High Efficiency 1MHz, 33V Output, Boost Converter

General Description

The SY26533 is a high efficiency, current-mode control, asynchronous Boost converter with an integrated 400mΩ $R_{DS(ON)}$ N-channel MOSFET. The fixed 1MHz switching frequency and internal compensation reduce external component count and save PCB space. The built-in internal soft start circuitry minimizes the inrush current at start-up.

When disabled SY26533 consumes only 5 µA of quiescent current to save power.

The device offers cycle-by-cycle current and thermal protections to ensure reliable operation.

Features

- Wide Input Range: 3-30V
- Output Voltage Range: VIN to $33V_{OUT, MAX}$
- 1MHz Switching Frequency
- Minimum ON Time: 100ns typical
- Minimum OFF Time: 100ns typical
- Low $R_{DS(ON)}$: 400mΩ
- RoHS Compliant and Halogen Free
- Accurate Reference: $1.24V_{REF}$
- Compact Package: SOT23-6

Applications

- Digital Cameras
- PDA, PMP, MP3
- LED/ Backlight Drivers

Typical Application

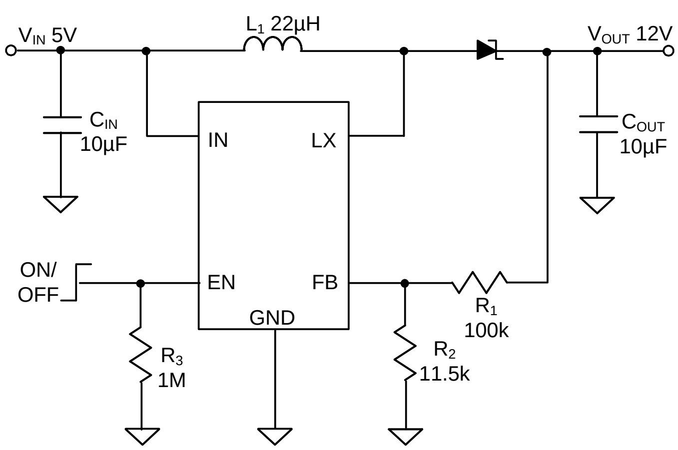


Figure 1. Schematic Diagram

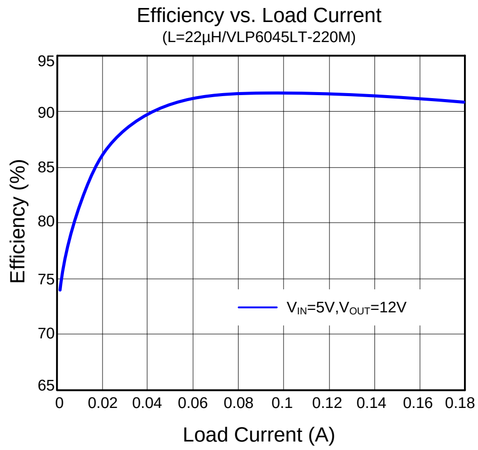


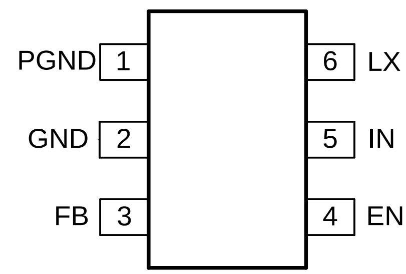
Figure 2. Efficiency vs. Load Current

Ordering Information

Ordering Part Number	Package Type	Top Mark
SY26533ABC	SOT23-6 RoHS Compliant and Halogen Free	**Y8*xyz***

x=year code, y=week code, z= lot number code

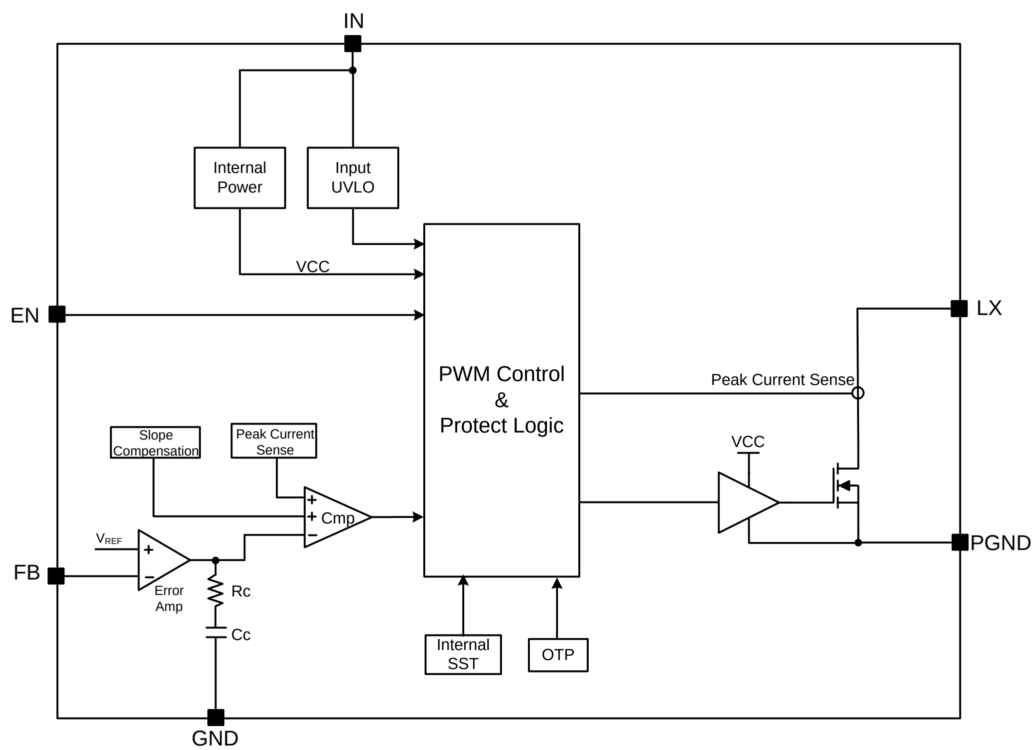
Pinout (top view)



