

4.5V to 48V, 0.6A, 1.6MHz, Synchronous, Step-Down Converter

LA1631

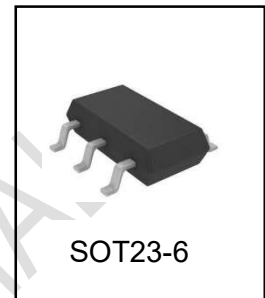
Overview

The LA1631 is an easy to use synchronous step-down Buck, which integrated with high-side and low-side power MOSFETs. The LA1631 can provide up to 0.6A of output current efficiently with current-mode control for fast loop response.

The LA1631 employs 1.6MHz switching frequency for small solution size, with wide 4.5V to 48V input range accommodates a variety of power meter step-down applications. The quiescent current of LA1631 is only 1uA when shutdown with 15V input voltage. The LA1631 uses high duty cycle and low dropout mode for low power meter input voltage conditions.

The LA1631 achieves high power conversion efficiency over a wide load range by scaling down the switching frequency under light-load conditions to reduce switching and gate driving losses.

The LA1631 has built-in full protection features, cycle-by-cycle current limit, hiccup mode short-circuit protection, and thermal shutdown in case of excessive power dissipation. The LA1631 is available in a cost-effective SOT23-6 package.



Features

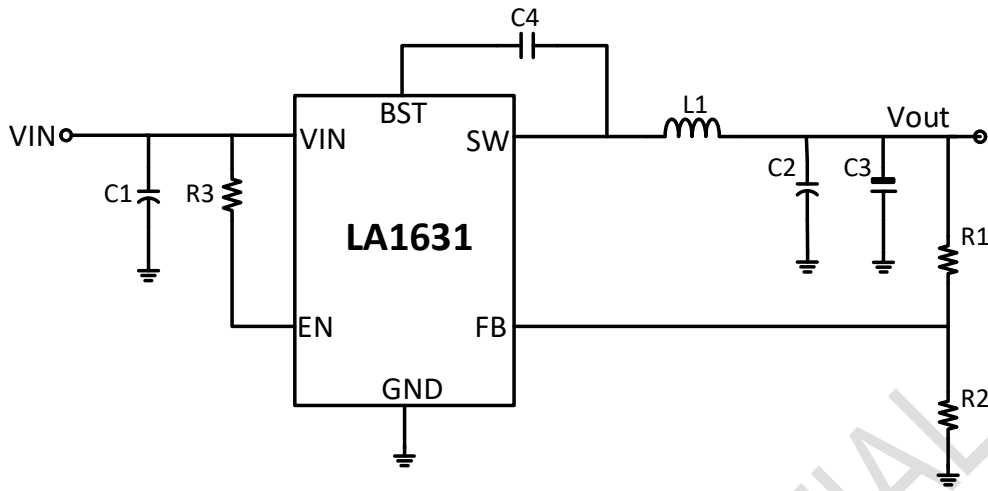
- 4.5V to 48V Input Voltage Range
- 50V Absolute Maximum Rating
- 600mA Continuous Output Current
- 100ns Minimum Switching-On Time
- 2%~98% Large Range Duty Cycle
- Stable with Ceramic/Electrolytic Output Capacitors
- 1.6MHz Switching Frequency
- Light Load Pulse Frequency Modulation
- 420mΩ/220mΩ Internal Power MOSFETs
- Support Startup with Pre-Biased Output
- Short Circuit Protection with Hiccup Mode
- ±1.5% Tolerance Voltage Reference at 25°C
- Output Voltage Adjustable from 0.8V
- Precision Enable
- Over Temperature Protection

Applications

- Power Meter
- Industrial Application
- Automotive



Typical Application

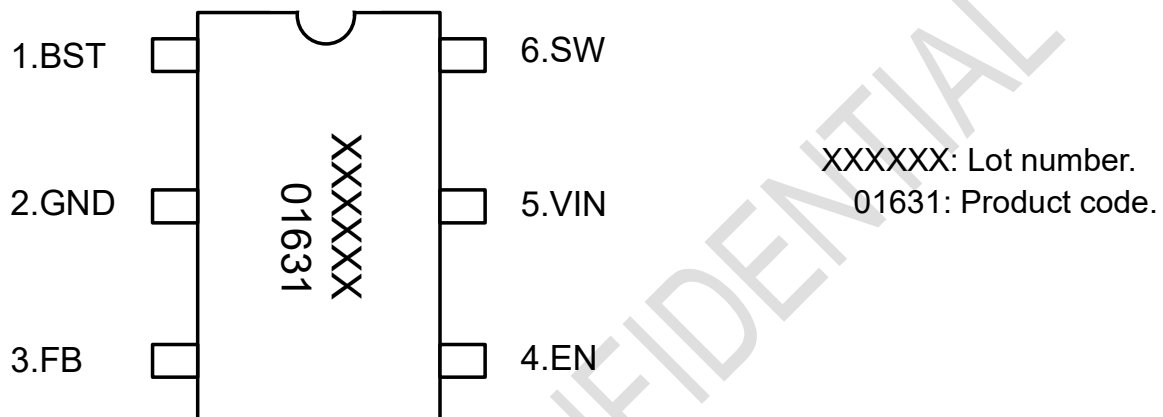


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Package Mark and Order Information

Device	Package	Temperature range	Packaging Type	Purchase Contact
LA1631	SOT23-6	-40 to 150°C	T/R 3000pcs/roll	sales@latticeart.com

