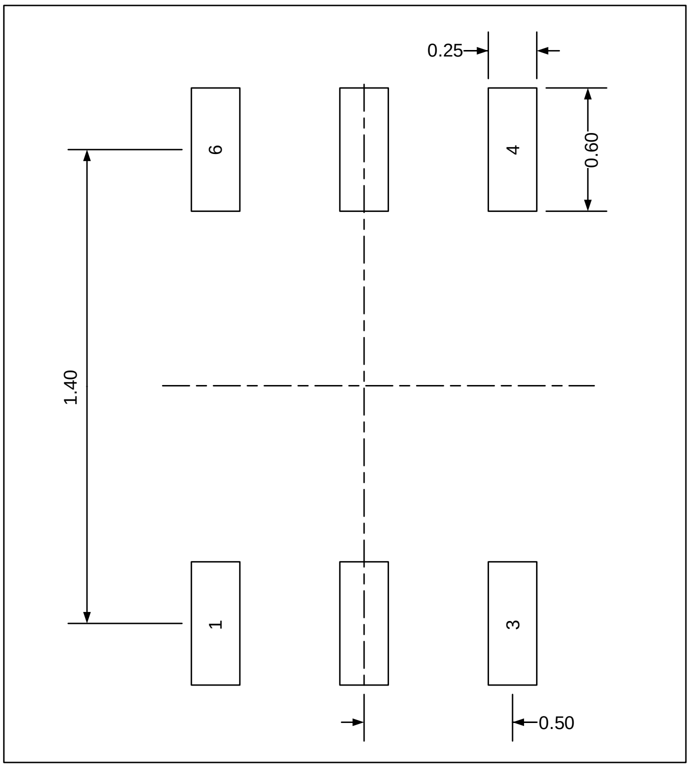


Table 10-1 SOT563 dimensions

Symbol	Min	Nom	Max
A	0.53	—	0.60
A1	0.00	—	0.05
b	0.19	—	0.27
b1	0.18	0.20	0.23
c	0.11	—	0.16
c1	0.10	0.11	0.12
D	1.50	1.60	1.70
E	1.503	1.60	1.70
E1	1.10	1.20	1.30
e	0.50BSC		
L	0.10	0.20	0.30
L1	0.20	0.30	0.40

(Original dimensions are in millimeters)

Figure 10-2 SOT563 recommend footprint



(Original dimensions are in millimeters)

10.2 SOT23-6 package outline dimensions

Figure 10-3 SOT23-6 package outline

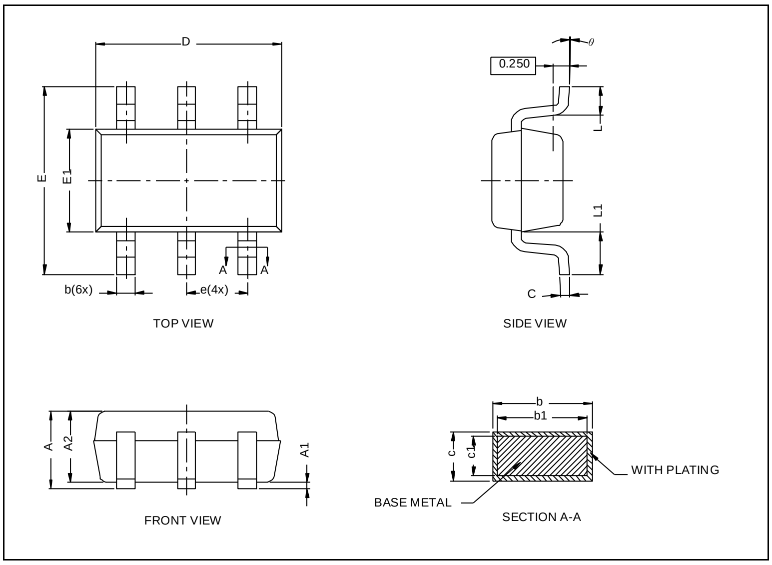
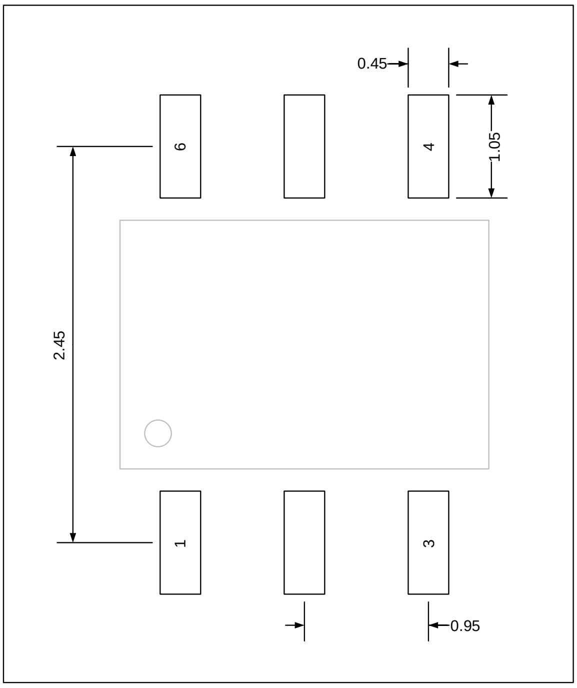