Pin Description

Pin Name	Pin Number	Pin Description
PGND	1	Power ground pin.
GND	2	Signal ground pin.
FB	3	Feedback pin. Connect a resistor R_1 between V_{OUT} and FB, and a resistor R_2 between FB and GND to program the output voltage: $V_{OUT}=1.24V\times(R_1/R_2+1)$.
EN	4	Enable control. Drive high to turn on the device. Don't leave it floating.
IN	5	Input pin. Decouple this pin to the GND pin with a 10μF ceramic capacitor.
LX	6	Inductor node. Connect an inductor between the IN pin and the LX pin.

Function Block



Figue3. Block Diagram

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
LX	-0.3	36	V
IN, EN	-0.3	33	
FB	-0.3	4	
LX, 50ns Duration	IN+3	GND-4	
Lead Temperature (Soldering, 10 sec.)		260	°C
Junction Temperature, Operating	-40	150	
Storage Temperature	-65	150	

Thermal Information

Parameter (Note 2)	Typ	Unit
θ_{JA} Junction-to-ambient Thermal Resistance	161	°C/W
θ_{JC} Junction-to-case Thermal Resistance	130	
P_D Power Dissipation T_A=25°C	0.6	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
IN	3	30	V
Junction Temperature, Operating	-40	125	°C
Ambient Temperature	-40	85	

Electrical Characteristics

(V_{IN} = 5V, V_{OUT}=12V, I_{OUT}=100mA, T_J= -40°C to +125°C. Typical values are at T_J=25°C, unless otherwise specified. The values are guaranteed by test, design or statistical correlation.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		3		30	V
IN UVLO Rising Threshold	$V_{IN, UVLO}$		1.3		2.2	V
Quiescent Current	I_Q	V_{FB}=1.3V		100	150	μA
Shutdown Current	I_{SHDN}	EN=0		5	20	μA
Low Side Main FET R_{ON}	$R_{DS(ON)}$			400	600	mΩ
Main FET Current Limit	I_{LIM1}	55% Duty cycle	450	750	925	mA
Main FET Leakage Current	I_{LK}	EN=0			1	μA
Switching Frequency	fsw		0.8	1	1.32	MHz
Feedback Reference Voltage	V_{REF}		1.21	1.24	1.265	V
EN Rising Threshold	V_{ENH}		1.5			V
EN Falling Threshold	V_{ENL}				0.4	V
EN Leakage Current	I_{EN}	EN=5V	-1		1	μA
Max Duty Cycle	D_{MAX}		85	90		%
Min ON Time	$t_{ON, MIN}$			100	150	ns
Min OFF Time	$t_{OFF, MIN}$			10%	15%	T_S
Thermal Shutdown Temperature	T_{SD}			150		°C
Thermal Shutdown Hysteresis	T_{HYS}			10		°C

Note 1: Stresses beyond "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. 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.

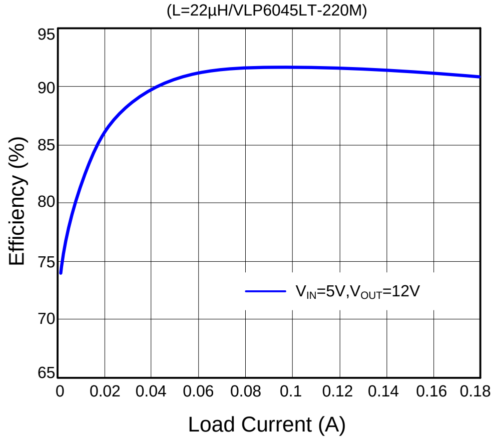
Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard. Test condition: Device mounted on 2” x 2” FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

Note 3: The device is not guaranteed to function outside its operating conditions.

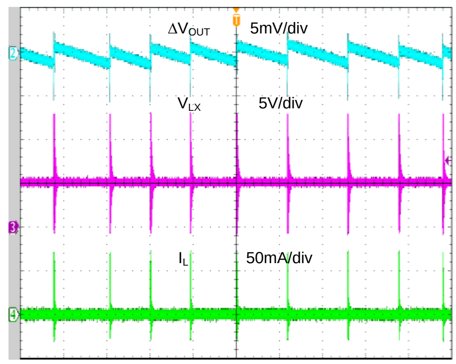
Typical Performance Characteristics (Boost)

(T_A= 25℃, V_{IN}=5V, V_{OUT} = 12V, L = 22μH, C_{OUT}= 10μF, unless otherwise specified)

Efficiency vs. Load Current
(L=22μH/VLP6045LT-220M)

