LP6454

18V/4A Synchronous BUCK Switching Converter

Features

- Wide input voltage range: 4.2V – 18V
- Output voltage range: V_{ref} – 7V
- High efficiency operation
  - Integrated an 33-mΩ LS-MOSFET and an 55-mΩ HS-MOSFET
  - 90% efficiency at 4A load from 12V to 5V conversion
- Constant-on time (COT) control with fast transient response.
- ±1% Vref accuracy
- Typical 1.2-MHz switching frequency
- Startup from Pre-biased output voltage
- 1.0ms typical soft-start time
- Integrated UVLO, OVP, OCP, SCP, and OTP protections
- 1.6mm X 2.9mm SOT23-6 package
- RoHS Compliant and 100% Lead (Pb) Free

Applications

- Industrial PC
- Network/digital video recorder (NVR/DVR)
- TV and TV box
- 12V Industrial bus applications

General Description

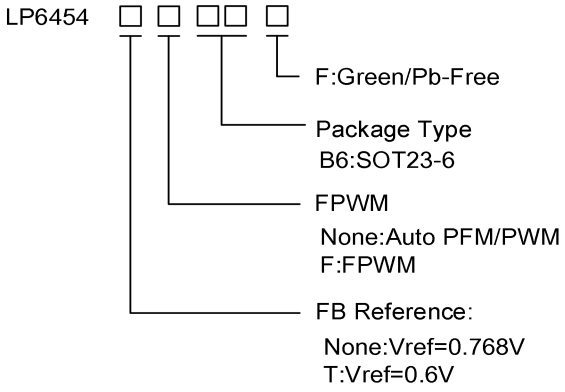
The LP6454 series is a high efficiency synchronous buck converter supporting up to 4A output current and low heat. The LP6454 series employs an adaptive constant-on-time (COT) control scheme to achieve fast load transient response and without external compensation. The external components are minimized, requiring only one inductor, two resistors, and two capacitors.

The LP6454 series supports both aluminum polymer capacitors and ceramic capacitors without extra compensation components.

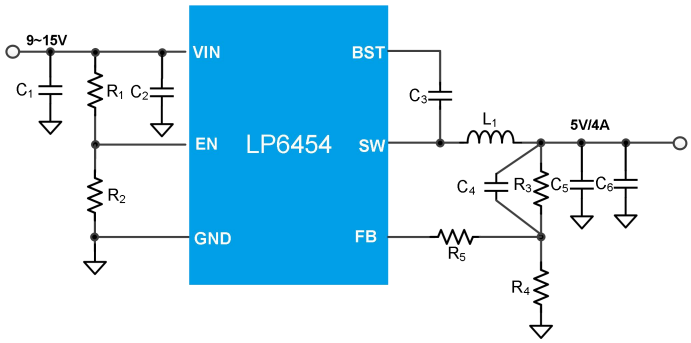
The LP6454 series integrates PFM (Pulse Frequency Modulation) operation, which helps maintain the system efficiency at light load. The LP6454 series also integrates multiple protection functions, i.e., over-current protection (OCP), over-temperature protection (OTP), under-voltage lockout (UVLO), and short circuit protection (SCP).

The LP6454 series is available in a small 6-pin 1.6mmX2.9mm SOT23-6 package.

Order Information



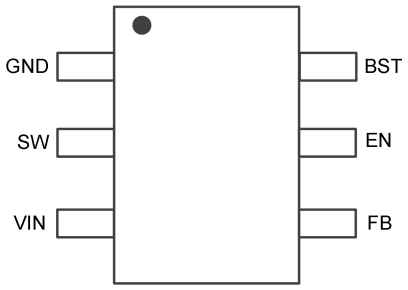
Typical Application Circuit



Device Information

Part Number	Top Marking	Operation Mode	V_{ref}	Package	Shipping
LP6454B6F	LPS AXYWX	PFM	0.768V	SOT23-6	3K/REEL
LP6454FB6F	LPS K8YWX	FPWM	0.768V	SOT23-6	3K/REEL
LP6454TB6F	LPS AyYWX	PFM	0.6V	SOT23-6	3K/REEL
Marking indication: Y: Year code. W: Week code. X: Batch numbers.					

Pin Diagram



SOT23-6
(Top View)

LP6454 Pinout

Pin Description

Pin # SOT23-6	Name	Description
1	GND	Power ground of the IC.
2	SW	The switching node of the converter.
3	VIN	IC power supply input.
4	FB	Feedback pin. Use a resistor divider to set the desired output voltage
5	EN	Enable input. This pin can be used to control the system power sequence as well
6	BST	Bootstrap pin. Power supply for high-side MOSFET gate driver. A 0.1-μF capacitor must be connected between this pin and SW pin.

Absolute Maximum Ratings (Note)

VIN, SW, and EN to GND ---------- -0.3V to 18V
FB to GND ---------- -0.3V to 6.5V
BST to SW ---------- -0.3V to 6.5V
SW to GND (20ns transient) ---------- -3.5V to 20V
Junction Temperature Range (TJ)---------- -40°C to 150°C
Maximum Soldering Temperature (at leads, 10 sec)---------- 260℃

Note: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD Ratings

HBM (Human Body Model) ---------- 2kV
CDM (Charged-device Model) ---------- 500V

Thermal Information

θ_{JA} (Junction-to-Ambient Thermal Resistance, SOT23-6) ---------- 100℃/W

Recommended Operating Conditions

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage	4.2		18	V
V_{OUT}	Output voltage	0.768		7	V
L	Inductor	1		4.7	μH
T_A	Ambient temperature range	-40		85	°C
C_{IN}	Input decoupling capacitor	4.7		100	μF
C_{OUT}	Output capacitor	10		100	μF

Electrical Characteristics

(The specifications are measured under conditions V_{IN} = 12V, T_A = 25°C, unless otherwise specified.)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT SECTION						
V_{ULVO_R}	Input under voltage lockout threshold	V_{IN} rising threshold	3.8	4.0	4.2	V
V_{ULVO_H}	UVLO hysteresis	V_{IN} falling threshold		0.3		V
I_{q_VIN}	Input quiescent current	No switching, EN=3V, FB=1.0V		440	550	μA
I_{sd_VIN}	Input shutdown current	EN=0, V_{IN}=12V		1.5	5	μA
BUCK CONVERTER						
I_{LIM}	Low-side valley current limit	T_A=25℃	4.0	5.2		A

V_{ref}	Reference voltage	T_A=25℃, LP6454/FB6	0.76	0.768	0.776	V
		T_J=-40℃ ~125℃, LP6454/FB6	0.753		0.783	V
		T_A=25℃, LP6454TB6	0.594	0.6	0.606	V
		T_J=-40℃ ~125℃, LP6454TB6	0.588		0.612	V
R_{dson_HS}	High-side FET on resistance	V_{IN}=12V		55		mΩ
R_{dson_LS}	Low-side FET on resistance	V_{IN}=12V		33		mΩ
F_{sw}	Switching frequency			1200		kHz
t_{on-min}	Minimum on-time[1]			50		ns
$t_{off-min}$	Minimum off-time[1]	V_{FB}=V_{ref} - 0.2V		100		ns
t_d	EN delay time[1]	From EN high to first switching		500		μs
t_{ss}	Soft-start time[1]	From first switching to 95%Vref		750		μs
T_{jsd}	Thermal shutdown threshold	Rising threshold		160		℃
	Thermal shutdown threshold	Falling threshold		135		℃
I_{leak_FB}	FB pin leakage current			0.01		μA
EN Logic						
V_H	EN pin logic high threshold	EN Rising threshold	1.14	1.2	1.26	V
V_{hys}	EN pin threshold hysteresis			0.2		V
	EN pin internal pull-down resistance			900		kΩ

