Application Note: SY9329

High Efficiency, 28V Input Single Inductor Synchronous Step Up/Down Regulator

Preliminary Specification

General Description:

The SY9329 is a high voltage buck-boost converter for USB type C applications. With user-selectable source mode and sink mode, it features bidirectional power delivery. In source mode, the output voltage V_{VBUS} is 5V, 7V, 9V, 12V, 15V, 20V selectable. In sink mode, the output voltage V_{BAT} is adjustable with an external resistor divider.

The device operates over a wide input voltage range from 4V to 28V and the maximum average inductor current is limited to a typical value of 10A. The four integrated low R_{DS}(on) switches minimize the conduction loss.

The SY9329 integrates an I^2C compatible interface for mode selecting, output voltage setting, frequency setting, protection setting, and etc.

The device is available in compact QFN4x4-32 package.

Ordering Information

SY9329 □(□□)□

- Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY9329QFC	QFN4x4-32	

Features:

- Bidirectional power delivery: source mode and sink mode
- 4V to 28V input voltage range.
- Low $R_{DS(ON)}$ for internal switches: 25mΩ
- Internal soft start
- 8-bit ADC for output voltage, input voltage and VBUS output current detection.
- Fully protected for output over current, short-circuit and over-temperature
- I^2C compatible interface
  - Support interrupt for status feedback
  - Selectable switching frequency: 250 kHz, 500kHz, 750kHz, 1MHz
  - Selectable VBUS output voltage: 5V,7V,9V,12V,15V,20V
  - Selectable inductor current limit and VBUS output current limit
- Compact package: QFN4x4-32

Applications:

- Docking Station
- Laptop
- High-End Power Bank
- Monitor
- Car Charger
- USB PD

Typical Application

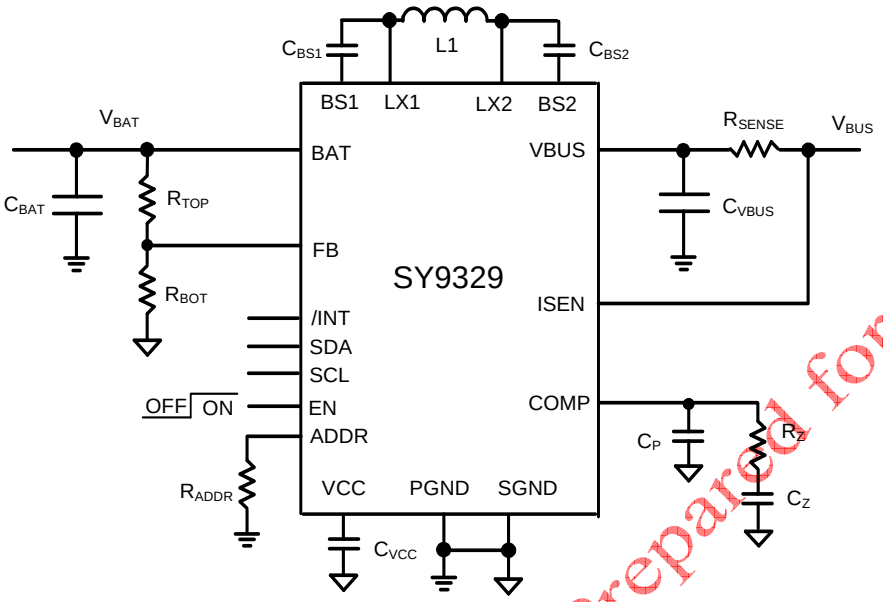
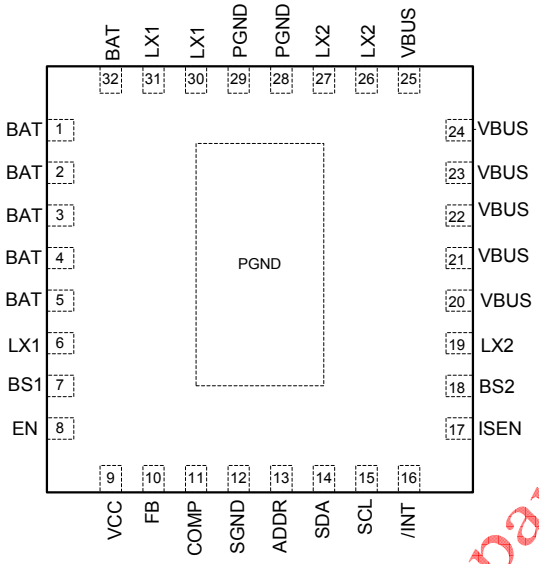


Fig.1 Typical Schematic Diagram

PINOUT (Top View)



Top Mark: BED*xyz* (Device code: BED, ***x=year code, y=week code, z= lot number code***)