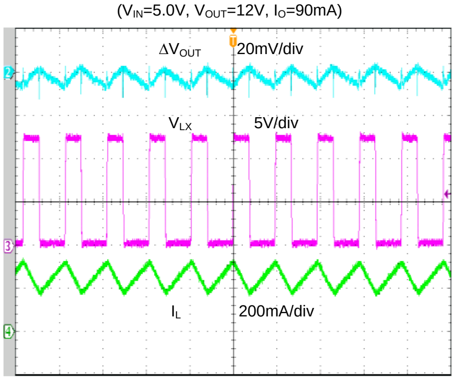


Output Ripple
(V_{IN}=5.0V, V_{OUT}=12V, I_O=0mA)



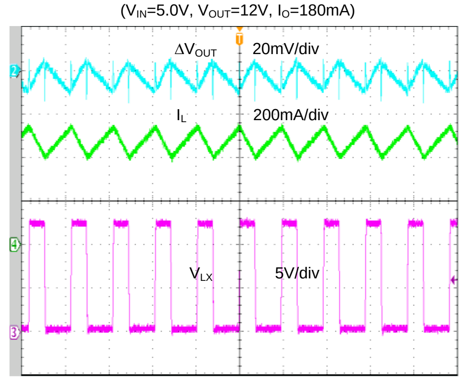
Time (100μs/div)

Output Ripple
(V_{IN}=5.0V, V_{OUT}=12V, I_O=90mA)



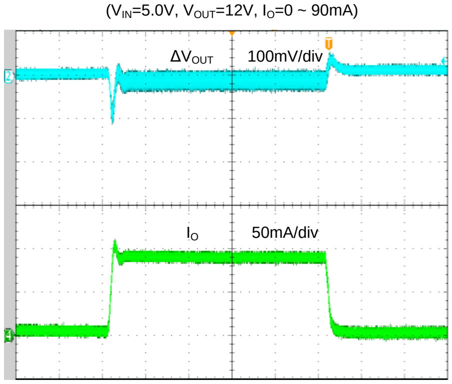
Time (1μs/div)

Output Ripple
(V_{IN}=5.0V, V_{OUT}=12V, I_O=180mA)



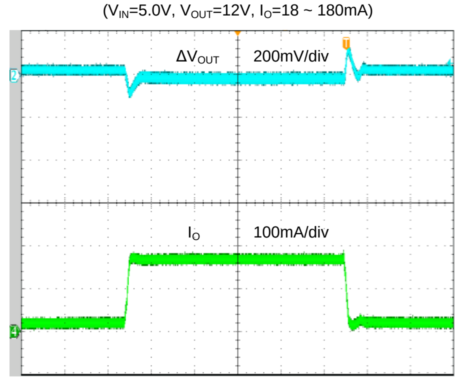
Time (1μs/div)

Load Transient
(V_{IN}=5.0V, V_{OUT}=12V, I_O=0 ~ 90mA)



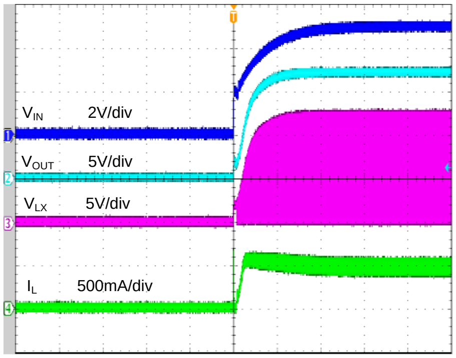
Time (400μs/div)

Load Transient
(V_{IN}=5.0V, V_{OUT}=12V, I_O=18 ~ 180mA)



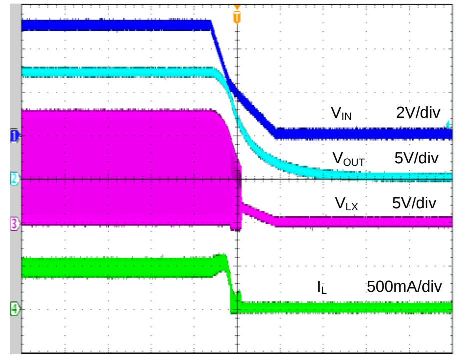
Time (400μs/div)

Startup from V_{IN}
(V_{IN}=5.0V, V_{OUT}=12V, I_O=180mA)



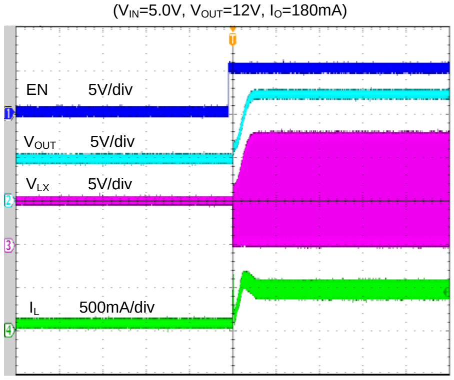
Time (4ms/div)

Shutdown from V_{IN}
(V_{IN}=5.0V, V_{OUT}=12V, I_O=180mA)



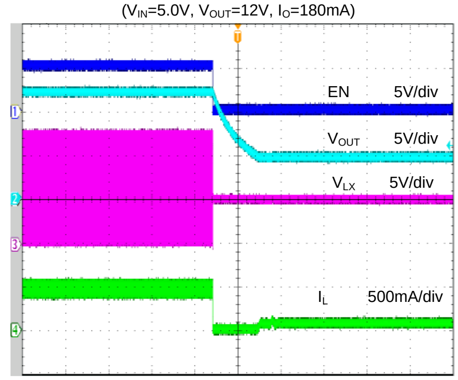
Time (2ms/div)

