ASL1500SHN

Single phase boost converter

Rev. 4 — 26 October 2017 Product data sheet

1. Introduction

The ASL1500SHN is a highly integrated and flexible single phase DC-to-DC boost converter IC. It has an SPI interface allowing control and diagnostic communication with an external microcontroller.

It is designed primarily for use in automotive LED lighting applications and provides an optimized supply voltage for ASLx415SHN Multi-channel LED Buck Driver.

2. General description

The ASL1500SHN has a fixed frequency peak current mode control with parabolic/non-linear slope compensation. It can operate with input voltages from 5.5 V to 40 V. It can be configured via SPI for output voltages of up to 80 V, to power the LED buck driver IC.

The ASL1500SHN boost converter drives one external low-side N channel MOSFET from an internally regulated adjustable supply to drive either logic or standard level MOSFET.

The integrated SPI interface also allows for programming the supply under/over voltage range, output voltage range and DC-to-DC switching frequency. It enables the optimization of external components and flexibility for EMC design. This interface can also be used to provide diagnostic information such as the driver temperature.

Additional features include input under-voltage lockout and thermal shutdown when the junction temperature of the ASL1500SHN exceeds +175 °C.

The device is housed in a very small HVQFN32 pin package with an exposed thermal pad. It is designed to meet the stringent requirements of automotive applications. It is fully AEC Q100 grade 1 qualified. It operates over the −40 °C to +125 °C ambient automotive temperature range.

3. Features and benefits

- The ASL1500SHN is an automotive grade product that is AEC-Q100 grade 1 qualified.
- Operating ambient temperature range of –40 °C to +125 °C
- Wide operating input voltage range from +5.5 V to +40 V
- Output voltage programmable via SPI interface
- Flexible output voltage with 3 % accuracy programmable via SPI
- Fixed Frequency Operation via built-in oscillator
- Slope compensation to track the frequency and output voltage
- Programmable control loop compensation
- Fast high efficiency FET switching
- Programmable internal gate driver voltage regulator
- Gate switching is halted when overvoltage on output is detected
- Support both Logic Level and Standard Level FETs
- Low Electro Magnetic Emission (EME) and high Electro Magnetic Immunity (EMI)
- Output voltage monitoring
- Supply voltage measurement
- Control signal to enable the device
- Read-back programmed voltage and frequency range via SPI
- Junction temperature monitoring via SPI
- Small package outline HVQFN32
- Low quiescent current <5 μA at 25 °C when EN = 0

4. Applications

- Automotive LED lighting
  - Daytime running lights
  - Position or park light
  - Low beam
  - High beam
  - Turn indicator
  - Fog light
  - Cornering light

5. Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
ASL1500SHN	HVQFN32	plastic thermal enhanced very thin quad flat package; no leads; 32 terminals; body 5 × 5 × 0.85 mm	SOT617-12

6. Block diagram

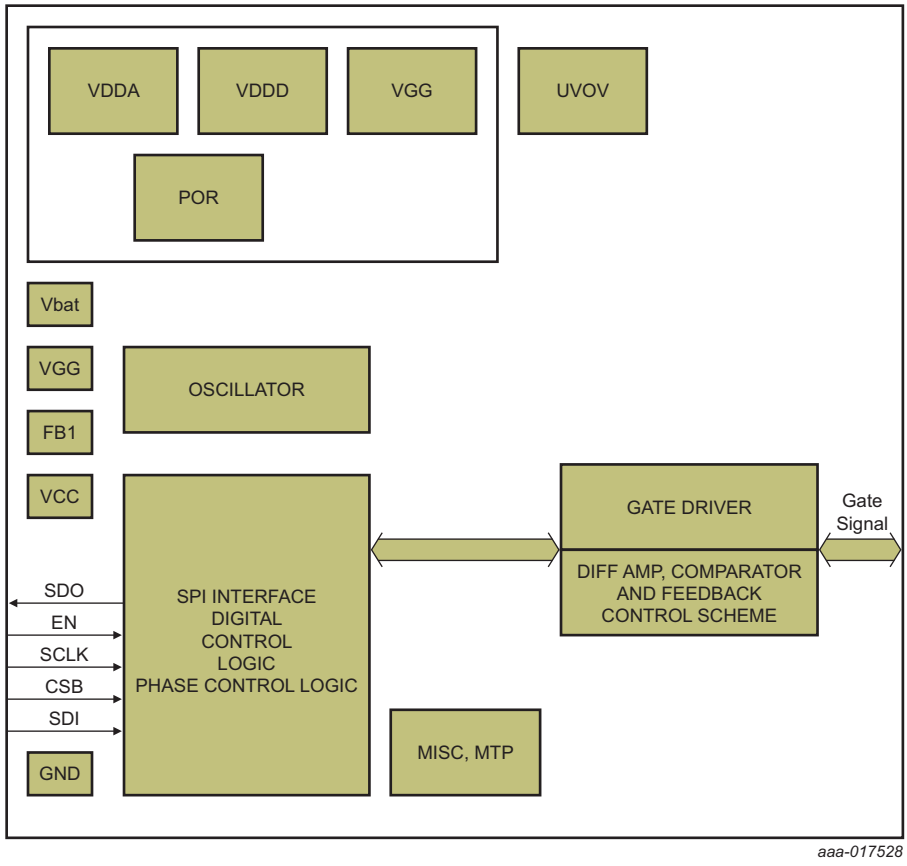


Fig 1. Block diagram

7. Pinning information

7.1 Pinning

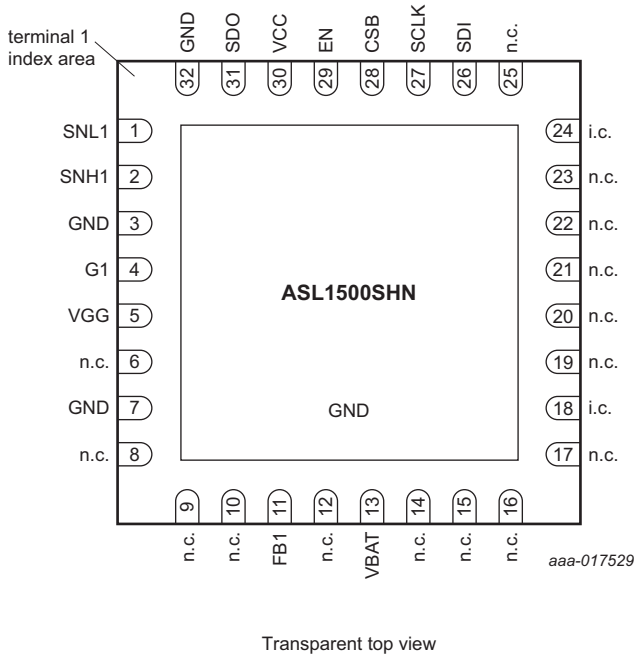


Fig 2. Pin configuration

7.2 Pin description

Table 2. Pin description[1]

Symbol	Pin	Description
SNL1	1	phase 1 sense low
SNH1	2	phase 1 sense high
GND	3	ground
G1	4	phase 1 gate driver
VGG	5	gate driver supply
n.c.	6	not connected
GND	7	ground
n.c.	8	not connected
n.c.	9	not connected
n.c.	10	not connected
FB1[2]	11	feedback, output 1
n.c.	12	not connected
VBAT	13	battery supply
n.c.	14	not connected
n.c.	15	not connected

Table 2. Pin description[1] …continued

Symbol	Pin	Description
n.c.	16	not connected
n.c.	17	not connected
i.c.[3]	18	internally connected
n.c.	19	not connected
n.c.	20	not connected
n.c.	21	not connected
n.c.	22	not connected
n.c.	23	not connected
i.c.[3]	24	internally connected
n.c.	25	not connected
SDI	26	SPI Data Input
SCLK	27	SPI Clock
CSB	28	SPI chip select
EN	29	enable signal
VCC	30	external 5 V supply
SDO	31	SPI Data Out
GND	32	chip ground

[1] Not connected (n.c.) pins are internally not connected and can be left floating or can be connected to any voltage level.

[2] See Figure 4 and Figure 14 for recommend connections for pin FB1.

[3] Internally connected pins should be connected to GND.

For enhanced thermal and electrical performance, the exposed center pad of the package should be soldered to board ground (and not to any other voltage level).

8. Functional description

8.1 Operating modes

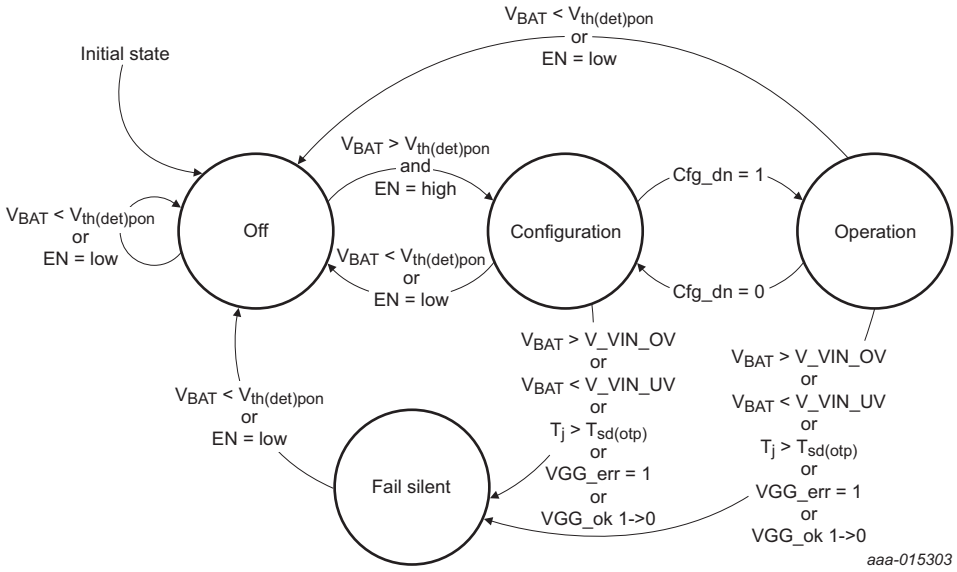


Fig 3. State diagram

Table 3. Operating modes

Mode	Control registers	Configuration registers	Diagnostic registers	VGG	Vout1	Remarks
Off	n.a.	n.a.	n.a.	off	off	device is off, no communication possible.
Configuration	read/write	read/write	read	off	off	VGG is off if no outputs were previously enabled
			read	according to register	off	VGG is on as soon as one of the outputs has been enabled
Operation	read/write	read	read	locked	according to register	configuration registers are locked
Fail silent	read/write	read	read[1]	off	off	communication possible, but all outputs off. Restart via EN possible.

