SY21082

High-Efficiency, Fast-Response, 2A, 18V Input Synchronous Step-Down Regulator

General Description

The SY21082 high-efficiency synchronous step-down DC/DC regulator operates over a wide input voltage range of 4.2V to 18V, and can deliver an output current up to 2A. It integrates a main switch and a synchronous switch with very low $R_{DS(ON)}$ to minimize conduction loss. The 500kHz pseudo-constant switching frequency enables using small external inductor and capacitor values.

The SY21082 operates using Instant-PWM™ architecture to achieve high efficiency at light loads and fast transient response for applications with high step-down ratios. It also provides cycle-by-cycle current limiting and thermal shutdown protection.

The SY21082 is available in a SOT23-6 package.

Features

- 4.2V to 18V Input Voltage Range
- Up to 2A Output Current
- Quiescent Current I_Q: 200 μA (typ.)
- Shutdown Current I_{SHDN}: 5 μA (typ.)
- Low $R_{DS(ON)}$ for Internal Switches: 130mΩ Top, 105mΩ Bottom
- 500kHz Switching Frequency Minimizes Required External Components
- Constant-On-Time and Ripple-Based Control
- Stable with 10μF C_{OUT} and 2.2μH Inductor
- Instant-PWM Architecture to Achieve Fast Transient Responses
- Cycle-by-Cycle Peak/Valley Current Limits
- Internal Soft-Start Limits the Inrush Current
- Hiccup Mode for Short-Circuit Protection
- Thermal Shutdown with Auto-Recovery
- Output Auto-Discharge Function
- RoHS-Compliant and Halogen-Free
- Compact Package: SOT23-6

Applications

- Set-Top Box
- LCD TV
- DSL Modem/Networking
- IP Camera

Typical Application

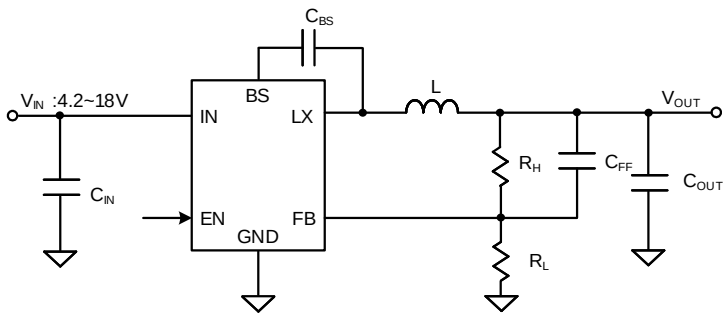


Figure 1.Typical Application Circuit

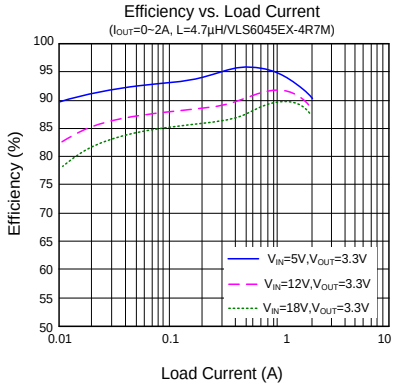


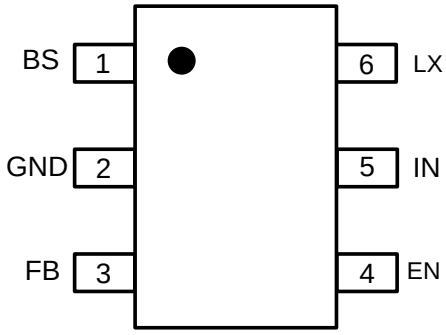
Figure 2. Efficiency vs. Output Current

Ordering Information

Ordering Part Number	Package type	Top Mark
SY21082ABC	SOT23-6 RoHS-Compliant and Halogen-Free	**Q9*xyz***

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

Pinout (top view)



Pin Description

Pin No	Pin Name	Pin Description
1	BS	Bootstrap pin. Supply for high-side gate driver. Connect a 0.1μF ceramic capacitor between the BS and LX pins.
2	GND	Power ground pin.
3	FB	Output feedback pin. Connect this pin to the center point of the output resistor-divider as shown in Figure 1. V_{OUT} = 0.6 × (1 + RH/RL)
4	EN	Enable pin. Pull low to disable the device, pull high to enable. Do not leave this pin floating.
5	IN	Power input. Decouple this pin from the GND pin with at least a 10μF ceramic capacitor.
6	LX	Inductor pin. Connect this pin to the switching node of the inductor.