Startup from Enable
(V_{IN}=5.0V, V_{OUT}=12V, I_O=180mA)



Time (2ms/div)

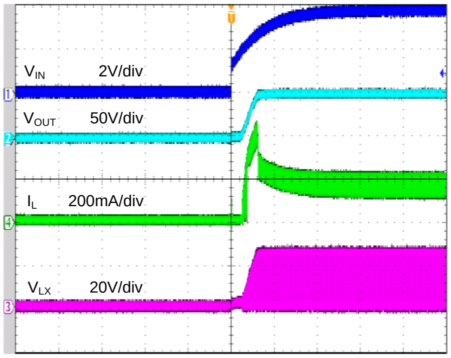
Shutdown from Enable
(V_{IN}=5.0V, V_{OUT}=12V, I_O=180mA)



Time (800μs/div)

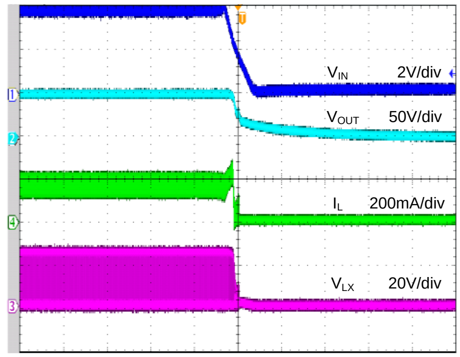
Typical Performance Characteristics (Charge pump)

Startup from V_{IN}
(V_{IN}=3.7V, V_{OUT}=50V, I_O=10mA)



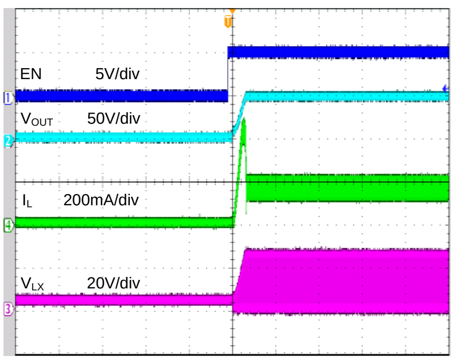
Time (4ms/div)

Shutdown from V_{IN}
(V_{IN}=3.7V, V_{OUT}=50V, I_O=10mA)



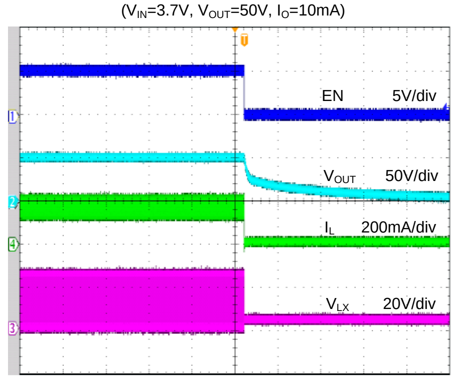
Time (4ms/div)

Startup from Enable
(V_{IN}=3.7V, V_{OUT}=50V, I_O=10mA)



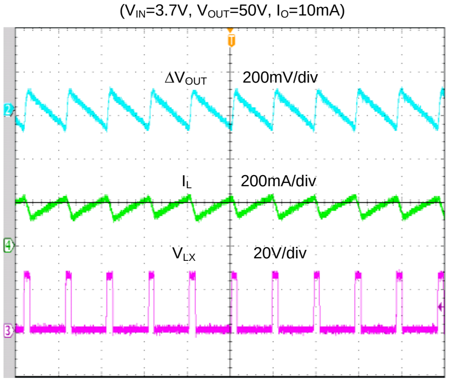
Time (2ms/div)

Shutdown from Enable
(V_{IN}=3.7V, V_{OUT}=50V, I_O=10mA)



Time (2ms/div)

Output Ripple
(V_{IN}=3.7V, V_{OUT}=50V, I_O=10mA)



Time (1μs/div)

Applications Information

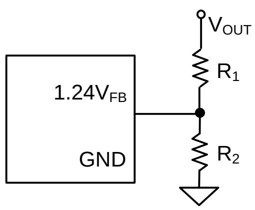
The SY26533 regulates the output using a peak current mode control loop. The device operates at a fixed frequency of around 1MHz. Each switching cycle starts by the MOSFET being turned on. As a result, the current through the inductor ramps up. The MOSFET is turned off when the current reaches the threshold level set by the error amplifier output. When the power MOSFET turns off, the external Schottky diode starts conducting. The operation repeats every switching cycle. An internal slope compensation is used to avoid subharmonic oscillation at duty cycles higher than 50%.

The following paragraphs provide information on selecting the components required when designing with SY26533, in order to meet the target specifications.

Feedback Resistor Dividers R_1 and R_2:

Choose R_1 and R_2 to program the proper output voltage. To minimize the power consumption under light loads, it is desirable to choose large resistance values for both R_1 and R_2. A value of between 10kΩ and 100kΩ is recommended for both resistors. If R_1=is chosen, then R_2 can be calculated to be:

$$R_2 = (R_1 \times 1.24V)/(V_{OUT} - 1.24V)$$



Input Capacitor C_{IN}:

When selecting an input capacitor ensure that its voltage rating is at least 20% greater than the maximum voltage of the input supply. X5R or X7R dielectric types are the most often selected due to their small size, low cost, surge current capability and high RMS current rating over wide temperature and voltage ranges.

In situations where the input rail is supplied through long wires it is recommended adding some bulk capacitance like electrolytic, tantalum or polymer type capacitors to reduce the overshoot and ringing caused by the added parasitic inductance.