[1] Setting the bit cfg_dn to 0 also grants write access to the configuration registers.

8.1.1 Off mode

The ASL1500SHN switches to off mode, if the input voltage drops below the power-on detection threshold ($V_{th(det)pon}$) or the EN pin is low.

The SPI interface and output are turned off when the ASL1500SHN is in the Off mode.

8.1.2 Configuration mode

The ASL1500SHN switches from off mode to configuration mode, as soon the input voltage is above the power-on detection threshold ($V_{th(det)pon}$) and pin EN is high.

The configuration registers can be set when the ASL1500SHN is in the Configuration mode.

8.1.3 Operation mode

The ASL1500SHN switches from configuration mode to operation mode, as soon as the configuration done bit is set. Once the bit is set, the configuration registers are locked and cannot be changed.

In operation mode, the output is available as configured via the SPI interface. Setting the bit Vout1en, starts up the gate driver. Once the gate driver is in regulation (signaled by bit VGG_ok), the output voltage $V_{o1(prog)}$ is turned on accordingly. When the converters are on, the battery monitoring functionality is available.

8.1.4 Fail silent mode

The ASL1500SHN switches from Operation mode to Fail silent mode, when the junction temperature exceeds the over temperature shutdown threshold or a VGG error is detected. It will also switch modes when the input voltage is below the under voltage detection threshold or above the over voltage detection threshold.

In Fail silent mode, the output is turned off and only the SPI interface remains operational.

8.2 Boost converter configuration

The ASL1500SHN is an automatic boost converter IC delivering constant DC-to-DC voltage to a load. It has a fixed frequency current-mode control for an enhanced stable operation.

The ASL1500SHN offers one phase. The phase consists of a coil, a resistor, a MOSFET and a diode as shown in Figure 4.

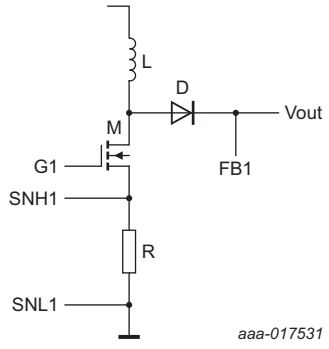


Fig 4. Phase of the boost converter with IC and application connections

To allow flexible use of the ASL1500SHN, the configuration is based on virtual phases. These phases are then mapped to a real, physical phase according to the physical connections and conditions of the circuitry around the ASL1500SHN as shown in Figure 5.

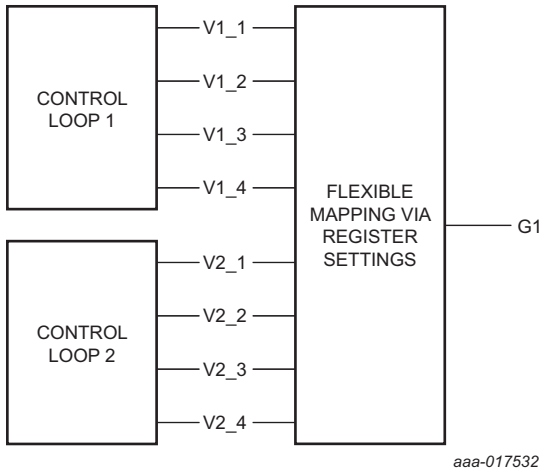


Fig 5. Mapping of virtual phases (V1_1 to V2_4) to physical phase (G1)

8.2.1 Configuration of the virtual phases

The ASL1500SHN can generate up to four internal phases at up to two virtual outputs. With the internal phase control enable registers, it can be selected, how many virtual phases are generated for the individual virtual outputs.

Table 4. Internal phase control enable for output 1, address 0x0Bh

Bit	Symbol	Description	Value	Function
7:4		reserved	0000	reserved; should remain cleared for future use
3	EN_P4_1	phase 4 enabled	0	phase 4 is off
			1	phase 4 is enabled
2	EN_P3_1	phase 3 enabled	0	phase 3 is off
			1	phase 3 is enabled
1	EN_P2_1	phase 2 enabled	0	phase 2 is off
			1	phase 2 is enabled
0	EN_P1_1	phase 1 enabled	0	phase 1 is off
			1	phase 1 is enabled

Table 5. Internal phase control enable for output 2, address 0x0Ch

Bit	Symbol	Description	Value	Function
7:4	-	reserved	0000	reserved; should remain cleared for future use
3	EN_P4_2	phase 4 enabled	0	phase 4 is off
			1	phase 4 is enabled
2	EN_P3_2	phase 3 enabled	0	phase 3 is off
			1	phase 3 is enabled
1	EN_P2_2	phase 2 enabled	0	phase 2 is off
			1	phase 2 is enabled
0	EN_P1_2	phase 1 enabled	0	phase 1 is off
			1	phase 1 is enabled

8.2.2 Association of physical phases to the output voltages

The phase that the ASL1500SHN offers, must be associated to the output.

Table 6. Gate driver output, address 0x02h

Bit	Symbol	Description	Value	Function
7:1		reserved	0000000	reserved; should remain clear for future use
0	O_G1	association phase 1	0	phase 1 is connected to Vout1
			1	not allowed

8.2.3 Association of connected phases to the internal phase generation

The physical phase that the ASL1500SHN offers, must be associated to one of the virtual phases of the output. It is established with the gate driver phase and phase select configuration registers.

Table 7. Gate driver phase, address 0x0Fh

Bit	Symbol	Description	Value	Function
7:1		reserved	000000	reserved; should remain clear for future use
0	O_GP1	association phase 1	0	phase 1 is connected to Vout1
			1	not allowed

Table 8. Phase select configuration, address 0x10h

Bit	Symbol	Description	Value	Function
7:2		reserved	0000	reserved; should remain clear for future use
1:0	Phsel1[1:0]	association phase 1	0x0h	routing from phase 1
			0x1h	routing from phase 2
			0x2h	routing from phase 3
			0x3h	routing from phase 4

8.2.4 Enabling of connected phases

The gate driver enable register is used to configure which of the phases is active.

Table 9. Gate driver enable, address 0x01h

Bit	Symbol	Description	Value	Function
7:1		reserved	0000000	reserved; should remain clear for future use
0	EN_G1	phase 1 enabled	0	phase 1 is off
			1	phase 1 is enabled

8.2.5 Configuration of the boost converter frequencies

The operation frequency of the boost converter can be set with via several SPI registers. For the regulation loop, an integer number downscales the internal oscillator frequency. The slower clock controls the off-time of a phase and the delay from one phase of the regulation loop to the next internal phase. The number of phases determinates finally when the phase is turned on again and defines so the operation frequency of the boost converter.

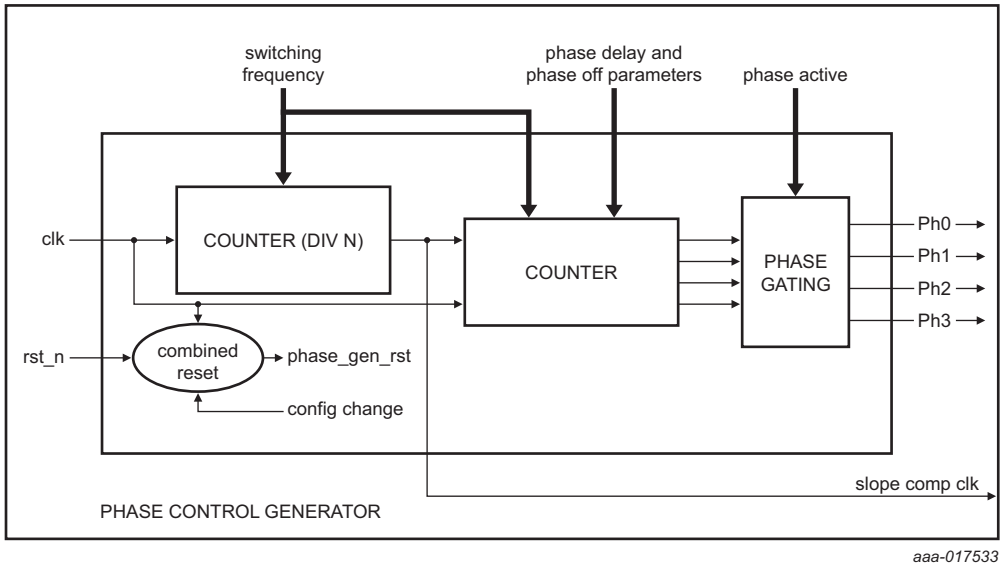


Fig 6. Phase control generator

Table 10. Clock divider for Vout1, address 0x09h

Bit	Symbol	Description	Value	Function
7:0	Clkdiv1 [7:0]	clock divider for output voltage 1	0x00h	clock is not divided
			...	clock is divided by clkdiv1[7:0]+1
			0xFFh	clock is divided by 256

Table 11. Phase-off time and phase delay of output 1, address 0x0Dh

Bit	Symbol	Description	Value	Function
7:3	Phdel1 [4:0]	delay to next phase of output1	0x0h	phase delay is 1 clock period of the divided clock
			...	phase delay is Phdel1[4:0]+1 clock period of the divided clock
			0x1Fh	phase delay is 32 clock periods of the divided clock
2:0	Phoff1 [2:0]	phase-off time of output1	0x0h	phase-off time is 1 clock period of the divided clock
			...	phase-off time is Phoff1[2:0] clock period of the divided clock
			0x7h	phase-off time is 7 clock periods of the divided clock

Note: To obtain the best performance of the internal slope compensation, keep the settings of the delay between the phases as close to 32 as possible.