Block Diagram

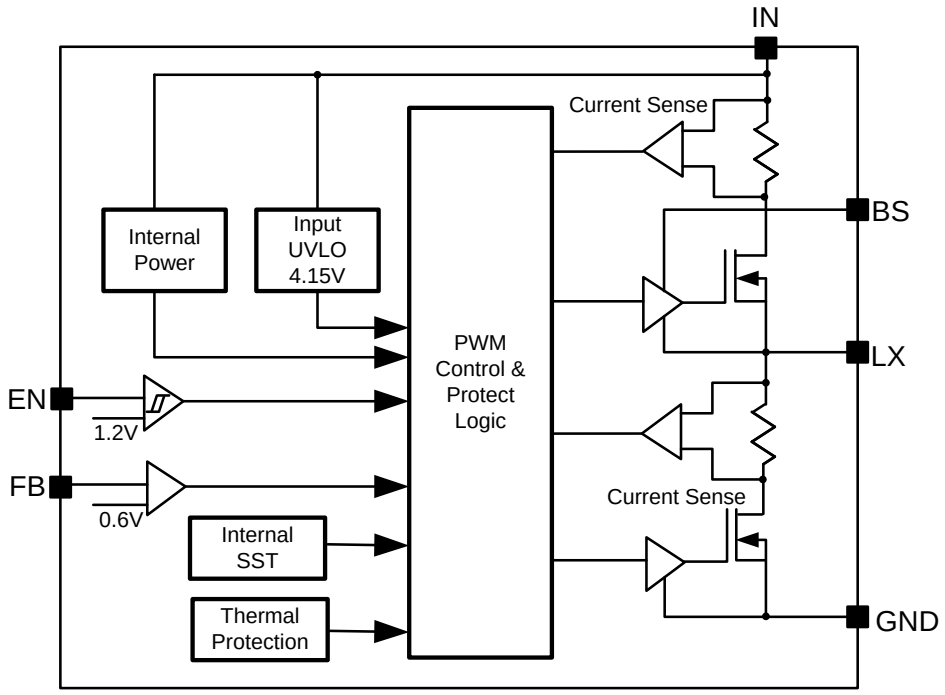


Figure 3. Block Diagram

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
IN	-0.3	19	V
EN, LX	-0.3	IN + 0.3	
LX, 20ns duration	-5	IN + 3	
BS	LX - 0.3	LX + 4	
FB	-0.3	4	
Junction Temperature, Operating	-40	150	°C
Lead Temperature (Soldering,10s)		260	
Storage Temperature	-65	150	

Thermal Information

Parameter (Note 2)	Max	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
IN	4.2	18	V
Output Current		2	A
Junction Temperature	-40	125	°C

Electrical Characteristics

V_{IN} = 12V, V_{OUT} = 3.3V, L = 4.7µH, C_{OUT} = 10µF, T_J = 25°C, I_{OUT} = 1A unless otherwise specified

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Input	Voltage	V_{IN}		4.2		18	V
	UVLO, Rising	$V_{IN,UVLO}$				4.15	V
	UVLO, Hysteresis	$V_{IN,HYS}$			0.6		V
	Shutdown Current	I_{SHDN}	V_{EN} = 0V		5	10	µA
	Quiescent Current	I_Q	I_{OUT} = 0, V_{FB} = V_{REF} × 105%		200		µA
FB	Reference Voltage	V_{REF}		591	600	609	V
	Input Current	I_{FB}	V_{EN} = 2V, V_{FB} = 1V	-50	0	50	nA
Power Switch	On-Resistance	$R_{DS(ON)HS}$	V_{BS-LX} = 3.3V		130		mΩ
	Current Limit	$I_{LMT,HS}$		3			A
Synchronous Rectifier	On-Resistance	$R_{DS(ON)LS}$			105		mΩ
	Current Limit	$I_{LMT,BOT}$		2			A
Enable (EN)	Rising Threshold	$V_{EN,R}$		1.08	1.2	1.32	V
	Falling Threshold	$V_{EN,F}$		0.9	1.0	1.1	V
	Input Current	I_{EN}	V_{EN} = 2V		0		µA
Soft-Start (SS)	Turn-On Delay	$t_{ON,DLY}$	From EN high to LX start switching		300		µs
	Soft-Start Time	t_{SS}	V_{OUT} from 0 to 100%		1		ms
Undervoltage Protection	Threshold	V_{UVP}			33		%V_{REF}
	Delay	$t_{UVP,DLY}$			200		µs
UVP/OCP Hiccup On-Time		$t_{HICCUP,ON}$			1.4		ms
UVP/OCP Hiccup Off-Time		$t_{HICCUP,OFF}$			5.2		
Switching Frequency		f_{SW}	I_{OUT} = 1A		500		kHz
Min On-Time		$t_{ON,MIN}$			50		ns
Min Off-Time		$t_{OFF,MIN}$			100		ns
Thermal Shutdown Temperature		T_{SD}			150		˚C
Thermal Shutdown Hysteresis		T_{HYS}			15		˚C

Note 1: Stresses beyond the “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification 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 2oz two-layer Silergy evaluation board. Paddle of SOT23-6 package is the case position for SY21082 θ_{JC} measurement.