Pin Diagram

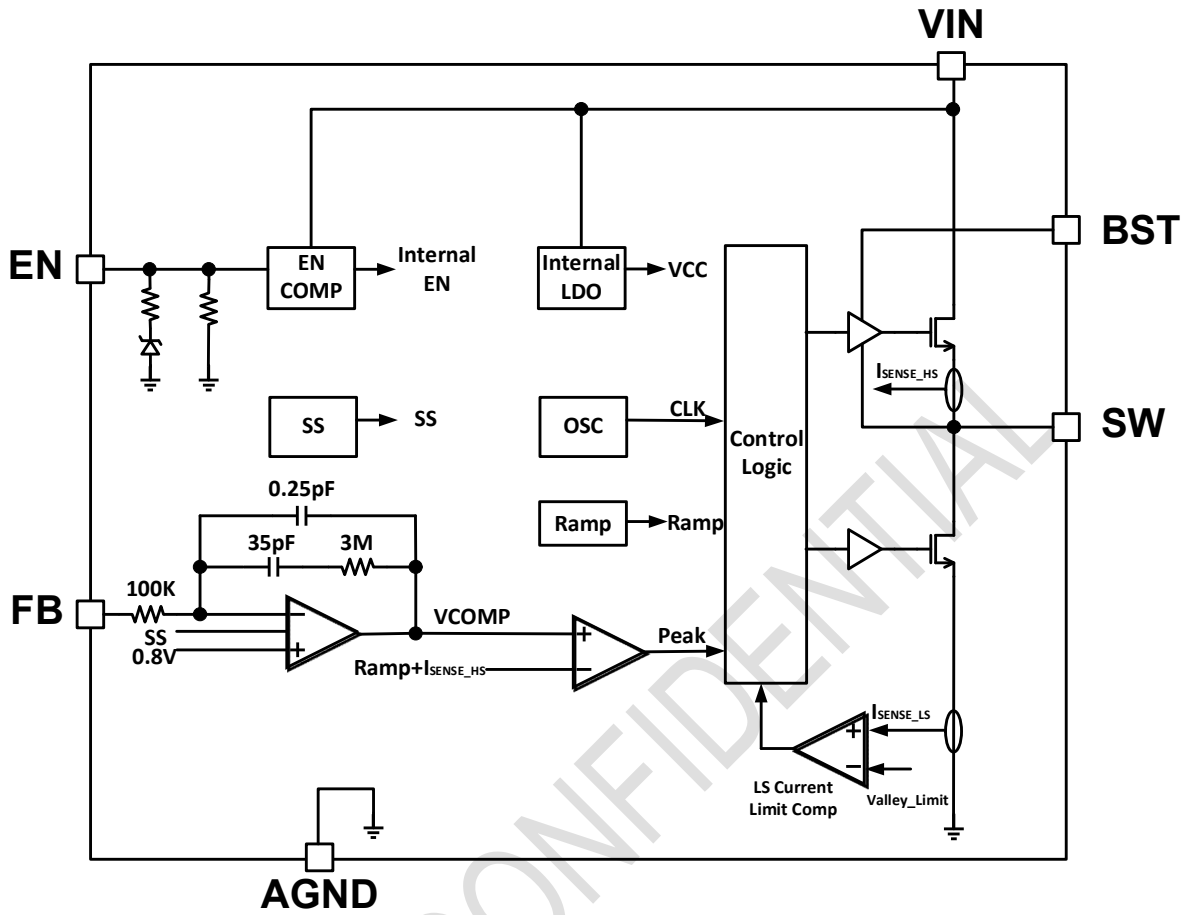


Pin Description

Pin No.	Symbol	Pin Description
1	BST	Bootstrap capacitor connection for high-side FET driver. Connect a high quality 100nF capacitor from this pin to the SW pin.
2	GND	Power Ground terminal.
3	FB	Feedback input to the convertor. Connect a resistor divider to set the output voltage. Never short this terminal to ground during operation.
4	EN	Precision enable input to the convertor. High = on, Low or float = off. Can be tied to VIN by a resistor. Precision enable input allows adjustable UVLO by external resistor divider.
5	VIN	Supply input terminal to internal bias LDO and high-side FET. Connect to input supply and input bypass capacitors CIN. Input bypass capacitors must be directly connected to this pin and GND.
6	SW	Switching output of the converter. Internally connected to source of the high-side FET and drain of the low-side FET. Connect to power inductor.



Block Diagram



Absolute Maximum Ratings (Note 1)

$T_A=25^{\circ}\text{C}$, unless otherwise specified.

Symbol	Definition	Ratings	Unit
V_{IN}	VIN to GND	-0.3~50	V
SW	SW to GND	-0.7 (-5V in 10ns)~VIN + 0.7	V
EN	Max Input current to EN pin	400	uA
BST	BST to SW	-0.3~6	V
All Other Pins		-0.3~6	V
T_{STG}	Storage temperature	-55 to150	$^{\circ}\text{C}$
T_j	Junction temperature	-40 to150	$^{\circ}\text{C}$

Note 1: Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are not tested at manufacturing.

Recommended Operating Conditions

Symbol	Definition	Ratings	Unit
BST	BST to SW	4~5	V
FB	FB to GND	0~1	V
EN	EN to GND	0~5	V
V_{IN}	VIN to GND	4.5~48	V
V_{OUT}	V_{OUT} to GND	0.8~0.98xVIN	V
I_{OUT}	Max Continuous Output Current	0.6	A

Thermal Resistance (Note 2)

Symbol	Definition	Ratings	Unit
$R_{\theta JC}$	Junction to case thermal resistance	55	$^{\circ}\text{C}/\text{W}$
$R_{\theta JA}$	Junction to ambient thermal resistance	100	$^{\circ}\text{C}/\text{W}$

Note 2: Measured on JESD51-7, 4-Layer PCB, and the PCB has no copper for thermal dissipation. Normal PCB with copper thermal resistance will be smaller.

Electrical Characteristics

$V_{IN}=12V$, $V_{EN}=2V$, $T_A=25^{\circ}C$, unless otherwise specified.

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{FB}	Feedback voltage	$T_J = -40^{\circ}C$ to $+125^{\circ}C$	781	797	813	mV
		$T_J = +25^{\circ}C$	785	797	809	
I_{LK_FB}	Feedback leakage	$V_{EN} = 1V$, $V_{FB} = 2V$			0.1	μA
R_{ON_HS}	High-side switch on resistance	$V_{BST} - V_{SW} = 5V$		420	840	m Ω
R_{ON_LS}	Low-side switch on resistance	$V_{IN} = 15V$		220	440	m Ω
LKG_{HS}	High-side switch leakage	$V_{EN} = 0V$, $V_{SW} = 0V$			1	μA
LKG_{LS}	Low-side switch leakage	$V_{EN} = 0V$, $V_{SW} = 45V$			1	μA
I_{LIM_HS}	High-side Current limit			1.25		A
I_{LIM_LS}	Low-side Current limit		0.8	1	1.2	A
V_{IN_UVR}	V_{IN} UVLO rising threshold		4.15	4.3	4.45	V
V_{IN_UVF}	V_{IN} UVLO falling threshold		3.85	4.05	4.25	V
$V_{IN_UV_hys}$	V_{IN} UVLO hysteresis			0.3		V
T_{SS}	Soft-start time	V_{FB} from 10% to 90%	0.35	0.6	0.85	ms
f_{sw}	Oscillator frequency		1.4	1.6	1.9	MHz
t_{ON_MIN}	Minimum switch on time ⁽⁵⁾			100		ns
t_{ON_MAX}	Maximum switch on time ⁽⁵⁾			5.2		μs
t_{OFF_MIN}	Minimum switch off time ⁽⁵⁾			92		ns
I_{QS}	Shutdown supply current	$V_{EN} < 0.3V$ $V_{IN}=15V$		1	2	μA
I_Q	Quiescent supply current	No load, $V_{FB} = 0.83V$, no switching		150	220	μA
V_{EN_R}	Enable rising threshold	Low to high	1.5	1.55	1.6	V
V_{EN_F}	Enable falling threshold	High to low	1.1	1.22	1.3	V



Electrical Characteristics

$V_{IN}=12V$, $V_{EN}=2V$, $T_A=25^{\circ}C$, unless otherwise specified.

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{EN_Hys}	Enable Threshold Hysteresis			0.3		V
T_{OTP_R}	Thermal shutdown (5)			151		$^{\circ}C$
T_{OTP_Hys}	Thermal shutdown hysteresis ⁽⁵⁾			21		$^{\circ}C$

