SY21031

High-Efficiency, 1.2MHz, 55V Input, 0.8A Asynchronous Step-Down Regulator

General Description

The SY21031 high-efficiency asynchronous step-down DC/DC regulator is using an adaptive constant off-time architecture, and can deliver 0.8A current over a wide input voltage range from 4.5V to 55V. It integrates a main switch with low $R_{DS(ON)}$ to minimize conduction loss.

The 1.2MHz switching frequency permits low output-voltage ripple and reduces the external inductor and capacitor sizes. The SY21031 also provides cycle-by-cycle current limiting and hiccup short-circuit protection.

The feedback resistors (R_H and R_L), the input capacitor C_{IN}, the output capacitor C_{OUT}, the output inductor L, along with the freewheeling Schottky diode D1, need to be selected for the targeted application.

The SY21031 is available in a compact SOT23-6 package.

Features

- 4.5V to 55V Input Voltage Range
- Up to 0.8A Output Current
- Low $R_{DS(ON)}$ for Internal N-Channel Power FET: 700mΩ
- 1.2MHz Pseudoconstant Switching Frequency
- Adaptive Constant Off-Time Control
- Internal Soft-Start Limits Inrush Current
- ±1% 0.6V Reference
- Hiccup Mode Short-Circuit Protection
- EN On/Off Control with Accurate Threshold
- Cycle-by-Cycle Peak Current Limit
- RoHS-Compliant and Halogen-Free
- Compact SOT23-6 Package

Applications

- Non-Isolated Telecommunication Buck Regulator
- Secondary High-Voltage Post Regulator
- Automotive Systems

Typical Application

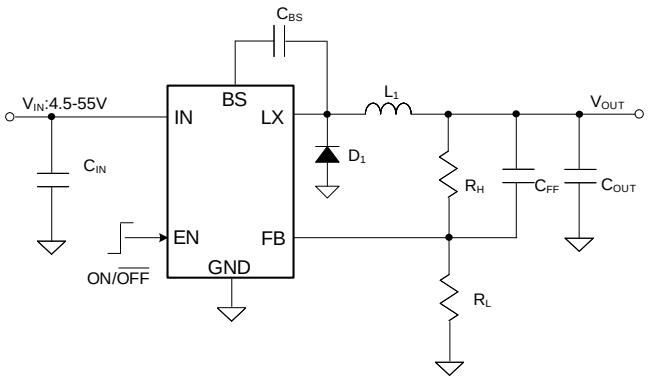


Figure 1. Typical Application Circuit

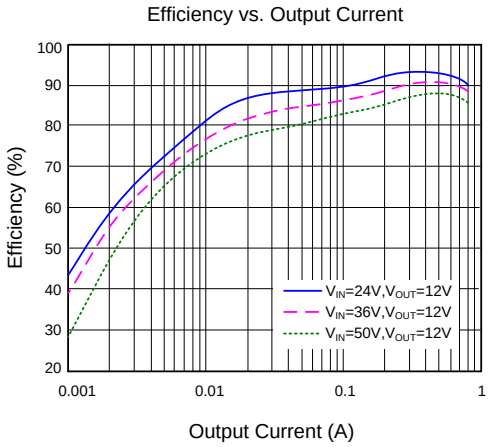


Figure 2. Efficiency vs. Output Current

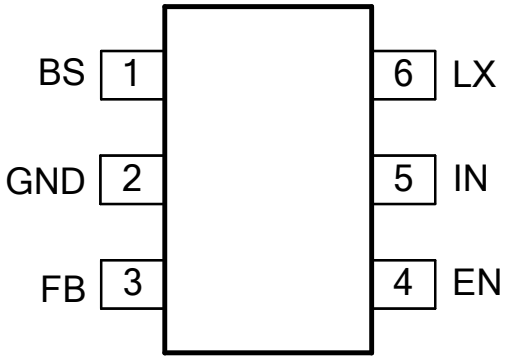
Ordering Information

SY21031□(□□)□
- Temperature Code
- Package Code
- Optional Spec Code

Ordering Part Number	Package type	Top Mark
SY21031ABC	SOT23-6 RoHS-Compliant and Halogen-Free	**My*xyz***

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

Pinout (top view)



(SOT23-6)

Pin Description

Pin No	Pin Name	Pin Description
1	BS	Bootstrap pin. Supply for the high-side gate driver. Connect a 0.1μF ceramic capacitor between the BS and the LX pin.
2	GND	Ground pin.
3	FB	Output feedback pin. Connect this pin to the center point of the output resistor-divider (as shown in Figure 1) to program the output voltage using the following equation: $V_{OUT} = 0.6 \times (1 + R_H / R_L)$
4	EN	Enable control pin. Pull high to turn on. Do not leave floating.
5	IN	Input pin. Decouple this pin to the GND pin with at least a 1μF ceramic capacitor.
6	LX	Inductor pin. Connect this pin to the switching node of the inductor.