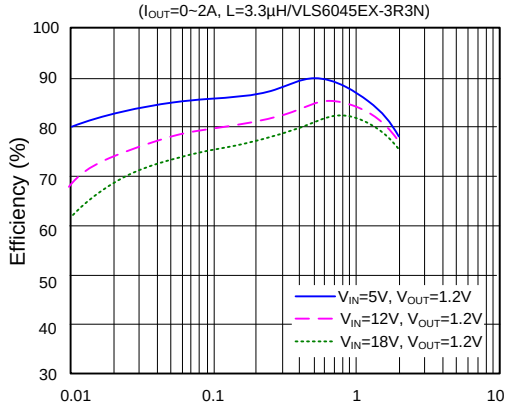
Note 3: The device is not guaranteed to function outside its operating conditions.

Typical Performance Characteristics

(T_A = 25°C, V_{IN} = 12V, V_{OUT} = 3.3V, L = 4.7µH, C_{OUT} = 10µF, unless otherwise noted)

Efficiency vs. Load Current

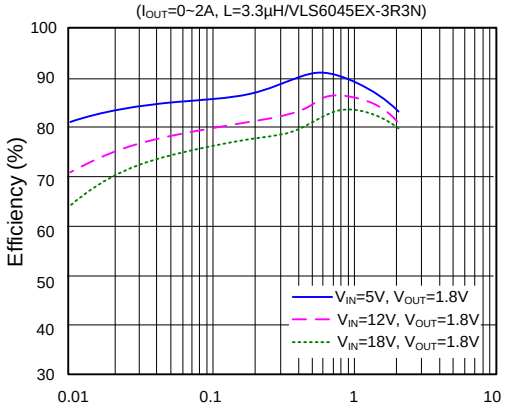
(I_{OUT}=0~2A, L=3.3µH/VLS6045EX-3R3N)



Load Current (A)

Efficiency vs. Load Current

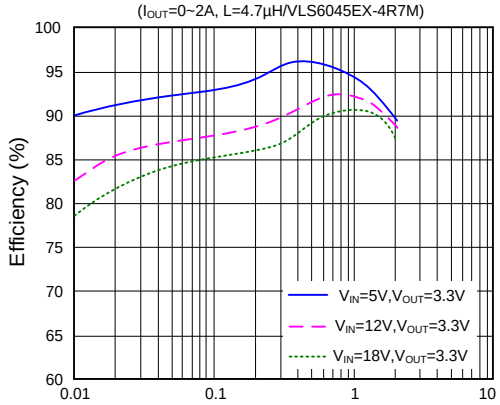
(I_{OUT}=0~2A, L=3.3µH/VLS6045EX-3R3N)



Load Current (A)

Efficiency vs. Load Current

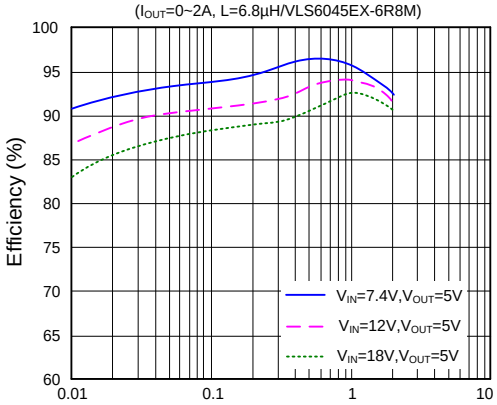
(I_{OUT}=0~2A, L=4.7µH/VLS6045EX-4R7M)



Load Current (A)

Efficiency vs. Load Current

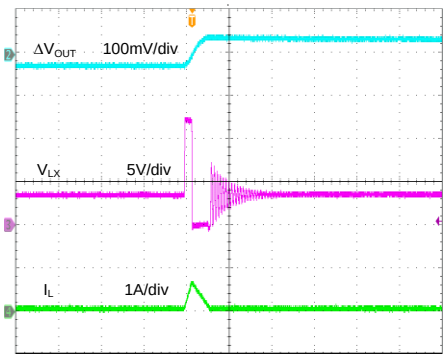
(I_{OUT}=0~2A, L=6.8µH/VLS6045EX-6R8M)



Load Current (A)

Output Ripple

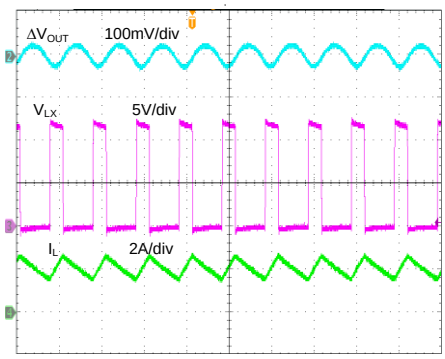
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=0A)



