

AS8506C

Battery Cell Monitor and Balancer IC

General Description

The AS8506C is a battery management IC dedicated to support cell voltage measurement, monitoring, cell balancing and temperature measurement functions in Li-lon battery stacks for industrial/consumer/PV battery applications.

Ambient temperature range is from -40°C to +85°C.

It features cell voltage diagnosis with externally adjustable upper and lower cell voltage limits, fast cell voltage capture on request through 12-bit SAR ADC, passive cell balancing by simultaneous comparison of actual cell voltages with a reference cell voltage and temperature measurement on two external NTC sensors through 12-bit ADC.

Cells that are above reference will sequentially be discharged through integrated switches and one external resistor.

There is also an active balancing option AS8506C A through factory setting to sequentially charge cells which are below reference from an external DC-DC Flyback converter and an integrated low side driver.

The device can be used flexibly for battery stacks up to 7 cells with a minimum stack voltage of 6V and a maximum stack voltage of 32V.

It can be chained to support battery packs of virtually any number of cells in synchronized mode through chained clock and trigger signal.

The status of the battery stack is communicated to outside world through OR'd voltage_ok signal and balance ready signal.

Ordering Information and Content Guide appear at end of datasheet.



Key Benefits & Features

The benefits and features of AS8506C, Battery Cell Monitor and Balancer IC are listed below:

Figure 1: Added Value of using AS8506C

Benefits	Features
Reduce filter / synchronization effort. Acquired data have same time stamp to inherently generate accurate comparison results independent from load transients.	Simultaneous cell voltage capture for safe operating area (SOA) monitoring and balancing.
Strongly reduces data communication and data processing and thereby improves EMC robustness.	Autonomous balancing and SOA monitoring.
To compensate accumulative charge differences only. This mitigates cases of occasional wrong balance decisions due to flat OCV characteristic or mismatch in cell temperature	Autonomous passive balancing in the 100 mA range
Intrinsic inter module balancing through charge redistribution, efficiency improvement in case of leakage path due to defect induced leakage in particular cells.	Option for active charge balancing with very few external components.
For OCV capture, cell impedance calculation, diagnosis	Absolute cell voltage read out, read out of two temperature sensors.
Small form factor, low BOM	40-pin MLF (6x6) package, very low number of external components.

Applications

The applications of AS8506C include:

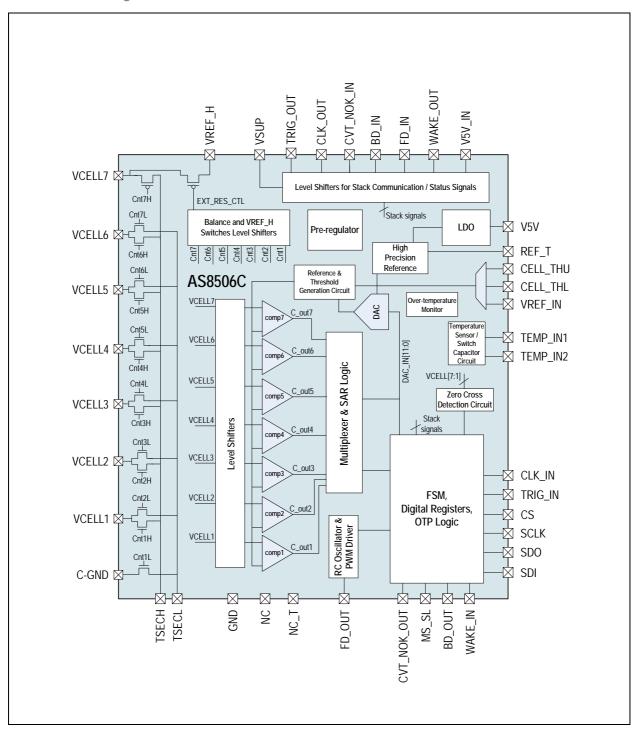
- The AS8506C is ideal for simultaneous cell monitoring and cell balancing in stacked energy storage systems. Current levels in the 100 mA range enables to compensate accumulative SOC mismatch over the entire cell pack.
- Typical applications are
 - Li-Ion batteries up to 200 cells,
 - Energy storage systems to buffer energy from PV panels or for emergency power supplies,
 - Battery management for e-scooters and e-bikes,



Block Diagram

The functional blocks of this device for reference are shown below:

Figure 2: AS8506C Block Diagram





Pin Assignment

Figure 3: Pin Diagram of AS8506C

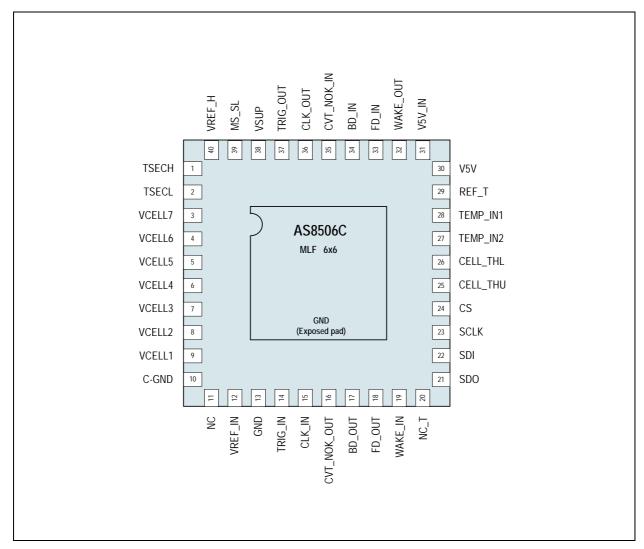




Figure 4: Pin Description

Pin Number	Pin Name	Pin Type	Description				
1	TSECH		Flyback converter transformer secondary high side				
2	TSECL		Flyback converter transformer secondary low side				
3	VCELL7		Battery cell 7 high level pin				
4	VCELL6		Battery cell 6 high level pin				
5	VCELL5	Analog input / output	Battery cell 5 high level pin				
6	VCELL4	·	Battery cell 4 high level pin				
7	VCELL3		Battery cell 3 high level pin				
8	VCELL2		Battery cell 2 high level pin				
9	VCELL1		Battery cell 1 high level pin				
10	C-GND	Power supply input	Battery cell 1 low level pin				
11	NC		Not connected				
12	VREF_IN	Analog input / output	Cell voltage reference value (cell target voltage of battery)				
13	GND	Power supply input	Ground to the IC				
14	TRIG_IN	Digital input	This pin triggers the cell balancing in the device. Short pulse is for receiving status and continuous 'High' for cell balancing. It also acts as a data line during 3-wire communication.				
15	CLK_IN		Clock input pin in the Slave device. This pin also acts as a clock during 3-wire communication. Scan clock in scan mode.				
16	CVT_NOK_OUT		This pin alerts when the cell voltage or the device/cell temperature is not within limits. During 3-wire communication, the CRC error is indicated on this pin. The internal device cell voltage or temperature status is ORed with CVT_NOK_IN on this pin.				
17	BD_OUT	Digital output	The 'device internal balance done' and 'balance done from above device' are ANDed on this pin. This pin in Master device indicates the complete system balance done. During address allocation process, this pin will be 'High' if BD_IN is 'High'.				
18	FD_OUT		Flyback converter gate/opto coupler drive (pad is push-pull type) can drive up to 12mA.				



Pin Number	Pin Name	Pin Type	Description
19	WAKE_IN	Digital input with pull-up	The wake pulse on this pin brings the IC into NORMAL mode. This pin has a pull-up resistor to the internal regulator. Should be driven with an open drain or external NMOS.
20	NC_T	Analog input / output	Not connected. Only used in Test mode.
21	SDO	Digital output	SPI data out
22	SDI	Digital input	SPI data in
23	SCLK	Digital iliput	SPI clock
24	CS	Digital input with pull-up	SPI chip select
25	CELL_THU		Cell voltage upper threshold
26	CELL_THL		Cell voltage lower threshold
27	TEMP_IN2	Analog input /	Temperature input2 to the IC (NTC input; if NTC is not connected, then should be connected to GND with 1K resistor).
28	TEMP_IN1	output	Temperature input1 to the IC (NTC input; if NTC is not connected, then should be connected to GND with 1K resistor).
29	REF_T		Supply to temperature sensor (Reference voltage to DAC and ADC).
30	V5V	Power supply	LDO 5V output.
31	V5V_IN	input	Supply to the bottom IC from the cascaded top IC.
32	WAKE_OUT	Digital output open drain	Open drain o/p on the VSUP+5V domain. WAKE_IN information will be transmitted to top device.
33	FD_IN	Digital input	Flyback converter gate drive input in daisy chain connection. (If FD_IN is 'high' then FD_OUT will be PWM o/p in balance mode).
34	BD_IN	Digital input with pull-down	In cell stack system, the device gets balance done status of above device. During address allocation process if this pin is 'High', then the device address is decremented by '1'.
35	CVT_NOK_IN		Indicates cell voltage or temperature status of above device.



Pin Number	Pin Name	Pin Type	Description		
36	CLK_OUT		This pin propagates the clock to next device in the stack system. In case of Master device internal RC clock is transmitted on this pin to Slave device.		
37	TRIG_OUT	Digital output	This pin transmits the data from TRIG_IN for balance and measurement phase. This pin is also used for propagating the data information to next device in stack system in SPI3.		
38	VSUP	Power supply input	Supply to the IC.		
39	MS_SL	Digital input	This pin informs the device whether it should act as the Master or Slave. If this pin is connected to GND , then device will act as Master. If this pin is connected to VSUP then device will act as Slave.		
40	VREF_H	Analog input / output	High sides PMOS switch for external resistive divided input to VREF_IN can be taken from external resistive divider in one of the options.		



Absolute Maximum Ratings

Stresses beyond those listed under "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 under "Operating Conditions" on page 10 is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Figure 5:
Absolute Maximum Ratings

Symbol	Parameter	Min	Тур	Max	Units	Comments				
	Electrical Parameters									
V _{VSUP}	Voltage at positive supply pin	-0.3		42	V	VSUP pin				
V _{GND}	Voltage at negative supply pin	-0.3		0	V	GND, C-GND; Reference potential				
V _{V5V_IN}	Voltage at high side supply	-0.3		VSUP + 0.3	V	MS_SL,VREF_H, TSECH and TSECL				
VSUP + V5V_IN	High side supply from top device	VSUP - 0.3		VSUP + 5.5	V	TRIG_OUT, CLK_OUT, CVT_NOK_IN, FD_IN, BD_IN, WAKE_OUT				
V _{V5V}	Voltage at on LDO o/p pins	-0.3		7	V	V5V pin				
V _{ESD}	Voltage on 5V pins	-0.3		V5V+0.3	V	All pins expect VSUP, VCELL1, VCELL2, VCELL3, VCELL4, VCELL5, VCELL6, VCELL7, MS_SL, WAKE_IN				
VCELL1 to VCELL7	Voltage on pins VCELL1, VCELL2, VCELL3, VCELL4, VCELL5, VCELL6, VCELL7	-0.3		7	V	Applied cell voltages				
I _{SCR}	Latch-up Immunity	-100		+100	mA					



Symbol	Parameter	Min	Тур	Max	Units	Comments				
	Electrostatic Discharge									
		±2				VSUP, VREF_IN, SDI, SDO, CS, SCLK, CELL_THU, CELL_THL, TEMP_IN1, TEMP_IN2, REF_T, V5V, V5V_IN, MS_SL, VREF_H, NC_T				
ESD	Electrostatic discharge voltage HBM standard ⁽¹⁾	±4			kV	GND, C-GND, CELL1 – CELL7 (Cell-voltage pins,), TSECH, TSECL, TRIG_IN, TRIG_OUT, CLK_IN, CLK_OUT, CVT_NOK_IN, CVT_NOK_OUT, WAKE_IN, WAKE_OUT, FD_IN, FD_OUT, BD_IN and BD_OUT				
		Continuo	us Powe	er Dissipation						
P _{tot}	Maximum power dissipation			1	W					
	Tem	perature Rai	nges and	l Storage Con	ditions					
T _{stg}	Storage temperature	-55		150	°C					
R _{thj_36}	Thermal resistance package		30		°C/W					
T _{BODY}	Package body temperature			260	°C	Norm: IPC/JEDEC J-STD-020 ⁽²⁾				
MSL	Moisture Sensitive Level		3							

Note(s) and/or Footnote(s):

^{1.} Human body model: $R = 1.5k\Omega$; C = 100pF.