8.2.6 Control loop parameter setting

The ASL1500SHN is able to operate with a wide range of external components and offers wide range of operating frequencies. To achieve maximum performance for each set of operation conditions, set the control loop parameters in accordance with the external components and operating frequency.

Table 12. Loop filter proportional configuration, address 0x11h

Bit	Symbol	Description	Value	Function
7:4		reserved	0000	reserved; should remain cleared for future use
3:0	Prop1[3:0]	proportional factor output 1	0x0h	proportional factor output 1 is 0.05
			...	proportional factor output 1 is Prop1[3:0]*0.05+0.05
			0xFh	proportional factor output 1 is 0.8

Table 13. Loop filter integral configuration, address 0x12h

Bit	Symbol	Description	Value	Function
7:4		reserved	0000	reserved; should remain cleared for future use
3:0	Integ1[3:0]	integral factor output 1	0x0h	integral factor output 1 is 0.005
			...	integral factor output 1 is Integ1[3:0]*0.005+0.005
			0xFh	integral factor output 1 is 0.08

Table 14. Slope compensation configuration, address 0x13h

Bit	Symbol	Description	Value	Function
7:4		reserved	0000	reserved; should remain cleared for future use
3:0	Slpcmp1[3:0]	slope compensation factor output 1	0x0h	slope compensation factor output 1 = 112 kΩ
			0x1h	slope compensation factor output 1 = 84 kΩ
			0x2h	slope compensation factor output 1 = 70 kΩ
			0x4h	slope compensation factor output 1 = 56 kΩ
			0x8h	slope compensation factor output 1 = 28 kΩ

Table 15. Current sense slope resistor configuration, address 0x14h

Bit	Symbol	Description	Value	Function
7:2		reserved	0000	reserved; should remain cleared for future use
1:0	Slpr1[1:0]	slope resistor configuration for gate driver 1	0x0h	2'b00 - 250 Ω
			0x1h	2'b01 - 500 Ω
			0x2h	2'b10 - 1000 Ω
			0x3h	2'b11 - 1500 Ω

8.3 Output voltage programmability

The ASL1500SHN provides the possibility to program the output voltage and output overvoltage protection of the output via the SPI interface.

8.3.1 Output voltage target programming

The target output voltage can be programmed via the Output voltage registers. As the ASL1500SHN is a boost converter, the output voltage cannot be lower than the supply voltage minus the drop of the converter diode (Dx in Figure 4).

Table 16. Output voltage 1 register, address 0x03h

Bit	Symbol	Description	Value	Function
7:0	V_Vout_1[7:0]	target voltage output 1	0x00h	output 1 is turned off
			...	target voltage output 1 = 0.3606 * V_Vout_1[7:0]
			0xFFh	maximum target output voltage = 90 V

8.3.2 Output overvoltage protection programming

Due to fast changes in the supply or the output, it is possible that the output voltage is disturbed. To avoid high voltages that may result into damage of attached components, the ASL1500SHN offers a programmable overvoltage protection threshold. Once the output voltage is above this threshold, the gate pin of the output stops toggling. It results in a halt of the energy delivery to the output.

Once the output voltage recovers and is below the threshold again, the gate pin starts toggling again. The regulation loop regulates the output back to the target value.

For stable operation of the device, the limit voltage output register should be programmed around 5 V higher than the output voltage registers.

Table 17. Limit voltage output 1 register, address 0x05h

Bit	Symbol	Description	Value	Function
7:0	Vmax_Vout_1[7:0]	limit voltage output 1	0x00h	output 1 is turned off
			...	target voltage output 1 = 0.3606 * Vmax_Vout_1[7:0]
			0xFFh	maximum output over voltage protection output 1 = 90 V

8.4 Coil peak current limitation

The ASL1500SHN offers a function to limit peak current inside the coil and therefore to limit the input current for the system. Furthermore this functionality can be used to avoid magnetic saturation of the coils. It also allows some soft start feature to be realized with this function.

With the Max phase current Vout1 register, the maximum peak current for the phase can be configured. Once the voltage between pins SNSLx and SNSHx reaches this level, the gate will be turned off until the next switching cycle. To avoid sub harmonic oscillations when the coil peak current limitation is becoming active, the slope compensation remains active. It reduces the coil peak current towards the end of the switching cycle to ensure stable operation of the system.

In order to avoid that this function interferes with the normal regulation, the limit should be placed well above the max expected current.

Table 18. Maximum phase current Vout1 register, address 0x07h

Bit	Symbol	Description	Value	Function
7:0	I_max[7:0]	coil current limitation	0x00h	no current allowed
			...	maximum peak current = (I_max_per_phase_Vout1 [7:0] * 1.8 V / 256 - 0.24 V) / R_{sense}
			0x80	max allowed setting = (128/255*1,8V-0,24) V / R_{sense}
			...	not allowed
			0xFFh	not allowed

8.5 Enabling the output voltage

The ASL1500SHN provides one output voltage. In operation mode, the output voltage is turned on with the bit Vout1en.

As soon as the output is turned on, the VGG voltage regulator is turned on. After the gate driver start-up time, the gate driver starts switching, provided the bit VGG_ok is set.

Table 19. Function control register, address 0x00h

Bit	Symbol	Description	Value	Function
7:4		reserved	0000	reserved; should remain cleared for future use
3	Cnt_CSB	count chip select time	0	chip select low count feature is disabled
			1	chip select low count feature is enabled
2		reserved	0	reserved; should remain cleared for future use
1	Vout1en	enable output 1	0	output 1 is turned off
			1	output 1 is turned on when the device is in operation mode
0	Cfg_dn	configuration done bit	0	device is in configuration mode - no configuration lock
			1	device is in operation mode - configuration lock is active

8.6 Frequency trimming

To ensure the ASL1500SHN operates inside the specified oscillator frequency range, it is mandatory to adjust the internal oscillator frequency of the device.

To measure the actual internal frequency, the device is measuring the time that the CSB pin is low during an SPI transfer. This time information can be used to adjust the oscillator frequency of the device. The recommended procedure for the time adjustment is shown in Figure 7.

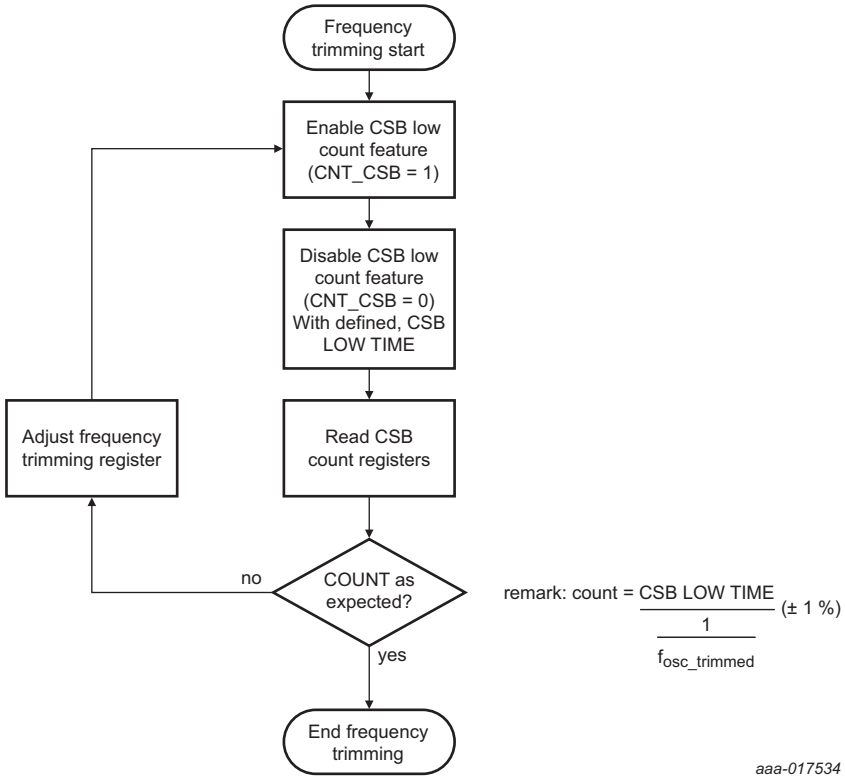


Fig 7. Frequency trimming flow

At the start of the sequence, the CSB low count feature is activated. It is done by setting the Cnt_CSB bit high in the frequency trimming control register (bit 3; register 0x00h). The device now measures the time with its internal time domain each time the CSB pin is low. It makes this information available in the CSB count registers. To allow an exact stable reading, set the Cnt_CSB bit low again with an accurately known CSB low time. Setting the bit low freezes the count registers. These registers store the last value, which in this case is the command that sets the Cnt_CSB bit low.