Table 10-2 SOT23-6 dimensions

Symbol	Min	Nom	Max
A	—	—	1.25
A1	0.04	—	0.10
A2	1.00	1.10	1.20
b	0.38	—	0.46
b1	0.37	0.40	0.43
c	0.13	—	0.17
c1	0.12	0.13	0.14
D	2.82	2.92	3.02
E	2.60	2.8	3.00
E1	1.50	1.6	1.70
e	0.95 BSC		
e1	1.90 BSC		
L	0.30	—	0.60
L1	060 REF		
θ	0°	—	8°

Figure 10-4 SOT23-6 recommend footprint



(Original dimensions are in millimeters)

10.3 Thermal characteristics

Thermal resistance is used to characterize the thermal performance of the package device, which is represented by the Greek letter "Θ". For semiconductor devices, thermal resistance represents the steady-state temperature rise of the chip junction due to the heat dissipated on the chip surface.

Θ_{JA}: Thermal resistance, junction-to-ambient.

Θ_{JB}: Thermal resistance, junction-to-board.

Θ_{JC}: Thermal resistance, junction-to-case.

Ψ_{JB}: Thermal characterization parameter, junction-to-board.

Ψ_{JT}: Thermal characterization parameter, junction-to-top center.

$\Theta_{JA} = (T_J - T_A)/P_D$

$\Theta_{JB} = (T_J - T_B)/P_D$

$\Theta_{JC} = (T_J - T_C)/P_D$

Where, T_J = Junction temperature.

T_A = Ambient temperature

T_B = Board temperature

T_C = Case temperature which is monitoring on package surface

P_D = Total power dissipation

Θ_{JA} represents the resistance of the heat flows from the heating junction to ambient air. It is an indicator of package heat dissipation capability. Lower Θ_{JA} can be considerate as better overall thermal performance. Θ_{JA} is generally used to estimate junction temperature.

Θ_{JB} is used to measure the heat flow resistance between the chip surface and the PCB board.

Θ_{JC} represents the thermal resistance between the chip surface and the package top case. Θ_{JC} is mainly used to estimate the heat dissipation of the system (using heat sink or other heat dissipation methods outside the device package).

Table 10-3. SOT563 Package thermal characteristics(1)

Symbol	Condition	Package	Value	Unit
Θ_{JA}	Natural convection, 2S2P PCB	SOT563	88.8	°C/W
Θ_{JB}	Cold plate, 2S2P PCB	SOT563	28.3	°C/W
Θ_{JC}	Cold plate, 2S2P PCB	SOT563	55.6	°C/W

Table 10-4. SOT23-6 Package thermal characteristics(1)

Symbol	Condition	Package	Value	Unit
Θ_{JA}	Natural convection, 2S2P PCB	SOT23-6	117.71	°C/W
Θ_{JB}	Cold plate, 2S2P PCB	SOT23-6	59.55	°C/W
Θ_{JC}	Cold plate, 2S2P PCB	SOT23-6	34.00	°C/W
Ψ_{JB}	Natural convection, 2S2P PCB	SOT23-6	59.46	°C/W
Ψ_{JT}	Natural convection, 2S2P PCB	SOT23-6	2.27	°C/W

(1) Thermal characteristics are based on simulation, and meet JEDEC specification.