^{2.} The reflow peak soldering temperature (body temperature) is specified according IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices".



Typical Operating Characteristics

All defined tolerances for external components in this specification need to be assured over the whole operation conditions range and also over lifetime.

Figure 6: Operating Conditions

Symbol	Parameter	Min	Тур	Max	Unit	Note
VSUP	Positive supply voltage	6		32	V	Normal operating condition
VSS	Negative supply voltage	-0.3		0	V	With reference to all the voltages
T _{AMB}	Ambient temperature	-40		85	۰C	Maximum junction temperature (T _J) 115°C
	Supply current, NORMAL mode	2	3	6	mA	VSUP=32V, in <i>NORMAL</i> mode
I _{SUPP,} nom	Supply current, NORMAL mode, With External Components	15	20	40	mA	VSUP=32V, in the balancing phase with stack connection (50% PWM duty cycle)
I _{SUPP, sleep}	Supply current, SLEEP mode	10	17	35	μΑ	



Electrical Characteristics

Device Level Specifications

-40°C < Tj < 115°C.

Figure 7: Device Level Specifications

Symbol	Parameter	Min	Тур	Max	Unit	Note
Vcell_in	Cell Input voltage measurement	1.8		4.5		
ADC/DAC	ADC/DAC Reference		±7	±15	mV	0 hour, specification does not include solder stress / board stress effects
DAC_error	Error of the DAC		2		mV	0.1% error because of the DAC/Guaranteed by design
Com_off	Error because of the comparator resolution		1		mV	Guaranteed by design
Sign_path_accuracy	Signal path accuracy		±5	±15	mV	Typical value is from the lab evaluation data. Maximum value is from the test data. 0 hour accuracy, specification does not include solder stress / board stress effects.
T _{INITIALIZATION}	Initialization time			50	ms	After Initialization, the system will go to sleep mode and waits for wake signal.
T _{WAKE-UP}	Wake up time from the Wake signal to system wait mode			75	ms	After wake signal, device enters into wait mode and stays for two seconds for TRIG_IN signal, if no TRIG_IN event occurs, device goes to sleep mode.
Tmeas	Cell voltage and Temperature measurement time		16		ms	At10KHz clock time
Tspi3_read5k	SPI3 read time for		13.6			At 5KHz clock time
Tspi3_read20k	single channel		3.4		ms	At 20KHz clock time
Tspi3_read40k	measurement		1.7			At 40KHz clock time



Low Dropout Regulator (5V Output LDO)

-40°C < T $_{\rm J}$ < 115°C; all voltages are with respect to ground (GND); positive current flows into the pin, *NORMAL* operating mode, if not otherwise mentioned. The LDO block is a linear voltage regulator, which provides a regulated 5V.

Figure 8: LDO Parameters

Symbol	Parameter	Min	Тур	Max	Unit	Note
V _{SUP}	Input supply voltage	6	12	32	V	
V5V	Output voltage range	4.75	5.0	5.25	V	
I _{LOAD}	Load Current			50	mA	
ICC_SH	Output short circuit current		85	250	mA	NORMAL mode
PSRR	PSRR		60		dB	f=1kHz / No production test
1 3/111	13/11		35		uв	f=1MHz / No production test
CL1	LDO output Capacitor 1	2.2		10	μF	Electrolytic
ESR1	LDO output capacitor i	1		10	Ω	Liectrolytic
CL2	LDO output Capacitor 2	100		220	nF	Ceramic
ESR2	200 output capacitor 2	0.02		1	Ω	Ceramic

Note(s) and/or Footnote(s):

- 1. In NORMAL mode, maximum load current will be 50mA. After internal thermal shutdown, current limit is 20mA.
- 2. The LDO is disabled in SLEEP mode.



High-precision Bandgap Reference

-40°C < T_J < 115°C; all voltages are with respect to ground (GND).

Figure 9: Bandgap Reference Parameters

Symbol	Parameter	Min	Тур	Max	Unit	Note	
BG_Out	Reference output after trim	1.2	1.235	1.27	V	After temperature trim	
BG_out_T _{var}	Reference variation with respect to Temperature		±2.5	±4	mV	After trim on the absolute	
PSRR1K	PSRR at 1KHz	20			dB	- No production test	
PSRRDC	PSRR at DC	80			dB		

Note(s) and/or Footnote(s):

1. This bandgap output is the reference for the V5V (LDO) regulator.

Digital to Analog Converter

-40°C < T_J < 115°C; all voltages are with respect to ground (GND).

Figure 10:
Digital to Analog Converter

Symbol	Parameter	Min	Тур	Max	Unit	Note
V _{SUP_DAC}	Input supply voltage	4.75	5	5.25	V	LDO output as supply
V _{INREF}	Input reference voltage	4.485	4.5	4.515	V	After absolute trim at 0 hours, specification does not include solder stress/board stress effects
D _{IN}	Resolution		12		bits	Guaranteed by design
F _{DAC}	Update rate		10		KHz	
T _{SETT_DAC}	Settling time		50		μs	No production test
DAC _{INL}	INL		±4		LSB	The production test
DAC _{DNL}	DNL		±0.5		LSB	



Analog to Digital Converter

-40°C < T_J < 115°C; all voltages are with respect to ground (GND).