Block Diagram

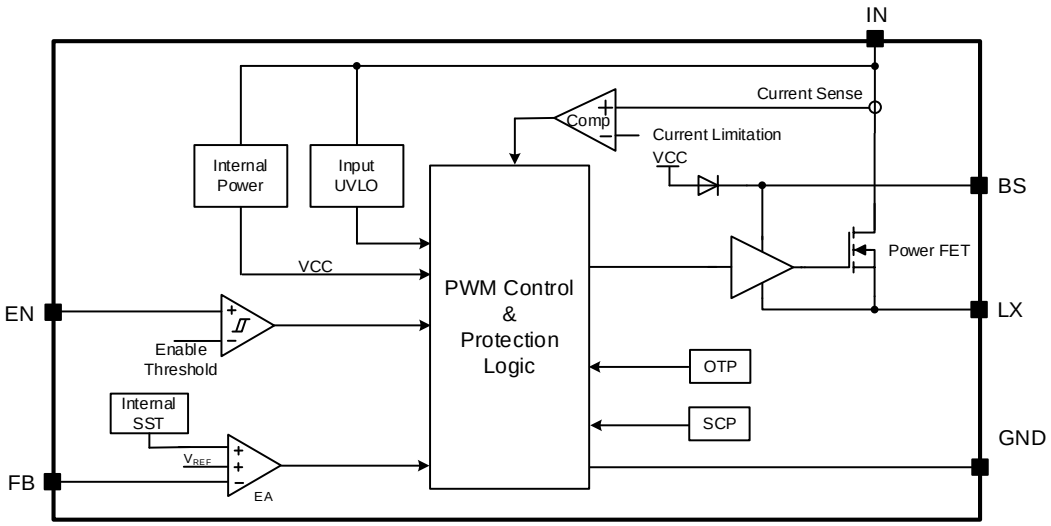


Figure 3. Block Diagram

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
IN	-0.3	60	V
FB, EN	-0.3	IN + 0.3	
BS-LX	-0.3	4	
Dynamic LX Voltage in 10ns Duration	GND - 5	IN + 3	
Junction Temperature, Operating	-40	150	°C
Lead Temperature (Soldering, 10s)		260	
Storage Temperature	-65	150	

Thermal Information

Parameter (Note 2)	Typ	Unit
θ_{JA} Junction-to-Ambient Thermal Resistance	100	°C/W
θ_{JC} Junction-to-Case Thermal Resistance	25	
P_D Power Dissipation T_A = 25°C	1	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
Supply Input Voltage	4.5	55	V
Junction Temperature	-40	125	°C
Ambient Temperature	-40	85	

Electrical Characteristics

(V_{IN} = 20V, V_{OUT} = 12V, L = 6.8µH, C_{OUT} = 10µF, T_A = 25°C, I_{OUT} = 0.1A unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Input	Voltage Range	V_{IN}		4.5		55	V
	UVLO Threshold	V_{UVLO}	V_{IN} rising			4.5	V
	Quiescent Current	I_Q	LX not switching		150		µA
	Shutdown Current	I_{SHDN}	EN = 0		5	10	µA
Output	Feedback Reference Voltage	V_{REF}		0.594	0.6	0.606	V
	Soft-Start Time	t_{SS}			1.4		ms
	FB Input Current	I_{FB}	$V_{FB} = V_{IN}$	-50		50	nA
MOSFET	Power FET $R_{DS(ON)}$	$R_{DS(ON)}$			700		mΩ
	Power FET Peak Current Limit	I_{LMT}		1.05		1.65	A
Enable (EN)	Rising Threshold	$V_{EN,H}$		1.18	1.23	1.28	V
	Falling Threshold	$V_{EN,L}$		0.94	1	1.06	V
Frequency	Switching Frequency	f_{SW}			1.2		MHz
	Switching Frequency Accuracy			-20		20	$\%f_{SW}$
	Min On-Time	$t_{ON,MIN}$			100		ns
	Min Off-time	$t_{OFF,MIN}$			80		ns
OTP	Temperature	T_{OTP}			150		°C
	Temperature Hysteresis	$T_{OTP,HYS}$			15		°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 may affect device reliability.

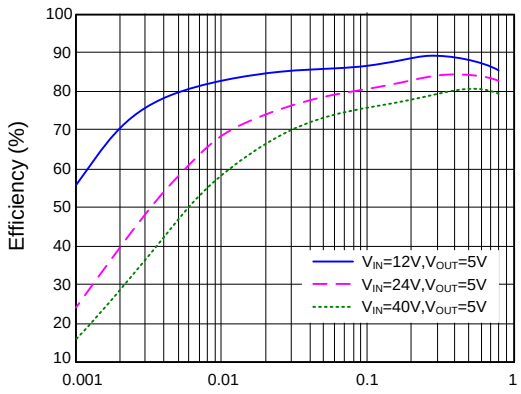
Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a high effective thermal conductivity four-layer test board per JESD51-7. Pin 2 of SOT23-6 package is the case position for θ_{JC} measurement.