Time (2µs/div)

Output Ripple

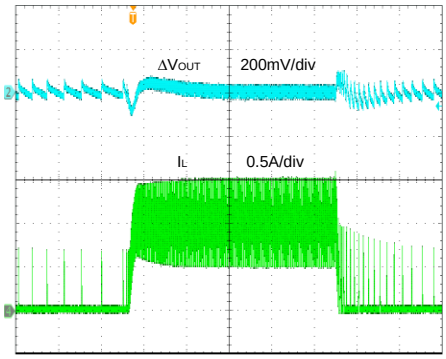
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=2A)



Time (2µs/div)

Load Transient

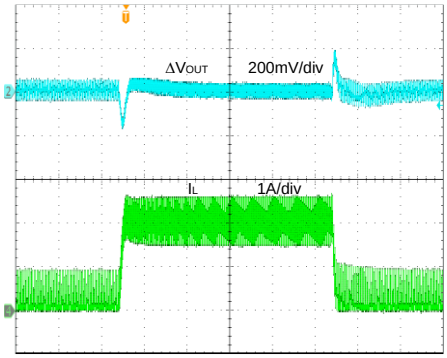
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=0-1A)



Time (100μs/div)

Load Transient

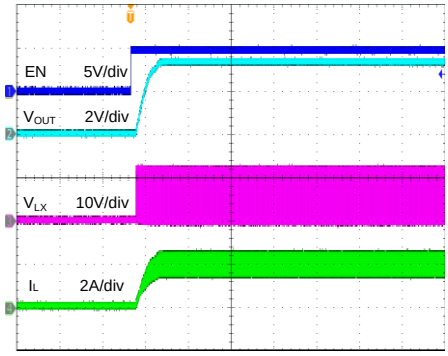
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=0.2-2A)



Time (100μs/div)

Startup from Enable

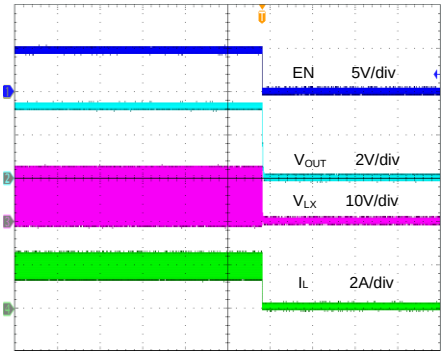
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=2A)



Time (2ms/div)

Shutdown from Enable

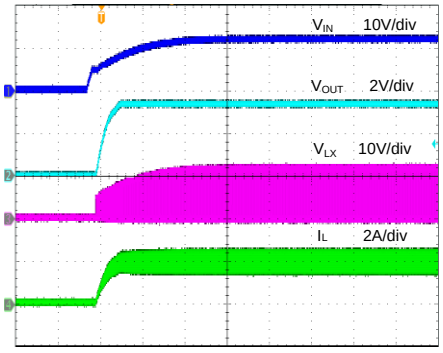
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=2A)



Time (2ms/div)

Startup from V_{IN}

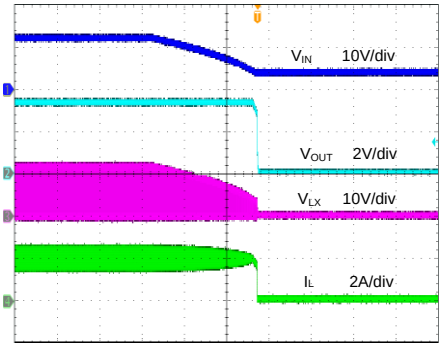
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=2A)



Time (2ms/div)

Shutdown from V_{IN}

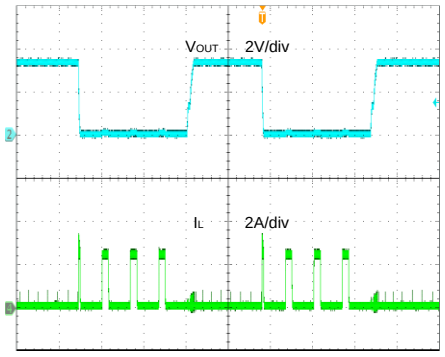
(V_{IN}=12V, V_{OUT}=3.3V, I_{LOAD}=2A)



Time (2ms/div)

Short Circuit Protection

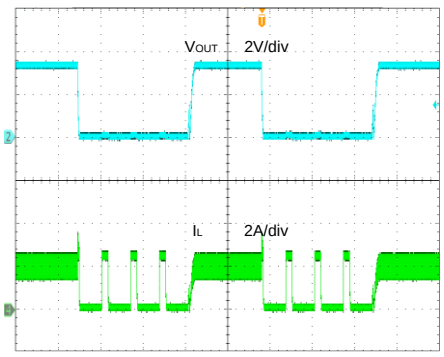
(V_{IN}=12V, V_{OUT}=3.3V, Open to Short)