The CSB count registers contain the count of the CSB low time of the last SPI command the CSB low count feature was enabled. CSB count register 1 contains the bits 7 to 0 of the counter, while the CSB count register 2 contains the bits 15:8.

Table 20. CSB count register 1, address 0x41h

Bit	Symbol	Description	Value	Function
7:0	CSB_cnt[7:0]	CSB count low	...	count value (bits 7:0)

Table 21. CSB count register 2, address 0x42h

Bit	Symbol	Description	Value	Function
7:0	CSB_cnt[15:8]	CSB count high	...	count value (bits 15:8)

The count, the CSB count register returns, should correspond to the real time of the CSB low time. 1 count should correspond with 1/ $f_{osc\_trimmed}$ (see Table 39).

When the count that the CSB count registers return, deviates from the applied CSB low time, the device internal timing must be adjusted by modifying the frequency trimming register.

Table 22. Frequency trimming register, address 0x1Ch

Bit	Symbol	Description	Value	Function
7:6		reserved		not allowed
5:0	Freq_trim[5:0]	frequency trim bits	010001	default frequency −33.33 %
			010011	default frequency −30.56 %
			010101	default frequency −27.78 %
			010111	default frequency −25.00 %
			011001	default frequency −22.22 %
			011011	default frequency −19.44 %
			011101	default frequency −16.67 %
			011111	default frequency −13.89 %
			000001	default frequency −11.11 %
			000011	default frequency −8.33 %
			000101	default frequency −5.56 %
			000111	default frequency −2.78 %
			001001	default frequency
			001011	default frequency + 2.78 %
			001101	default frequency + 5.56 %
			001111	default frequency + 8.33 %
			110001	default frequency + 11.11 %
			110011	default frequency + 13.89 %
			110101	default frequency + 16.67 %
			110111	default frequency + 19.44 %
			111001	default frequency + 22.22 %
			111011	default frequency + 25.00 %
			111101	default frequency + 27.78 %
			111111	default frequency + 30.56 %
			100001	default frequency + 33.33 %
			100011	default frequency + 36.11 %
			others	not allowed

To ensure that the adjustment had the desired effect, restart the procedure and check the count with the new settings in the frequency trimming register.

When the device internal time matches the applied CSB low time, no further adjustment is needed and the trimming procedure is finished.

8.7 Gate voltage supply

The ASL1500SHN has an integrated linear regulator to generate the supply voltage of the gate driver, which is internally connected to the pin VGG. The voltage generated by the linear regulator can be set via the VGG control register.

Table 23. VGG control register, address 0x15h

Bit	Symbol	Description	Value	Function
7:0	VGG[7:0]	supply voltage for gate driver	0x00h	not allowed
			...	not allowed
			0x5Dh	maximum output voltage = 10.04 V
			...	(255- VGG[7:0]) * 62 mV
			0xB7h	minimum output voltage = 4.46 V
			...	not allowed
			0xFFh	not allowed

The actual value of VGG can deviate from the target setting due to the tolerances of the VGG regulation loop (see $V_{o(reg)acc}$ in Table 38).

When a setting between 0x00h and 0x5Dh is used, the resulting gate driver target voltage exceeds the limiting values of the IC. The limiting values of the VGG pin can also be violated with target settings of 0xA6h to 0x5Dh due to these tolerances. A violation of the limiting values with the actual VGG voltage must be avoided. To ensure that only allowed settings are used for the gate driver target voltage, an immediate read back of the programmed value is required after setting the registers.

If a setting between 0xFFh and 0xB7h is used, the device may not start up VGG. If the device operates, parameters of VGG are not guaranteed.

8.7.1 Gate voltage supply diagnostics

The diagnostic options for the gate voltage supply are:

- VGG available. Details can be found in Section 8.10
- VGG protection active. Details can be found in Section 8.10

8.8 Supply voltage monitoring

The ASL1500SHN is continuously measuring the voltage at pin VBAT, when the output is enabled and bit VGG_ok is set. It allows the system to monitor the supply voltage without additional external components. It also offers the option to put an automatic under- and/or overvoltage protection in place.

Note: The VIN_UV and VIN_OV bits in the status register use the battery voltage measurement. Consequently the VIN_UV and VIN_OV bits are only reliable when the output is enabled.

8.8.1 Battery voltage measurement

The ASL1500SHN is continuously measuring the voltage at pin VBAT. The measurement result is available in the battery voltage register when the output is enabled.

Table 24. Battery voltage register, address 0x45h

Bit	Symbol	Description	Value	Function
7:0	V_VBAT[7:0]	battery voltage	0x00h	battery voltage = 0 V
			...	battery voltage = 0.3606 *V_VBAT[7:0]
			0xFFh	maximum measurable battery voltage = 90 V

8.8.2 Undervoltage detection

The ASL1500SHN offers a variable under voltage detection threshold. When the supply voltage drops below this threshold, the undervoltage detect bit is set and Fail silent mode is entered. The gate pin stops toggling and no more power is delivered to the output.

Table 25. Undervoltage threshold register, address 0x1Bh

Bit	Symbol	Description	Value	Function
7:0	V_VIN_UV[7:0]	undervoltage detection threshold	0x00h	undervoltage detection threshold = 0 V
			...	undervoltage detection threshold = 0.3606 *V_VIN_UV[7:0
			0xFFh	maximum undervoltage detection threshold = 90 V

8.8.3 Overvoltage detection

The ASL1500SHN offers a variable overvoltage detection threshold. When the supply voltage rises above this threshold, the overvoltage detect bit is set, and Fail silent mode is entered. The gate pin stops toggling and no more power is delivered to the output.

Table 26. Overvoltage threshold register, address 0x1Ah

Bit	Symbol	Description	Value	Function
7:0	V_VIN_OV[7:0]	overvoltage detection threshold	0x00h	overvoltage detection threshold = 0 V
			...	overvoltage detection threshold = 0.3606 *V_VIN_OV[7:0
			0xFFh	maximum overvoltage detection threshold = 90 V

8.9 Junction temperature information

The ASL1500SHN provides a measurement of the IC junction temperature. The measurement information is available in the junction temperature register.

Table 27. Junction temperature register, address 0x46h

Bit	Symbol	Description	Value	Function
7:0	T_junction[7:0]	junction temperature	...	device junction temperature below –40 °C
			0x18h	device junction temperature = –40 °C
			...	device junction temperature = T_junction[7:0] * (215/106) °C – 88 °C
			0x82h	device junction temperature = 175 °C

8.10 Diagnostic information

The diagnostic register contains useful information for diagnostic purposes. Details for each bit can be found in the following subchapters.

Table 28. Undervoltage threshold register, address 0x0Fh

Bit	Symbol	Description	Value	Function
7	Vout1_ok	Vout1 regulated	0	Vout1 is deviating from the target value
			1	Vout1 is regulated to the target value
6		reserved	0	Reserved; should remain clear for future use
5	VGG_ok	VGG regulation OK	0	VGG is not available
			1	VGG is available
4	Tj_err	device temperature is too high	0	device temperature below $T_{sd(otp)}$
			1	device temperature above $T_{sd(otp)}$
3	VIN_UV	VIN under voltage	0	no under voltage at VIN detected
			1	under voltage at VIN detected
2	VIN_OV	VIN over voltage	0	no over voltage at VIN detected
			1	over voltage at VIN detected
1	SPI_err	SPI error	0	last SPI command was executed correctly
			1	last SPI command was erroneous and has been discarded
0	VGG_err	VGG error	0	VGG overload protection not active
			1	VGG overload protection has turned on and VGG is deactivated

8.10.1 Bit VIN_OV

The bit VIN_OV depends on the battery monitoring functionality as described in Section 8.8. It indicates that the device has detected an overvoltage condition and entered Fail silent mode. A write access to the diagnostic register or when the Off mode has been entered, clears the bit. Independent of the clearing of the bit, the device stays in Fail silent mode.

8.10.2 Bit VIN_UV

The bit VIN_UV depends on the battery monitoring functionality as described in Section 8.8. It indicates that the device has detected an undervoltage condition and entered Fail silent mode. A write access to the diagnostic register or when the Off mode has been entered, clears the bit. Independent of the clearing of the bit, the device stays in Fail silent mode.

8.10.3 Bit SPI_err

The device is evaluating all SPI accesses to the device for the correctness of the commands. When the command is not allowed, the SPI_err bit is set.

A write access to the diagnostic register or when the Off mode is entered, clears the bit.

8.10.4 Bit Tj_err

The bit Tj_err indicates that the junction temperature has exceeded the maximum allowable temperature, and the device has entered Fail silent mode. A write access to the diagnostic register, or once Off mode has been entered, clears the bit. The device stays in Fail silent mode irrespective of the clearing of the bit. After leaving the OFF mode (at IC start-up), it is possible that bit Tj_err is set. To avoid wrong diagnostics, clear the diagnostic register before it is evaluated.

8.10.5 Bit VGG_err

Bit VGG_err is set when the gate driver does not reach the VGG_ok _window (when V_{VGG} is within range) within the regulator voltage start-up error time. Once bit VGG_err is set, it indicates that an error on the gate driver has been detected and the device has entered Fail silent mode. A write access to the diagnostic register, or once Off mode has been entered, clears the bit. The device stays in Fail silent mode irrespective of the clearing of the bit.

8.10.6 Bit VGG_ok

The bit VGG_ok indicates that the gate driver is regulated to the target voltage and allows the gate driver to drive the gate driver pin. If the gate driver is outside the VGG_ok window after $t_{startup}$, and V_{VGG} is within range, the device clears VGG_ok bit and enters Fail silent mode.