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

Typical Performance Characteristics

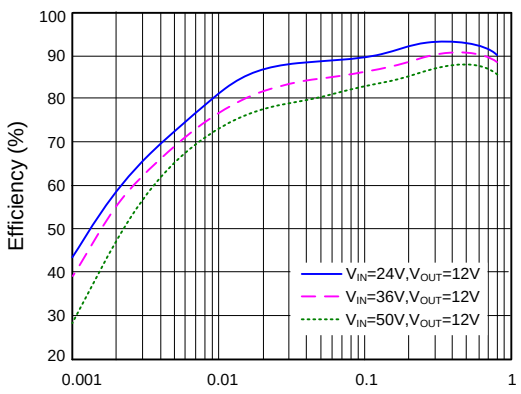
(T_A = 25°C, V_{IN} = 24V, V_{OUT} = 12V, L = 22μH, C_{OUT} = 22μF, unless otherwise specified)

Efficiency vs. Output Current



Output Current (A)

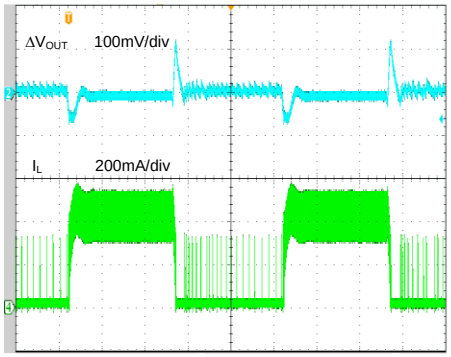
Efficiency vs. Output Current



Output Current (A)

Load Transient

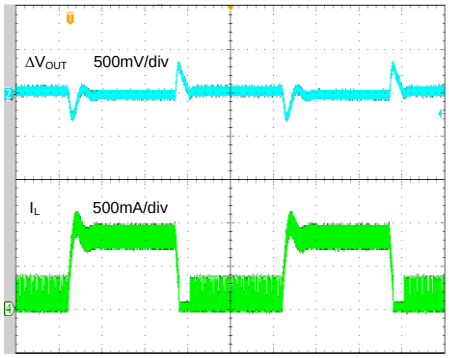
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0A~0.4A)



Time (200μs/div)

Load Transient

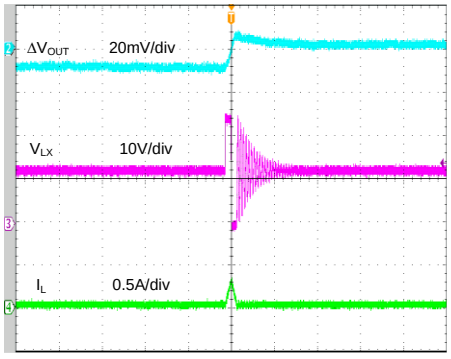
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.08A~0.8A)



Time (200μs/div)

Output Ripple

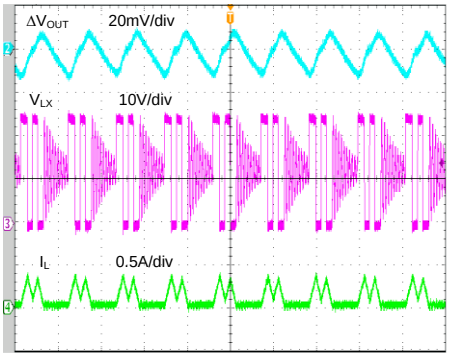
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0A)



Time (4μs/div)

Output Ripple

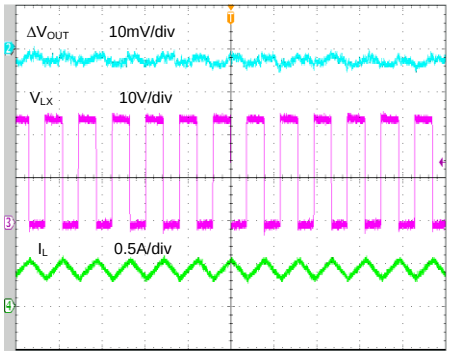
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.08A)



Time (4μs/div)

Output Ripple

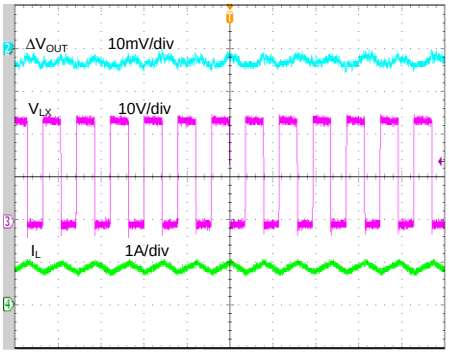
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.4A)