[1]: Not production tested. Guaranteed by design

Typical Characteristics

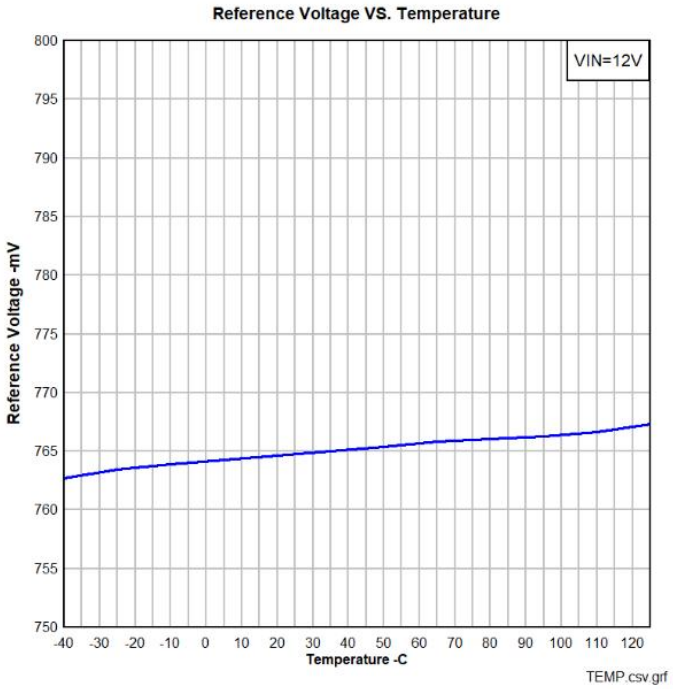


Figure 1. Reference Voltage VS. Junction Temperature, LP6454B6F

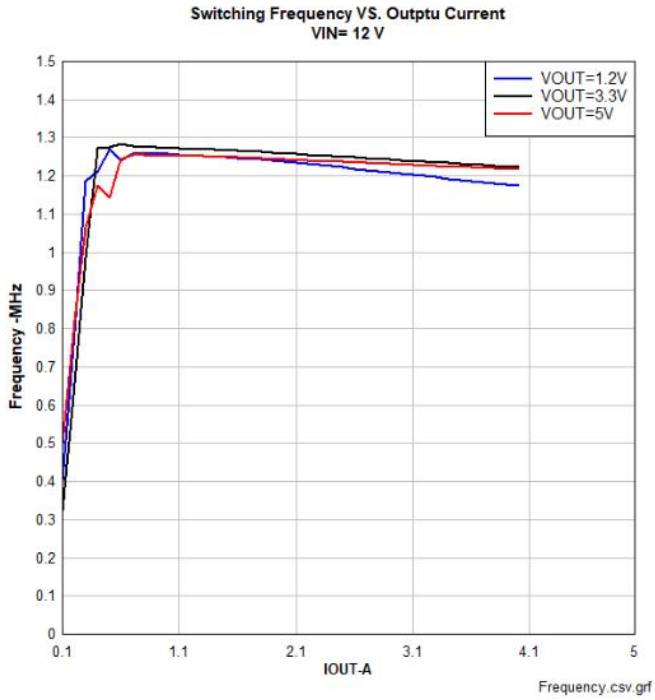


Figure 2. Switching Frequency VS. Output Current, LP6454B6F

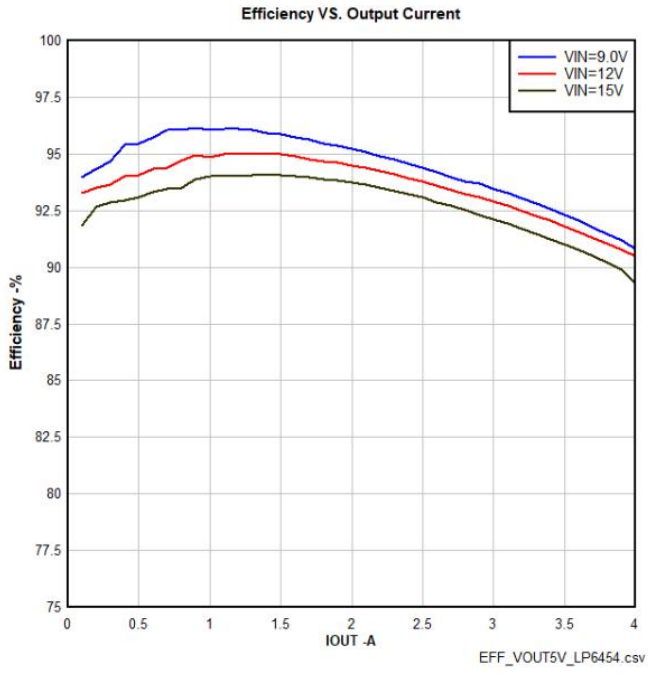


Figure 3. Efficiency, VOUT=5.0V, L=2.2 µ H, LP6454B6F

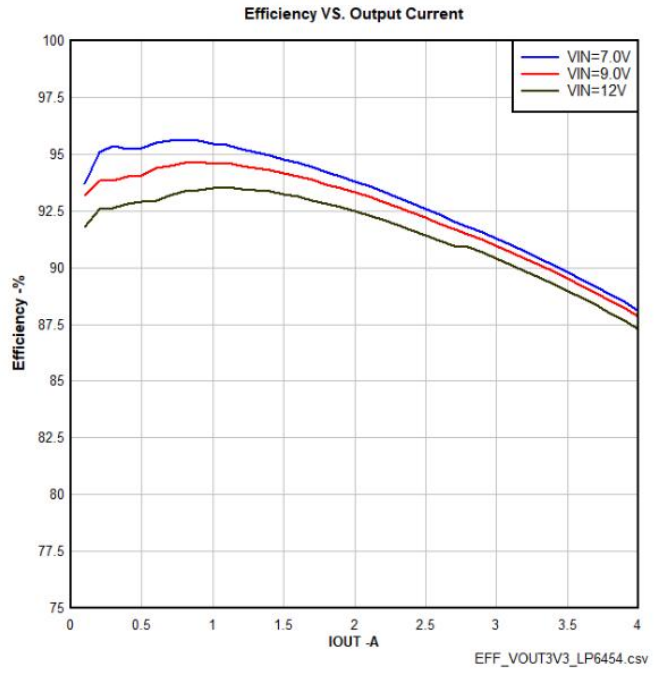