Time (10ms/div)

Short Circuit Protection

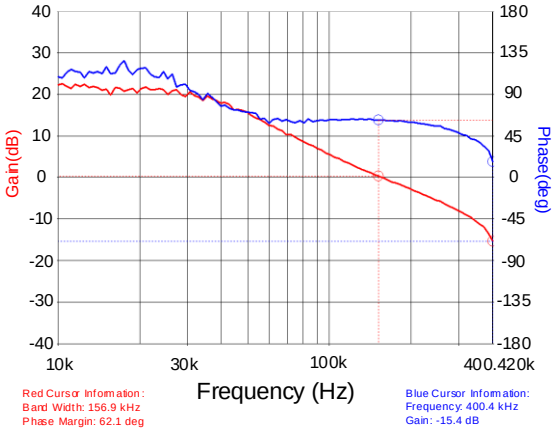
(V_{IN}=12V, V_{OUT}=3.3V, 2A to Short)



Time (10ms/div)

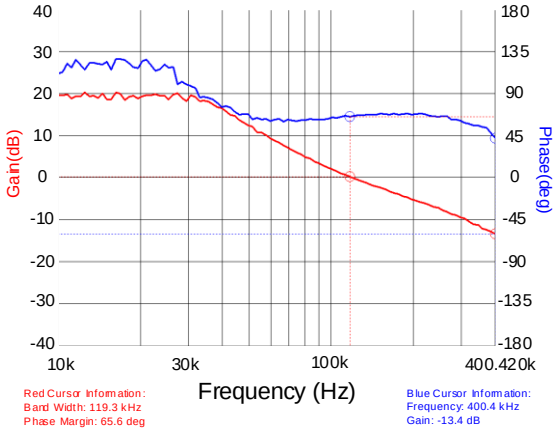
Bode Plot

(V_{IN}=12V, V_{OUT}=1.2V, I_{OUT}=2A)



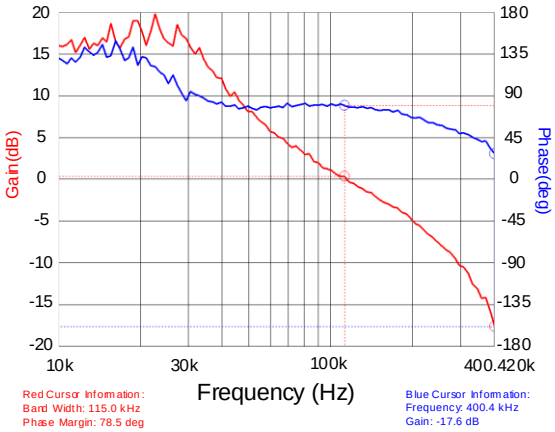
Bode Plot

(V_{IN}=12V, V_{OUT}=1.8V, I_{OUT}=2A)



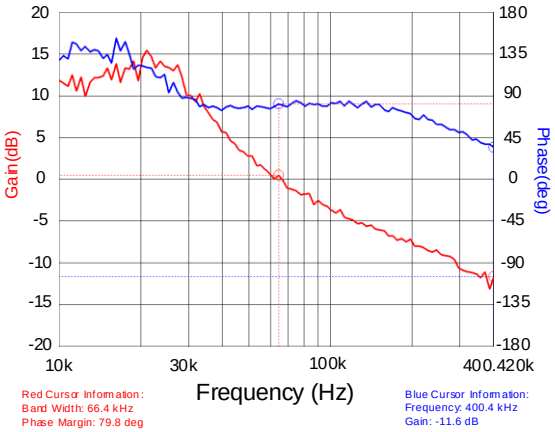
Bode Plot

(V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=2A)



Bode Plot

(V_{IN}=12V, V_{OUT}=5.0V, I_{OUT}=2A)



Operation

The SY21082 high-efficiency synchronous step-down DC/DC regulator operates over a wide input voltage range of 4.2V to 18V, and can deliver an output current up to 2A. It integrates a main switch and a synchronous switch with very low $R_{DS(ON)}$ to minimize conduction loss. The 500kHz pseudo-constant switching frequency enables using small external inductor and capacitor values. The SY21082 also provides cycle-by-cycle current limiting and thermal shutdown protection.

Constant-On-Time and Ripple-Based Control

The SY21082 operates using Instant-PWM™ architecture to achieve high efficiency at light loads and fast transient response for applications with high step-down ratios. It uses a constant-on-time and ripple-based control strategy, in which a virtual replica of the inductor current signal is synthesized internally and combined with the feedback voltage. When the sum of the above voltages is lower than the reference voltage, the bottom FET turns off and the top FET turns on for a fixed period of time (constant t_{ON}). t_{ON} is internally calculated according to the input voltage, output voltage, and desired switching frequency (f_{SW}):

$$t_{ON} = \frac{V_{OUT}/V_{IN}}{f_{SW}}$$

The top FET turns off after a period of t_{ON}.