Time (1μs/div)

Output Ripple

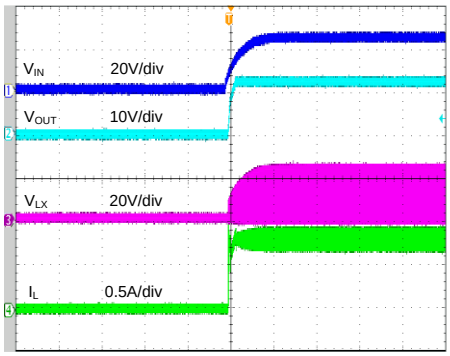
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (1μs/div)

Startup from V_{IN}

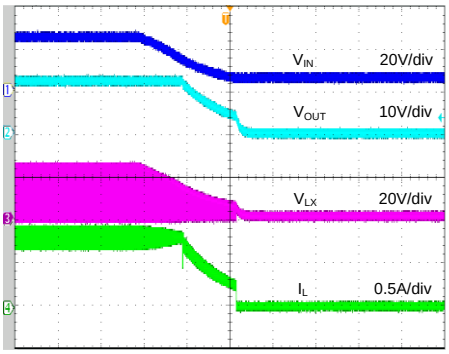
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (10ms/div)

Shutdown from V_{IN}

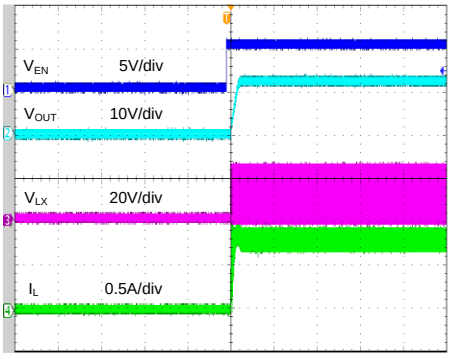
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (4ms/div)

Startup from Enable

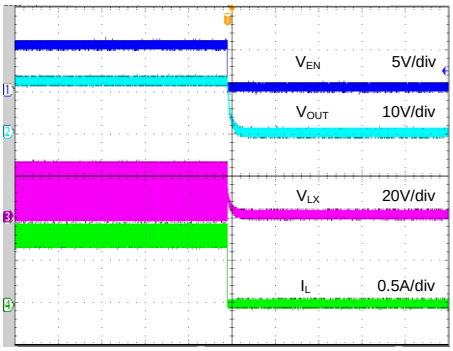
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (4ms/div)

Shutdown from Enable

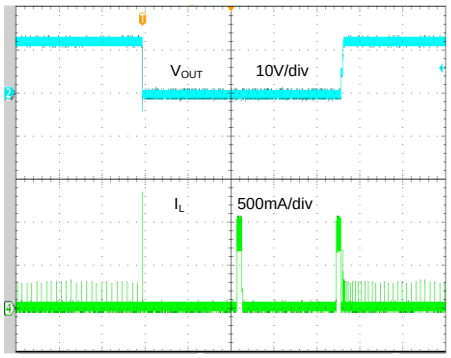
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (4ms/div)

Short Circuit Protection

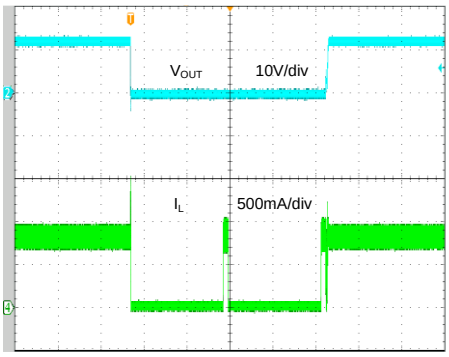
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0A~Short)



Time (20ms/div)

Short Circuit Protection

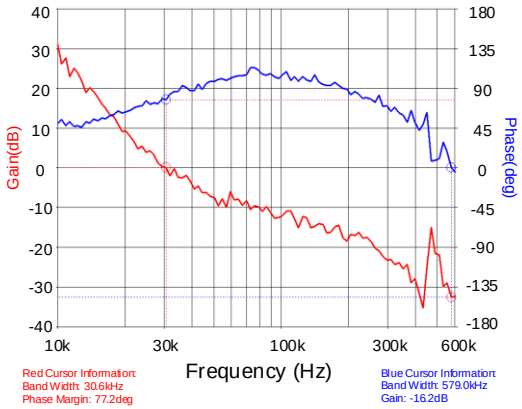
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A~Short)



Time (20ms/div)

Bode Plot

(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.4A)



Detailed Description

The SY21031 high-efficiency asynchronous step-down DC/DC regulator is controlled using adaptive constant off-time, and can deliver 0.8A current over a wide input voltage range from 4.5V to 55V. It integrates a main switch with low $R_{DS(ON)}$ to minimize conduction loss.