Figure 4. Efficiency, VOUT=3.3V, L=2.2 µ H, LP6454B6F

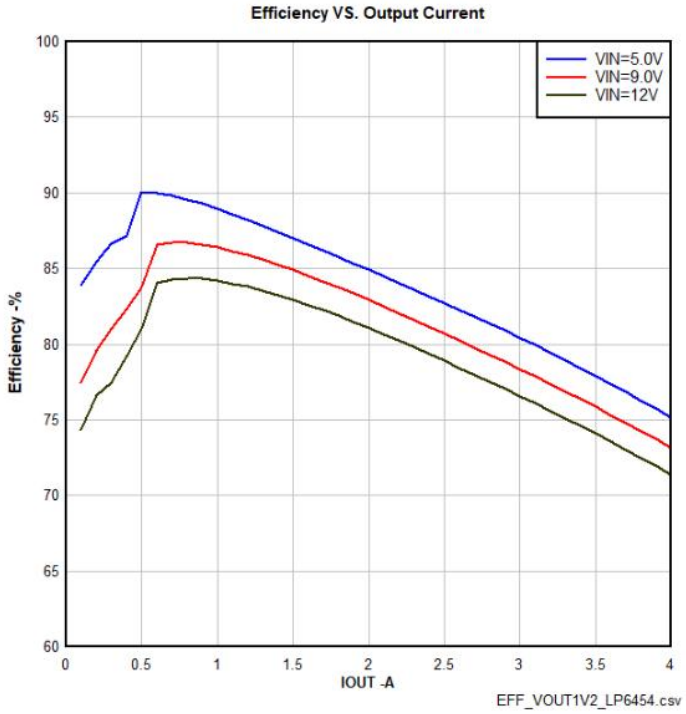


Figure 5. Efficiency, VOUT=1.2V, L=1μH, LP6454B6F

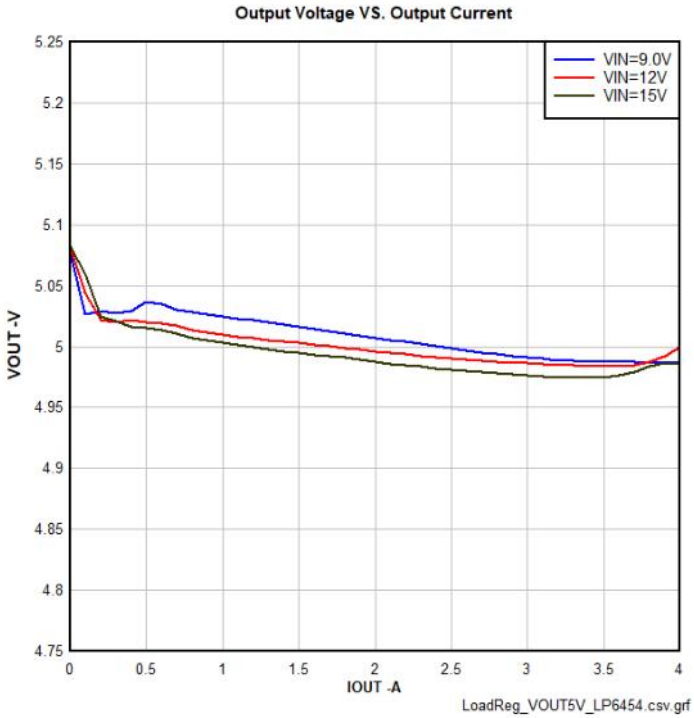


Figure 6. Regulation, VOUT=5.0V, L=2.2μH, LP6454B6F

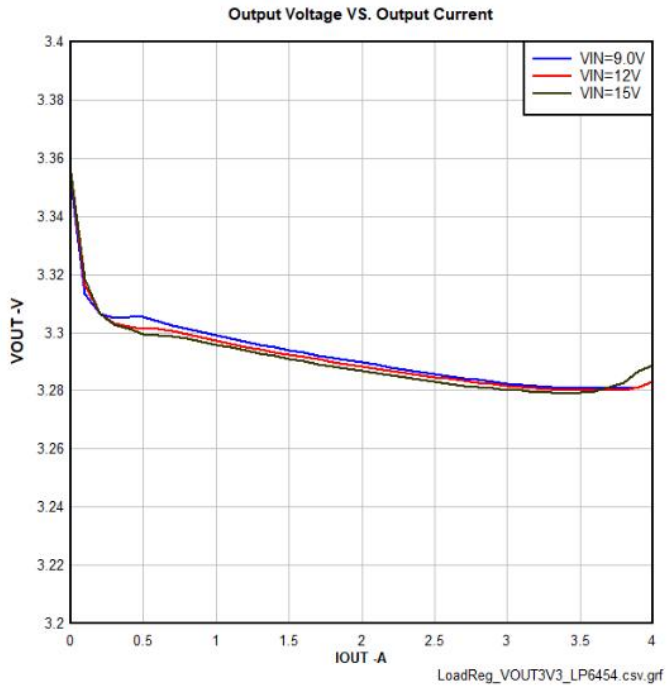


Figure 7. Regulation, VOUT=3.3V, L=2.2μH, LP6454B6F

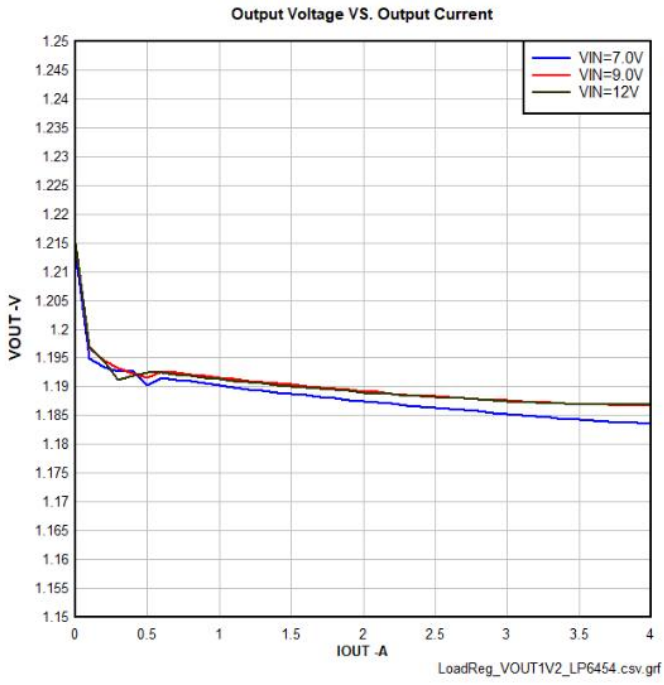
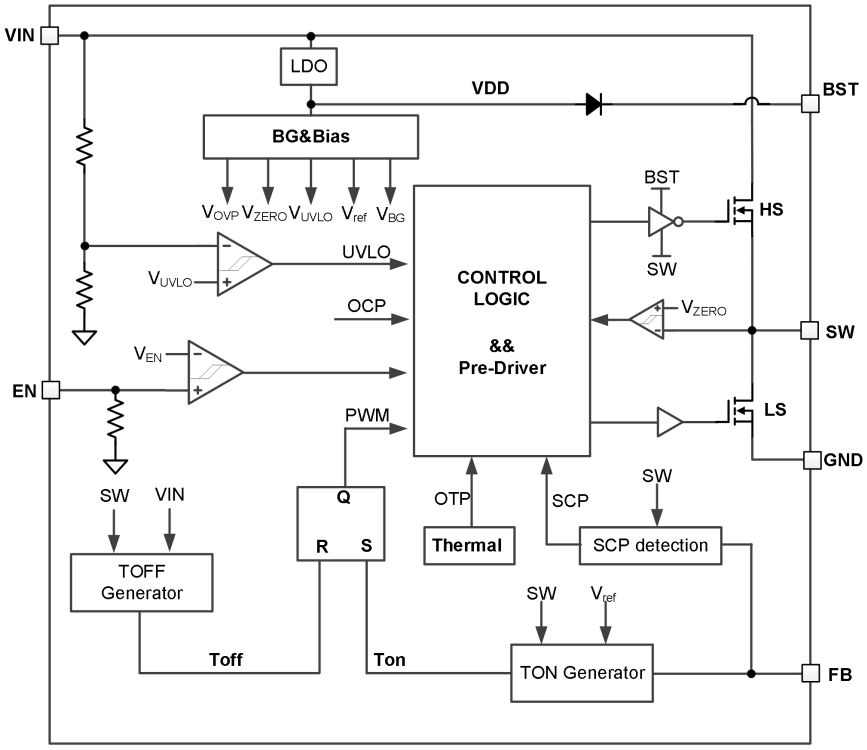