8.10.7 Bit Vout1_ok

The bit Vout1_ok indicates whether the output voltage is regulated to the target value or deviating from the target value. The bit is set, as soon as the output is within the Vout_ok window (when V_O is within the range) for more than Vout t_{fltr}. The bit is cleared when the output is outside the Vout_ok window for more than Vout t_{fltr}.

8.11 SPI

The ASL1500SHN uses an SPI interface to communicate with an external microcontroller. The SPI interface can be used for setting the LEDs current, reading and writing the control register.

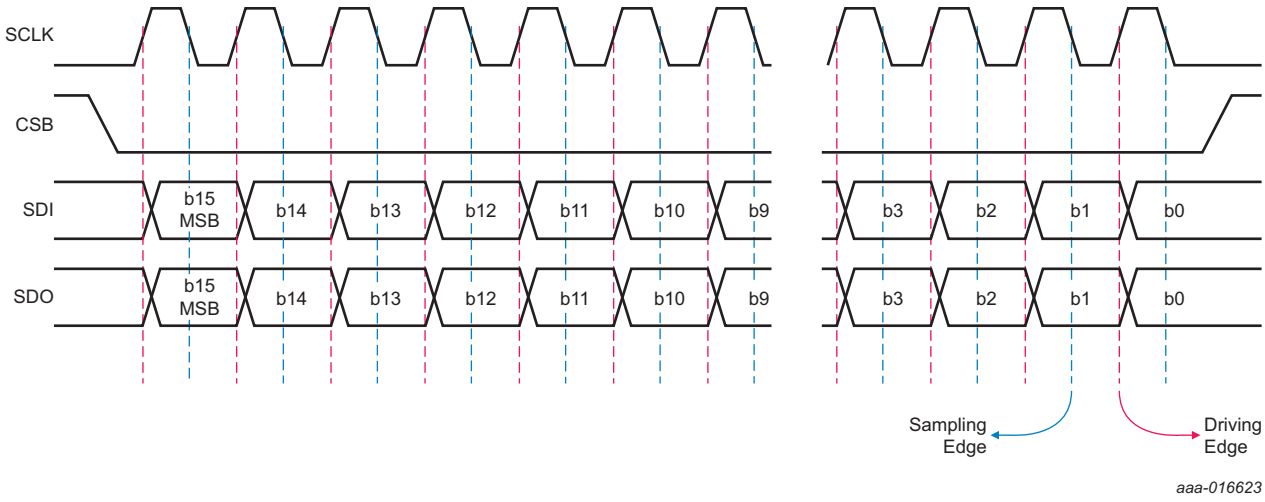
8.11.1 Introduction

The Serial Peripheral Interface (SPI) provides the communication link with the microcontroller, supporting multi-slave operations. The SPI is configured for full duplex data transfer, so status information is returned when new control data is shifted in. The interface also offers a read-only access option, allowing the application to read back the registers without changing the register content.

The SPI uses four interface signals for synchronization and data transfer:

- CSB - SPI chip select; active LOW
- SCLK - SPI clock - default level is LOW due to low-power concept
- SDI - SPI data input
- SDO - SPI data output - floating when pin CSB is HIGH

Bit sampling is performed on the falling clock edge and data is shifted on the rising clock edge as illustrated in Figure 8.



Format:

* Steady state SCLK = 0
* Data driving edge = positive edge
* Data sampling edge = negative edge

Fig 8. SPI timing protocol

The data bits of the ASL1500SHN are arranged in registers of one-byte length. Each register is assigned to a 7-bit address. For writing into a register, 2 bytes must be sent to the LED driver. The first byte is an identifier byte that consists of the 7-bit address and one read-only bit. For writing, the read-only bit must be set to 0. The second byte is the data that is written into the register. So an SPI access consists of at least 16 bit.

Figure 9 together with Table 29 and Table 30 demonstrate the SPI frame format.

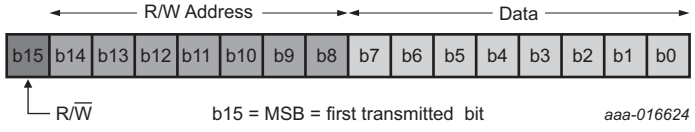


Fig 9. SPI frame format

Table 29. SPI frame format for a transition to the device

Bit	Symbol	Description	Value	Function
15	b15	R/W bits	0	write access
			1	read access
14:8	b14:8	address bits	...	selected address
7:0	b7:0	data bits	...	transmitted data

Table 30. SPI frame format for a transition from the device

Bit	Symbol	Description	Value	Function[1]
8:15	b8:15	diagnostic register	...	content of diagnostic register
7:0	b7:0	data bits	...	when previous command was a valid read command, content of the register that is supposed to be read
			...	when previous command was a valid write command, new content of the register that was supposed to be written

[1] The first SPI command after leaving the Off mode, will return 0x00h.

The Master initiates the command sequence. The sequence begins with CSB pin pulled low and lasts until it is asserted high.

The ASL1500SHN also tolerates SPI accesses with a multiple of 16 bits. It allows a daisy chain configuration of the SPI.

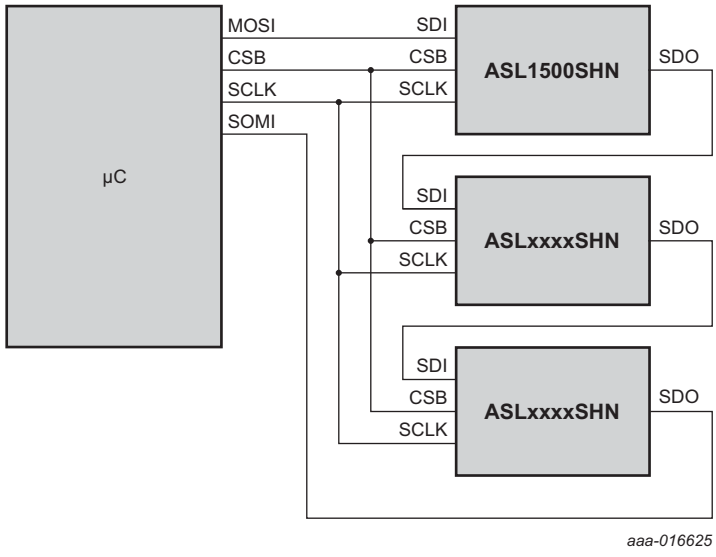


Fig 10. Daisy chain configuration

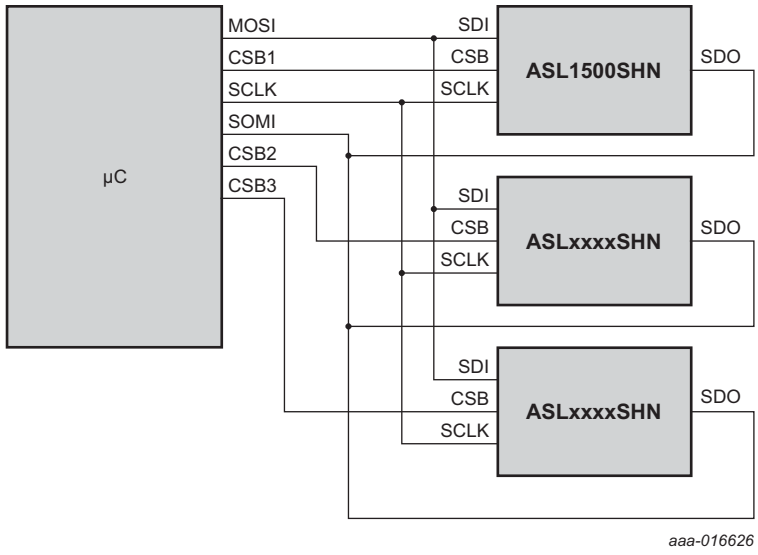


Fig 11. Physical parallel slave connection

During the SPI data transfer, the identifier byte and the actual content of the addressed registers is returned via the SDO pin. The same happens for pure read accesses. Here the read-only bit must be set on logic 1. The content of the data bytes that are transmitted to the ASL1500SHN is ignored.

The ASL1500SHN monitors the number of data bits that are transmitted. If the number is not 16, or a multiple of 16, then a write access is ignored and the SPI error indication bit is set.