The 1.2MHz switching frequency permits low output-voltage ripple and reduces external inductor and capacitor sizes. The SY21031 also provides cycle-by-cycle current limiting and hiccup short-circuit protection.

The SY21031 employs a constant off time and peak current mode control strategy. When the FET's current-sense signal reaches internal V_{COMP}, the FET turns off for a fixed period of time (constant t_{OFF}). t_{OFF} is internally calculated according to the input voltage, output voltage, and desired switching frequency (f_{SW}):

$$t_{OFF} = \frac{1 - V_{OUT}/V_{IN}}{f_{SW}}$$

The FET turns on after a period of t_{OFF}.

Schottky Diode

An external Schottky diode is required between the SW pin and GND to carry the inductor current when the internal switch is turned off. The recommended breakdown voltage should be at least 20% higher than the maximum input voltage. The diode current rating should be equal to the maximum output current. A 1A rated diode is recommended for most use cases.

Enable Control

Pulling the EN pin low (less than 0.94V) will shut down the device. During shutdown mode, the SY21031 shutdown current drops below 10μA. Driving the EN pin high (greater than 1.28V) will turn the IC on again.

External Bootstrap Capacitor

The external bootstrap capacitor provides the gate driver voltage for the internal high-side MOSFET. A 100nF low-ESR ceramic capacitor connected between the BS pin and the LX pin is recommended.

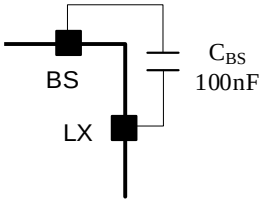


Figure 4. Bootstrap Capacitor Connection

Fault Protection Modes

Output Undervoltage Protection

With load current increasing, as soon as the FET's current exceeds the peak current-limit threshold, the FET will turn off. If the load current continues to increase, the output voltage will drop. When the output voltage falls below 33% of the regulation level, the output undervoltage protection will be activated and the SY21031 will operate in hiccup mode. The hiccup on-time is 5ms and the hiccup off-time is 50ms. If the hard short is removed, the SY21031 will return to normal operation.

Overtemperature Protection (OTP)

Instant-PWM architecture includes overtemperature protection (OTP) 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 by approximately 15°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 OTP threshold.

Application Information

The following paragraphs describe the selection process for the feedback resistors (R_H and R_L), the input capacitor C_{IN}, the output capacitor C_{OUT}, and the output inductor L.

Feedback Resistor-Divider RH and RL

Choose R_H and R_L to program the proper output voltage. Choose large resistance values between 10kΩ and 1MΩ for both R_H and R_L to minimize power consumption under light loads. If V_{OUT} = 1.2V and a value of 100kΩ is chosen for R_H, then using the following equation, R_L can be calculated as 100kΩ:

$$R_L = \frac{0.6V}{V_{OUT}\text{-}0.6V} R_H$$

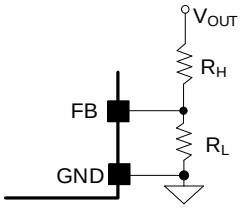


Figure 5. Feedback Resistor Selection

Input Capacitor C_{IN}

Input filter capacitors reduce the ripple voltage on the input, filter the switched current drawn from the input supply, and reduce EMI. When selecting an input capacitor, be sure to select a voltage rating at least 20% greater than the maximum voltage of the input supply and a temperature rating higher than the system requirements. X5R series ceramic capacitors are most often selected due to their small size, low cost, surge-current capability, and high RMS current ratings over a wide temperature and voltage range. However, systems that are powered by a wall adapter or other long and therefore inductive cabling may be susceptible to significant inductive ringing at the input to the device. In these cases, consider adding some bulk capacitance like electrolytic, tantalum, or polymer type capacitors. Using a combination of bulk capacitors (to reduce overshoot or ringing) in parallel with ceramic capacitors (to meet the RMS current requirements) is helpful in these cases.

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

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

The worst-case condition occurs at D = 0.5, then

$$I_{CIN\_RMS,MAX} = \frac{I_{OUT}}{2}$$

For simplicity, use an input capacitor with an RMS current rating greater than 50% of the maximum load current.

The input capacitor value determines the input voltage ripple of the converter. If there is a voltage ripple requirement in the system, choose an appropriate input capacitor that meets the specification.