Pin Name	Pin Number	Description
BAT	1,2,3,4,5,32	Power input/output pin, decouple this pin to PGND with at least 10μF ceramic capacitor. This pin is power input in source mode and power output in sink mode.
LX1	6,30,31	Switching node 1.
BS1	7	Boot-Strap pin. Supply high side gate driver. Decouple this pin to LX1 pin with 0.1uF ceramic cap.
EN	8	IC Enable control pin, logic high enable. This pin is internally pulled high by 400nA pull-up current.
VCC	9	3.3V LDO output, power supply for internal driver and control circuits. Decouple this pin to SGND with a minimum of 4.7μF ceramic capacitor.
FB	10	Sink mode output feedback pin. Connect this pin to the center point of the output resistor divider to adjust the V_{BAT} output voltage: $V_{BAT}=1V*(R_{TOP}+R_{BOT})/R_{BOT}$.
COMP	11	Compensation pin. Connect RC network between this pin and ground.
SGND	12	Signal ground.
ADDR	13	The device address set pin. Grounding this pin selects 0x70, connecting this pin to GND with an external resistor selects 0x71(50kΩ<R_{ADDR}<100kΩ) or 0x72(400kΩ<R_{ADDR}<500kΩ), and floating this pin selects 0x73.
SDA	14	I^2C interface serial data pin. Logic level input/output
SCL	15	I^2C interface serial clock pin. Logic level input.
/INT	16	The /INT pin is an open-drain output. When an interrupt event happens, the /INT pin is internally pulled low to inform the host about fault condition. After the host reads the interrupt register, the /INT pin is externally pulled high. A 10 kΩ pull-up resistor is recommended.
ISEN	17	Current sense pin. Connect a 10mΩ resistor R_{SENSE} between VBUS and ISEN to detect source mode output current.
BS2	18	Boot-strap pin. Supply high side gate driver. Decouple this pin to LX2 pin with 0.1uF ceramic cap.
LX2	19,26,27	Switching node 2.

PGND	28,29, Exposed Pad	Power ground.
VBUS	20,21,22,23, 24,25	Power input/output pin, decouple this pin to PGND with at least 10μF ceramic capacitor. This pin is power output in source mode and power input in sink mode.

Block Diagram:

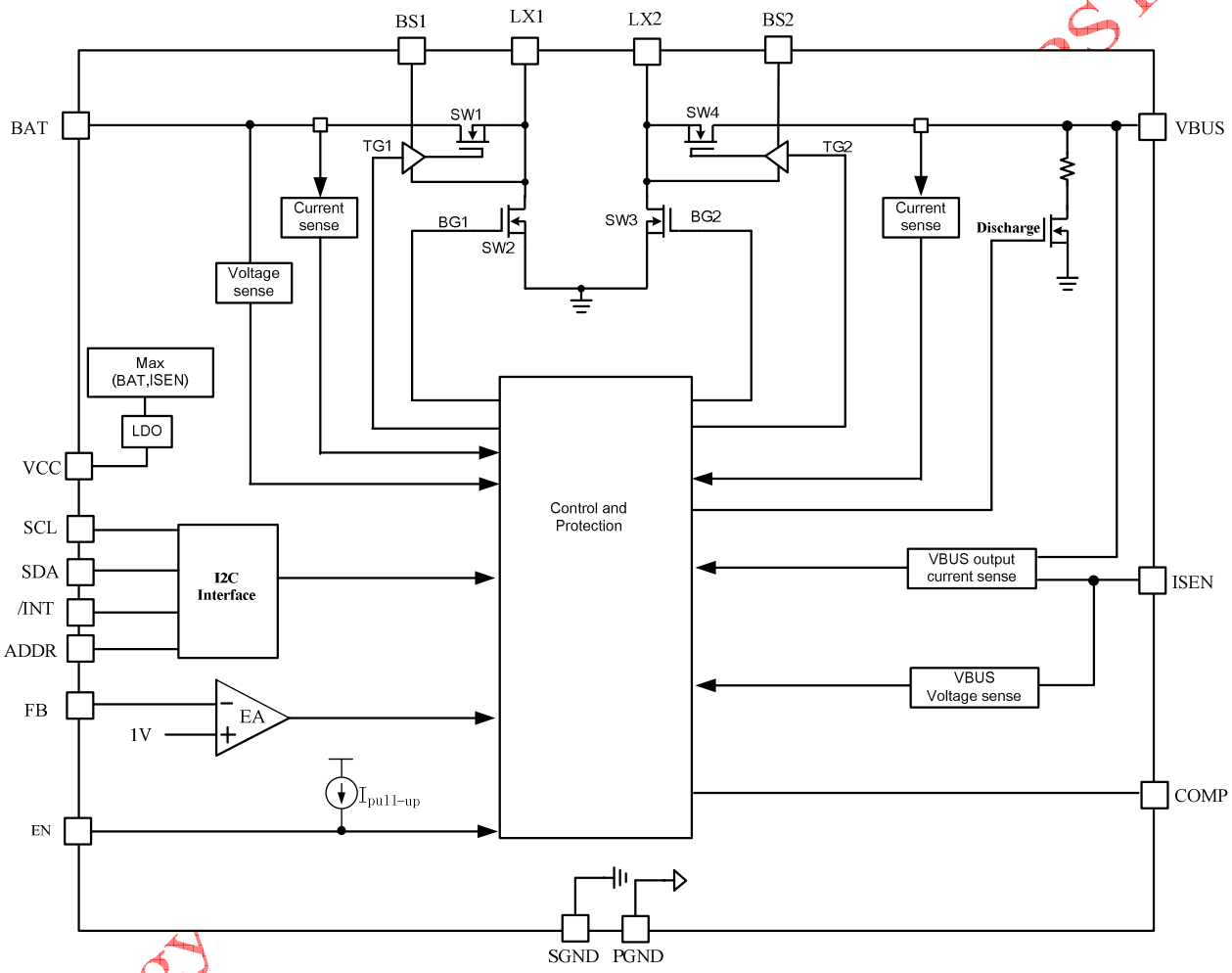


Fig.2 Block Diagram

Absolute Maximum Ratings (Note 1)

BAT, LX1, LX2, VBUS, ISEN, EN,SDA, SCL, FB, COMP---------- -0.3V to 30V
BS-LX, VCC,ADDR, /INT---------- -0.3V to 4V
Power Dissipation, P_D @ T_A = 25°C QFN4X4-32 ---------- 4W
Package Thermal Resistance (Note 2)
θ_{JA} ---------- 28°C/W
θ_{JC} ---------- 2.8°C/W
Junction Temperature Range ---------- 150°C
Lead Temperature (Soldering, 10 sec.) ---------- 260°C
Storage Temperature Range ---------- -65°C to 150°C