Figure 11: Analog to Digital Converter

Symbol	Parameter	Min	Тур	Max	Unit	Note
V _{SUP}	Input supply voltage	4.75	5	5.25	V	LDO output as supply
V _{INREF}	Input reference voltage	4.485	4.5	4.515	V	After absolute trim at 0 hours, specification does not include solder stress/board stress effects
D _{OUT}	Resolution		12		bits	
T _{MEAS_ADC}	Measurement time per channel		1.4		ms	
ADC _{INL}	INL		±4		LSB	No production test.
ADC _{DNL}	DNL		±2		LSB	No production test.

Pre-Regulator

This Pre_reg is an internal regulator which provides supply to digital and a few analog blocks..

-40 °C < T $_{\rm J}$ < 115 °C; all voltages are with respect to ground (GND).

Figure 12: Pre-reg Parameters

Symbol	Parameter	Min	Тур	Max	Unit	Note
V_{SUP}	Input supply voltage	6	12	32	٧	
P5V	Prereg_output voltage range	4.3	5.0	5.5	٧	
3V3	3.3V_output voltage range	2.8	3.3	3.6	V	



PWM Driver

40°C < T_J < 115°C; all voltages are with respect to ground (GND).

Figure 13: PWM Driver

Symbol	Parameter	Min	Тур	Max	Unit	Note
V5V	Output voltage	4.5	5	5.5	V	
F _{PWM}	Frequency of PWM	25	100	200	KHz	
		22	25	28	%	
F _{Duty}		12	15	18	%	
	Duty cycle	17	20	23	%	
		27	30	33	%	CMOS load mode,
		30	35	38	%	Optocoupler load mode
		37	40	43	%	
		42	45	48	%	
		47	50	53	%	
F _{duty_error}	Duty cycle error	7	12	20	%	
tr _{pwm}	Rise time	30	50	80	ns	CMOS load mode, Optocoupler load mode
tf _{pwm}	Fall time	30	50	80	ns	Guaranteed by design
Idrive _{opto}	Driver strength		10	12	mA	Optocoupler load mode
Cload _{fd_out}	Driver switch load capacitance		60	100	pF	



PWM Oscillator

-40°C < T_J < 115°C; all voltages are with respect to ground (GND).

Figure 14: PWM Oscillator

Symbol	Parameter	Min	Тур	Max	Unit	Note
f _{OSC}	Frequency	90	100	110	kHz	 After the frequency trim. Programmable frequency options for 25KHz, 50KHz and 200KHz are available.
f _{OSC_ACC}	Accuracy		±15		%	

Oscillator for Digital Circuit

-40 °C < T $_{J}$ < 115 °C; all voltages are with respect to ground (GND).

Figure 15: Oscillator for Digital Circuit

Symbol	Parameter	Min	Тур	Max	Unit	Note
f _{OSC-DIG}	Frequency	9	10	11	kHz	Oscillator for Digital circuit
f _{OSC_ACC}	Accuracy		±15		%	



External Temperature Thresholds

-40°C < T_J < 115°C; all voltages are with respect to ground (GND).

Figure 16: External Temperature Thresholds

Symbol	Parameter	Min	Тур	Max	Unit	Note
	Code 0000	3.084	3.165	3.238		
	Code 0001	3.148	3.231	3.306		
	Code 0010	3.213	3.297	3.373		
	Code 0011	3.277	3.363	3.441		
	Code 0100	3.341	3.429	3.508		
	Code 0101	3.406	3.495	3.576		
	Code 0110	3.470	3.561	3.643	V	16 reference thresholds are with a step of 66mV.
Ref_ext_warn/sutdown	Code 0111	3.534	3.627	3.711		
nei_ext_waiii/sutdowii	Code 1000	3.599	3.693	3.779	V	
	Code 1001	3.663	3.759	3.846		
	Code 1010	3.727	3.825	3.914		
	Code 0011	3.792	3.891	3.981		
	Code 0100	3.856	3.957	4.049		
	Code 0101	3.920	4.023	4.116		
	Code 0110	3.984	4.089	4.184		
	Code 0111	4.049	4.155	4.25	-	



Ron of the Shuttle Switches (Internal Switch for Charging/Discharging)

-40°C $< T_J < 115$ °C.

Figure 17: Ron of the Shuttle Switches

Symbol	Parameter	Min	Тур	Max	Unit	Note
Ron_shut	Shuttle switch ON resistance		5	20	Ω	The maximum charging/discharging current limit through shuttle switch is 100mA. Only for Cell1 maximum charging/discharging current is limited to 30mA less than 2V of cell voltage at 115 junction of cell voltage.

Over-Temperature Measurement

Figure 18: OTM Parameters

Symbol	l Parameter		Тур	Max	Unit	Note
T _{jshut}	Shut down temperature	115	135	145	°C	Junction temperature for Shutdown
T _{jwarn}	Warning temperature	100	125	140	°C	Junction temperature for Warning
T _{jrecv}	Recovery temperature	100	115	130	°C	Junction temperature for Recovery



Weak Cell Detection (Voltage Comparator)

Figure 19: Weak Cell Detection

Symbol	Parameter		Тур	Max	Unit	Note
V _{CELL}	Supply voltage	-0.3	3.6	4.5	V	
V _{LOW}	Low voltage detection	-100		100	mV	
	Minimum input spike filter		2		- μs	No production test. Programmable option.
Tl_spike			4			
п_эріке			6			
			8			

Power on Voltage Detection

Figure 20: Power on Voltage Detection

Symbol	Parameter Min Typ Max Unit		Note			
VSUP_POR	VSUP Power-on-Reset threshold ON	5.2	5.5	5.8	٧	Rising edge of VSUP
VSUP_RESET	VSUP Power-on-Reset threshold OFF	4.6	4.85	5.1	V	Master reset for device
V5V_IN_POR	V5V_IN Power-on-Reset threshold ON	3.8	4.45	4.8	٧	Voltages are with respect to VSUP measure as pass fail
V5V_IN_RESET	V5V_IN Power-on-Reset threshold OFF	3.6	4.1	4.5	٧	test
V5V_POR	V5V Power-on-Reset threshold ON	4.1	4.5	4.7	V	Rising edge of V5V
V5V_RESET	V5V_RESET V5V Power-on-Reset threshold OFF 3.8 4.1 4.3 V		Falling edge of V5V			



Electrical Characteristics for Digital Inputs and Outputs

All pull-up, pull-downs have been implemented with active devices.