Figure 8. Regulation, VOUT=1.2V, L=1μH, LP6454B6F

Functional Block Diagram



Detailed Description

Overview

The LP6454 series is a 4A integrated MOSFET synchronous buck converter, supporting 4.2-18V input voltage range. This device adopts adaptive COT control scheme which enables fast transient respond and minimizes the output capacitance. The LP6454 supports both aluminum polymer capacitors and low-ESR ceramic capacitors without external compensation circuit. The LP6454 automatically transfers between PFM at light load and PWM at heavy load according to the output current.

Under Voltage Lockout (UVLO)

When the input voltage VIN is lower than the UVLO threshold, all functions are shut down. When the input voltage is higher than the UVLO rising threshold, the LP6454 can be enabled by the EN pin. This function is non-latching.

EN Control and Soft-start

The EN pin can be used to control the system power-up sequence. A precise voltage reference is used as the threshold. When the VIN is above the UVLO threshold and EN voltage rises above the EN pin logic high threshold (1.2V typically), the LP6454 enables all the internal circuits and begins the soft-start. The EN pin has an internal 900kΩ pull-down resistor to ground.

The LP6454 integrates soft-start function with a typical startup time of 0.75ms (t_{ss}) . After passing the UVLO threshold and enabled by the EN pin with the 500us delay(t_d), the internal reference voltage ramps from zero to the Vref in 0.75-ms and the output voltage ramps up accordingly.

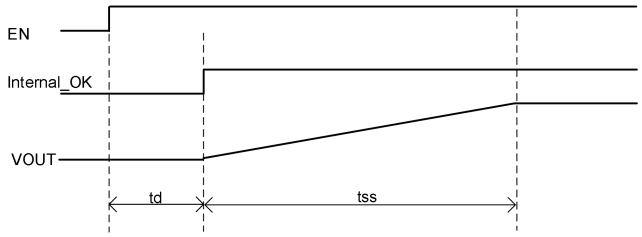


Figure 9. Soft Start Sequence

If the output capacitor is pre-biased at startup, the device initiates switching and starts ramping up only after the internal reference voltage becomes higher than the feedback voltage.

Constant-ON Time (COT) Control Scheme

The LP6454 integrates the COT control scheme for pseudo-fixed- frequency operation when operating in continuous conduction mode (CCM). Refer to the Functional Block Diagram for better understanding of the operation. The internal on-time generator block monitors the FB-pin voltage and turns on the high-side MOSFET to start a switching cycle, when the FB-pin voltage drops to an internal reference voltage Vref. Then the internal circuits start to calculate the on-time of the high-side MOSFET, which is proportional to the input voltage and inversely proportional to the output voltage. Once the on-time is finished, the TOFF generator turns off the high-side MOSFET and turns on the low-side MOSFET.

PFM Operation

The LP6454 is designed to maintain high efficiency at light load by adopting pulse-frequency modulation (PFM). In the PFM, the switching cycle is still initiated by the TON generator monitoring the FB-pin voltage. The high-side MOSFET is turned on for TON time and then turned off, followed by turning on the low-side MOSFET. The inductor current falls when the low-side MOSFET is on. When the inductor current reaches zero, detected by the zero-current detection (ZCD) comparator, the low-side MOSFET is turned off, together with the high-side MOSFET. Both MOSFETs remains off until a new switching cycle begins, determined by TON generator. As the load current decreases, the duration for both MOSFETs to remain off increases, leading to a lower switching frequency and higher power efficiency.

FPWM Operation (LP6454F)

The LP6454AF is designed to work at FPWM to maintain the good regulation and transient performance. When the

output decreases, the inductor is allowed to flow from the output to the ground plane. In this way, the switching frequency is kept the same even without load.
The FPWM operation mode reduced the output ripple under light load at the cost of lower light load efficiency.

Bootstrap Capacitor

The LP6454 integrates two N-MOSFET to achieve high efficiency. The high-side MOSFET is powered by the bootstrap capacitor $C_{BST,}$ which is between the BST pin and SW pin.

Over Current Protection and Short Circuit Protection (SCP)

The LP6454 protects an over current situation by limiting the inductor valley current. The current of low-side MOSFET is monitored all the time to sense the inductor valley current when the LP6454 is enabled. The high-side MOSFET cannot be turned on if the valley current is higher than the low-side valley current limit. The inductor current is limited to the valley current limit pluses a half of the inductor ripple current in this way.

The SCP is realized by monitoring the FB-pin voltage when the inductor current is limited. Once the output load draws more current than the current limit, the output voltage drops. When the FB voltage drops to 50% of the Vref for 1.5-ms, the LP6454 shuts down. The LP6454 will restart automatically after at least 500us waiting time. If the SCP condition still holds after soft-start, the LP6454 shutdown again, repeating the operation described above.

When the over current condition is removed, the output voltage returns to normal operation.

Thermal Protection

The LP6454 has a thermal protection function. The device will shut down when the internal temperature is higher than 160°C and will restart after the temperature drops below 135°C.

Application Information

Design Requirements

The table 1 showes the design parameters for a typical 5V output voltage in the IPC application.