Consider the RMS current rating of the input capacitor, paralleling additional capacitors if required to reduce the input voltage ripple.

A single 10 µF X5R capacitor is recommended for most applications.

Output Capacitor C_{OUT}:

The output capacitor is selected to handle the output ripple 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 a X5R or better grade ceramic capacitor with 50V rating and more than 10µF capacitance. Additional information on how to calculate the output capacitance required for meeting a target maximum voltage ripple is presented below:

When the main MOSFET is in the ON state, the switching current flowing to the load is filtered by the output capacitor. The voltage ripple is proportional with the load current. The minimum capacitance required for a specified output voltage ripple can be calculated using the following formula:

$$C_{OUT} = I_{LOAD} \times \frac{D}{(\Delta V_{OUT} \times fsw)}$$

Where I_{LOAD} is the maximum load current, D is the duty-cycle and ΔV_{OUT} is the maximum acceptable voltage ripple. The output voltage ripple contribution from the output capacitor(s) ESR can be calculated as:

$$\Delta V_{ESR} = I_{LOAD} \times R_{ESR}$$

Where R_{ESR} represents the equivalent series resistance of the output capacitors.

The total output ripple is the sum of the ripple caused by the capacitance and the ripple caused by the ESR of the capacitor.

Boost 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 average input current. The inductance is calculated as:

$$L = \left(\frac{V_{IN}}{V_{OUT}}\right)^2 \frac{(V_{OUT} - V_{IN})}{f_{SW} \times I_{OUT\_MAX} \times 40\%}$$

Where f_{SW} is the switching frequency and I_{OUT_MAX} is the maximum load current.

The SY26533 is tolerant to different ripple current amplitudes. Consequently, the final choice of the inductance can be slightly different than the calculated 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.

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

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<50mΩ to achieve a good overall efficiency.

Enable Operation

Pulling the EN pin low (<0.4V) will shut down the device. During the shutdown mode, the SY26533 current is reduced to lower than 5μA. Driving the EN pin high (>1.5V) enables normal operation.

Soft-start (EN Control)

The SY26533 has a built-in soft-start to control the rise rate of the output voltage and limit the inrush current during the start-up.

Diode Selection

Using a Schottky diode is recommended for achieving high efficiency, because of its low forward voltage drop and fast reverse recovery.

The Schottky diode reverse breakdown voltage should be higher than the maximum output voltage in the application.

The peak current through the Schottky diode is equal to the minimum saturation current of inductor estimated as:

$$I_{PEAK\_DIODE} = \left(\frac{V_{OUT}}{V_{IN} \times \eta}\right) \times I_{OUT\_MAX} + \frac{\Delta I_L}{2}$$

ΔIL is the inductor current ripple and can be calculated using the equation:

$$\Delta I_L = \frac{V_{IN} \times D}{f_{SW} \times L}$$

Where D is the duty-cycle, and can be calculated assuming that the device operates in continuous conduction mode (CCM) and at maximum load:

$$D = \frac{V_{OUT} - V_{IN\_MIN}}{V_{OUT}}$$

As an example, for a maximum load current of 50 mA, V_{INMIN} = 4.5V, V_{OUT} = 30V, L = 22 μH and η = 0.8 the following values can be calculated to obtain the maximum current through the Schottky diode:

D = 0.85

ΔIL = 0.174 A

I_{PEAK_DIODE} = 0.504A

A diode that can handle 1A of continuous current is recommended for most applications.

Light Load Operation

The SY26533 operates in burst mode during light load conditions to maintain high-efficiency. DCM operation is automatically initiated when the inductor current falls to zero. As the load decreases further the resulting switching frequency will also decrease in order to keep the output close to the target value.

Overcurrent Protection

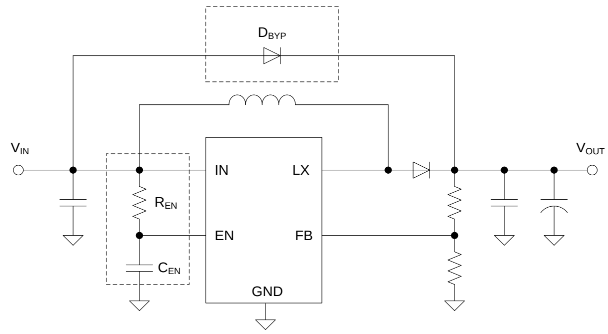
The SY26533 provides cycle by cycle overcurrent protection and turns off the power MOSFET once the inductor current reaches the overcurrent limit threshold. The limit status resets itself at the beginning of the next switching cycle. During the overcurrent protection, the output voltage drops as a function of the load on the output.

Thermal protection

The SY26533 includes over temperature protection circuitry to prevent overheating due to excessive power dissipation. This will shut down the device when the junction temperature exceeds 150°C. Once the junction temperature cools down by approximately 10°C, the device will resume normal operation after a complete soft-start cycle. For continuous operation, provide adequate cooling so that the junction temperature does not exceed the thermal protection threshold.