Minimum Duty Cycle and Maximum Duty Cycle

There is no limitation for minimum duty cycle in COT architecture. This is because when the on-time is close to the minimum on-time, the switching frequency can be reduced as needed to always ensure proper operation.

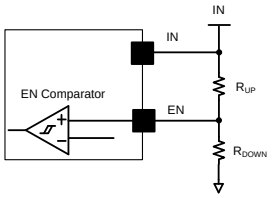
The SY21082 can support approximately 75% maximum duty cycle operation under T_J = -40–125°C condition.

Soft-Start

The SY21082 has a built-in soft-start to control the rise rate of the output voltage and limit the input current surge during IC start-up. The typical soft-start time is 1ms.

Enable and Adjusting Undervoltage Lockout

The EN pin provides programmable ON/OFF control by connecting an external resistor-divider, and has accurate rising and falling thresholds. The SY21082 will operate while the EN pin voltage exceeds the rising threshold. If the EN pin voltage is pulled below the falling threshold, the regulator will stop switching and enter shutdown state.



It is not recommended to connect EN to the IN node directly. A resistor with a value between 1kΩ and 1MΩ is recommended if the EN pin is pulled high to the IN node.

Fault-Protection Modes

Overcurrent and Short-Circuit Protection

If the high-side power FET current exceeds the peak current-limit threshold, the high-side FET will turn off and the low-side FET will turn on. If the low-side FET current exceeds the valley current-limit threshold, the low-side FET will stay on until the low-side FET current decreases below the valley current-limit threshold. As a result, both peak and valley currents are limited. If the load current continues to increase, the output voltage will drop. If the output voltage falls below 33% of the regulation level, an output short condition is assumed and the SY21082 will start operating in hiccup mode. The hiccup ON time is 1.4ms and the hiccup OFF time is 5.2ms. If the hard short is removed, the SY21082 will return to normal operation.

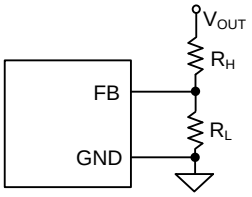
Application Information

The selection process for the input capacitor C_{IN}, output capacitor C_{OUT}, output inductor L, and feedback resistors R_H and R_L is described in the following sections.

Feedback Resistor-Divider R_H and R_L

Choose R_H and R_L to program the proper output voltage. A value between 1kΩ and 1MΩ is recommended for both resistors to minimize power consumption under light loads. If V_{OUT} = 3.3V and R_H is chosen as 100kΩ, for example, then R_L can be calculated as follows:

$$RL = \frac{0.6}{V_{OUT} - 0.6V} \times R_H$$



With a calculated value of 22.2kΩ for R_L, a standard 1% 22.1kΩ resistor is selected.

Input Capacitor C_{IN}

For the best performance, select a typical X5R or better grade ceramic capacitor with a 10V rating, and at least 10μF capacitance. The capacitor should be placed as close as possible to the device, while also minimizing the loop area formed by C_{IN} and the IN/GND pins.

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 a wide temperature and voltage range.

In situations where the input rail is supplied through long wires, it is recommended to add 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 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}

Select the output capacitor C_{OUT} to handle the output ripple requirements. Both steady-state ripple and transient requirements must be taken into consideration when selecting C_{OUT}. For the best performance, use an X5R or better grade ceramic capacitor with a 16V rating, and capacitance of at least 10μF.

For applications where the design must meet stringent ripple requirements, the following considerations must be followed.

The output voltage ripple at the switching frequency is caused by the inductor-current ripple (ΔI_L) on the output capacitor's ESR (ESR ripple), as well as the stored charge (capacitive ripple). When calculating total ripple, consider both.

$$V_{RIPPLE,ESR} = \Delta I_L \times ESR$$

$$V_{RIPPLE,CAP} = \frac{\Delta I_L}{8 \times C_{OUT} \times f_{SW}}$$

The capacitive ripple might be higher because the effective capacitance for ceramic capacitors decreases with the voltage across the terminals. The voltage derating is usually included as a chart in the capacitor datasheet, and the ripple can be recalculated after taking the target output voltage into account.

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 SY21082 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.

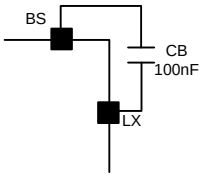
2) The inductor's saturation current rating must be greater than the peak inductor current under full load:

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

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

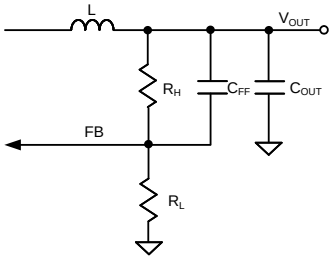
External Bootstrap Capacitor

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.