Table 1: Design Parameters

Parameter	Target
Input voltage range	9~15V
Output voltage	5V
Transient ripple	±200mV
Operating frequency	1200kHz

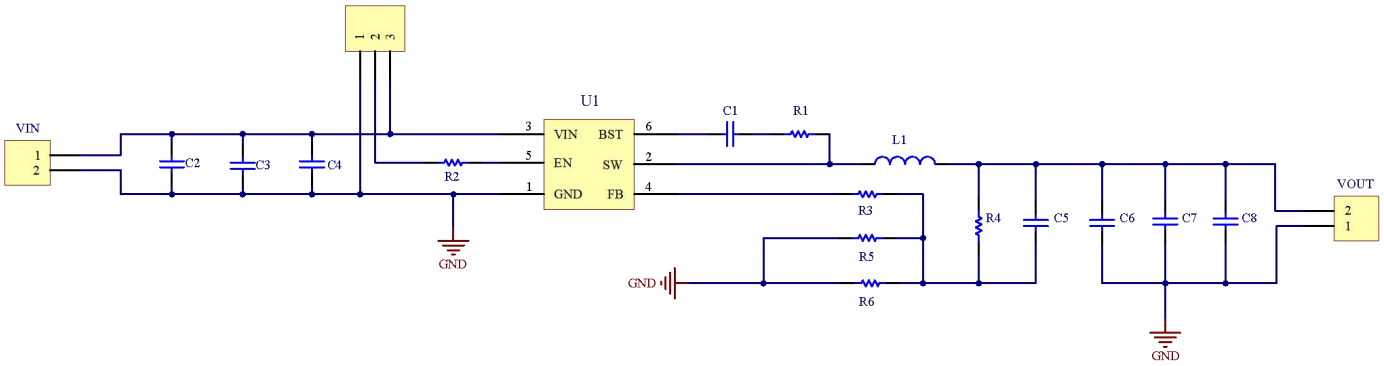


Figure 10. Typical schematic

Output Voltage Setting

The output voltage can be programmed by adjusting the external resistor divider R_{UP} and R_{DOWN} according to the equation below:

$$V_{OUT} = \left(\frac{R_{UP}}{R_{DOWN}} + 1\right) * V_{ref}$$

When the output voltage is in regulation, the typical voltage at FB pin is 0.768V for LP6454B6F.

For better accuracy, the R_{DOWN} is recommended to be lower than 10kΩ to ensure the current flowing through R_{DOWN} is at least 100 times larger than the FB pin leakage current.

For a 5V-output application, a 10kΩ R_{DOWN} is selected and the R_{UP} is 55kΩ.

A resistor with higher than 1kΩ but lower than 10kΩ should be placed between the resistor divider and FB pin if a C_{ff} capacitor is soldered.

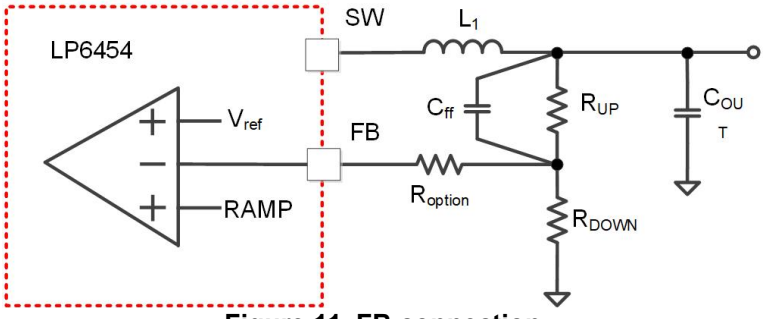


Figure 11. FB connection

EN Design

The LP6454 allows the user to design a precise VIN voltage to enable the converter during power on. The startup sequence can be designed by adjusting the resistor divider of R_{UP_EN} and R_{DOWN_EN} with the equation below,

$$V_{EN} = \frac{900k\Omega // R_{DOWN\_EN}}{R_{UP\_EN} + 900k\Omega // R_{DOWN\_EN}} * VIN$$

where V_{EN} is the EN rising threshold voltage at which the converter is enabled, which is 1.2V typically. A 47pF-1nF capacitor is recommend to be soldered in parallel with the R_{EN_DOWN} to avoid the high-frequency noise influence from the switching node.

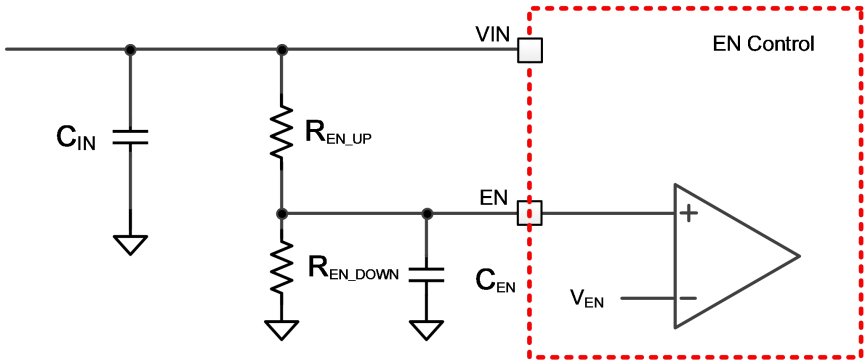


Figure 12. EN connection

Inductor and Output Capacitor Setting

The inductor ripple is calculated by the equation below:

$$I_{PP} = \left(\frac{V_{OUT}}{L * Fsw} * \frac{V_{IN} - V_{OUT}}{V_{IN}}\right)$$

To get a better efficiency, the inductor ripple is recommended to be controlled under 40% of the output current to minimize the AC loss of the inductor and power MOSFETs.
For a typical 12V input voltage and 5V output voltage, a low DCR value, 2.2-μH inductor is recommended.
The output capacitor not only impacts the output ripple but also the loop stability. Please follow the design rules in the table below. A feedforward capacitor C_{FF} can be selected to improve the transient behavior. The typical capacitance can be 10-100pF. For this design, four 6.3V, X5R, 22μF capacitors (GRM188R60J226ME15) from Murata are soldered at the VOUT to GND.

Table 2: Recommend R/L/C values for LP6454B6F

Vout	Inductor-L	Cout	R_{UP}	R_{DOWN}	R_{option}	C_{ff}
1.2V	1μH/1.2μH	22μF*3	5.7 kΩ	10 kΩ	0 Ω	NA
3.3V	1.5μH/2.2μH	22μF*3	33 kΩ	10 kΩ	10 kΩ	10-100pF
5.0V	2.2μH/3.3μH	22μF*4	55 kΩ	10 kΩ	10 kΩ	10-100pF

Bootstrap capacitor

A 0.1-μF ceramic capacitor is needed to supply power for the high-side N-MOSFET driver. The capacitor should be at least 10V.

Input capacitor

A typical 22-μF ceramic capacitor is needed to serve as the bulk capacitor at the VIN pin of the LP6454. An additional 0.1μF is strongly recommended to provide additional high frequency filtering and should be placed to the VIN pin and GND as close as possible.