Figure 21: Digital Inputs and Outputs

Port Type	Symbol	Parameter	Min	Тур	Max	Unit	Note					
	CS											
	Vt-	Negative-going threshold	1.62		2.22	V	. V5V=5V					
INPUT Schmitt Trigger	Vt+	Positive-going threshold	2.27		3.42	V	, A2A-2A					
mgger												
	I _{lil_cs}	Pull-up current	-100		-30	μΑ	In CS pad, Pulled up to V5V . (ISUP_HV)					
SDO												
	V _{OH}	High level output voltage	2.5			V						
	V _{OL}	Low level output voltage			0.4	V	VSUP ≥ 6V					
OUTPUT Tristate	V _{IH}	High level input voltage	0.7*V5V			V						
	V _{IL}	Low level input voltage			0.3*V5V	V						
	I _O	Output drive current			4	mA						
			SCLK, S	DI								
IO Buffer	V _{IH}	High level input voltage	0.7*V5V			٧						
10 bullet	V _{IL}	Low level input voltage			0.3*V5V	٧						



Port Type	Symbol	Parameter	Min	Тур	Max	Unit	Note
			CVT_NOK	OUT			
	V _{OH}	High level output voltage	2.4			V	
OUTPUT Buffer	V _{OL}	Low level output voltage			0.4	V	VSUP ≥ 6V
	I _O	Output drive current			2	mA	
			BD_OL	JT	1		
	V _{OH}	High level output voltage	2.4			V	
OUTPUT Buffer	V _{OL}	Low level output voltage			0.4	V	VSUP ≥ 6V
	I _O	Output drive current			1	mA	
		TR	IG_OUT, C	LK_OU1	Ī		
	V _{OH}	High level output voltage	2.4			V	
OUTPUT Buffer	V _{OL}	Low level output voltage			0.4	٧	VSUP ≥ 6V
	I _O	Output drive current			4	mA	
			FD_OU	T			
	V _{OH}	High level input voltage	2.4			V	
OUTPUT Buffer	V _{OL}	Low level input voltage			0.4	V	VSUP ≥ 6V
	I _O	Output drive current			24	mA	
			MS_S	L			
INPUT Buffer	V _{IH}	High level input voltage			VSUP	V	High voltage input pad
in or builet	V _{IL}	Low level input voltage			0.3*V5V	V	
			CLK_IN, TR	IG_IN	•		
INPUT Schmitt	Vt-	High level input voltage	1.62		2.22	V	
Trigger	Vt+	Low level input voltage	2.27		0.3*V5V	V	



Port Type	Symbol	Parameter	Min	Тур	Max	Unit	Note			
	FD_IN,BD_IN, CVT_NOK_IN									
INPUT Buffer	V _{IH}	High level input voltage	0.7*V5V			V				
in or builer	V _{IL}	Low level input voltage			3.42	V				
WAKE_IN Pull up current	lpull_up	Pull-up current	-100		-30	μΑ	Internal pull			

Note(s) and/or Footnote(s):

^{1.} Test limits for lih and lil are 1.0uA and -1.0uA for input pads.



Detailed Description

The device consists of the following blocks:

- PWM driver
- LDO_5V with 5V / 50mA output
- Temperature monitor block
- High precision bandgap reference
- DAC for the reference voltage generation
- SAR ADC for cell voltage and external temperature measurement
- Oscillators for PWM drive and for the digital logic
- Pre-Regulator
- SC Comparator
- · Weak cell detection logic
- · PORs on different supplies

Voltage Regulator (LDO_5V)

Power input to the LDO is **VSUP** pin. It is switched ON when the device is in *NORMAL* mode and switched OFF in *SLEEP* mode. The LDO takes the input from Bandgap and scales it up to the required voltage. It starts charging only after entering *NORMAL* mode. This LDO is the supply for DAC, the PWM driver and Cell voltage comparators.It's additional features are as follows:

- Stability is better than ±2.5% over input range.
- Load current up to 50mA.

High Precision Bandgap (HPBG)

AS8506C has a high precision bandgap to generate accurate reference. This reference voltage is used to generate reference for DAC and ADC.

HPBG is trimmed with respect to temperature. Variation of the bandgap with temperature is ± 4 mV in the temperature range from -40°C to 115°C.

External Temperature Monitor and Measurement

Two sensor inputs **TEMP_IN1** and **TEMP_IN2** with a comparator on each pin, are available. If the temperature sensor connected to **TEMP_IN1** crosses its threshold, then a warning flag is set in the device (status can be read through SPI) and the device will continue balancing.

If the temperature sensor connected to **TEMP_IN2** crosses its threshold, then a flag is set in the device and balancing is stopped; but the device continues to stay in *NORMAL* mode for maintaining synchronism. In both the cases, the microcontroller will be interrupted by a pulse on **CVT_NOK_OUT** pin.



In case the external temperature sensors are not being used, then both the inputs must be connected to **GND** pin through 1k resistor. In the measurement phase, external temperature is measured through the SAR ADC. Both channels of temperature will be measured and stored in temp_in1_lsb_reg to temp_in2_msb_reg.