Recommended Operating Conditions (Note 3)

BAT Input Voltage ----------4V to 28V
VBUS Voltage ---------- 4V to 25V
Junction Temperature Range ---------- -40°C to 125°C
Ambient Temperature Range ---------- -40°C to 85°C

Electrical Characteristics

(V_{BAT} = 12V, V_{VBUS}=12V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
BAT Voltage Range	V_{BAT}		4		28	V
VBUS Voltage Range	V_{BUS}		4		25	V
LDO Voltage	VCC	I_{LDO}=50mA	3.2	3.3	3.37	V
LDO Current Limit	I_{LMT_LDO}			100		mA
LDO Dropout Voltage	$V_{DROPOUT}$	I_{LDO}=50mA		250		mV
Quiescent Current	I_Q	No switching		280	380	µA
Shutdown Current	I_{SD}	IC is disabled		9.6	15.5	µA
Feedback Reference Voltage	V_{REF}		0.985	1	1.015	V
FB Input Current	I_{FB}		-50		50	nA
VBUS Voltage Set-Point	$V_{BUS,SET}$	Source mode, VBUS voltage setting register 0x01[5:3]='000'	4.925	5	5.075	V
VBUS OVP Threshold	$V_{BUS,OVP}$	VBUS OVP point 0x02[4:3]='10'		120		% $V_{BUS,SET}$
Internal Power MOSFET $R_{DS(ON)}$	$R_{DS(ON)}$			25		mΩ
Inductor Average Current Limit	I_{AVG}	0x03[7:6]='00'		6		A
Inductor Peak Current Limit	I_{PK}	0x03[7:6]='00'	6.8	8.8	10.8	A
VBUS/BAT Input UVLO Threshold	V_{UVLO}		3.3		3.7	V
UVLO Hysteresis	V_{HYS}			0.2		V
EN Logic High Threshold	V_{ENH}	Rising		1.2	1.4	V
EN Logic Low Threshold	V_{ENL}	Falling	0.6	0.8		V
VBUS Output Current Limit	$V_{BUS.ILIM}$	0x02[7:5]='000'	13.6	18	22	mV
		0x02[7:5]='001'	17.8	22	27	mV
		0x02[7:5]='010'	22.4	27	31.3	mV
		0x02[7:5]='011'	27	31	35.2	mV
		0x02[7:5]='100'	31.6	36	40.1	mV
		0x02[7:5]='101'	40.5	45	49.1	mV

		0x02[7:5]='110'	49.7	54	58	mV
		0x02[7:5]='111'	58.9	64	68.7	mV
Oscillator Frequency	F_{OSC}	0x01[7:6]='01'	425	500	575	kHz
Min On Time	t_{ON_MIN}			150		ns
Thermal Shutdown Temperature	T_{SD}			150		°C
Thermal Shutdown Hysteresis	T_{HYS}			15		°C
Soft-Start Time	T_{ss}	Source mode, V_{VBUS}=5V		1.5		ms
ADC Control						
ADC Resolution				8		Bits
ADC Voltage Sense Accuracy		V_{BAT}=23V	-5		5	%
ADC Current Sense Accuracy		V_{VBUS}-V_{ISEN}=67mV	-11		11	%
V_{BAT} Full Scale Range			0		25	V
V_{BUS} Full Scale Range			0		25	V
Sense Current Full Scale Range			0		67	mV
I2C COMPATIBLE INTERFACE						
Maximum Operating Frequency				400		kHz
SDA and SCL Input Logic Threshold	Logic_L				1	V
	Logic_H		2			V
SDA Output Low Voltage					1	V

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 TA = 25°C on a two-layer Silergy Evaluation Board.

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

Typical Function Description

I²C Compatible Interface

SY9329 integrates an I²C compatible interface. To ensure compatibility with a wide range of system processors, the I²C interface supports clock speeds of up to 400kHz (“Fast-Mode”) and uses standard I²C commands. The SY9329 always operates as a slave device, and is addressed using a 7-bit slave address followed by an 8th bit, which indicates whether the transaction is a read-operation or a write-operation.

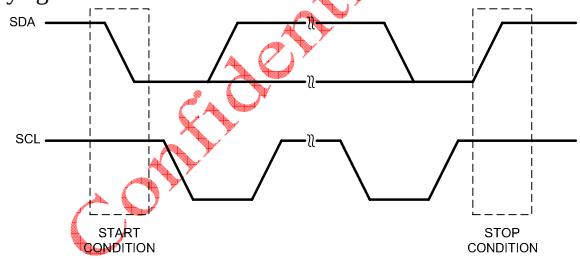
I²C Device Address:

When communicating with multiple devices using the I²C interface, each device must have its own unique address so the host can distinguish between the devices. The most significant 4-bits of the device address is '1110' The 5th,6th and 7th-bit device address is selected by ADDR pin.

ADDR	Device Address
ADDR short to GND	1110000
50kΩ<R_{ADDR}<100kΩ	1110001
400kΩ<R_{ADDR}<500kΩ	1110010
Floating or connect to VCC	1110011

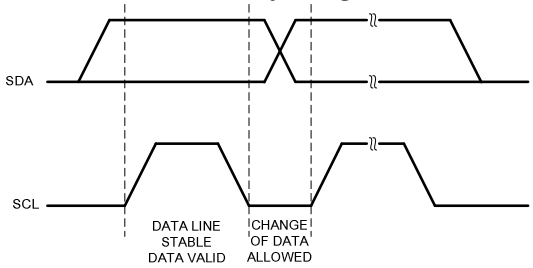
START and STOP Conditions:

The START condition is a HIGH to LOW transition of the SDA line while SCL is HIGH. The STOP condition is a LOW to HIGH transition on the SDA line while SCL is HIGH. A STOP condition must be sent before each START condition. The I²C master always generates the START and STOP conditions.