Given the very low ESR and ESL of ceramic capacitors, the input voltage ripple can be estimated using the formula:

$$V_{CIN\_RIPPLE,CAP} = \frac{I_{OUT}}{f_{SW} \times C_{IN}} \times D \times (1-D)$$

The worst-case condition occurs at D = 0.5, then

$$V_{CIN\_RIPPLE,CAP,MAX} = \frac{I_{OUT}}{4 \times f_{SW} \times C_{IN}}$$

The capacitance value is less important than the RMS current rating. A single 10µF X5R capacitor is sufficient in most applications.

Output Capacitor C_{OUT}

The output capacitor is selected to handle the output ripple noise requirements. Both steady state ripple and transient requirements must be taken into consideration when selecting this capacitor. For most applications, an X5R or better grade ceramic capacitor larger than 22µF capacitance can work well. The capacitance derating with DC voltage must be considered.

Output Inductor L

Consider the following when choosing this inductor:

1) Choose the inductance to provide a ripple current that is approximately 40% of the maximum output current. The recommended inductance is calculated as:

$$L = \frac{V_{OUT}(1 - V_{OUT} / V_{IN,MAX})}{f_{sw} \times I_{OUT,MAX} \times 0.4}$$

where f_{SW} is the switching frequency and $I_{OUT,MAX}$ is the maximum load current.

The SY21031 has high tolerance for ripple current amplitude variation. As a result, the final choice of inductance can vary slightly from the calculated value with no significant performance impact.

2) The inductor's saturation current rating must be greater than the peak inductor current under full load:

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

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

Load-Transient Considerations

The SY21031 regulator integrates compensation components to achieve fast transient responses and improved stability. In some applications, adding a 22pF ceramic capacitor in parallel with R_H may further speed up the load-transient responses and is therefore recommended for applications with large load-transient step requirements

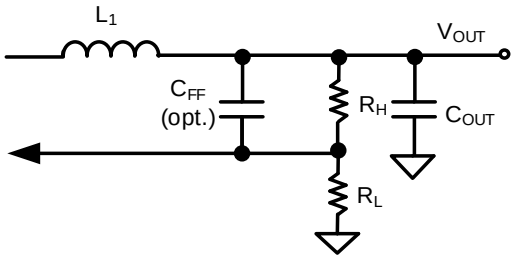
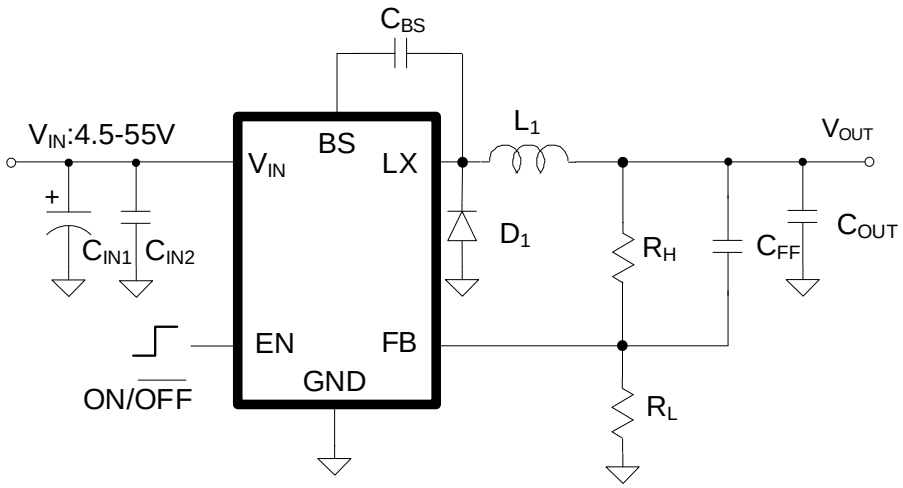


Figure 6. Feed-Forward Network

Application Schematic (V_{OUT} = 12V)



BOM List

Designator	Description	Part Number	Manufacturer
D_1	3A, 100V Schottky	SS310	
C_{IN1}	47μF/100V Electrolytic Cap		
C_{IN2}	1.0μF/100V/1206	GRM31CR72A105K	mμRata
C_{BS}	0.1μF/50V/0603	C1608X7R1H104K	TDK
C_{FF}	47pF/50V/0603	C1608C0G1H470J	TDK
C_{OUT}	22μF/16V/1206	C3216X5R1C226M	TDK
L_1	22μH/1.6A inductor	VLP6045LT-220M	TDK
R_H	100kΩ, 1%, 0603		TDK
R_L	5.23kΩ, 1%, 0603		TDK

Recommend Component Values for Typical Applications

V_{OUT}(V)	R_H(kΩ)	R_L(kΩ)	C_{FF}(pF)	L_1/Part Number
5	100	13.7	47	10μH/VLP6045LT-100M
12	100	5.23	47	22μH/VLP6045LT-220M

Layout Design

Follow these PCB layout guidelines for optimal performance and thermal dissipation.