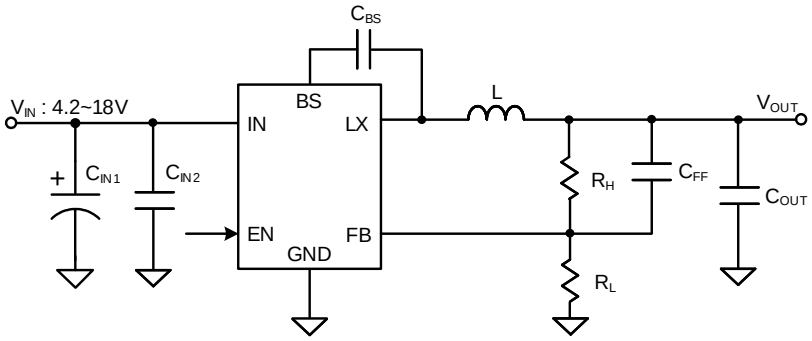


Load-Transient Considerations

The SY21082 integrates compensation components to achieve fast transient response and improved stability. In some applications, adding a ceramic capacitor (feed-forward capacitor C_{ff}) in parallel with R_H may further speed up the load-transient response, and is therefore recommended for applications with large load-transient step requirements.



Application Schematic (V_{OUT} = 3.3V)



BOM List

Reference Designator	Description	Part Number	Manufacturer
C_{IN1}	47µF/50V Electrolytic Capacitor		
C_{IN2}	10µF/25V/X5R,1206	GRM319R61E106KA12D	muRata
C_{FF}	47pF/50V/C0G, 0603	GRM1885C1H470JA01D	muRata
C_{OUT}	10µF/16V/X5R,1206	GRM319R61C106KE15D	muRata
C_{BS}	0.1µF/50V/X5R,0603	GRM188R61H104KA93D	muRata
L	4.7µH/4.2A	VLS6045EX-4R7M	TDK
R_H	100kΩ, 1%, 0603		
R_L	22.1kΩ, 1%, 0603		

Recommend Components for Typical Applications

V_{OUT} (V)	R_H (kΩ)	R_L (kΩ)	C_{FF} (pF)	L/(Rated/Saturating Current)	C_{OUT1}
1.2	100	100	10	3.3μH/(4.95A/6.5A)	10μF/16V/X5R,1206
1.8	100	49.9	10	3.3μH/(4.95A/6.5A)	10μF/16V/X5R,1206
3.3	100	22.1	47	4.7μH/(4.2A/5.8A)	10μF/16V/X5R,1206
5	100	13.7	47	6.8μH/(3.6A/4.7A)	10μF/16V/X5R,1206

Layout Design

To achieve optimal design, follow these PCB layout considerations:

- For minimum noise and maximum efficiency, place the following components close to the IC: C_{IN}, L, R_H and R_L.
- To achieve the best thermal and noise performance, maximize the PCB copper area connecting to the GND pin. A ground plane is highly recommended if board space allows.
- C_{IN} must be close to pins IN and GND. Minimize the loop area formed by C_{IN}, V_{IN}, and GND.
- To reduce the switching noise, minimize the PCB copper area connected to the LX pin.
- In order to reduce crosstalk, R_H, R_L, and the trace connected to the FB pin must not be adjacent to the LX net on the PCB layout.
- 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.

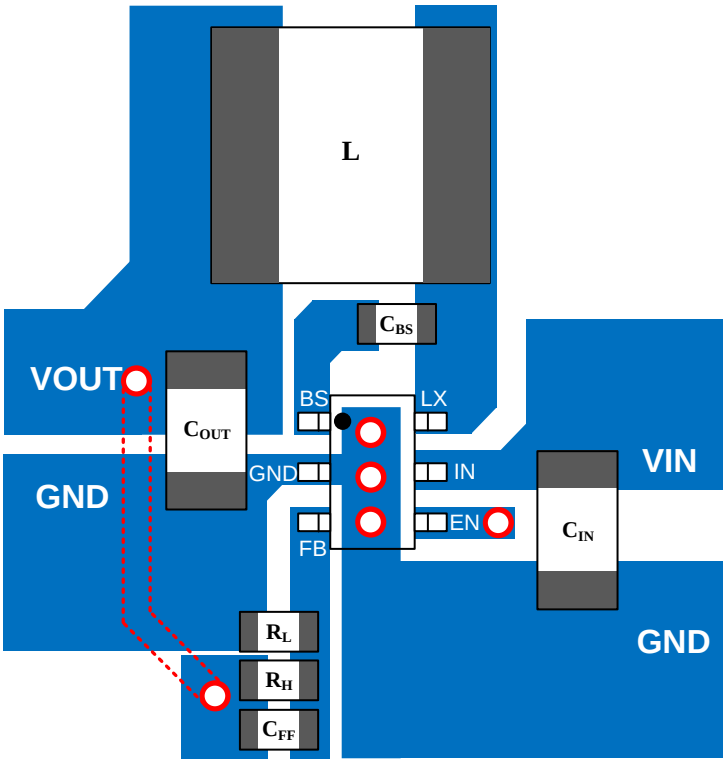
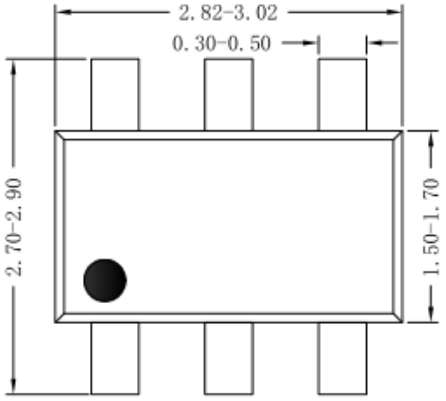
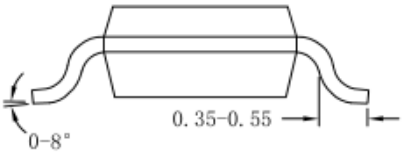