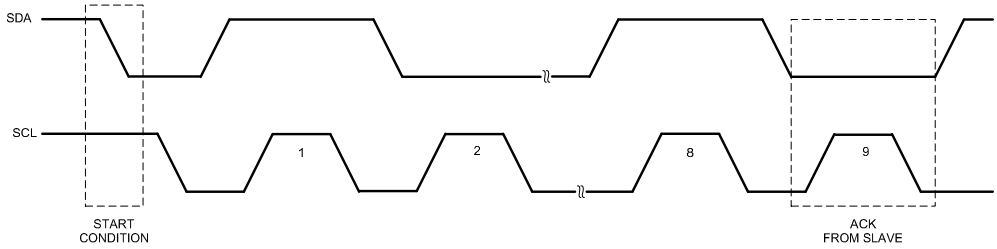
Data Validity:

The data on the SDA line must be stable during the HIGH period of the SCL, unless generating a START or STOP condition. The HIGH or LOW state of the data line can only change when the clock signal on the SCL line is LOW.



Acknowledge:

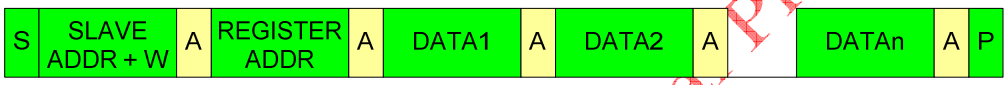
Each address and data transmission uses 9-clock pulses. The ninth pulse is the acknowledge bit (ACK). After the START condition, the master sends 7-slave address bits and an R/$\overline{W}$ bit during the next 8-clock pulses. During the ninth clock pulse, the device that recognizes its own address holds the data line low to acknowledge. The acknowledge bit is also used by both the master and the slave to acknowledge receipt of register addresses and data.



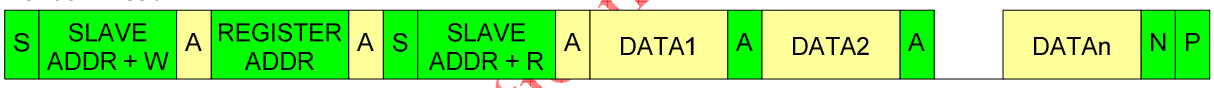
Data Transactions:

All transactions start with a control byte sent from the I^2C master device. The control byte begins with a START condition, followed by 7-bits of slave address followed by the R/W bit. The R/W bit is 0 for a write or 1 for a read. If any slave devices on the I^2C bus recognize their address, they will acknowledge by pulling the SDA line low for the last clock cycle in the control byte. If no slaves exist at that address or are not ready to communicate, the data line will be 1, indicating a Not Acknowledge condition. Once the control byte is sent, and the slave acknowledges it, the 2nd byte sent by the master must be a register address byte. The register address byte tells the slave which register the master will write or read. Once the slave receives a register address byte it responds with an acknowledge. If a STOP condition is detected after the register address byte is received, the SY9329 takes no further action but storing the register address byte. The register address byte auto increase when multiple date bytes are transited.

Write



Random Read



Register Map:

Address	Data	Note
00	Control Register 1	R/W
01	Control Register 2	R/W
02	Protection setting 1	R/W
03	Protection setting 2	R/W
04	State Register	R
05	/INT Register	Read then Clear
06	BAT Voltage Value Register	R
07	VBUS Voltage Value Register	
08	VBUS Output Current Sense Voltage Register	

Control Register1 (0x00)

Name	# of Bits	Access	Default	Description
Regulator Enable	7	R/W	0	0:Disable 1:Enable
Low Battery Voltage Setting	6	R/W	0	000:10.2V[12V Car Battery] 001:10.7V[12V Car Battery] 010:11.2V [12V Car Battery] 011:11.7V [12V Car battery] 100: 22.0V [24V Car Battery] 101: 22.5V [24V Car Battery] 110: 23V [24V Car Battery] 111:23.5V [24V Car Battery]
	5	R/W	0	
	4	R/W	0	
ADC ON/OFF	3	R/W	0	0:Inactive; 1:Active
ADC Mode Select	2	R/W	0	0: Single detect mode; 1: Auto detect mode
VBUS Discharge Control	1	R/W	0	0: Active discharge when regulator is disabled 1: Inactive discharge when regulator is disabled
Reserved	0	R/W	0	

Control Register2 (0x01)

Name	# of Bits	Access	Default	Description
Switching Frequency	7	R/W	1	00: 250KHz 01: 500KHz 10: 750KHz 11: 1MHz
	6	R/W	1	
VBUS Voltage Setting	5	R/W	0	000:5V 001:5V 010:5V 011:7V 100:9V 101:12V 110:15V 111: 20V If 0x00[7]='0', this bit is reset to '0' and cannot be overwritten
	4	R/W	0	
	3	R/W	0	
VBUS Voltage Adjust	2	R/W	0	000: -2.5% 001: -1.25% 010: ±0% 011: +1.25% 100:+2.5% 101: +3.75% 110:+5%
	1	R/W	1	
	0	R/W	0	

				111:+6.25%

Protection setting 1 (0x02)