Internal Temperature Monitor

The internal temperature monitor has two thresholds at T_{jwarn} 125°C and T_{jshut} 135°C. If the internal temperature exceeds 125°C, then a warning flag is set in the device (status can be read through SPI) and the device will continue balancing.

If the internal temperature exceeds 135°C, then a flag is set in the device and balancing is stopped; but the device continues to stay in *NORMAL* mode for maintaining synchronism. In both the cases, the microcontroller will be interrupted by a pulse on **CVT_NOK_OUT** pin. The balance recovery temperature is 115°C.

PWM Generator

In the Balance phase of the AS8506C, based on the decision made during the Compare phase, some part of the cell is charged with the Flyback converter. To drive the external Flyback converter, AS8506C generates a PWM signal to drive external FET or Optocoupler or Isolation device.

The frequency and of the PWM generator can be controlled by timer_cntl_reg register.

PWM frequency is not used for the passive balancing.

RC Oscillator

The AS8506C has a trimable RC oscillator. It is designed to generate $f_{osc-dig}$ clock for the digital circuit and for the clocking of the IC. Each oscillator will be trimmed with the process to get the accuracy to $f_{osc-accy}$ with 5-bit OTP Factory trim code.

DAC for the Reference Generation

AS8506C has a 12-bit DAC to generate the cell reference voltage, cell threshold low and high voltage. The DAC code is written into AS8506C with SPI interface from microcontroller. The output of the DAC is given to one of the inputs of the comparators, to compare the cell voltages synchronously. Reference for the DAC is 4.5V, which is internally generated and is available as reference for temperature inputs on REF_T.



SAR ADC

AS8506C has a 12-bit SAR ADC to measure the cell voltage and external temperature. The SAR ADC uses the 12-bit DAC to generate the digital code. The SAR ADC range is 1.8V to 4.5V for cell voltage measurement and 0.2V to 4.5V for the temperature measurement.

Cell voltage and temperature is measured in the short trigger phase. After the trigger goes 'high', compare phase starts and then all the cell voltages and external temperature are measured and stored in the digital registers.

Pre-Regulator

AS8506C has an internal pre-regulator, which generates supply voltages for the internal blocks. Pre-Regulator output is used as a supply for the oscillators. All the digital logic and the FSM will work on the pre-regulator supply.

In *SLEEP* mode only the pre-regulator will be working along with the **WAKE_IN** detect circuit.

Cell Threshold

AS8506C has the potential to set the two threshold levels to the cell voltage through pins **CELL_THU** and **CELL_THL**. These values can be set externally, (or) through OTP trim bits, (or) from the external microcontroller by writing DAC code into the cell threshold registers in the register space.

Weak Cell Detection

AS8506C has the ability to detect the weak cell. During load conditions, if the cell reaches voltage of about 0.1V to -0.2V, then this variation is detected and stored in the zero cross detection register. This event is indicated to the master device by a pulse on CVT_NOK_OUT pin in Compare and Balance phase. The master device indicates the microcontroller by setting $\textbf{CVT}_\textbf{NOK}_\textbf{OUT}$ 'high'. In WAIT mode only this will be stored in the register; there won't be any $\textbf{CVT}_\textbf{NOK}_\textbf{OUT}$ to μC . The register is cleared on μC reading.

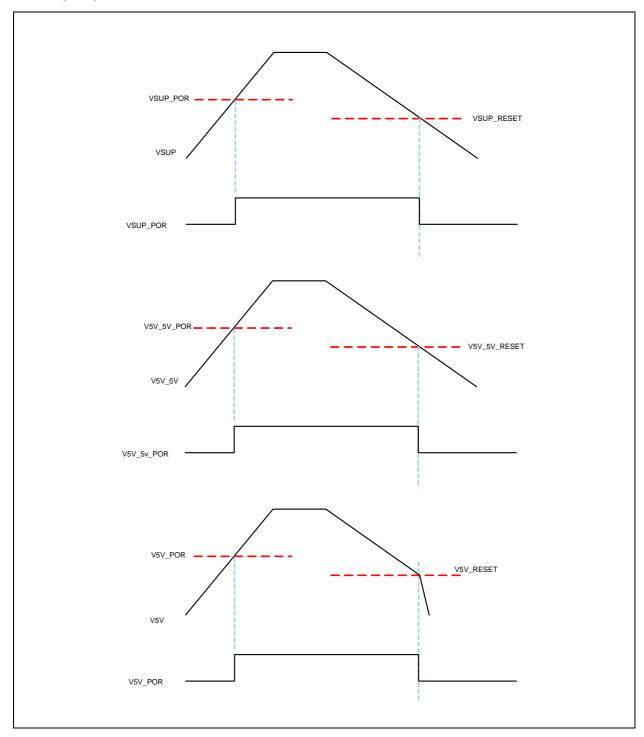
External Resister Divider Control

AS8506C has the provision to enable the external divider to give the desired cell voltage to the at **VREF_IN** pin. External resister divider can be connected between **VREF_H** pin to ground. Typical internal ON resistance of the VREF_H switch is 30Ω .Calculate the external resister divider values such that the output of the divider will provide the desired reference value. When comparison is not happening, this divider can be disabled using SPI. PORs on Different Supplies



AS8506C has power-on-reset blocks on **VSUP**, **V5V**and **V5V_IN** supply pins. The values for POR and Reset thresholds are given in Figure 20.