Application Waveforms (Vin=12V,L=2.2μH, Cout=22μF*3)

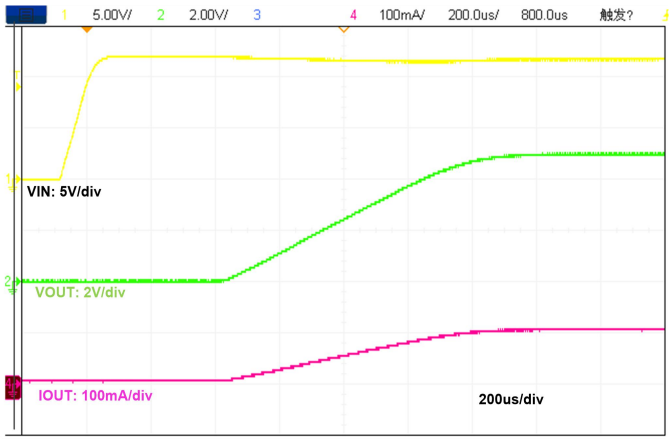


Figure 13. Startup by VIN, 50Ω load

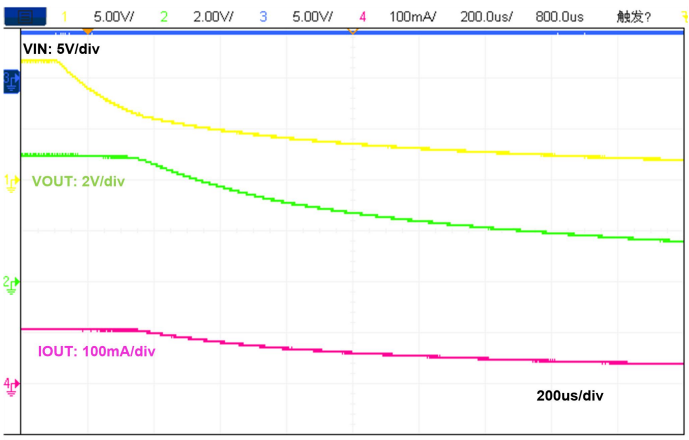


Figure 14. Shutdown by VIN, 50Ω load

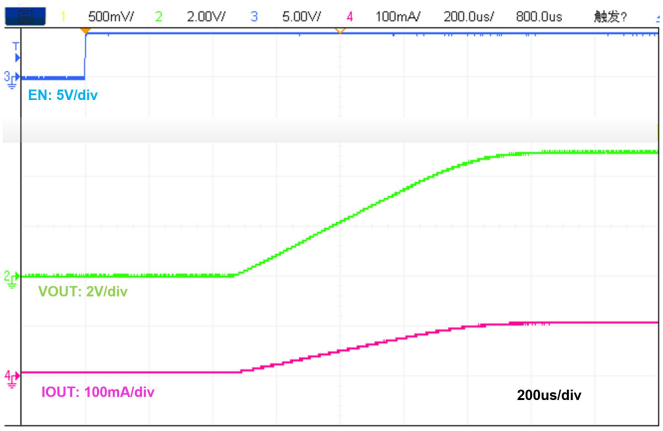


Figure 15. Startup by EN, 50Ω load

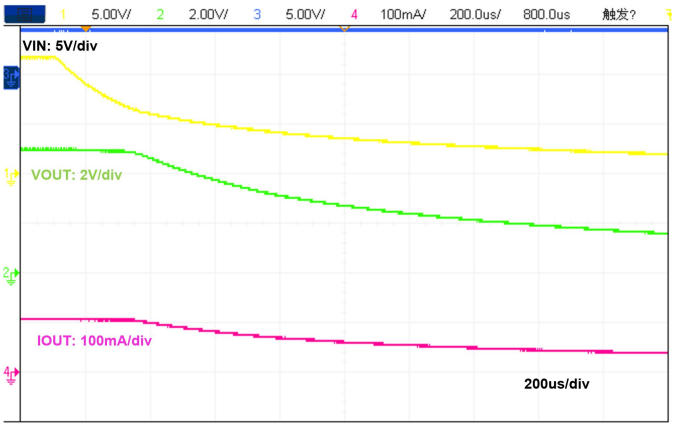


Figure 16. Shutdown by EN, 50Ω load

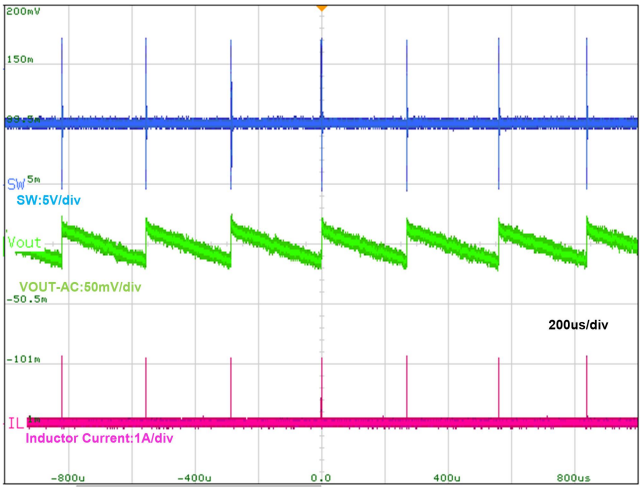


Figure 17. Switching Waveform, 0A load

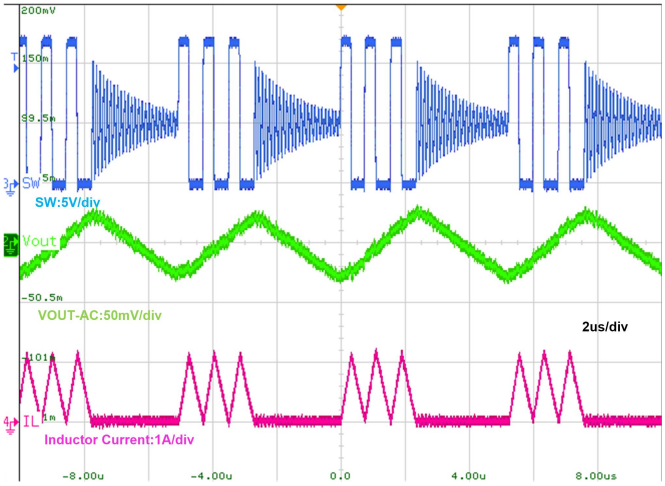


Figure 18. Switching Waveform, 250mA load

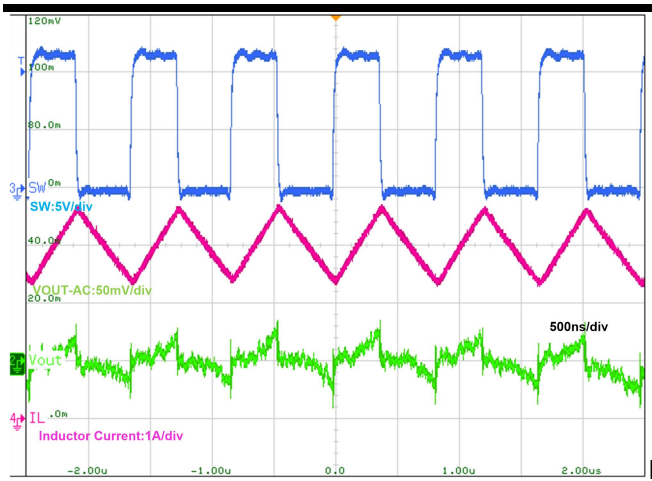


Figure 19. Switching Waveform, 3A load

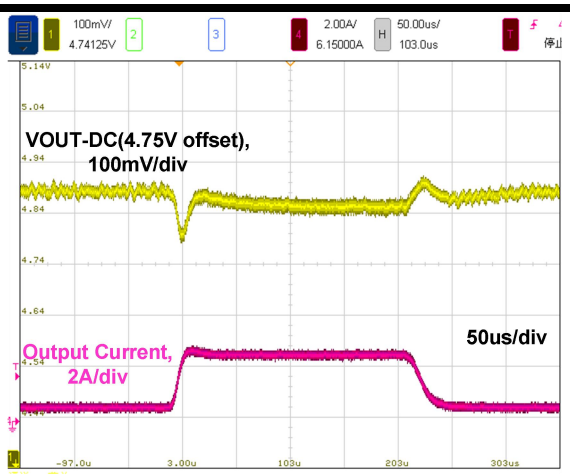


Figure 20. Load Transient, 0.2A-2.5A-0.2A

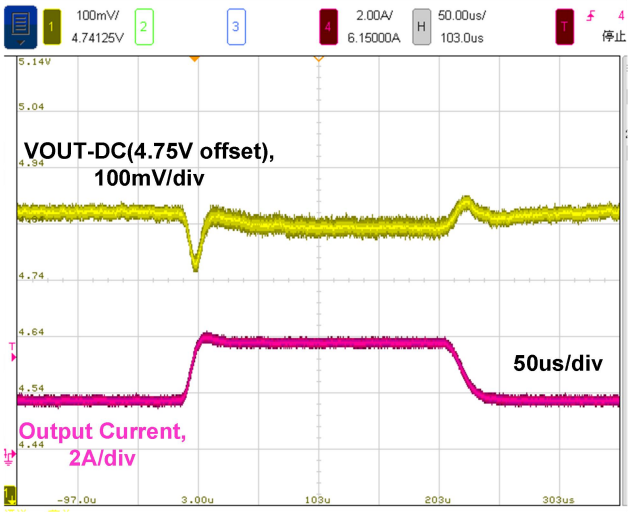


Figure 21. Load Transient, 1.6A-4A-1.6A

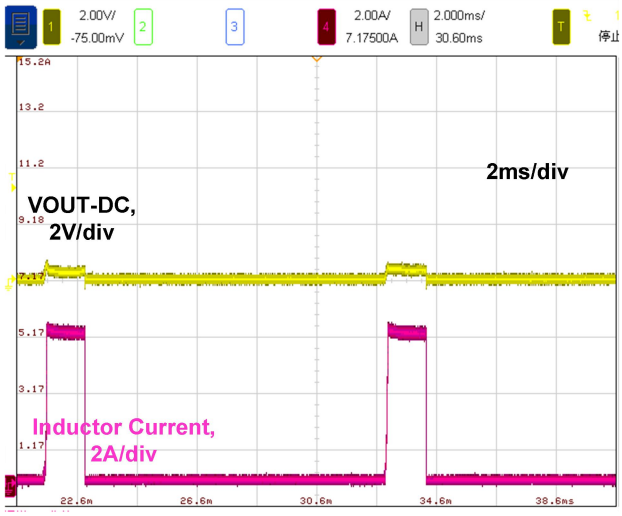


Figure 22. Output SCP, VIN=12V, VOUT=5V

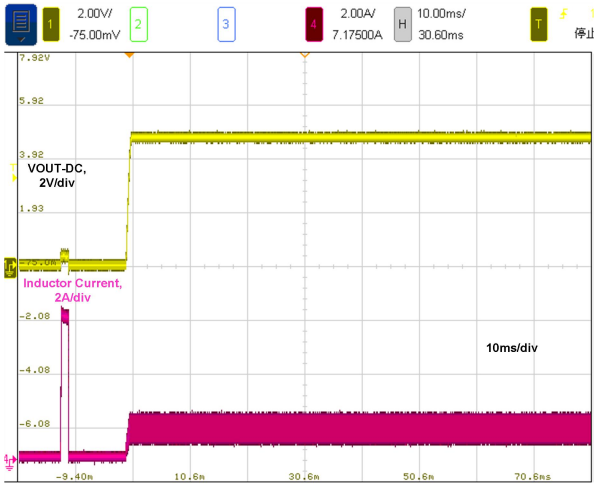


Figure 23. SCP Recovery, VIN=12V, VOUT=5V, 1A load

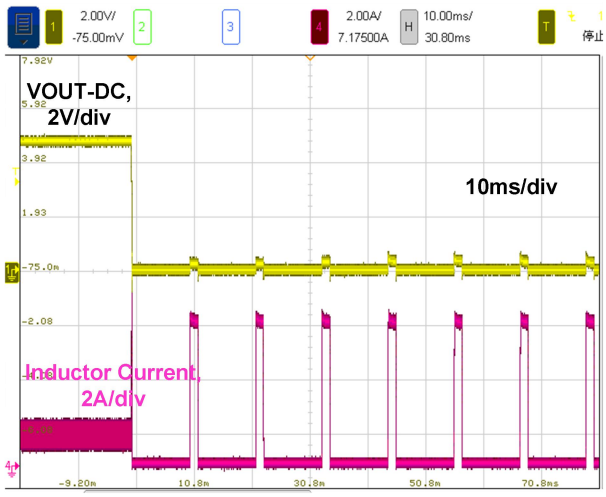


Figure 24. Output SCP, VIN=12V, VOUT=5V, 1A load

PCB Layout Guidelines