Name	# of Bits	Access	Default	Description
Output current Limit Voltage Threshold (Source mode)	7:5	R/W	011	000: 18mV 001: 22mV 010: 27mV 011: 31mV 100: 36mV 101: 45mV 110: 54mV 111: 64mV
VBUS OVP Threshold	4	R/W	1	00:110% $V_{BUS,SET}$ 01:115% $V_{BUS,SET}$ 10:120% $V_{BUS,SET}$ 11:125% $V_{BUS,SET}$
	3	R/W	0	
VBUS UVP Threshold	2	R/W	1	00:50% $V_{BUS,SET}$ 01:60% $V_{BUS,SET}$ 10:70% $V_{BUS,SET}$ 11:80% $V_{BUS,SET}$
	1	R/W	0	
Reserved	0	R/W	0	

Protection setting 2 (0x03)

Name	# of Bits	Access	Default	Description
Inductor Average Current Limit Setting	7	R/W	0	00: 6A 01: 6A 10: 8A 11: 10A
	6	R/W	0	
Inductor Average Current Limit Protection Mode	5	R/W	0	0: Latch off: 0x00[7] is reset to '0' 1: Auto recover: 0x01[5:3] is reset to '000'
VBUS Under Voltage Protection Mode	4	R/W	0	0: Latch off: 0x00[7] is reset to '0' 1: Auto recover: hiccup mode, 0x01[5:3] is reset to '000'
Over Temperature Protection Mode	3	R/W	0	0: Latch off: 0x00[7] is reset to '0' 1: Auto recover, 0x01[5:3] is reset to '000'
Bidirectional Mode	2	R/W	0	0: Source mode 1: Sink mode If 0x00[7]='0', this bit is reset to '0' and cannot be overwritten
Reserved	1	R/W	0	
Reserved	0	R/W	0	

State Register (0x04)

Name	# of Bits	Access	Description
Power Good State	7	R	0: Power is not in good range 1: Power good (feedback is 90%~120% Vref)
BAT/VBUS Voltage Relation	6	R	0:BAT voltage > VBUS voltage 1: BAT voltage < VBUS voltage
BAT Power State	5	R	0: Normal 1: Low BAT voltage
Reserved	4:0	R	

Interrupt Register (0x05)

Name	# of Bits	Access	Description
ADC Data Ready	7	Read then Clear	0: None 1: Data ready
VBUS Over Current Limit	6	Read then Clear	0: Normal 1:VBUS output current OCP
Inductor Current Protection	5	Read then Clear	0: Normal 1: Inductor OCP
VBUS UVP	4	Read then Clear	0: Normal 1:UVP
Over Temperature Protection	3	Read then Clear	0: Normal 1: OTP
Reserved	2:0	Read then Clear	

BAT Voltage Register (0x06)

Name	# of Bits	Access	Description
BAT Voltage Value	7:0	R	00000000: 0V …… 11111111: 25V

VBUS Voltage Register (0x07)

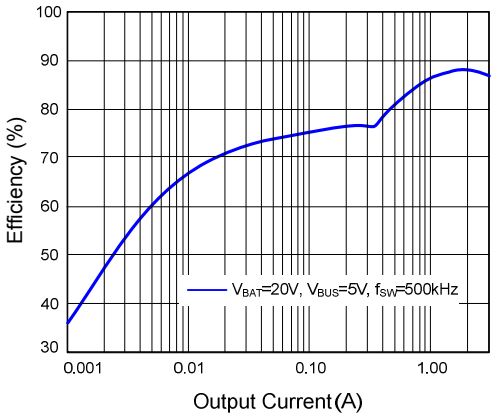
Name	# of Bits	Access	Description
VBUS Voltage Value	7:0	R	00000000: 0V …… 11111111: 25V

VBUS Output Current Sense Voltage Register (0x08)

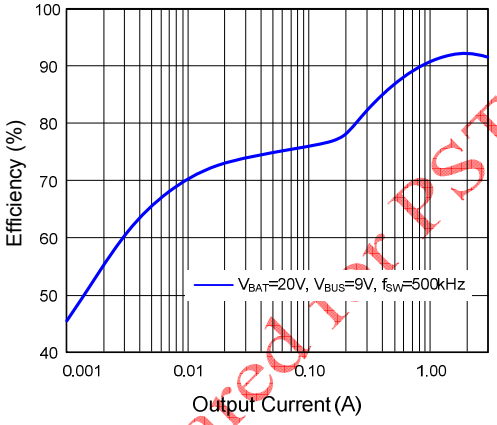
Name	# of Bits	Access	Description
VBUS Output Current Sense Voltage	7:0	R	00000000: 0mV …… 11111111: 67mV