- **Input Capacitors:** Place the input capacitor very near IN and GND, minimizing the loop formed by these connections. Connect the input capacitor to the IN and GND pins using a wide copper plane. A 0.1μF input ceramic capacitor is recommended to reduce input noise.
- **Output Capacitors:** Guarantee the C_{OUT} negative sides are connected to the GND pin by wide copper traces instead of vias, in order to achieve better accuracy and stability of the output voltage.
- **Feedback Network and Output Line:** Place the feedback components (C_{FF}) as close to the FB pin as possible. Avoid routing the feedback line near LX, BS or other high-frequency signals as it is noise-sensitive. Use a Kelvin connection between the feedback sampling point and C_{OUT} (rather than connecting it to the inductor output terminal).
- **LX Connection:** Keep LX area small to prevent excessive EMI, while providing wide copper traces to minimize parasitic resistance and inductance.
- **BS Capacitor:** Place the BS capacitor on the same layer as the device and keep the BS voltage path (BS, LX, and C_{BS}) as short as possible.
- **Control Signals:** If the system chip interfacing with the EN pin has a high impedance state during shutdown mode, and the IN pin is connected directly to a power source such as a Li-ion battery, add a 1MΩ pulldown resistor between the EN and GND pins to prevent noise from falsely triggering the regulator during shutdown mode.
- **GND Vias:** Place adequate number of vias on the GND layer around the device for better thermal performance. Especially, make one good thermal heating GND copper trace.

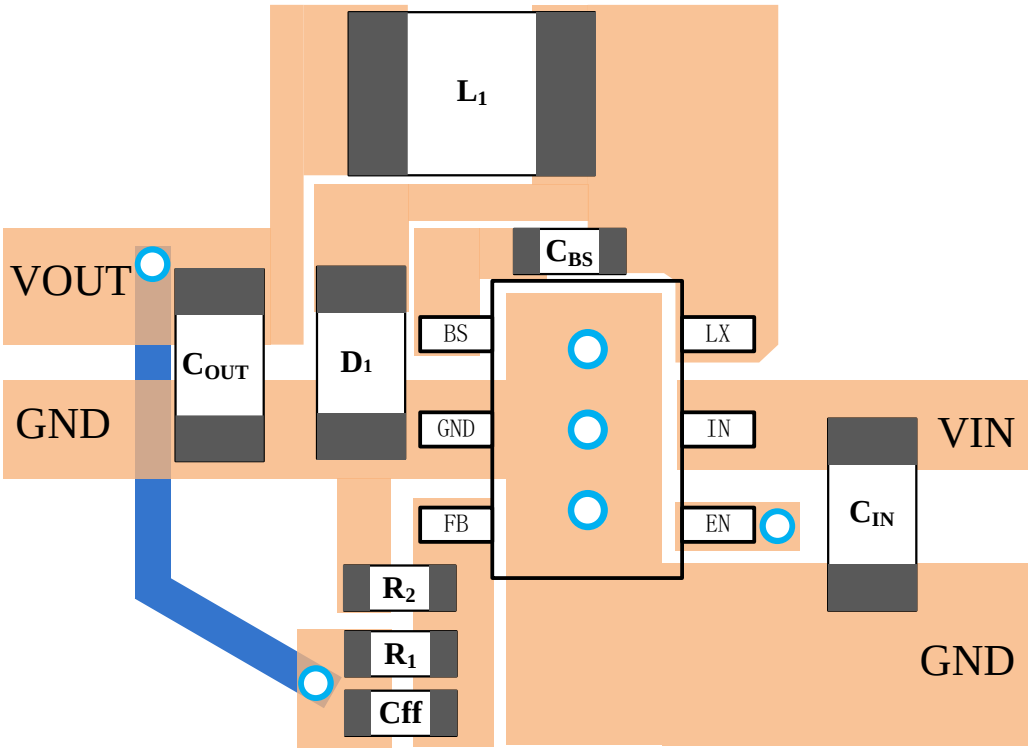
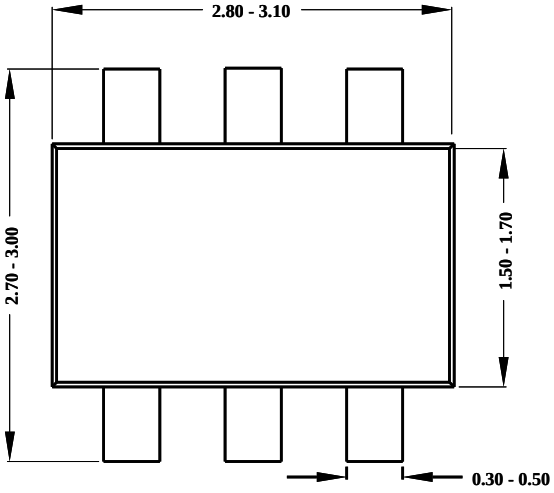
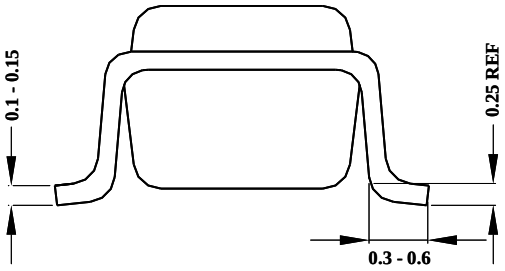