Proper layout of the components to minimize high frequency current path loop is important to prevent electrical and magnetic field radiation and high frequency resonant problems. Follow this specific order carefully to achieve the proper layout.

- Place input capacitor (C2 and C4) as close as possible to VIN pin and GND pin and use shortest copper trace connection or GND plane.
- Put output capacitor near to the inductor output terminal and the device. Ground connections need to be tied to the IC ground with a short copper trace or GND plane
- Place inductor input terminal to SW pin as close as possible and limit SW node copper area to lower electrical and magnetic field radiation. Do not use multiple layers in parallel for this connection. Minimize parasitic capacitance from this area to any other trace or plane.
- R1 is reserved to slow down the switching speed for noise sensitive applications and R3 with higher than 1kΩ resistor should be soldered if the feedforward capacitor is soldered at the same time.

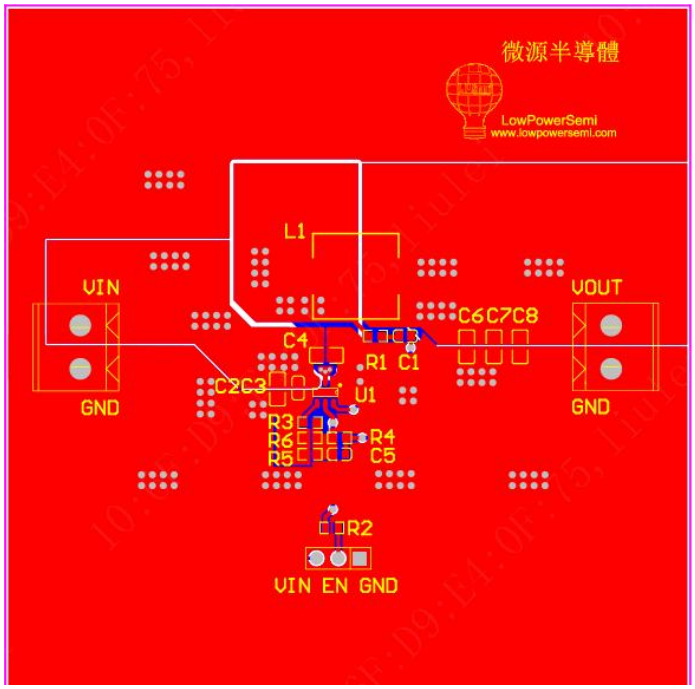
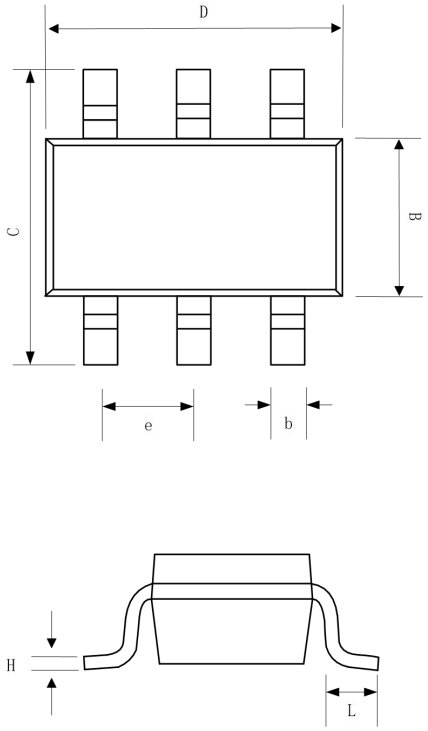
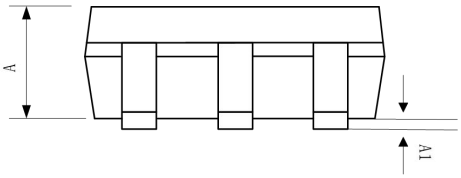