Figure 22: Power-up Sequence of VSUP, V5V and VSUP+5V





AS8506C System Operation

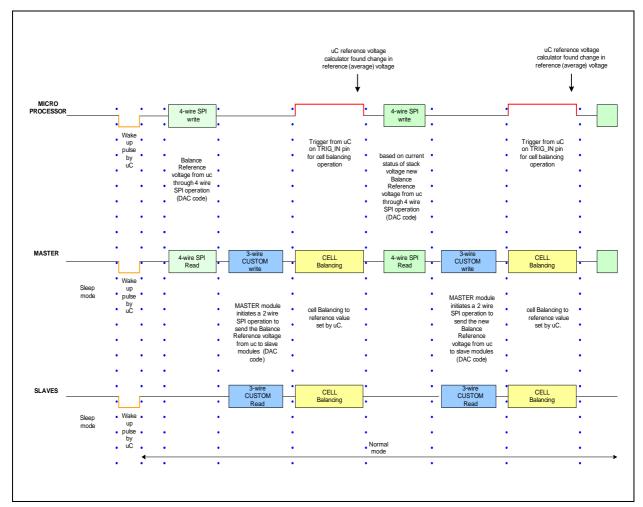
The AS8506C battery stack system can be set up by configuring one AS8506C device as 'Master' and the rest as 'Slave' devices. The AS8506C Master device is connected to the microcontroller, and the Slave devices are connected to Master through a daisy-chain of 3-wire customized SPI protocol. The microcontroller can communicate to the Slave devices through the Master. On power-up of the system, the microcontroller must assign an address to all AS8506C devices including the Master. The microcontroller can assign the address to AS8506C devices by initiating the address allocation process, by writing $a\,top\,most\,Slave\,device\,address\,into\,dadd_for_allc_reg\,register$ of Master and then writing '07' data into spi3_cmd_reg. Once the address allocation process is successful, the microcontroller can start the cell balancing. If cell balancing or check status command is not triggered by the microcontroller, after WAIT mode timeout period all devices enter into SLEEP mode.

The complete system communication procedure is explained below.

- The microcontroller gives wake pulse on WAKE_IN to bring the Master and Slaves in NORMAL mode.
- After the wake-up time period, the microcontroller (μC) sends the reference voltage digital code to the Master device through a 4-wire SPI.
- After receiving the digital reference code from μC, the Master device initiates a 3-wire custom SPI operation to send the digital reference code to the Slave devices.
- The microcontroller waits for the 3-wire SPI operation time period. After the 3-wire SPI time period, it initiates the cell balancing through TRIG_IN. The balancing will continue as long as TRIG_IN is 'High'.
- The microcontroller can change the reference value at any time by making TRIG_IN 'Low' and initiating a 4-wire SPI with new value of reference code. From here on, the procedure is same as from point 3.
- The balance done is indicated on **BD_OUT** pin.
- The failure in the 3-wire SPI operation is indicated on CVT_NOK_OUT pin.



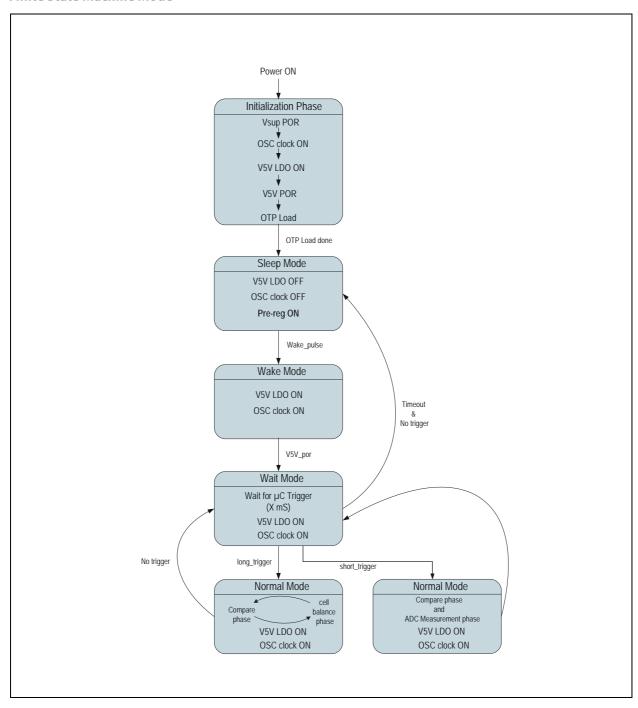
Figure 23: Functional Diagram of AS8506C





Functional State Diagram

Figure 24: Finite State Machine Mode





Operating Modes

The AS8506C has two main operating modes *NORMAL* and *SLEEP*, and has two transition modes *WAIT* and *WAKE*. The transition modes are intermediate modes for switching from *SLEEP* to *NORMAL* and vice versa. The detailed operation of each mode is explained in subsequent sections. The initialization phase is explained in "Initialization Sequence" on page 37.

NORMAL Mode

The device enters into NORMAL from WAKE when it receives a short or long trigger. The NORMAL mode is a full functional mode, where all the power supply and analog blocks are in ON-state and the digital is fully functional.

The NORMAL mode has two phases of operation:

- · Diagnosis phase
- Compare and Balance phase

Diagnosis Phase

In Diagnosis phase AS8506C detects the number of cells connected to the device. The connected cell voltages are then compared with upper & lower thresholds and target cell voltage of all cells connected. Upper and lower cell voltage thresholds as well as target cell voltages are provided from external in analog or digital format. The Diagnosis phase sequence of operation is explained below.

- Detects number of cells connected to the device by comparing each cell terminals to cell detect threshold voltage.
- Simultaneously compares each connected cell voltage with set lower operating voltage threshold Vlimit_L. If any of the cell voltages is less than the set lower operating threshold, then an indication is given on CVT_NOK_OUT pin stating that one/more cell voltages are not within the operating voltage threshold range. Each cell status is stored in cel_low_thsld_stat_reg register.
- Simultaneously compares each connected cell voltage with set higher operating voltage threshold Vlimit_H. If any of the cell voltages is greater than the set higher operating threshold, then an indication is given on CVT_NOK_OUT pin stating that one/more cell voltages are not within the operating voltage threshold range. Each cell status is stored in cel_high_thsld_stat_reg register.
- Simultaneously compares each connected cell voltage with reference value. This result is stored in cel_ref_stat_reg register and used in balance phase. Cell reference can be provided by microcontroller by writing into register or by providing input at external pin VREF_IN.
- Enables the SAR ADC and measures each cell voltage and two temperature inputs sequentially. The 12 bits cell voltage and temperature inputs information is stored in respective registers.