Figure 7. Suggested PCB Layout

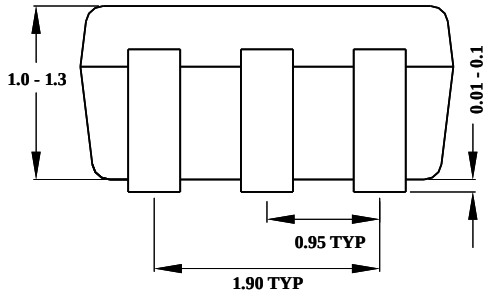
SOT23-6 Package Outline and PCB Layout



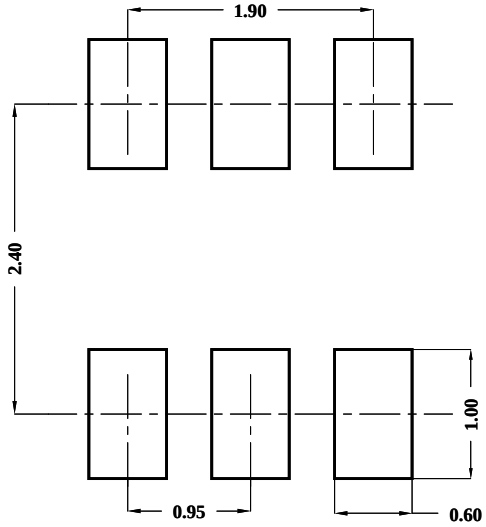
Top view



Side view



Front view

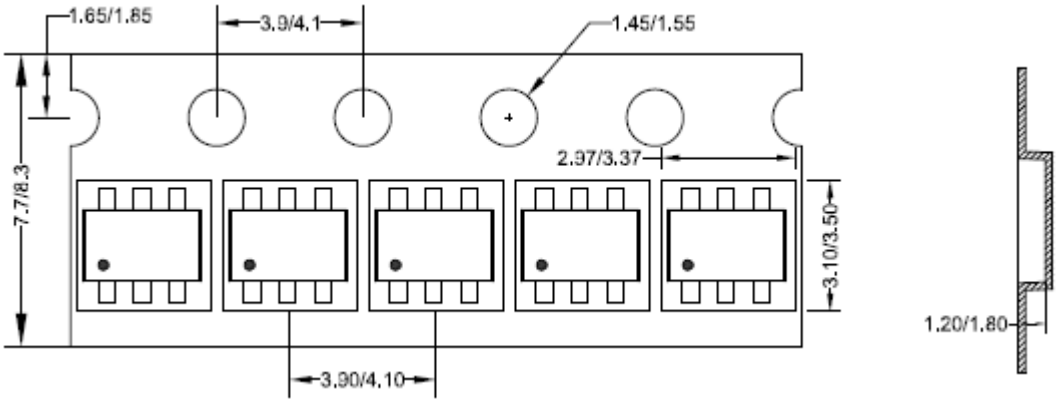


Recommended pad layout (reference only)

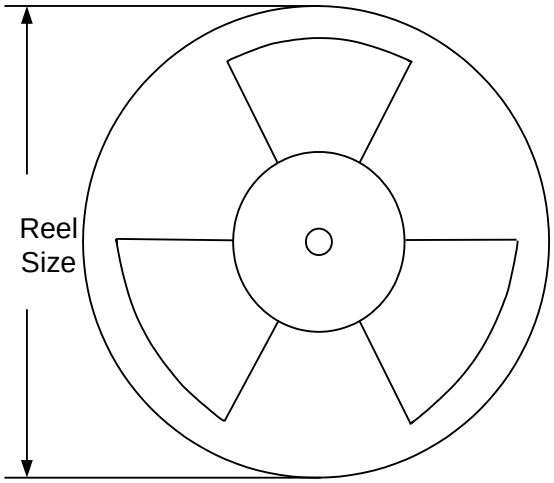
Note: *All dimensions are in millimeters and exclude mold flash and metal burr.*

Taping and Reel Specification

SOT23-6 taping orientation



Carrier tape and reel specification for packages



Package types	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

Others: NA

Revision History

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

Date	Revision	Change
Aug.17,2023	Revision 1.0	Language improvements for clarity
Dec.12.2018	Revision 0.9A	Update in Absolute Maximum Rating (Page 3)
Dec.19, 2016	Revision 0.9	Initial Release

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