11 Ordering information

Table 11-1 Part order code for GD30DC1301x devices

Ordering Code	Package	Package Type	Packing Type	MOQ	Temperature Junction Range
GD30DC1301SOTR-S	SOT563	Green	Tape&Reel	5000	−40°C to +125°C
GD30DC1301SSTR-S	SOT23-6	Green	Tape&Reel	3000	−40°C to +125°C

12 Revision history

Table 12-1 Revision history

Revision No.	Description	Date
1.0	Initial Release	2023
1.1	1. Chapter 8 Typical application circuit, add R4 and C2 recommended value range. 2. Modify section 10.2 *SOT23-6 package outline dimensions* to include A with a maximum value of 1.25mm, E typical value equal to 2.8mm, and E1 typical value equal to 1.6mm.	2023
1.2	1. Remove RT and Rbst resistors, modify Cbst 1uF to 0.1uF	2024

Important Notice

This document is the property of GigaDevice Semiconductor Inc. and its subsidiaries (the "Company"). This document, including any product of the Company described in this document (the “Product”), is owned by the Company according to the laws of the People’s Republic of China and other applicable laws. The Company reserves all rights under such laws and no Intellectual Property Rights are transferred (either wholly or partially) or licensed by the Company (either expressly or impliedly) herein. The names and brands of third party referred thereto (if any) are the property of their respective owner and referred to for identification purposes only.

The Company makes no representations or warranties of any kind, express or implied, with regard to the merchantability and the fitness for a particular purpose of the Product, nor does the Company assume any liability arising out of the application or use of any Product described in this document. Any information provided in this document is provided only for reference purposes. It is the sole responsibility of the user of this document to determine whether the Product is suitable and fit for its applications and products planned, and properly design, program, and test the functionality and safety of its applications and products planned using the Product. Unless otherwise expressly specified in the datasheet of the Product , the Product is designed, developed, and/or manufactured for ordinary business, industrial, personal, and/or household applications only, and the Product is not designed or intended for use in (i) safety critical applications such as weapons systems, nuclear facilities, atomic energy controller, combustion controller, aeronautic or aerospace applications, traffic signal instruments, pollution control or hazardous substance management; (ii) life-support systems, other medical equipment or systems (including life support equipment and surgical implants); (iii) automotive applications or environments, including but not limited to applications for active and passive safety of automobiles (regardless of front market or aftermarket), for example, EPS, braking, ADAS (camera/fusion), EMS, TCU, BMS, BSG, TPMS, Airbag, Suspension, DMS, ICMS, Domain, ESC, DCDC, e-clutch, advanced-lighting, etc.. Automobile herein means a vehicle propelled by a self-contained motor, engine or the like, such as, without limitation, cars, trucks, motorcycles, electric cars, and other transportation devices; and/or (iv) other uses where the failure of the device or the Product can reasonably be expected to result in personal injury, death, or severe property or environmental damage (collectively "Unintended Uses"). Customers shall take any and all actions to ensure the Product meets the applicable laws and regulations. The Company is not liable for, in whole or in part, and customers shall hereby release the Company as well as its suppliers and/or distributors from, any claim, damage, or other liability arising from or related to all Unintended Uses of the Product. Customers shall indemnify and hold the Company, and its officers, employees, subsidiaries, affiliates as well as its suppliers and/or distributors harmless from and against all claims, costs, damages, and other liabilities, including claims for personal injury or death, arising from or related to any Unintended Uses of the Product.

Information in this document is provided solely in connection with the Product. The Company reserves the right to make changes, corrections, modifications or improvements to this document and the Product described herein at any time without notice. The Company shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. Information in this document supersedes and replaces information previously supplied in any prior versions of this document.