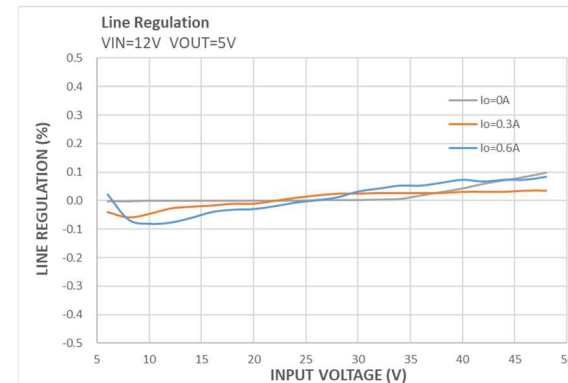
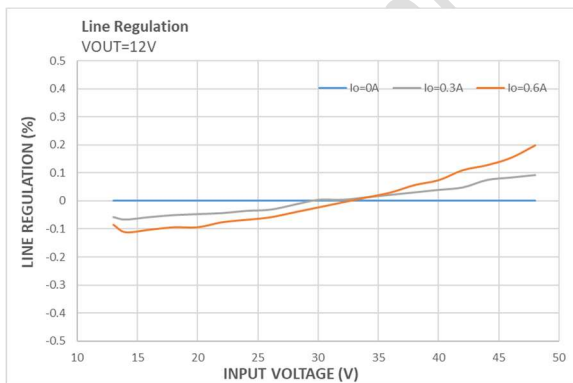
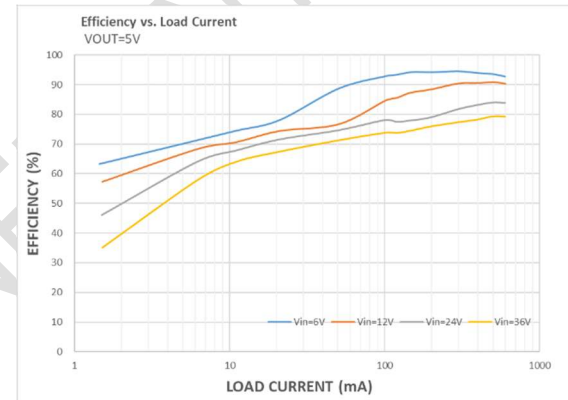
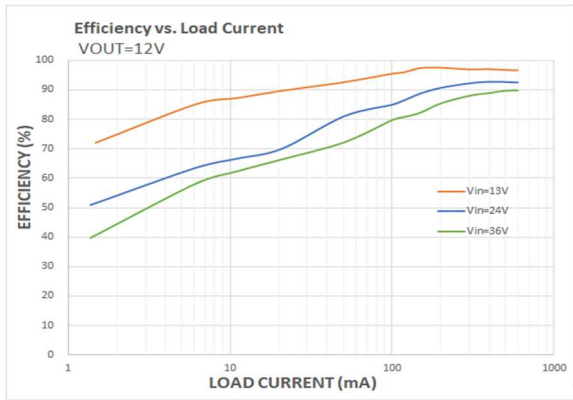
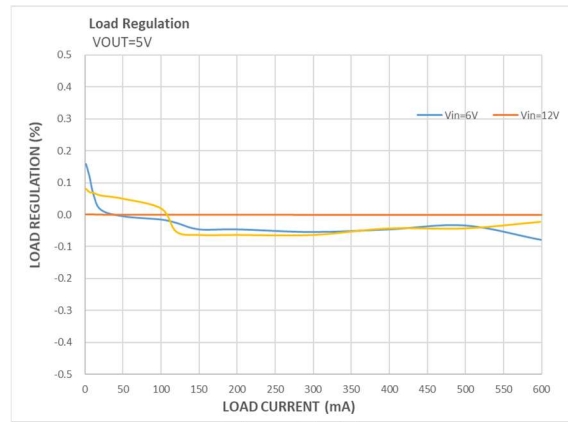
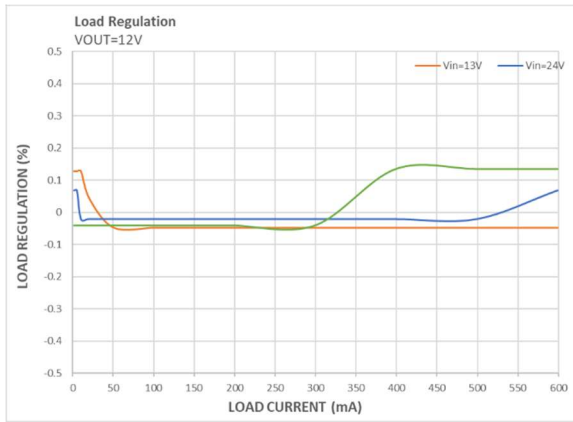
5) Not tested in production and derived from bench characterization.

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Typical Performance Characteristic

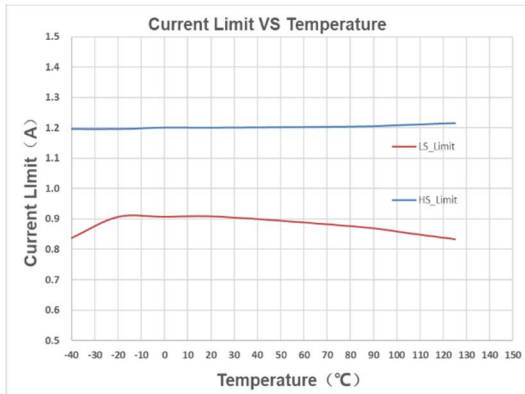
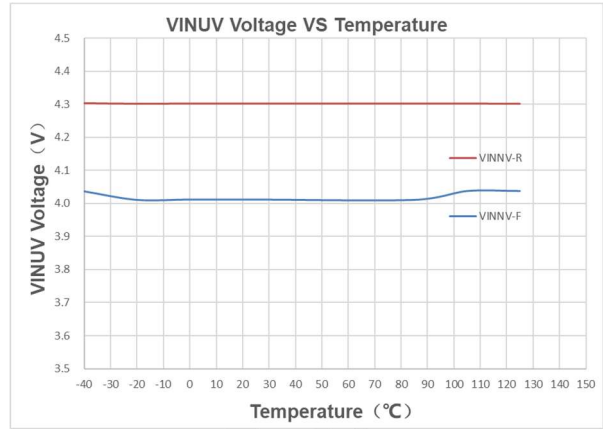
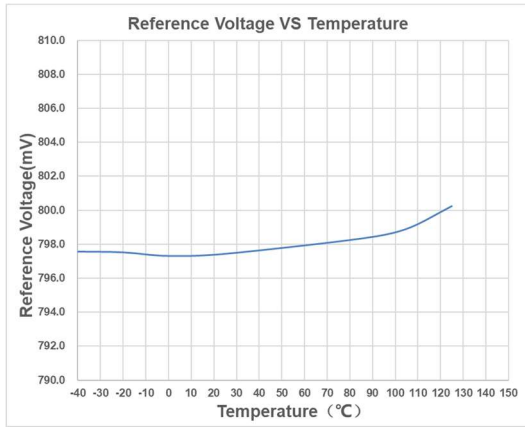
$V_{OUT}=12V$: $V_{IN} = 24V$, $C1 = 10\mu F$, $C2 = 10\mu F$, $C3 = 470\mu F$, $L1 = 22\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.





Typical Performance Characteristic

$V_{OUT}=12V$: $V_{IN} = 24V$, $C1 = 10\mu F$, $C2 = 10\mu F$, $C3 = 470\mu F$, $L1 = 22\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.

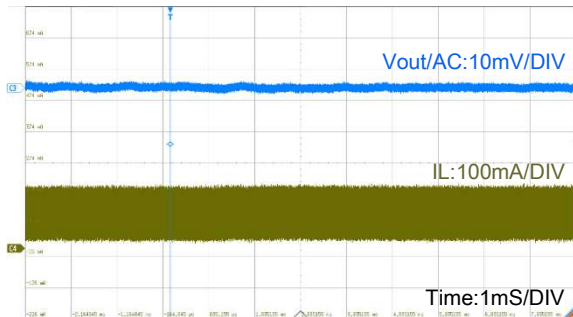


Typical Performance Characteristic (continued)

$V_{IN} = 24V$, $V_{OUT} = 12V$, $C1 = 10\mu F$, $C2 = 10\mu F$, $C3 = 470\mu F$, $L1 = 22\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.