Typical Performance Characteristics

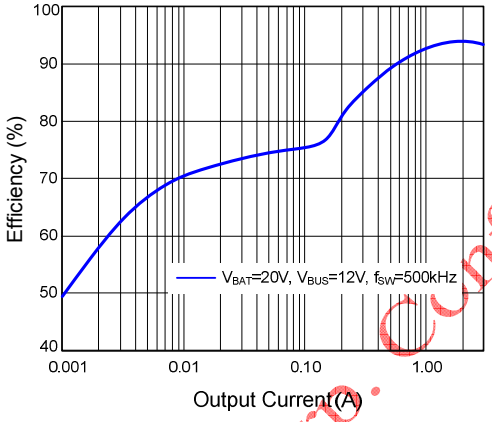
Efficiency vs. Output Current



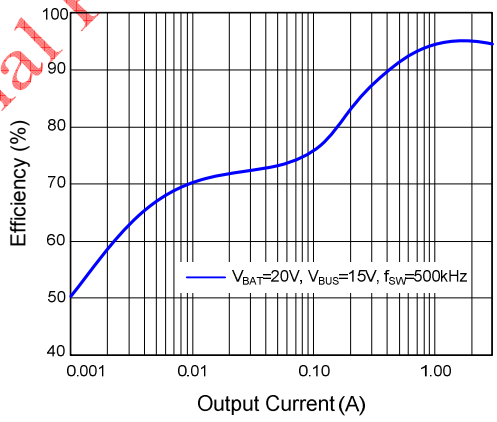
Efficiency vs. Output Current



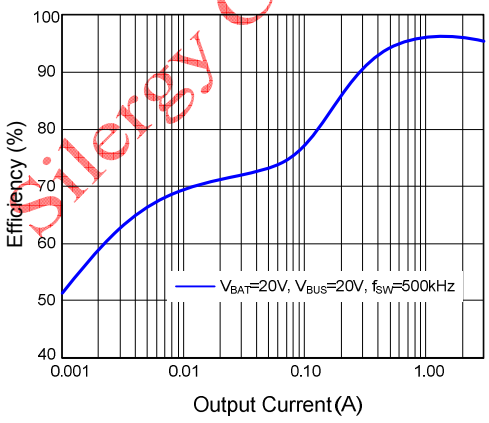
Efficiency vs. Output Current



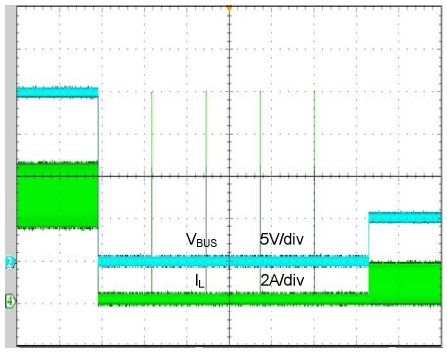
Efficiency vs. Output Current



Efficiency vs. Output Current

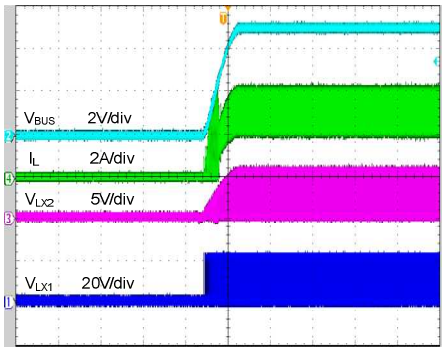


Short Circuit Test (Auto Recover)
(V_{BAT}=20V,V_{BUS}=20V,R_{LOAD}=6.7Ω)



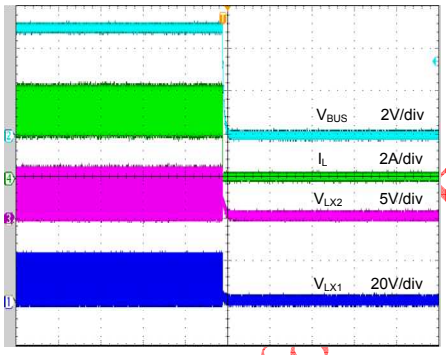
Time (2s/div)

Regulator Enable
(V_{BAT}=20V,V_{BUS}=5V,I_{LOAD}=3A)



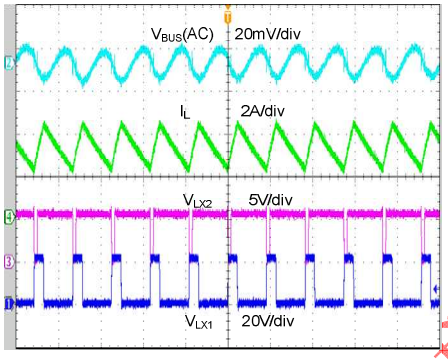
Time (2ms/div)

Regulator Disable
(V_{BAT}=20V,V_{BUS}=5V,I_{LOAD}=3A)



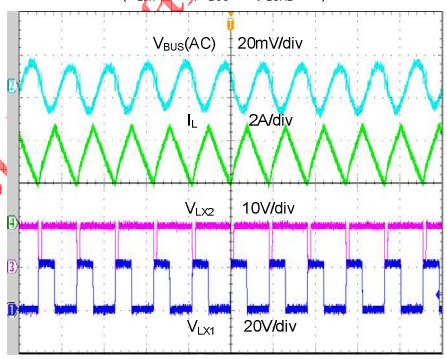
Time (2ms/div)

Output Ripple
(V_{BAT}=20V,V_{BUS}=5V,I_{LOAD}=3A)



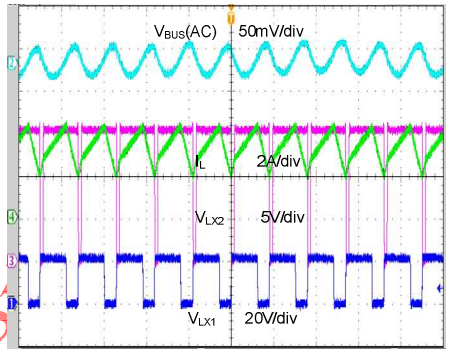
Time (2μs/div)

Output Ripple
(V_{BAT}=20V,V_{BUS}=9V,I_{LOAD}=3A)



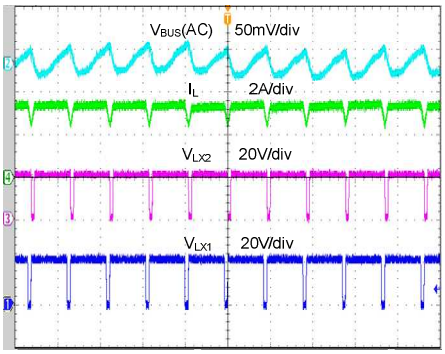
Time (2μs/div)

Output Ripple
(V_{BAT}=20V,V_{BUS}=15V,I_{LOAD}=3A)



Time (2μs/div)

Output Ripple
(V_{BAT}=20V,V_{BUS}=20V,I_{LOAD}=3A)



Time (2μs/div)

Applications Information

Bidirectional Buck-Boost Regulator Operation Mode

The SY9329 is a bidirectional device which can be operated under both source mode and sink mode. 0x03[2]='0' selects source mode while 0x03[2]='1' selects sink mode.