8.11.2 Typical use case illustration (Write/Read)

Consider a daisy chain scheme with one master connected to 4 slaves in daisy chain fashion. The following commands are performed during one sequence (first sequence):

- Write data 0xFF to register 0x1A Slave 1
- Read from register 0x02 of Slave 2
- Write data 0xAF to register 0x2F of Slave 3
- Read from register 0x44 of Slave 4

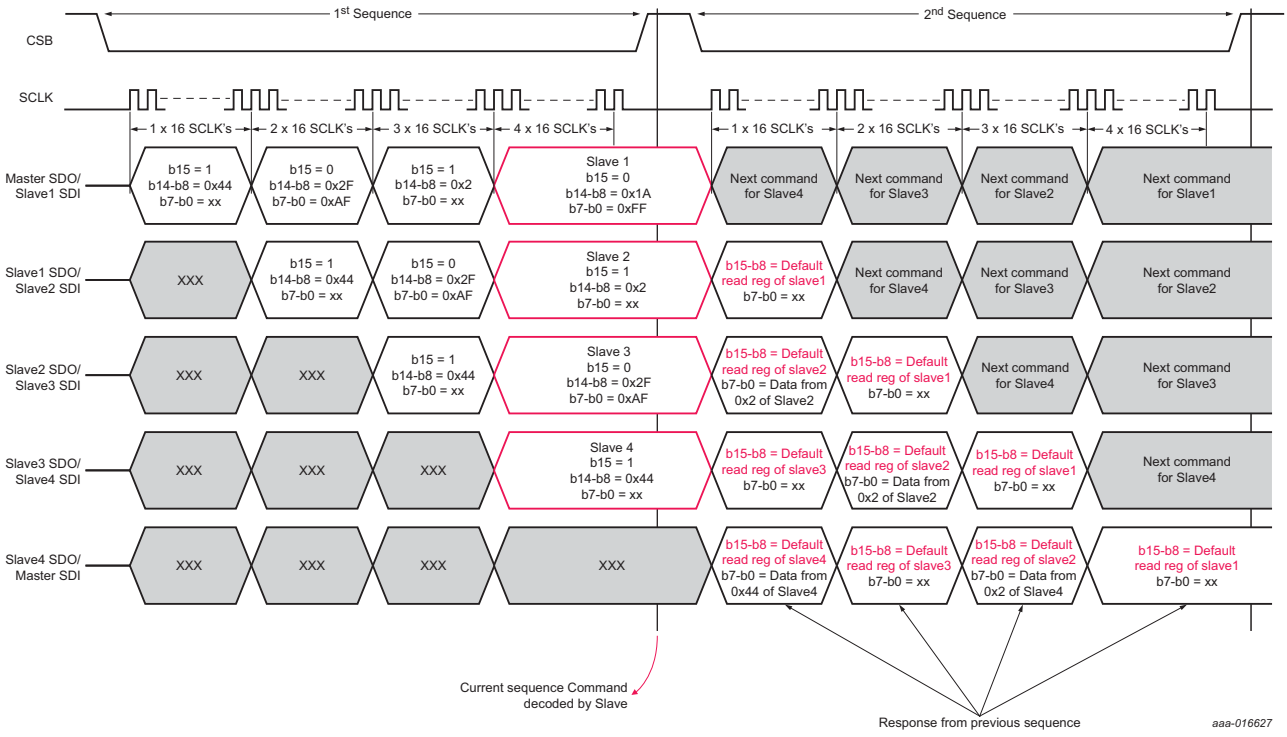


Fig 12. SPI frame format

8.11.3 Diagnostics for the SPI interface

The device is evaluating all SPI access to the device for the correctness of the commands. When the command is not allowed, the SPI_err bit is set. The conditions that are considered as erratic accesses are:

- SPI write is attempted to a read-only location or reserved location
- SPI read is attempted from a reserved location
- SPI command does not consist of a multiple of 16 clock counts

If an SPI access is considered to be erratic, no modifications to a SPI register are made. The access after the erratic SPI command returns the diagnostic register and zero in the data field.

For details about the SPI_err bit, see Section 8.10.3.

8.12 Register map

The addressable register space amounts to 128 registers from 0x00 to 0x7F. They are separated in two groups as shown in Table 31. The register mapping is shown in Table 32, Table 33, Table 34 and Table 35. The functional description of each bit can be found in the dedicated chapter.

Table 31. Register space grouping

Address range	Description	Content
0x00 ... 0x1F	control registers	control registers
0x20 ... 0x7F	diagnostic registers	diagnostic information

8.12.1 Control registers

Table 32 provides an overview of the control registers and their reset value.

Table 32. Control register group overview

Address	Name	Reset value	7	6	5	4	3	2	1	0
0x00h	function control	0x00h	-	-	-	-	Cnt_CSB	-	Vout1en[1]	Cfg_dn
0x01h	gate driver enable	0x00h	-	-	-	-	-	-	-	EN_G1[2]
0x03h	target voltage output 1	0x00h	V_Vout_1[7:0]							
0x05h	limit voltage output 1	0x00h	Vmax_Vout_1[7:0]							
0x07h	maximum phase current Vout1	0x46h	I_max[7:0]							
0x1Ch	frequency trimming register	0x09h	-	-	Freq_trim[5:0]					

[1] Bit is locked with bit Cfg_dn is high. When bit Cfg_dn is low, bits can be changed. Read is always possible.

[2] If the gate driver is enabled when bits Cfg_dn and VGG_ok are set high, it can be turned on and off during operation of the system. The gate driver, disabled when bits Cfg_dn and VGG_ok are set high, remains off, even when the gate enable bit is set high later.

8.12.2 Configuration registers

Table 33 provides an overview of the configuration registers. The configuration registers inside the control block can only be written in configuration mode. In the other modes, this register can only be read.

Table 33. Configuration register group overview

Address	Name	Reset value	7	6	5	4	3	2	1	0
0x02h	gate driver output	0x00h	-	-	-	-	-	-	-	O_G1
0x09h	clock divider for output 1	0x0Fh	Clkdiv1[7:0]							
0x0Bh	internal phases output 1	0x0Fh	-	-	-	-	EN_P4_1	EN_P3_1	EN_P2_1	EN_P1_1
0x0Ch	internal phases output 2	0x0Fh	-	-	-	-	EN_P4_2	EN_P3_2	EN_P2_2	EN_P1_2
0x0Dh	phase off and delay output 1	0x39h	Phdel1					Phoff1		
0x0Fh	gate driver phase	0x00h	-	-	-	-	-	-	-	O_GP1
0x10h	phase selection configuration	0xE4h	-		-		-		Phsel1	
0x11h	loop filter proportional configuration	0x00h	-				Prop1[3:0]			
0x12h	loop filter integral configuration	0x00h	-				Integ1[3:0]			
0x13h	slope compensation configuration	0x88h	-				Slpcmp1[3:0]			
0x14h	current sense slope resistor configuration	0x00h	-		-		-		Slpr1[1:0]	

Table 33. Configuration register group overview *…continued*

Address	Name	Reset value	7	6	5	4	3	2	1	0
0x15h	VGG control	0xFFh	VGG[7:0]							
0x1Ah	over voltage detection threshold	0xFFh	V_VIN_OV[7:0]							
0x1Bh	under voltage detection threshold	0x00h	V_VIN_UV[7:0]							

8.12.3 Internal registers

The ASL1500SHN uses the SPI registers to control some internal functions. In order to avoid any unintended behavior of the device, do not modify these registers but leave them all at their default value.

Table 34. Internal register overview

Address	Name	Reset value	7	6	5	4	3	2	1	0
0x04h	Internal 1	0x00h	-	-	-	-	-	-	-	-
0x06h	Internal 2	0x00h	-	-	-	-	-	-	-	-
0x08h	Internal 3	0x46h	-	-	-	-	-	-	-	-
0x0Ah	Internal 4	0x0Fh	-	-	-	-	-	-	-	-
0x0Eh	Internal 5	0x39h	-	-	-	-	-	-	-	-
0x19h	Internal 6	0x82h	-	-	-	-	-	-	-	-
0x25h	Internal 7	0x27h	-	-	-	-	-	-	-	-
0x26h	Internal 8	0x3Bh	-	-	-	-	-	-	-	-
0x2Fh	Internal 9	0xE8h	-	-	-	-	-	-	-	-
0x30h	Internal 10	0x09h	-	-	-	-	-	-	-	-

8.12.4 Diagnostic registers

The ASL1500SHN provides diagnostic data via some SPI registers. These registers are read only, but error bits can be cleared via a write access to the register.

Table 35. Diagnostic register group overview

Address	Name	7	6	5	4	3	2	1	0
0x41h	CSB count low	CSB_cnt[7:0]							
0x42h	CSB count high	CSB_cnt[15:8]							
0x45h	battery voltage	V_VBAT[7:0]							
0x46h	junction temperature	T_junction[7:0]							
0x5Fh	diagnostic Register	Vout1_ok	-	VGG_ok	Tj_err	VIN_UV	VIN_OV	SPI_err	VGG_err

9. Limiting values

Table 36. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V_{BAT}	battery supply voltage	EN = low	–0.3	+60	V
		EN = high	–0.3	+40	V
V_{VCC}	voltage on pin VCC		–0.3	+5.5	V
V_{GND}	ground supply voltage	voltage between ground pins	–0.6	+0.6	V
V_{FBx}	voltage on feedback pins	FB1	–0.3	+90	V
V_O	output voltage	programmed target voltage according to register 0x03h	10	+80	V
$V_{I(dig)}$	digital input voltage	voltage on digital pins SDO, SDI, CSB, SCLK and EN	–0.3	+5.5	V
V_{VGG}	voltage on pin VGG		–0.3	+10	V
V_{sense}	sense voltage	voltage on sense pins SNH1 and SNL1	–0.3	+0.3	V
V_G	voltage on gate pin	G1	–0.3	+10	V
V_{ic}	voltage on internally connected pins	i.c.	–0.3	+1.8	V
T_j	junction temperature		–40	+175	°C
T_{stg}	storage temperature		–55	+175	°C
V_{ESD}	electrostatic discharge voltage	HBM[1]			
		at any pin	–2	+2	kV
		at pin VBAT with 100 nF at pin	–6	+6	kV
		CDM[2]			
		at any pin	–500	+500	V

[1] Human Body Model (HBM): according to AEC-Q100-002 (100 pF, 1.5 kΩ)

[2] Charged Device Model (CDM): according to AEC-Q100-011 (field Induced charge; 4 pF).

10. Thermal characteristics

Table 37. Thermal characteristics

Symbol	Parameter	Conditions	Typ	Unit
R_{th}	thermal resistance	HVQFN32 package JEDEC[1]	37	K/W

[1] According to JEDEC JESD51-2, JESD51-5 and JESD51-7 at natural convection on 2s2p board. Board with two inner copper layers (thickness: 35 μm) and thermal via array under the exposed pad connected to the first inner copper layer.