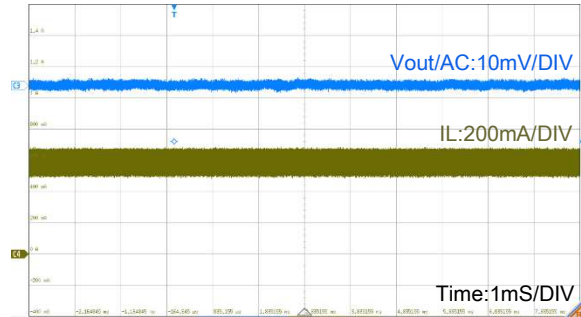
Output Voltage Ripple

$I_{OUT} = 0.125A$



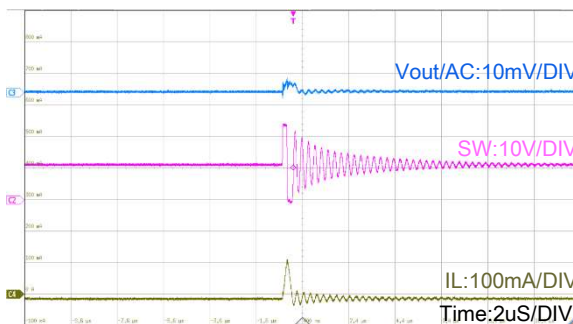
Output Voltage Ripple

$I_{OUT} = 0.6A$



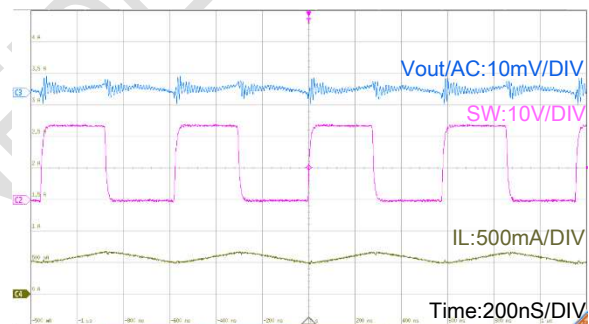
Steady State

$I_{OUT} = 0A$



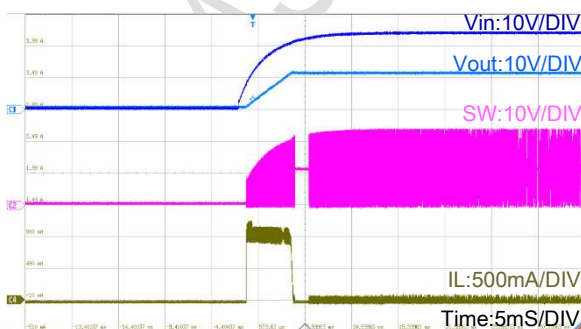
Steady State

$I_{OUT} = 0.6A$



Start-Up through V_{IN}

$I_{OUT} = 0A$



Start-Up through V_{IN}

$I_{OUT} = 0.6A$



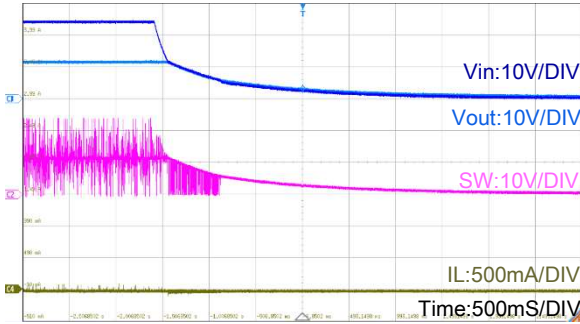


Typical Performance Characteristic (continued)

$V_{IN} = 24V$, $V_{OUT} = 12V$, $C1 = 10\mu F$, $C2 = 10\mu F$, $C3 = 470\mu F$, $L1 = 22\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.

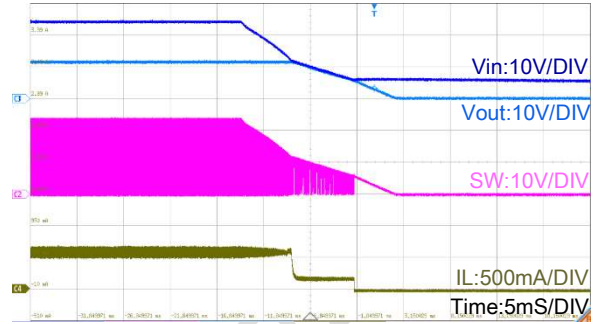
Shutdown through V_{IN}

$I_{OUT} = 0A$



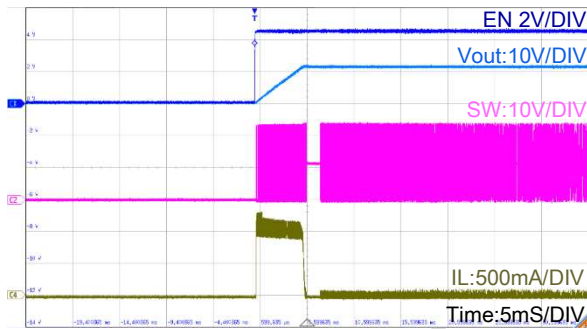
Shutdown through V_{IN}

$I_{OUT} = 0.6A$



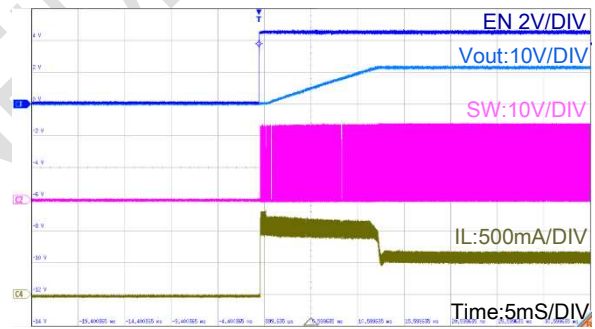
Start-Up through EN

$I_{OUT} = 0A$



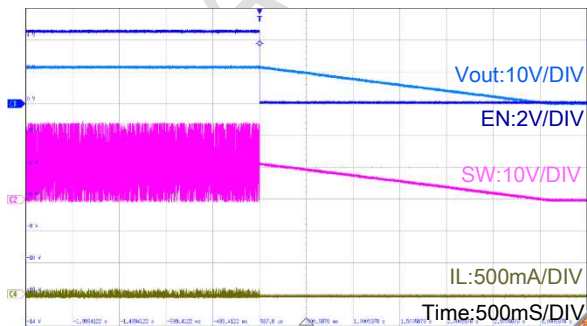
Start-Up through EN

$I_{OUT} = 0.6A$



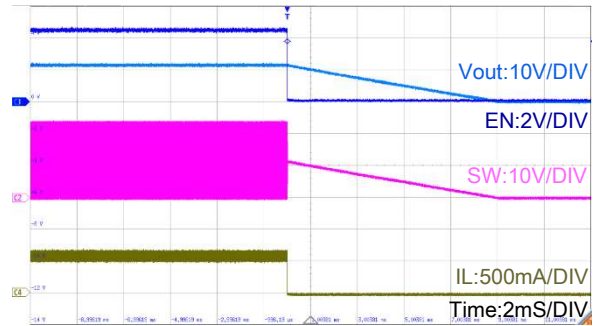
Shutdown through EN

$I_{OUT} = 0A$



Shutdown through EN

$I_{OUT} = 0.6A$

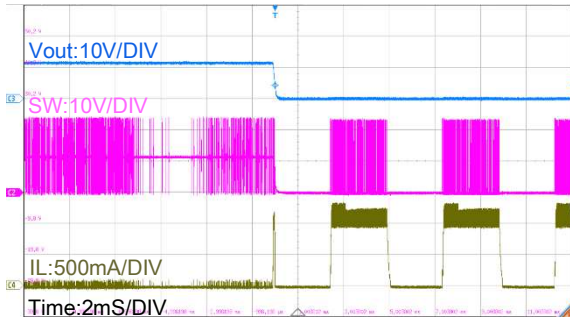


Typical Performance Characteristic (continued)

$V_{IN} = 24V$, $V_{OUT} = 12V$, $C1 = 10\mu F$, $C2 = 10\mu F$, $C3 = 470\mu F$, $L1 = 22\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.