Under source mode, which is also the default mode, the BAT pin is connected to the power input and the VBUS pin is the power output. The output voltage V_{VBUS} is configured by 'VBUS Voltage Setting' register 0x01[5:3]. Once the 'Regulator Enable' bit is cleared (0x00[7]='0'), operation mode will be reset to source mode(0x03[2] is reset to '0' and cannot be overwritten).

Under sink mode, the VBUS pin is connected to the power input, the BAT pin is the power output and the FB pin is the feedback input. The output voltage V_{BAT} is programmed by external voltage divider (see Fig. 4) with the 1V internal voltage reference as given in equation (1)

$$V_{BAT} = 1V \times \frac{R_{TOP} + R_{BOT}}{R_{BOT}} \quad (1)$$

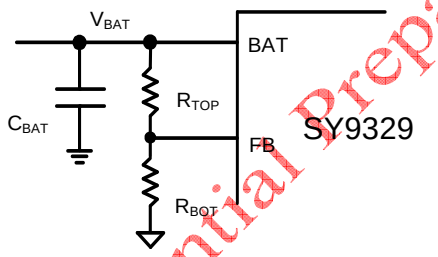


Fig. 4. Schematic of V_{BAT} under Sink Mode

Interrupt

When an interrupt event happens, the open drain /INT pin is pulled low to inform the host. After the host reads the interrupt register, the /INT pin will be pulled high by external pull-up resistor.

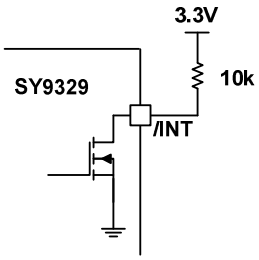


Fig .5 Description of Interrupt Function.

Under Voltage Protection

The SY9329 activates UVP(under voltage protection) function when output short occurs. There are two UVP protection modes. One is latch off operation by setting 0x03[4]='0', the other is auto recover operation with 0x03[4]='1'.

Latch off operation. Once the output voltage is lower than UVP threshold for 1ms, the regulator will be disabled(0x00[7]='0').

Auto recover operation (hiccup mode). When output voltage is lower than UVP threshold for 1ms, and the device will shut down for approximately 2.6s. The device will then restart with a complete soft-start cycle. If the short circuit condition remains another 'hiccup' cycle of shutdown and restart will continue indefinitely unless the OTP threshold is reached.

Average Inductor current limit

When average inductor current is greater than the threshold, the internal control loop will regulate the average inductor current by decreasing duty cycle. Both latch off operation and auto recover operation are provided by the device: 0x03[5]='0' enters latch off operation, and 0x03[5]='1' enters auto recover operation.

Latch off operation: When average inductor current exceeds a certain threshold for 1ms, the regulator is disabled(0x00[7]='0').

Auto recover operation: The device will regulate the average inductor current to the setting value. IC resumes normal operation when the fault condition is removed.

VBUS Output Current Limit

The SY9329 provides a function for VBUS output current limit by sensing the voltage drop between VBUS pin and ISEN pin (as shown in fig.6). Once the voltage difference (V_{VBUS}-V_{ISEN}) exceeds the voltage threshold, which can be configured by register 0x02[7:5], the internal control loop will regulate the output current by decreasing duty cycle until UVP or OTP is triggered. Noticing that the effects of R_{PIN} and R_{WIRE} cannot be ignored, the actual limit current I_{LIMIT} can be calculated as given in Equation (2):

$$I_{LIMIT} = \frac{V_{VBUS} - V_{ISEN}}{R_{SENSE} + R_{PIN} + R_{WRIE}} \quad (2)$$

where $R_{PIN} \approx 1.65m\Omega$.

R_{WIRE} depends on PCB layout..

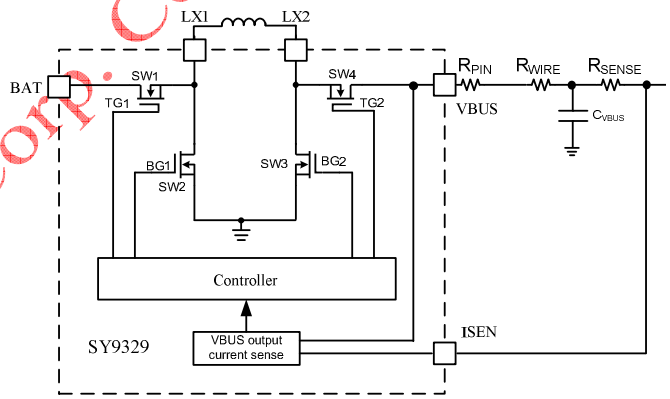


Fig. 6. Description of VBUS Output Current Limit

Note: The VBUS output current limit only functions under source mode, after finishing soft-start.

Over Temperature Protection

The device provides two protection modes for OTP(over temperature protection). If 0x03[5]='0', it selects latch off operation , and if 0x03[3]='1' , it is auto recover operation

Latch off operation: The regulator is disabled when the junction temperature exceeds 150℃.

Auto recover operation: The regulator stops switching when the junction temperature exceeds 150℃. Once the junction temperature falls below 135℃, the device will resume operation.

Device Enable

When the device is enabled, LDO is turned on, and then I^2C interface is fully functional. The device can be enabled when BAT voltage is above 3.5V and EN voltage is greater than 1.2V, or VBUS voltage exceeds 3.5V (see Fig. 7). To disable the device, the regulator should be disabled through I^2C first, and then the device will automatically discharge VBUS. After VBUS falls below 3.5 V, pull EN low to totally disable the device.