11. Static characteristics

Table 38. Static characteristics

Min and Max values are specified for the following conditions: V_{BAT} = 5.5 V to 40 V, V_{EN} = 4.5 V to 5.5 V, V_{VCC} = 4.5 V to 5.5 V and T_j = −40 °C to +175 °C[1]. All voltages are defined with respect to ground, positive currents flow into the IC. Typical values are given at V_{VIN} = 40 V. V_{EN} = 5 V, V_{VCC} = 5 V and T_j = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supply pin Vbat						
I_{DD}	supply current	operating; no load on VGG; Gate pins low; one phase; one output	5	13	-	mA
		operating; no load on VGG; Gate pins low	-	20	-	mA
I_{off}	off-state current	EN = low	-	-	5	µA
$V_{th(det)pon}$	power-on detection threshold voltage		-	-	4.5	V
Supply pin VCC						
I_{VCC}	supply current on pin VCC	operating	-	-	250	µA
Pin EN						
I_{EN}	current on pin EN	operating	-	-	2	mA
Output voltage						
$V_{O(acc)}$	output voltage accuracy	deviation from target set value	−0.03 × Vout1 − 0.721	-	+0.03 × Vout1 + 0.721	V
V_O	output voltage	bit Vout_ok is set when V_O is within the range with respect to the target value	−5.4	-	+2.4	V
Regulated voltage output						
V_{VGG}	voltage on pin VGG	$V_{BAT} \geq V_{VGG} + V_{do(reg)VGG}$	4.46	-	10.04	V
		bit VGG_ok is set when V_{VGG} is within the range regarding the target value	−2.4	-	+2.4	V
$V_{do(reg)VGG}$	regulator dropout voltage on pin VGG	$I_{reg} \leq 50$ mA; regulator in saturation	-	0.5	1.0	V
		$I_{reg} \leq 160$ mA; regulator in saturation	-	1.6	3.2	V
$V_{reg(acc)VGG}$	regulator voltage accuracy on pin VGG	25 °C to $T_{j(max)}$	−5	-	+5	%
		−40 °C to +25 °C	−7	-	+5	%
Serial peripheral interface inputs; pins SDI, SCLK and CSB						
$V_{th(sw)}$	switching threshold voltage		0.3 × V_{VCC}	-	0.7 × V_{VCC}	V
$R_{pd(int)SCLK}$	internal pull-down resistance on pin SCLK		40	-	80	kΩ
$R_{pd(int)CSB}$	internal pull-down resistance on pin CSB		40	-	80	kΩ
$R_{pd(int)SDI}$	internal pull-down resistance on pin SDI		40	-	80	kΩ

Table 38. Static characteristics *…continued*

Min and Max values are specified for the following conditions: V_{BAT} = 5.5 V to 40 V, V_{EN} = 4.5 V to 5.5 V, V_{VCC} = 4.5 V to 5.5 V and T_j = −40 °C to +175 °C[1]. All voltages are defined with respect to ground, positive currents flow into the IC. Typical values are given at V_{VIN} = 40 V. V_{EN} = 5 V, V_{VCC} = 5 V and T_j = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Serial peripheral interface data output; pin SDO						
V_{OH}	HIGH-level output voltage	I_{OH} = −4 mA; V_{VCC} = 4.5 V to 5.5 V	V_{VCC} − 0.4	-	-	V
V_{OL}	LOW-level output voltage	I_{OL} = 4 mA; V_{VCC} = 4.5 V to 5.5 V	-	-	0.4	V
I_{LOZ}	OFF-state output leakage current	V_{CSB} = V_{VCC}; V_O = 0 V to V_{VCC}	−5	-	+5	µA
Temperature protection						
ΔT_j	junction temperature variation	measurement provided via register 0x46h; T_j = 130 °C	−20	-	+20	°C
$T_{sd(otp)}$	overtemperature protection shutdown temperature		150	175	200	°C
Vbat monitoring						
ΔV_{BAT}	battery voltage accuracy	accuracy of V_{BAT} measurement	−0.035 × V_{BAT} − 0.3606	-	+0.035 × V_{BAT} + 0.3606	V

[1] All parameters are guaranteed over the virtual junction temperature range by design. Factory testing uses correlated test conditions to cover the specified temperature and power supply voltage range.

12. Dynamic characteristics

Table 39. Dynamic characteristics

Min and Max values are specified for the following conditions: V_{VIN} = 10 V to 80 V, V_{EN} = 4.5 V to 5.5 V, V_{VCC} = 4.5 V to 5.5 V and T_j = −40 °C to +175 °C[1]. All voltages are defined with respect to ground, positive currents flow into the IC. Typical values are given at V_{VIN} = 40 V. V_{EN} = 5 V, V_{VCC} = 5 V and T_j = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{DCDC}	DC-to-DC converter frequency		120	-	700	kHz
$f_{(DCDC)acc}$	DC-to-DC converter frequency accuracy	operating, trimmed	−5	-	+5	%
f_{osc}	oscillator frequency	internal oscillator, untrimmed	130	-	250	MHz
		target frequency for trimmed operation	-	180	-	MHz
Serial peripheral interface timing; pins CSB, SCLK, SDI and SDO						
$f_{clk(int)}/f_{SPI}$	Internal clock frequency to SPI clock frequency ratio	ratio between internal clock and SPI clock	-	20:1	-	1
$t_{cy(clk)}$	clock cycle time		250	-	-	ns
$t_{SPILEAD}$	SPI enable lead time		50			ns
t_{SPILAG}	SPI enable lag time		50	-	-	ns
$t_{clk(H)}$	clock HIGH time		125			ns
$t_{clk(L)}$	clock LOW time		125	-	-	ns
$t_{su(D)}$	data input set-up time		50			ns
$t_{h(D)}$	data input hold time		50	-	-	ns
$t_{v(Q)}$	data output valid time	pin SDO; C_L = 20 pF	-		130	ns
$t_{WH(S)}$	chip select pulse width HIGH		250	-		ns

Table 39. Dynamic characteristics *...continued*

Min and Max values are specified for the following conditions: V_{VIN} = 10 V to 80 V, V_{EN} = 4.5 V to 5.5 V, V_{VCC} = 4.5 V to 5.5 V and T_j = −40 °C to +175 °C[1]. All voltages are defined with respect to ground, positive currents flow into the IC. Typical values are given at V_{VIN} = 40 V. V_{EN} = 5 V, V_{VCC} = 5 V and T_j = 25 °C unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Gate driver characteristics for pin G1						
$t_{ch(G)}$	gate charge time	20 % to 80 %; V_{VGG}= 7.5 V; C_{gate} = 2000 pF	-	-	30	ns
$t_{dch(G)}$	gate discharge time	80 % to 20 %; V_{VGG}= 7.5 V; C_{gate} = 2000 pF	-	-	14	ns
Regulated voltage						
$t_{startup}$	start-up error time	of VGG; f_{osc} = 180 MHz	-	2.5	-	ms
$t_{err(startup)}$	error detection time	for VGG during operation; f_{osc} = 180 MHz	-	31.5	-	µs
$t_{fltr(ov)}$	output voltage filter time	for bit Vout1_ok and Vout2_ok; f_{osc} = 180 MHz	-	31.5	-	µs

[1] All parameters are guaranteed over the virtual junction temperature range by design. Factory testing uses correlated test conditions to cover the specified temperature and power supply voltage range.

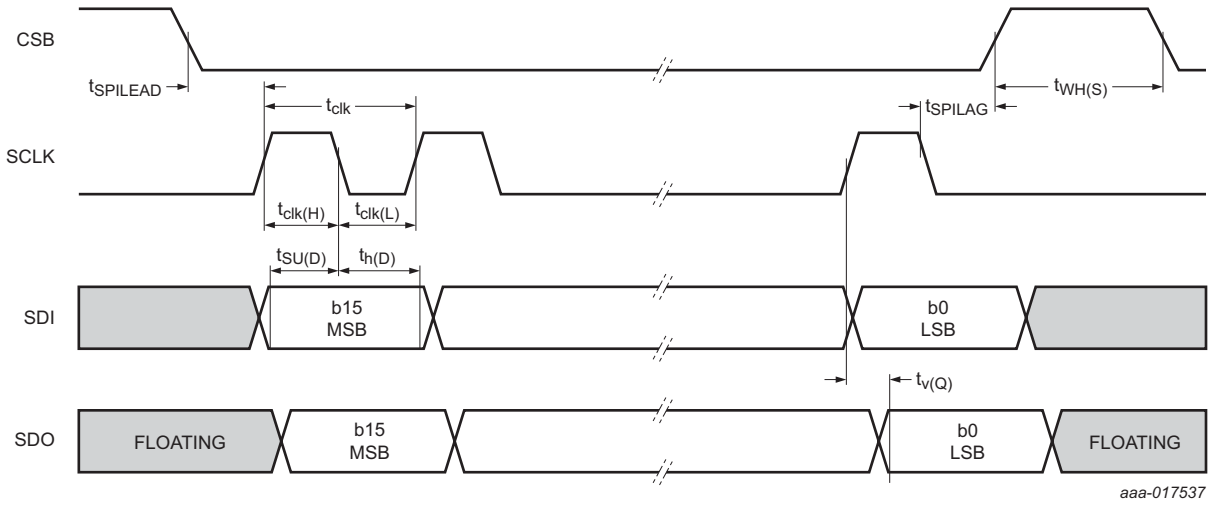


Fig 13. SPI timing diagram

13. Application information

Figure 14 provides an example for the ASL1500SHN in a typical 2-phase Boost converter IC with 1 output voltage.