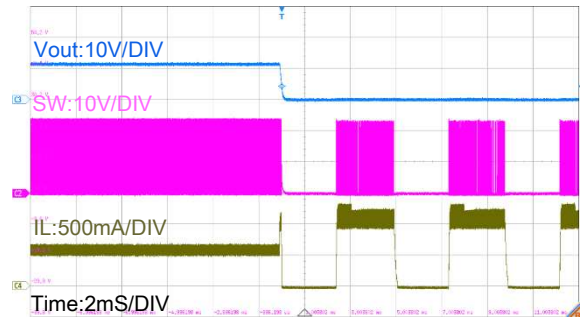
SCP Entry

$I_{OUT} = 0A$ to Short Circuit



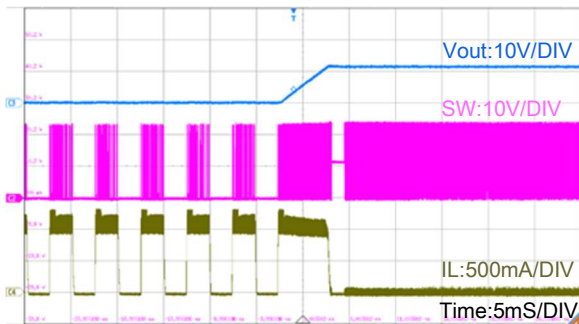
SCP Entry

$I_{OUT} = 0.6A$ to Short Circuit



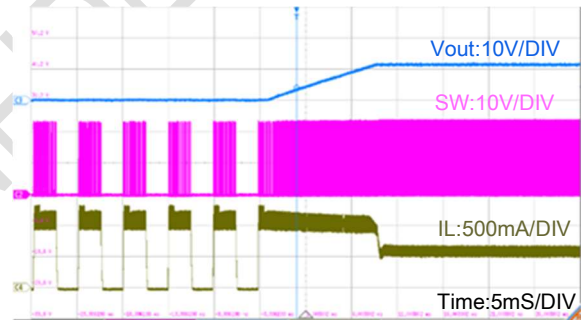
SCP Recovery

Short Circuit to $I_{OUT} = 0A$



SCP Recovery

Short Circuit to $I_{OUT} = 0.6A$

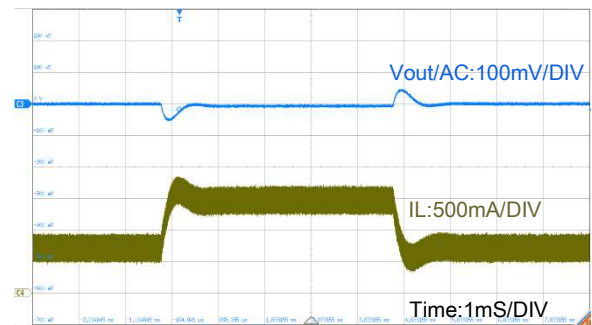


SCP Steady State



Load Transient

$I_{OUT} = 0.3A \leftrightarrow 0.6A, 3A/\mu s$

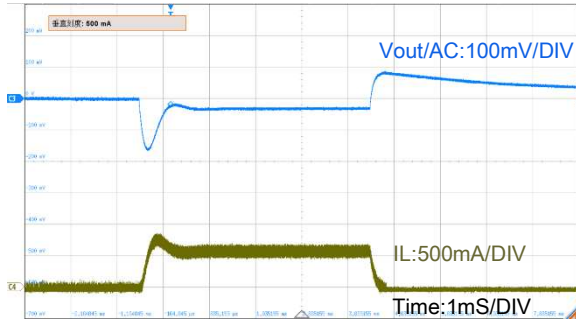


Typical Performance Characteristic *(continued)*

$V_{IN} = 24V$, $V_{OUT} = 12V$, $C1 = 10\mu F$, $C2 = 10\mu F$, $C3 = 470\mu F$, $L1 = 22\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.

Load Transient

$I_{OUT} = 0A \leftrightarrow 0.6A, 3A/\mu s$



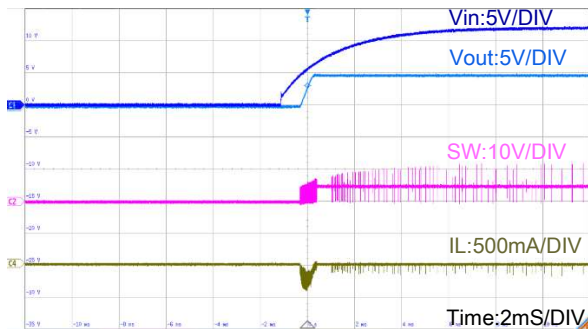
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Typical Performance Characteristic (continued)

$V_{IN} = 12V$, $V_{OUT} = 5V$, $C1 = 10\mu F$, $C2 = 22\mu F$, $C3 = NC$, $L1 = 4.7\mu H$, and $T_A = +25^\circ C$, unless otherwise noted.

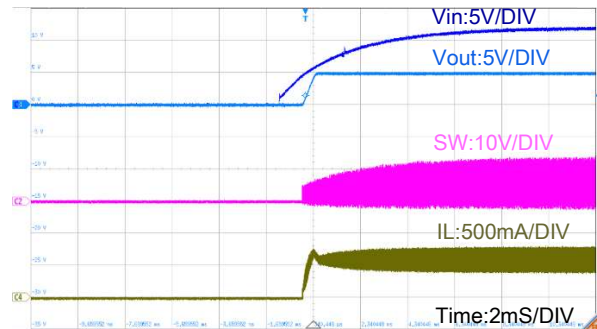
Start-Up through V_{IN}

$I_{OUT} = 0A$



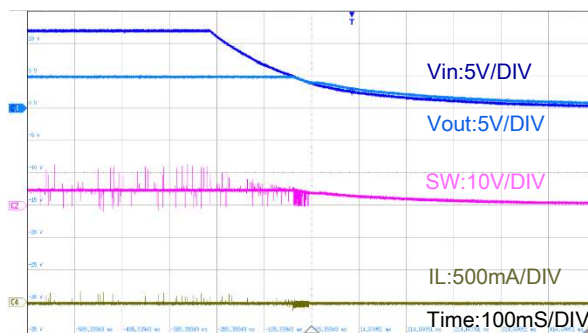
Start-Up through V_{IN}

$I_{OUT} = 0.6A$



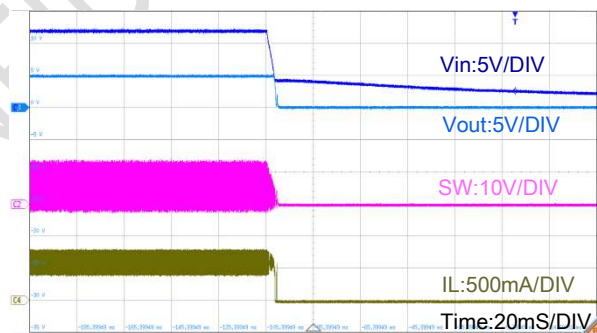
Shutdown through V_{IN}

$I_{OUT} = 0A$



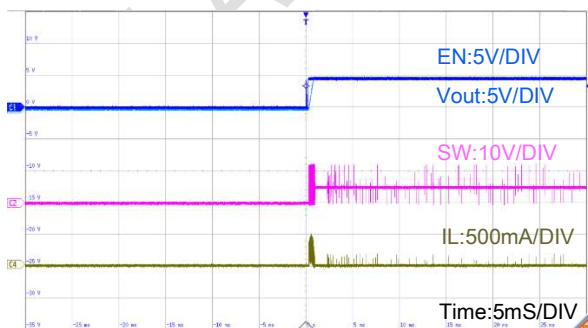
Shutdown through V_{IN}

$I_{OUT} = 0.6A$



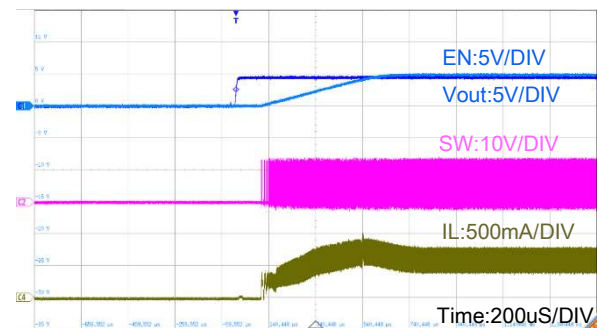
Start-Up through EN

$I_{OUT} = 0A$



Start-Up through EN

$I_{OUT} = 0.6A$

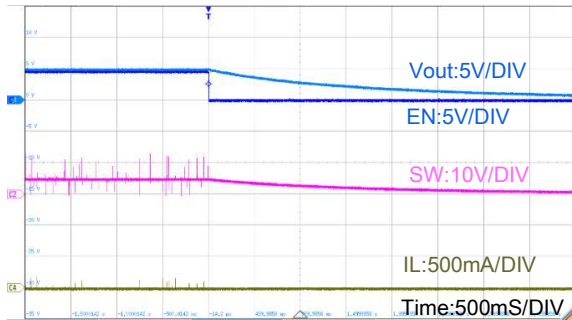


Typical Performance Characteristic (continued)