Figure 4. Recommended PCB Layout

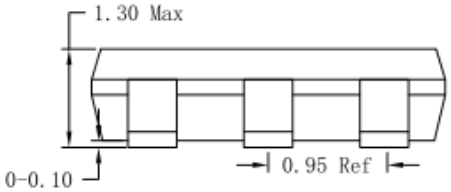
SOT23-6 Package Outline and PCB Layout Design



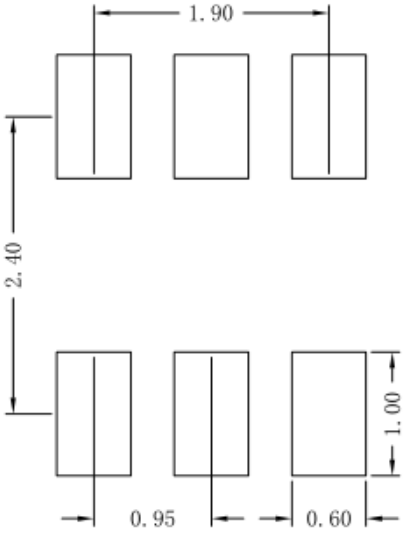
Top view



Side view



Front view

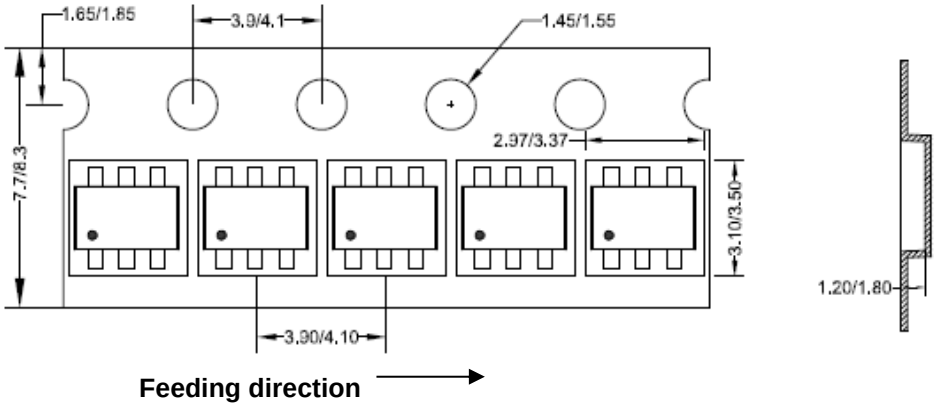


Recommended pad layout (reference only)

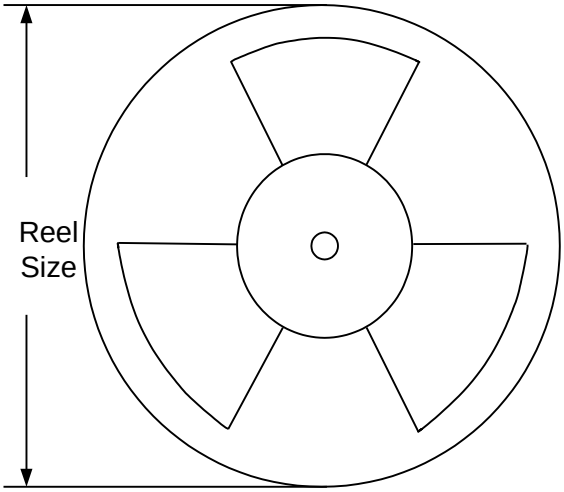
Note: *All dimensions are in millimeters and exclude mold flash and metal burr.*

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: N/A

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 an 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