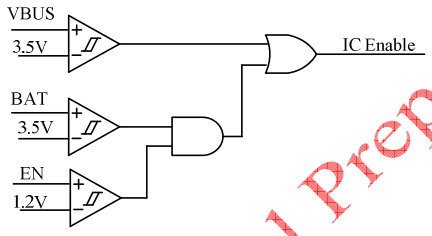
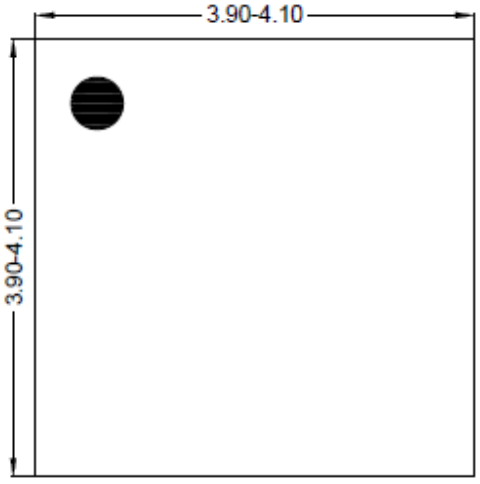
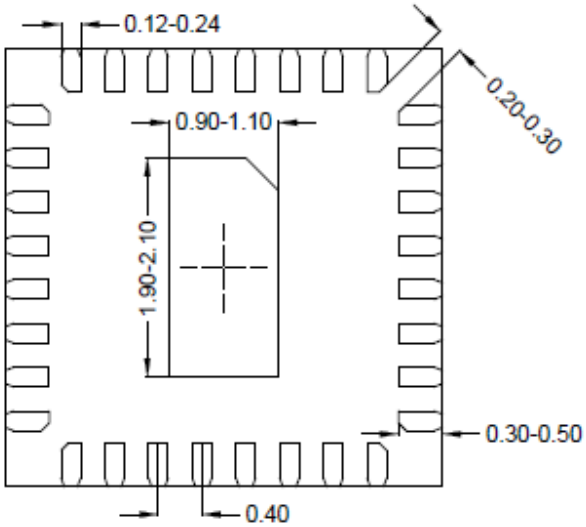


Fig. 7. Description of IC Enable Function

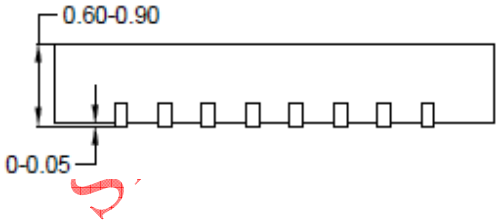
QFN4×4-32 Package Outline Drawing



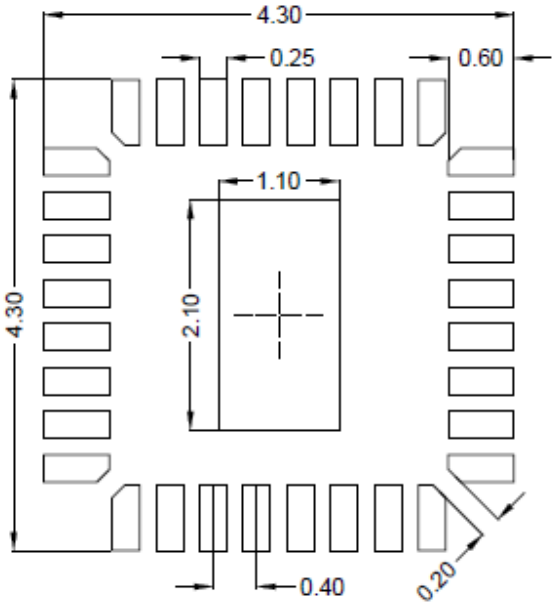
Top View



Side View



Side View



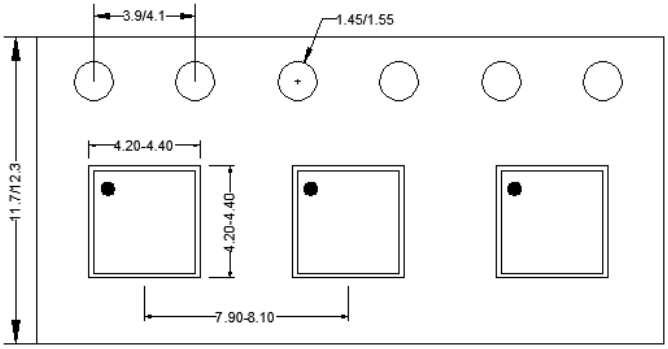
Recommended PCB layout (Reference only)

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

Taping & Reel Specification

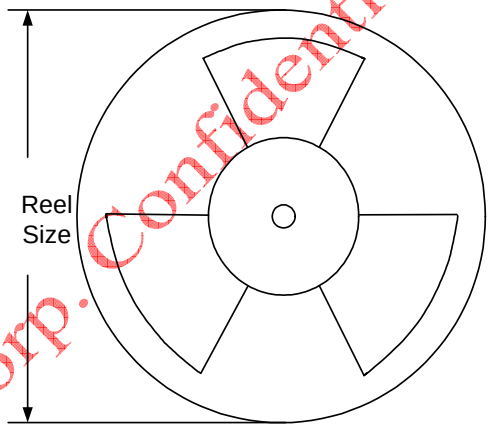
1. Taping orientation

QFN4×4



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 (pcs)
QFN4x4	12	8	13"	400	400	5000

3. Others: NA

单击下面可查看定价，库存，交付和生命周期等信息

>>SILERGY(矽力杰)