$V_{IN} = 12V$, $V_{OUT} = 5V$, $C1 = 10\mu F$, $C2 = 22\mu F$, $C3=NC$, $L1 = 4.7\mu H$, and $T_A = +25^\circ C$, unless otherwise noted

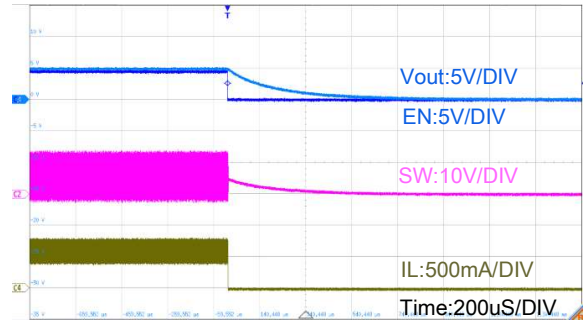
Shutdown through EN

$I_{OUT} = 0A$



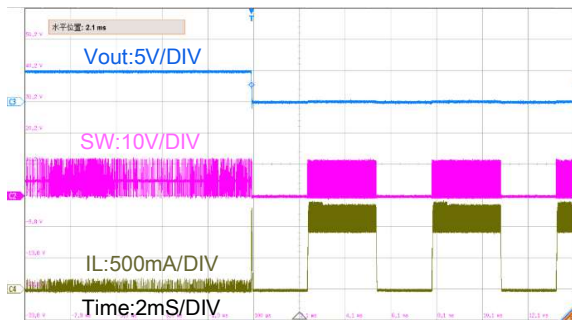
Shutdown through EN

$I_{OUT} = 0.6A$



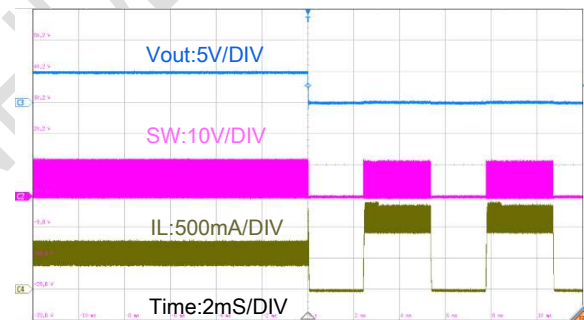
SCP Entry

$I_{OUT} = 0A$ to Short Circuit



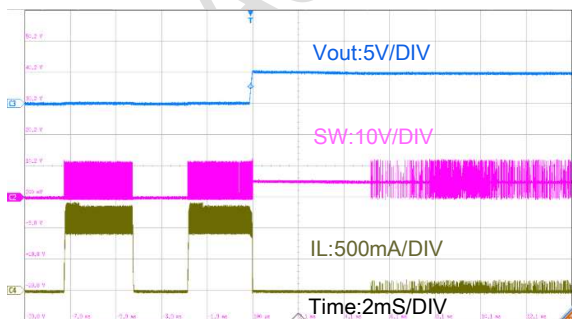
SCP Entry

$I_{OUT} = 0.6A$ to Short Circuit



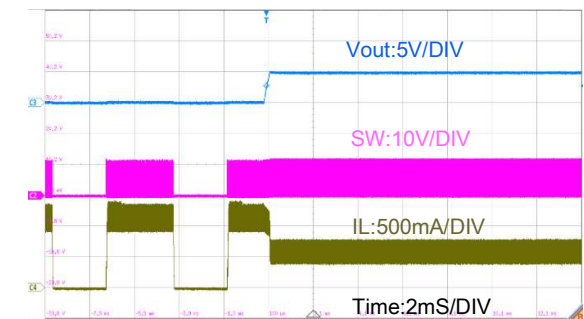
SCP Recovery

Short Circuit to $I_{OUT} = 0A$



SCP Recovery

Short Circuit to $I_{OUT} = 0.6A$

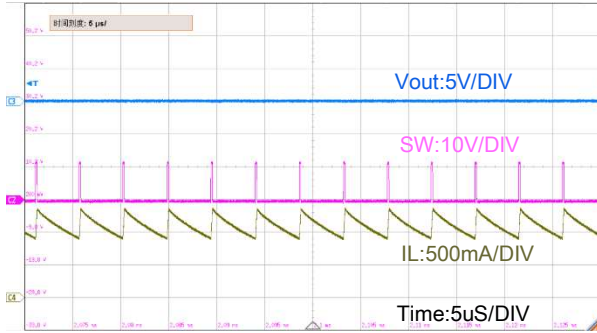




Typical Performance Characteristic *(continued)*

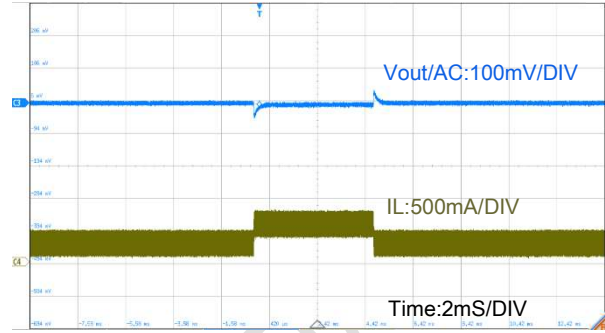
$V_{IN} = 12V$, $V_{OUT} = 5V$, $C1 = 10\mu F$, $C2 = 22\mu F$, $C3=NC$, $L1 = 4.7\mu H$, and $T_A = +25^\circ C$, unless otherwise noted

SCP Steady State



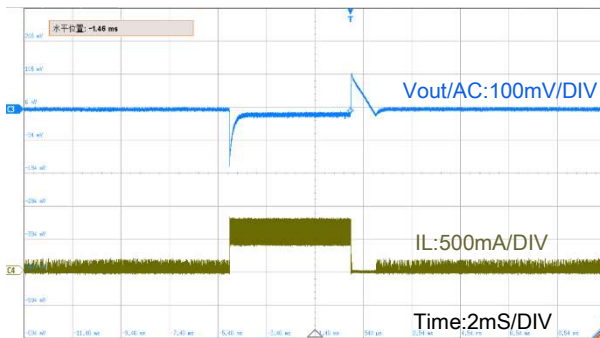
Load Transient

$I_{OUT} = 0.3A \leftrightarrow 0.6A$, $3A/\mu s$



Load Transient

$I_{OUT} = 0A \leftrightarrow 0.6A$, $3A/\mu s$



Function Descriptions

Pulse-Width Modulation (PWM) Control

At moderate-to-high output currents, LA1631 operates in a fixed-frequency, peak current control mode to regulate the output voltage. A pulse-width modulation (PWM) cycle initiated by the internal clock turns on the power high-side MOSFET (HS-FET). The HS-FET remains on until its current reaches the value set by the COMP voltage (VCOMP). After the HS-FET is off, the low-side MOSFET (LS-FET) turns on, and the inductor current flows through the LS-FET. To avoid a shoot-through, a dead time is inserted to prevent the HS-FET and LS-FET from turning on at the same time. For each turn-on and turn-off in a switching cycle, the HS-FET turns on and off with a minimum on and off time limit.

To prevent inductor current and output voltage runaway, the switching frequency folds back when the HS-FET minimum turn-on is detected internally. When the PWM signal goes low, the HS-FET turns off and remains off for at least 110ns before the next cycle begins. If the current in the HS-FET does not reach the COMP-set current value within one PWM cycle, the HS-FET remains on a max on time to avoid a turn-off operation.

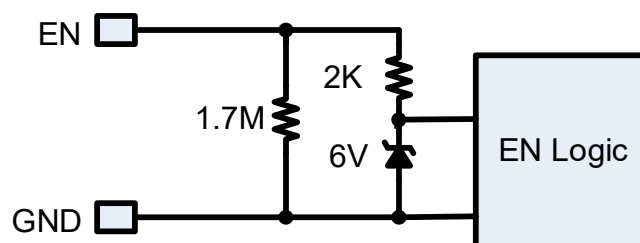
If the input voltage is too high, the on time will be short, getting close to the min on time. When the duty needs to be smaller than 2%, the LA1631 will keep the on time as min on time and extend the off time to regulate the output voltage, and keep stable and nice output ripple.