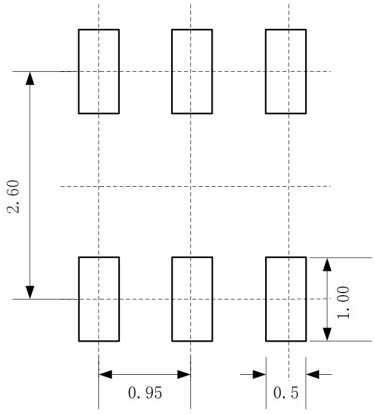
Figure 25 Layout example

Packaging Information

1.6mm x2.9mm SOT23-6 package





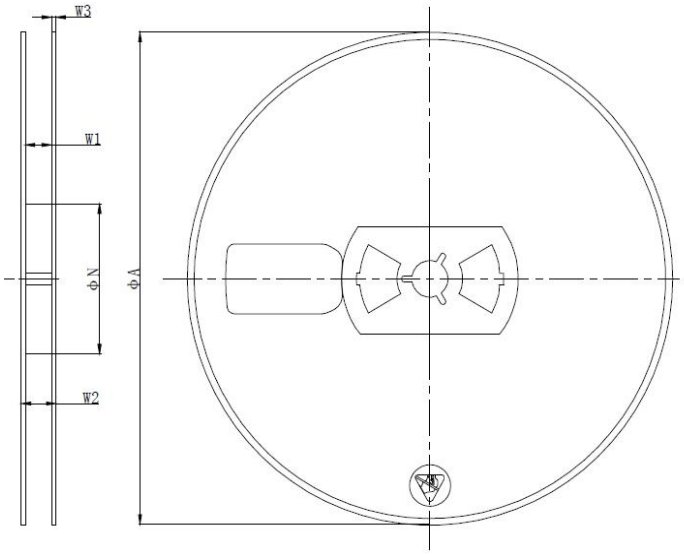


Recommended Land Pattern

SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.889	1.100	1.295
A1	0.000	0.050	0.152
B	1.397	1.600	1.803
b	0.28	0.35	0.559
C	2.591	2.800	3.000
D	2.692	2.920	3.120
e	0.95BSC		
H	0.080	0.152	0.254
L	0.300	0.450	0.610

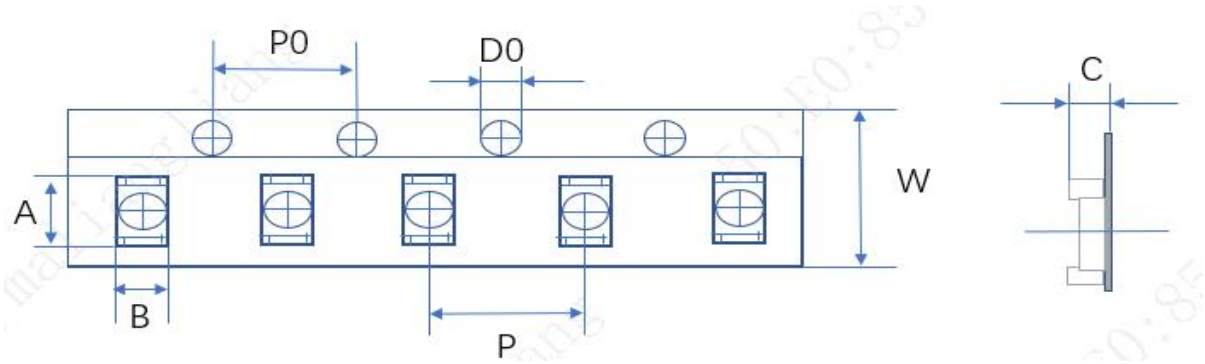
Tape and Reel information

REEL DIMENSIONS（Unit:mm)



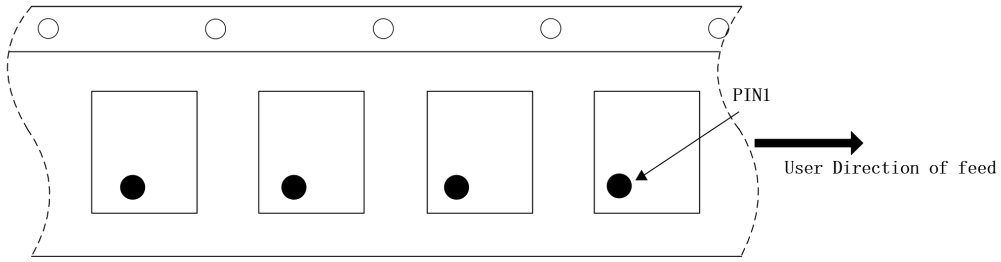
ΦA	W2
180±4	12±2

TAPE DIMENSIONS（Unit:mm)



口袋宽度A		口袋长度B		编带孔中心间距P0		IC中心间距P		孔径D0		编带宽度W		编带厚度C	
尺寸(mm)	公差	尺寸(mm)	公差	尺寸(mm)	公差	尺寸(mm)	公差	尺寸(mm)	公差	尺寸(mm)	公差	尺寸(mm)	公差
3.2	±0.2	3.26	±0.2	4	±0.1	4	±0.1	1.5	±0.15	8	±0.3	1.4	±0.2

PIN1 AND TAPE FEEDING DIRECTION



Revision History

Revision	Date	Change Description
Rev 1p0	6/1/2022	Initial release
Rev 1p1	9/1/2022	Add SW transient specification
Rev 1p2	12/12/2022	New Format
Rev 1p3	01/05/2024	1: Add LP6465TB6F 2: Vref update 3: Schematics and PCB layout update 4: Add tape and reel information
Rev 1p4	9/18/2024	1. Add LP6456FB6F 2. Add FPWM description 3. SW transient absolute maximum voltage changes form “5ns” to “20ns”