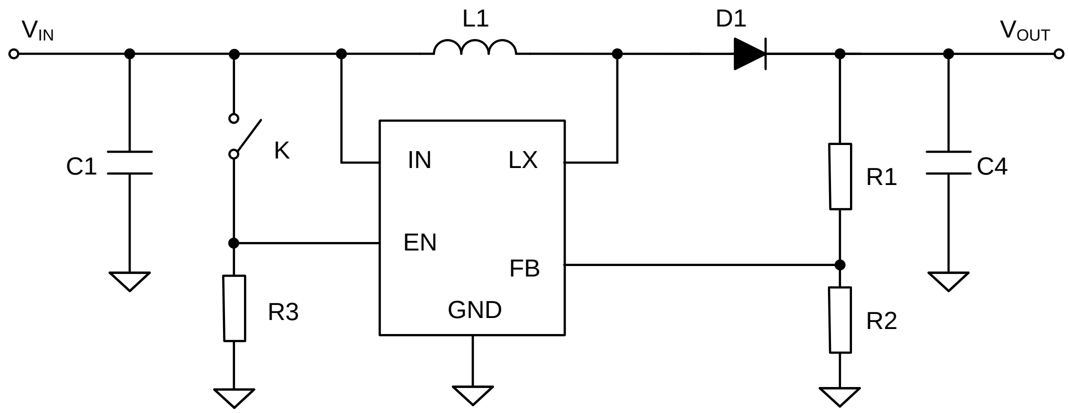
Applications with Large Bulk Capacitance

In applications with large bulk capacitance present on the output, a very high inrush current could flow through the inductor during power on. In order to limit the current flowing into the device and prevent damage, a Schottky diode connected from power input to the output, or a RC delay circuit added on the EN pin are recommended as shown below:



Typical Design

Typical Schematic



Design Specifications

Input Voltage (V)	Output Voltage (V)	Output Current Limit (A)
5-12	12	0.18

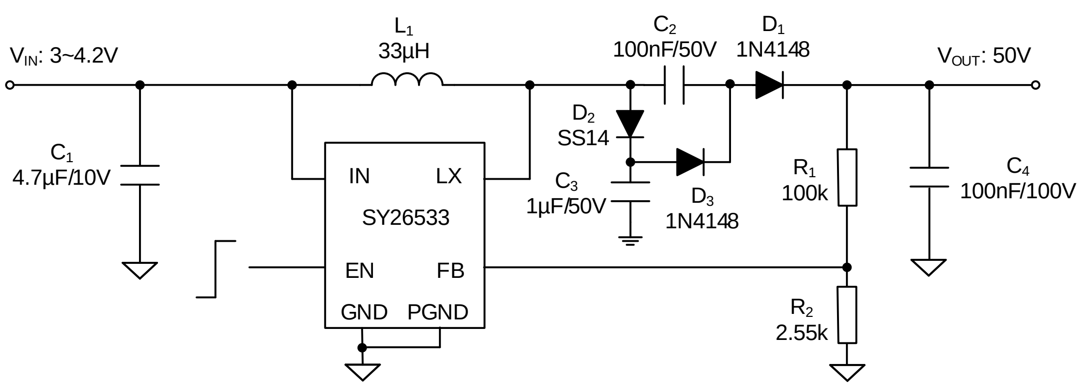
BOM List

Designator	Description	Part Number	Manufacturer
C_1, C_4	10μF/25V, 1206	C3216X7R1E106K	TDK
L_1	22μH	VLP6045-220M	
D_1	3A/40V, Schottky	SS34	
R_1	105kΩ, 1%, 0603		
R_2	12kΩ, 1%, 0603		
R3	1MΩ, 1%, 0603		

Recommend Table for Typical Applications

V_{OUT}(V)	R_H(kΩ)	R_L(kΩ)	L(μH)	C_{OUT}
12	105	12	22	10μF/25V/X7R,1206

Application Example 2 (Charge Pump Voltage Doubler)



Layout Design

The guidelines for the SY26533 regulator layout are presented below:

1) Place the following components close to the IC: C_{IN}, L, R_1 and R_2.

2) It is desirable to maximize the PCB copper area connecting to ground pin to achieve the best thermal transfer of the head and reduce switching noise. If the board space allows it, a ground plane or a large copper pour is highly desirable.

3) C_{IN} must be close to the IN pin and ground pin. The loop area formed by C_{IN} and ground pin must be minimized.

4) The PCB copper area associated with the LX pin must be minimized.

5) The components R_1, R_2 and the trace connecting to the FB pin must NOT be adjacent to the LX net on the PCB layout to avoid crosstalk.