When the LA1631 works in pulse-frequency modulation (PFM) mode during light-load operation, the LA1631 reduces the switching frequency automatically to maintain high efficiency, and the inductor current drops almost to zero. When the inductor current reaches zero, the low-side driver enters tri-state (high-Z). The output capacitors discharge slowly to GND through R1 and R2. When VFB drops below the reference voltage, the HS-FET is turned on. This operation improves device efficiency greatly when the output current is low.

Enable (EN) Control

Enable (EN) is a digital control pin that turns the regulator on and off. Drive EN high to turn on the regulator. Drive EN low to turn off the regulator. An internal 1.7MΩ resistor from EN to GND allows EN to be floated to shut down the chip. EN is clamped internally using a 6V Zener diode. EN can be connected to VIN directly by a resistor.

The EN Pin can connect to V_{IN} by a pull-up resistor, but EN input current need below 400uA. For example, if V_{IN}=24V, the $I_{Zener}=(24-6)/R_{PULL-UP}<400\mu A$, SO, $R_{PULL-UP}>45K\Omega$.



Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. The LA1631 UVLO comparator monitors the input voltage. The UVLO rising threshold is about 4.3V, while its falling threshold is about 4 V.

Internal Soft Start (SS)

Soft start (SS) prevents the converter output voltage from overshooting during start-up. When the chip starts, the internal circuitry generates a soft-start voltage (V_{SS}) that ramps up from 0V to 1V. When SS is below REF, SS overrides REF, so the error amplifier uses SS as the reference. When SS exceeds REF, the error amplifier uses REF as the reference. The SS time is set to 0.6ms internally.

When LA1631 startup with large output capacitor, IC current limit will be triggered which will limit the output rising slew rate. To avoid false trigger the hiccup protection with large output capacitor during startup period. LA1631 internal soft start time will be automatically extended in this condition.

Large Duty Cycle Operation

When LA1631 will automatically extend the frequency to support the application when V_{IN} is close to V_{OUT} . The frequency extend circuit will be triggered when T_{off} min time is reached. The LA1631 can support up to 98% maximum duty cycle.

Over-Current Protection (OCP) and Short Circuit Protection (SCP)

The LA1631 has both valley current-limit control and peak current limit control. During LS-FET on, the inductor current is monitored. When the sensed inductor current reaches the valley current limit, the LS-FET limit comparator. The device enters overcurrent protection (OCP) mode, and the HS-FET waits until the valley current limit disappears before turning on again. During the HS-FET on period, the inductor current is sensed and compare with the peak current-limit. If the peak current limit is triggered, the ON pulse will be terminated immediately. The output voltage drops until V_{FB} is below the under voltage (UV) threshold (typically 50% below the reference). Once UV is triggered, the LA1631 enters hiccup mode to restart the part periodically.

During OCP, the device attempts to recover from the over-current fault with hiccup mode. In hiccup mode, the chip disables the output power stage, discharges the soft start, and attempts to soft start again automatically. If the over-current condition still holds after the soft start ends, the device repeats this operation cycle until the over-current condition is removed and the output rises back to regulation levels. OCP is a non-latch protection.

Pre-Bias Start-Up

The LA1631 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.

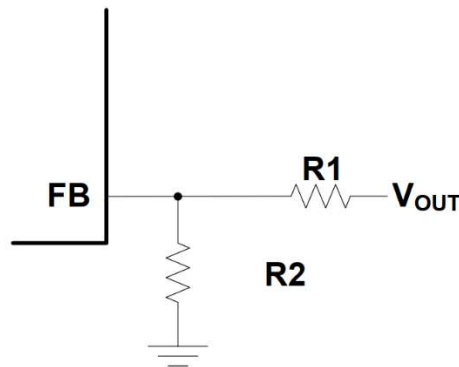
Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds its upper threshold, the entire chip shuts down. When the temperature falls below its lower threshold, the chip is enabled again.

Application Information

Setting the Output Voltage

The LA1631 output voltage can be set by the external resistor dividers. The reference voltage is fixed at 0.797V. The feedback network is shown below Figure.



Feedback Network

Choose R_1 and R_2 using Equation:

$$V_{OUT} = V_{FB} (R_1 + R_2) / R_2$$

Selecting the Inductor

For most applications, use a 3.3 μ H to 47 μ H inductor with a DC current rating at least 25% higher than the maximum load current. For the highest efficiency, use an inductor with a small DC resistance.

For most designs, the inductance value can be derived from Equation:

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

Where ΔI_L is the inductor ripple current.

Choose the inductor ripple current to be approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Table 1 lists the recommended feedback resistor values for common output voltages.

Table 1: Resistor Selection for Common Output Voltages ⁽⁷⁾

V _{OUT} (V)	R ₁ (k Ω)	R ₂ (k Ω)	L (μ H)	C _{OUT} (μ F)
12	210	15	22	10+470(Ecap)
5	604	115	4.7	22
3.3	604	191	3.3	22

Selecting the Output Capacitor

The output capacitor (C2, C3) maintains the DC output voltage ripple. Use ceramic, tantalum, or low-ESR electrolytic capacitors. For best results, use low ESR capacitors to keep the output voltage ripple low. The output voltage ripple can be estimated with Equation:

$$\Delta V_{OUT} = \frac{V_{OUT}}{F_{OSC} * L} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) * \left(R_{ESR} + \frac{1}{8 * F_{OSC} * C_{OUT}}\right)$$

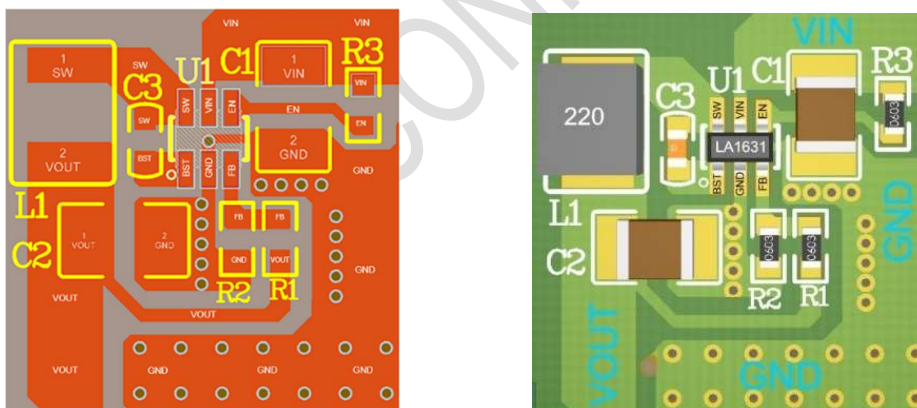
Where L is the inductor value, and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

The characteristics of the output capacitor also affect the stability of the regulation system. The LA1631 can be optimized for a wide range of capacitance and ESR values.