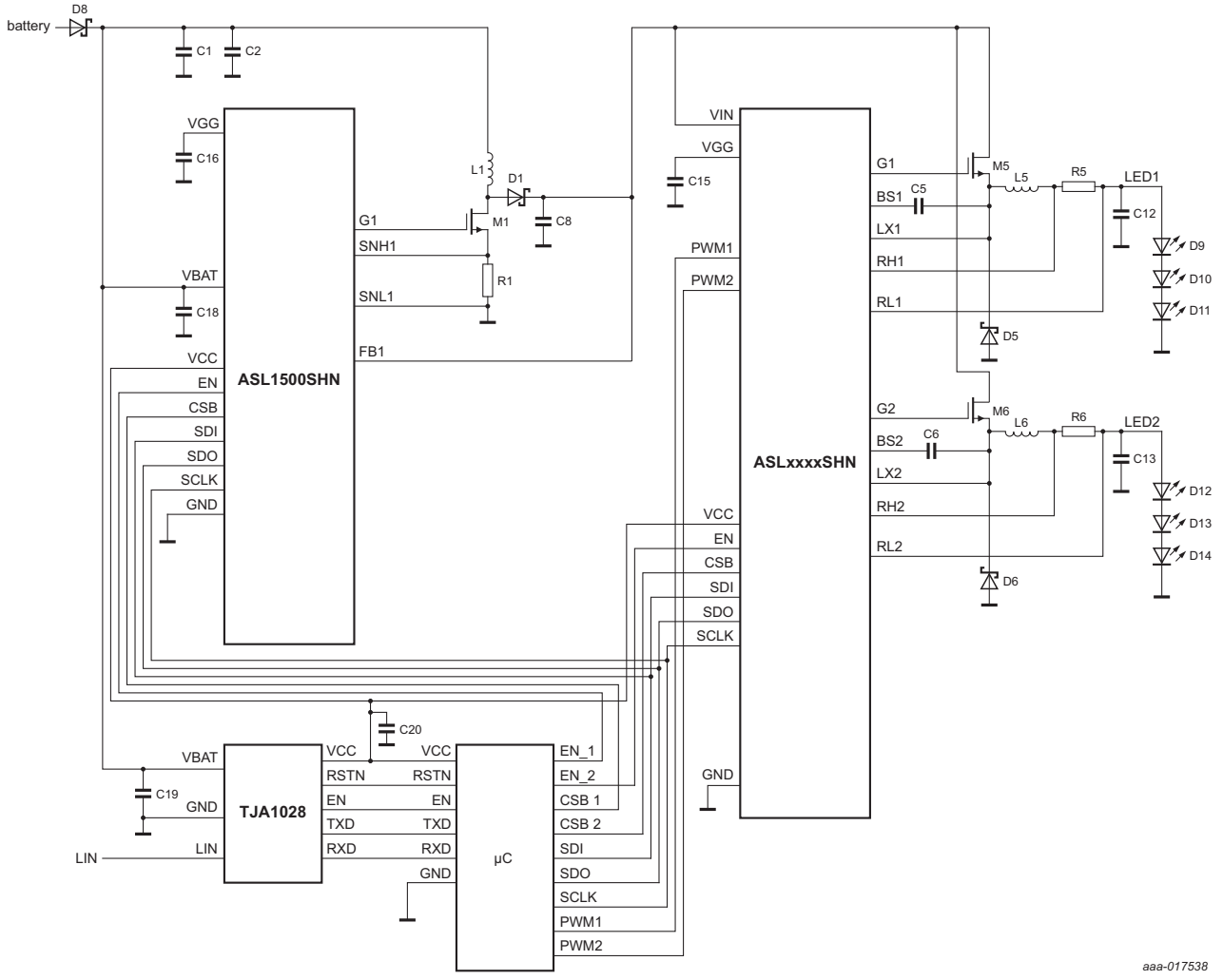


Fig 14. ASL1500SHN, single output boost converter

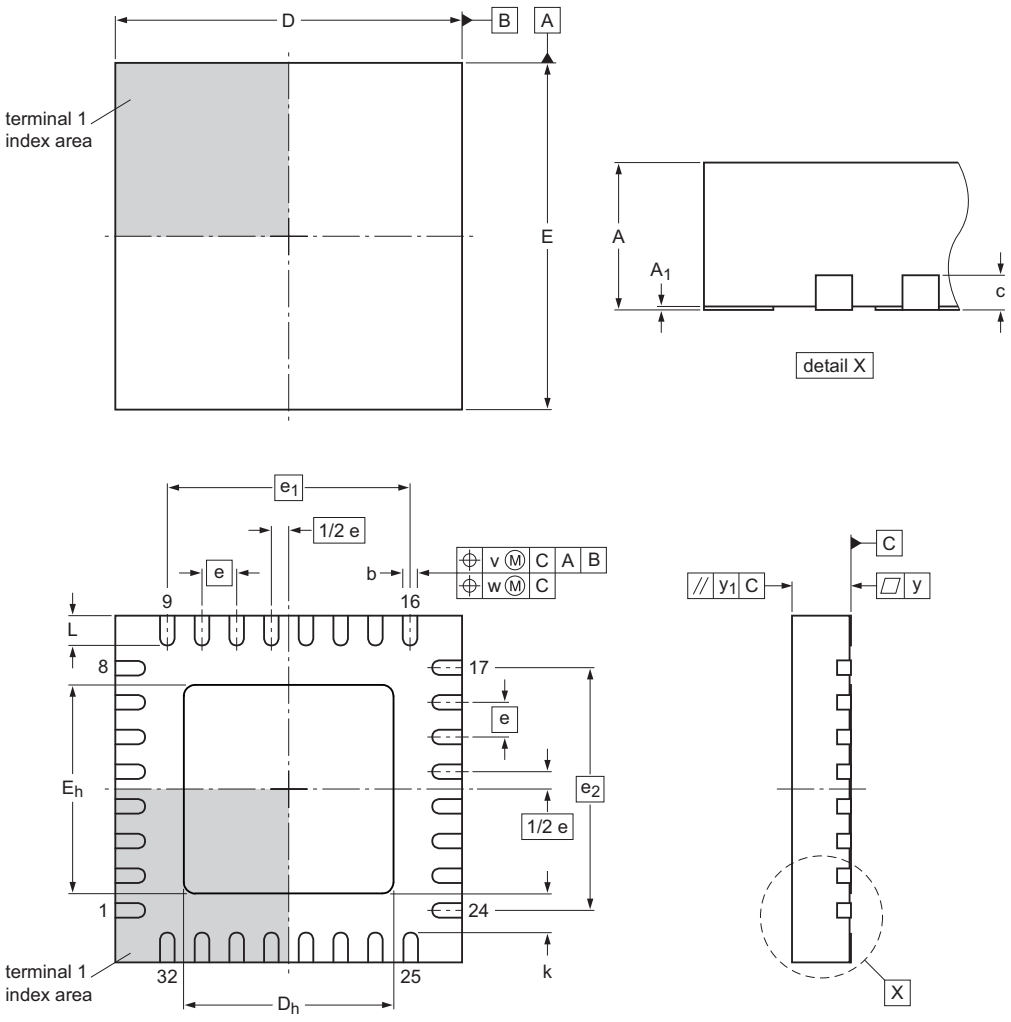
14. Test information

14.1 Quality information

This product has been qualified in accordance with the Automotive Electronics Council (AEC) standard Q100 Rev-H - *Failure mechanism-based stress test qualification for integrated circuits*, and is suitable for use in automotive applications.

15. Package outline

HVQFN32: plastic thermal enhanced very thin quad flat package; no leads; 32 terminals; body 5 x 5 x 0.85 mm **SOT617-12**



Dimensions (mm are the original dimensions)

Unit		A	A_1	b	c	$D^{(1)}$	D_h	$E^{(1)}$	E_h	e	e_1	e_2	k	L	v	w	y	y_1
	max	1.00	0.05	0.30		5.1	3.1	5.1	3.1					0.50				
mm	nom	0.85	0.02	0.21	0.2	5.0	3.0	5.0	3.0	0.5	3.5	3.5		0.44	0.1	0.05	0.05	0.1
	min	0.80	0.00	0.18		4.9	2.9	4.9	2.9				0.5	0.30				

Note
1. Plastic or metal protrusions of 0.075 mm maximum per side are not included.

sot617-12_po

Outline version	References				European projection	Issue date
	IEC	JEDEC	JEITA			
SOT617-12		MO-220				~~13-10-14~~ 13-11-05

Fig 15. Package outline HVQFN32

16. Revision history

Table 40. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
ASL1500SHN v.4	20171026	Product data sheet	-	ASL1500SHN v.3
Modifications:	• Section 8.7: clarified exceeding of limiting values • Formula for voltage conversion updated • Table 38: values of output voltage accuracy updated • Table 38: values of regulator voltage accuracy on pin VGG updated • Table 39: data output valid time updated			
ASL1500SHN v.3	20160413	Product data sheet	-	ASL1500SHN v.2
Modifications:	• Minor corrections made to Figure 3 “State diagram” on page 6 . • Text has been corrected and aligned with the ASLxxxxSHN series of data sheets.			
ASL1500SHN v.2	20150925	Product data sheet	-	ASL1500SHN v.1
Modifications:	• Minor corrections made to Figure 2, Figure 3 and Figure 14. • Text has been corrected and aligned with the ASLxxxxSHN series of data sheets. • A number of symbols have been upgraded to NXP standards. • Specification status upgraded to Product data sheet.			
ASL1500SHN v.1	20150624	Preliminary data sheet	-	-

17. Legal information

17.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

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19. Tables

20. Figures

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