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

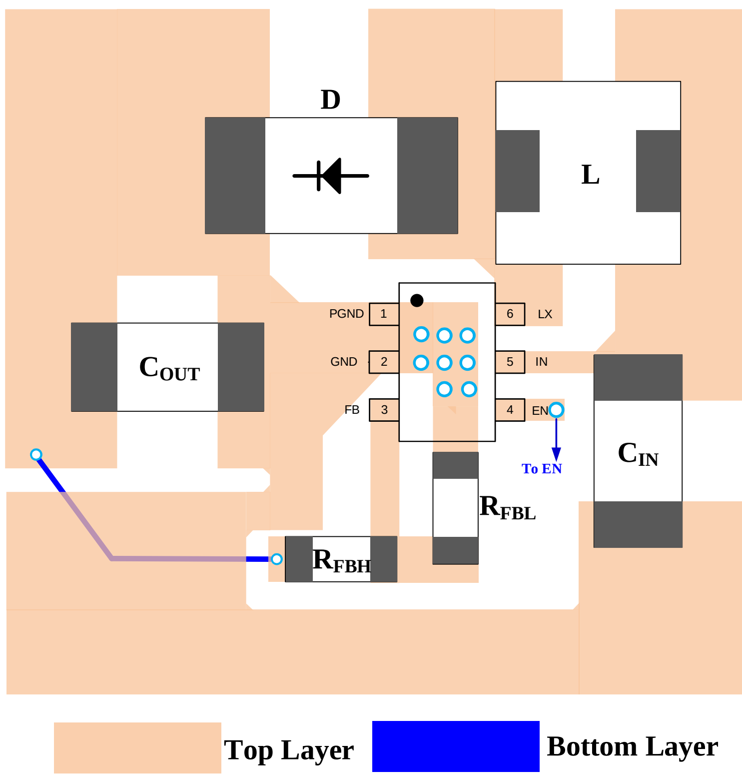


Fig.4 Boost Application

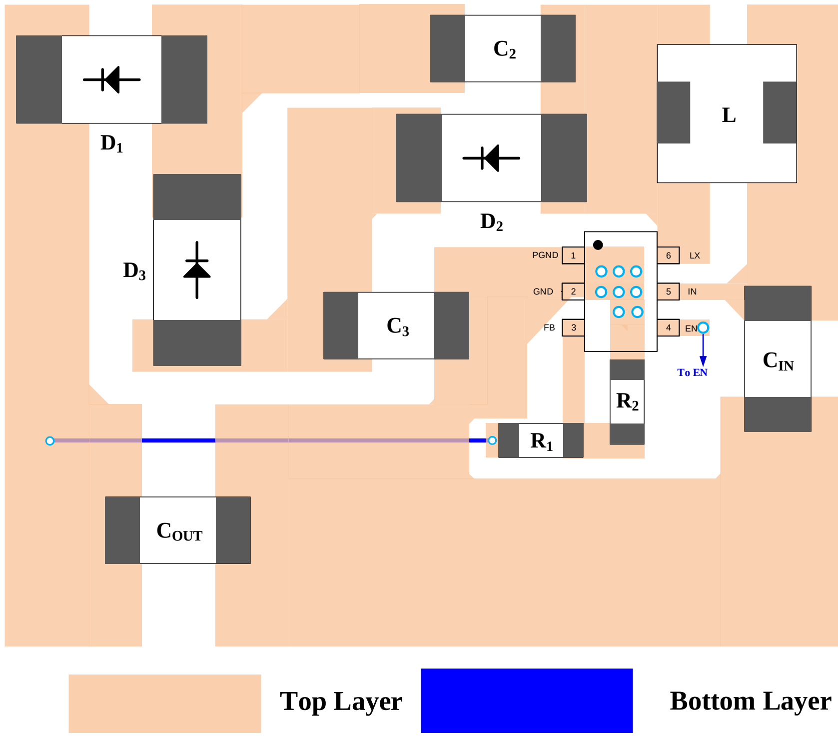
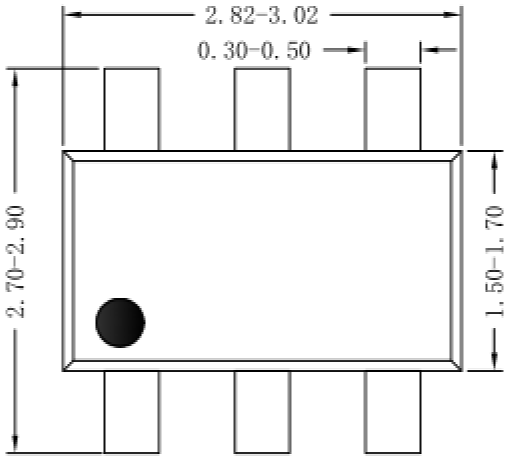
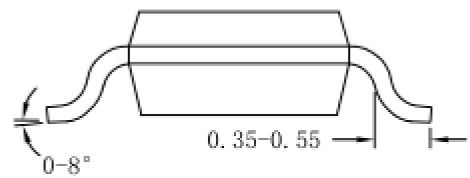


Fig.5 Charge Pump Application

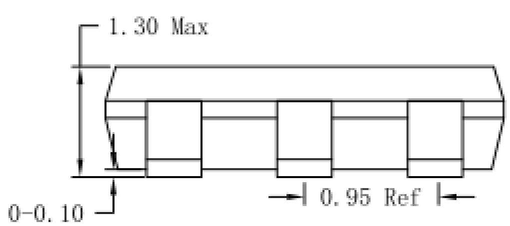
SOT23-6 Package Outline & PCB Layout Design