PCB layout Guidelines

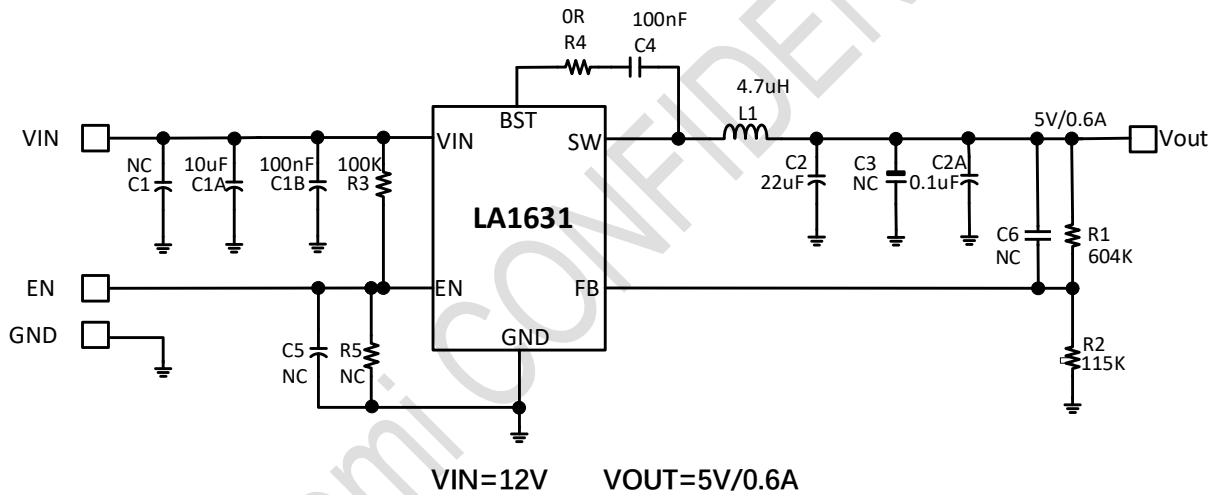
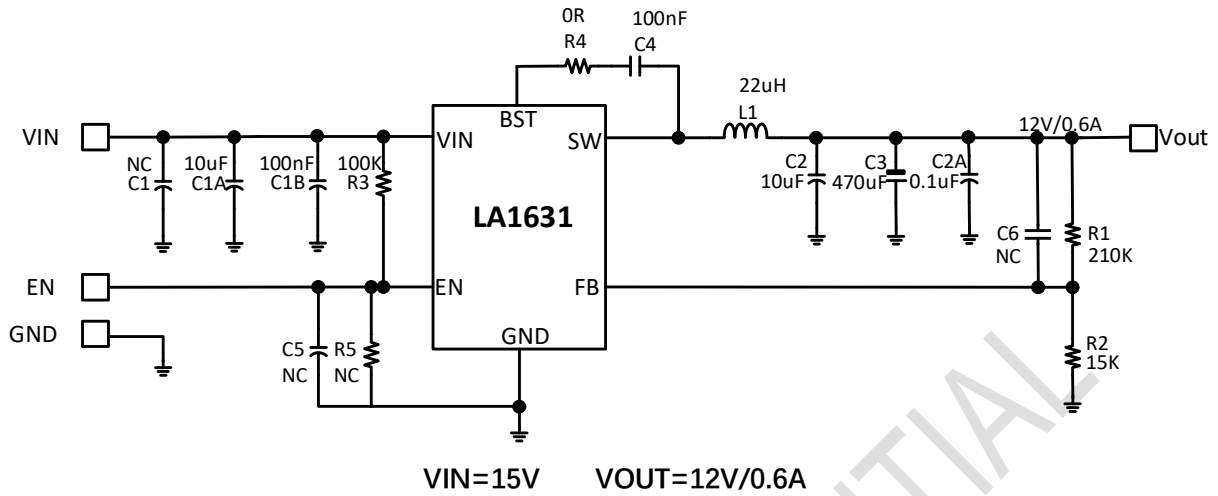
Efficient layout of the switching power supplies is critical for stable operation. For the high frequency switching converter, poor layout design may cause poor line or load regulation and stable issues. For best results, refer to below figure and follow the guidelines below.

- Place the input capacitor as close to VIN and GND as possible.
- Place the external feedback resistors as close to FB as possible.
- Keep the switching node (such as SW, BST) far away from the feedback network.
- Add a grid of thermal vias under the exposed pad to improve thermal conductivity.

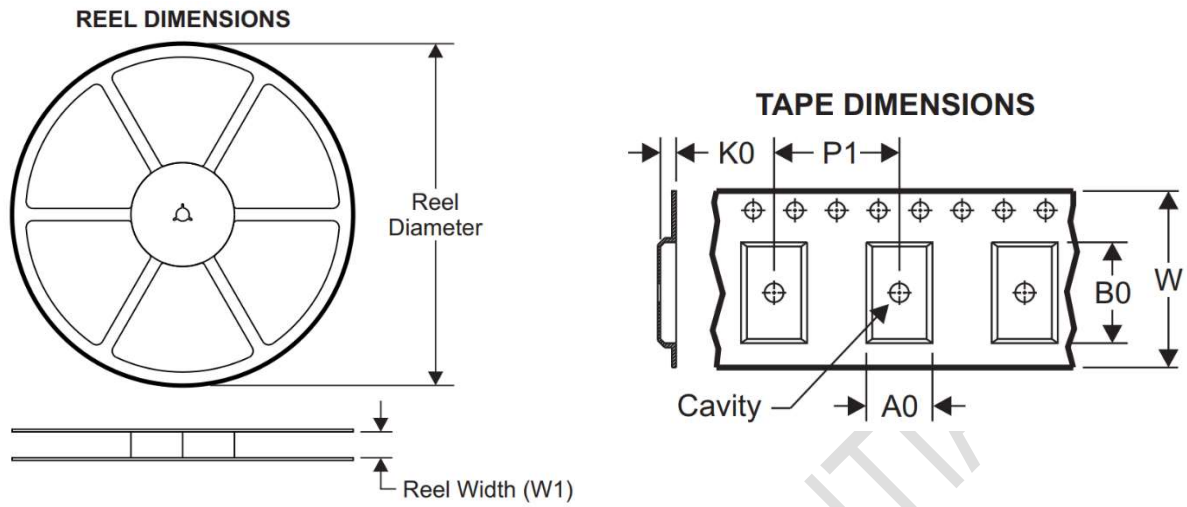




Typical Application Circuits



Tape and Reel Information



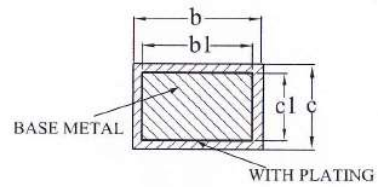
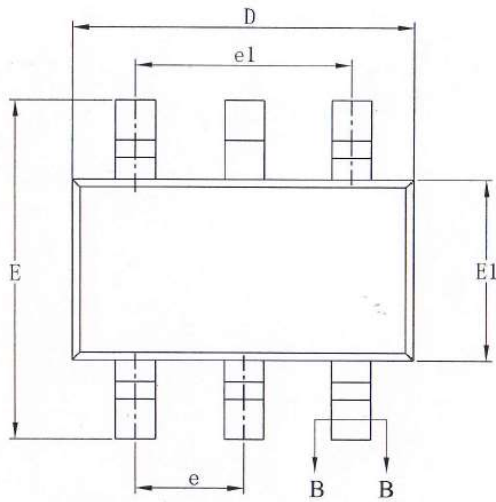
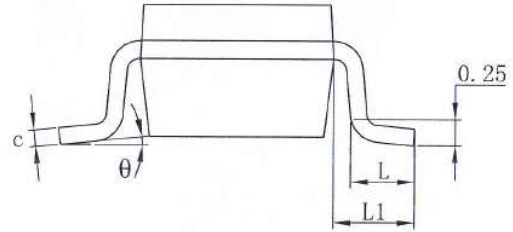
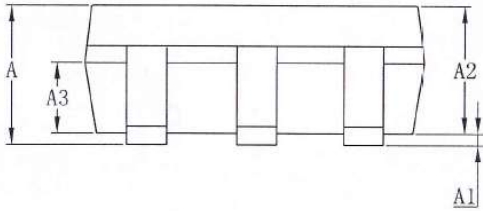
Information

Device	Package Type	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)
LA1631	SOT23-6	6	3000	180	8.6	3.26	3.3	1.4	4	8



Detail Package Outline Drawing

Package type: SOT23-6



SECTION B-B

SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.25
A1	0.04	—	0.10
A2	1.00	1.10	1.20
A3	0.60	0.65	0.70
b	0.33	—	0.41
b1	0.32	0.35	0.38
c	0.15	—	0.19
c1	0.14	0.15	0.16
D	2.82	2.92	3.02
E	2.60	2.80	3.00
E1	1.50	1.60	1.70
e	0.95BSC		
e1	1.90BSC		
L	0.30	—	0.60
θ	0	—	8°