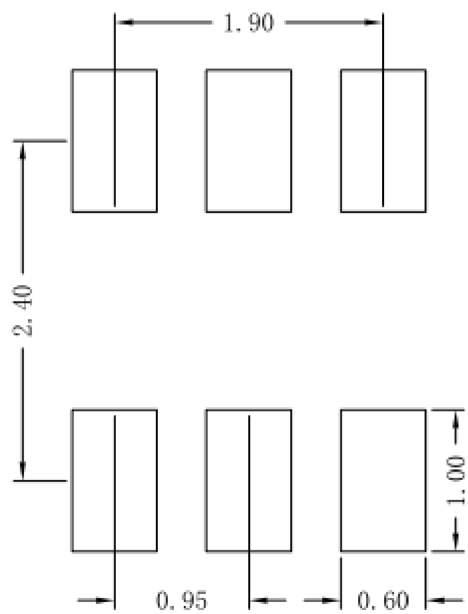
Top View



Side View



Side View

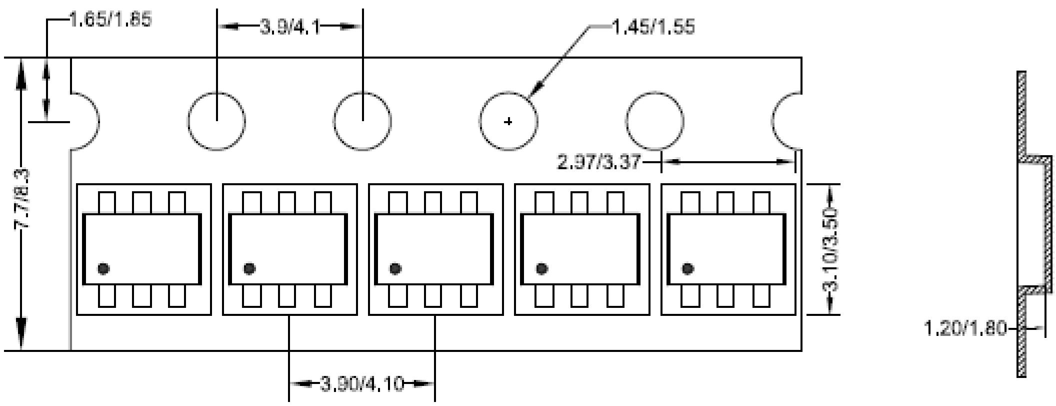


Recommended Pad Layout

Notes: **All dimension in millimeter and exclude mold flash & metal burr.**

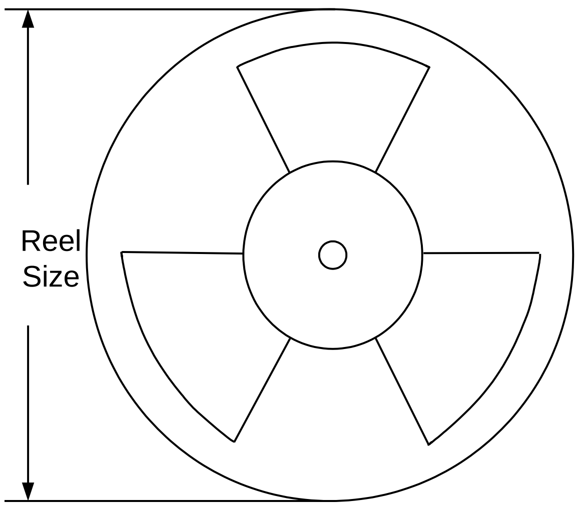
Taping & Reel Specification

1. Taping orientation for packages（SOT23-6）



Feeding direction ⟶

2. Carrier Tape & Reel specification for packages



Package type	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length (mm)	Leader length (mm)	Qty per reel
SOT23-6	8	4	7"	280	160	3000

3. Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
Apr.20, 2023	Revision 1.0	Language improvements for clarity.
June 20, 2021	Revision 0.9	Initial Release

IMPORTANT NOTICE

1. **Right to make changes.** Silergy and its subsidiaries (hereafter Silergy) reserve the right to change any information published in this document, including but not limited to circuitry, specification and/or product design, manufacturing or descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to Silergy's standard terms and conditions of sale.

2. **Applications.** Application examples that are described herein for any of these products are for illustrative purposes only. Silergy makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Buyers are responsible for the design and operation of their applications and products using Silergy products. Silergy or its subsidiaries assume no liability for any application assistance or designs of customer products. It is customer's sole responsibility to determine whether the Silergy product is suitable and fit for the customer's applications and products planned. To minimize the risks associated with customer's products and applications, customer should provide adequate design and operating safeguards. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Silergy assumes no liability related to any default, damage, costs or problem in the customer's applications or products, or the application or use by customer's third-party buyers. Customer will fully indemnify Silergy, its subsidiaries, and their representatives against any damages arising out of the use of any Silergy components in safety-critical applications. It is also buyers' sole responsibility to warrant and guarantee that any intellectual property rights of a third party are not infringed upon when integrating Silergy products into any application. Silergy assumes no responsibility for any said applications or for any use of any circuitry other than circuitry entirely embodied in a Silergy product.

3. **Limited warranty and liability.** Information furnished by Silergy in this document is believed to be accurate and reliable. However, Silergy makes no representation or warranty, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. In no event shall Silergy be liable for any indirect, incidental, punitive, special or consequential damages, including but not limited to lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges, whether or not such damages are based on tort or negligence, warranty, breach of contract or any other legal theory. Notwithstanding any damages that customer might incur for any reason whatsoever, Silergy' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Standard Terms and Conditions of Sale of Silergy.

4. **Suitability for use.** Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Silergy components in its applications, notwithstanding any applications-related information or support that may be provided by Silergy. Silergy products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of a Silergy product can reasonably be expected to result in personal injury, death or severe property or environmental damage. Silergy assumes no liability for inclusion and/or use of Silergy products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

5. **Terms and conditions of commercial sale**. Silergy products are sold subject to the standard terms and conditions of commercial sale, as published at http://www.silergy.com/stdterms, unless otherwise agreed in a valid written individual agreement specifically agreed to in writing by an authorized officer of Silergy. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. Silergy hereby expressly objects to and denies the application of any customer's general terms and conditions with regard to the purchase of Silergy products by the customer.

6. **No offer to sell or license**. Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights. Silergy makes no representation or warranty that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right. Information published by Silergy regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from Silergy under the patents or other intellectual property of Silergy.

For more information, please visit: www.silergy.com