At the end of the Diagnosis phase, if trigger signal is 'High' then it enters into Balance phase. If trigger signal is 'Low' it enters into *WAIT* mode.

The Diagnosis phase without the cell voltage and temperature measurement with SAR ADC is called **Compare phase**.

Compare and Balance Phase

The Balance phase is basically a charging cycle in case of active balancing and a discharging cycle in case of passive balancing. The Balance phase is divided into 7 time slots. The device will move through all 7 time slots irrespective of number of cells connected to the device. This is done to keep synchronization between each module in case of battery stack system. One time slot is assigned to each cell (sequential order) for charging or discharging. The period of time slots is programmable (see "Status Registers" on page 53).

In each time slot, following operations are done.

- Check CVT_NOK flag status. If CVT_NOK flag is set, then no operation is done till time slot is over. If CVT_NOK flag is not set, then move to the next step.
- Based on Diagnosis phase results, shuttle switch corresponding to current time slot cell is switched ON for charging that cell in case of active balancing, and discharging in case of passive balancing.
- The PWM generator is enabled and PWM driver start driving the Flyback converter FET (external component) in case of active balancing. The PWM frequency and duty cycles are factory programmable and also register controllable. In case of stack system, the bottom module PWM driver is enabled when there is a request of charging or discharging from top module on **FD OUT** pin.
- At the end of the current time slot, stop the PWM generator and then open the corresponding shuttle switches. The device moves to the next time slot.

In the Balance phase, at any point, if the trigger input goes 'Low', then the device suspends balancing operation and enters into *WAIT* mode.

An example of Compare and Balance (active balance) phase sequence with respect to time is given in Figure 25. In this example it is assumed that only 6 cells are connected to AS8506C and comparators' outputs at Diagnosis phase is "010010X";

Where:

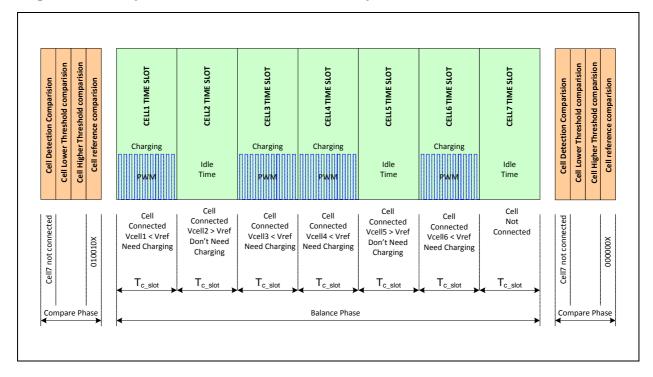
'0' indicates respective cell voltage is less than target voltage and needs charging.

'1' indicates respective cell voltage is more than target voltage and charging is not needed.

'X' indicates no cell is connected to respective comparator and output is neglected.



Figure 25:
Diagnosis and Compare and Balance Phase with Time Sequence for AS8506C



Sleep Mode

This is the least power consumption mode of AS8506C. In this mode only pre-reg is ON, rest all analog blocks are OFF and digital clock is disabled. Only a digital wake detection circuit is active. The device enters into this mode when there is no trigger from microcontroller for time greater than *WAIT* mode timeout period.

Wait Mode

This mode is a transition mode, where the device waits for command on **TRIG_IN** pin either from microcontroller, (or) from below module in case of stack system. The device will be in this state for T_{WMODE_TOUT} period. After the timeout, the device enters into *SLEEP* mode. In the *WAIT* period all power blocks are ON, all analog blocks are ON and digital is also functional. In this mode, power consumption is lesser than *NORMAL* mode because there are no charge balancing activities being carried out.

Wake Mode

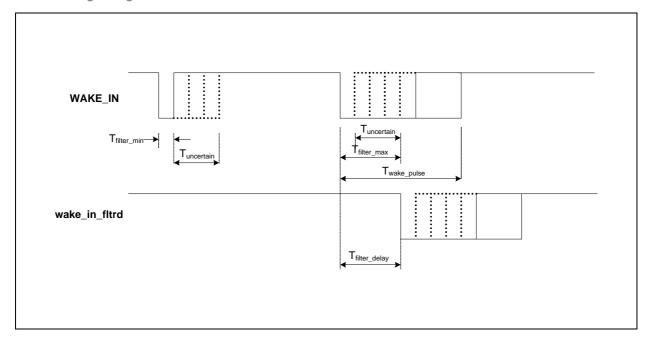
This is also a transition mode, where the device does initialization after exiting *SLEEP* mode. In the *SLEEP* mode if AS8506C receives a wake pulse of width T_{WAKE}, the device enters into *WAKE* mode. In the *WAKE* mode device enables the V5V LDO and waits for V5V_por_n signal. Once V5V_por_n signal becomes 'High', the device enters into *WAIT* mode.



Wake-up Event

The AS8506C device comes out of *SLEEP* mode by a wake pulse on the **WAKE_IN** pin. To avoid false wake by noises on the **WAKE_IN**, the wake signal (Low pulse) is taken through a low-pass filter from **WAKE_IN** pin. When a pulse of width T_{wake_pulse} is given on the **WAKE_IN** by the microcontroller, the device wakes up and enters into *WAKE* mode. The low-pass filter discards all signals having width less than T_{filter_min} and allows all signals with width greater than T_{filter_max} . The filter is uncertain in $T_{uncertain}$ region. The negative edge which is passing through the filter will wake the device from *SLEEP* mode. In chain of AS8506C devices, to propagate the negative edge the microcontroller has to give minimum low pulse of width T_{wake_pulse} . Before entering into *SLEEP* mode the wake pin must be 'High'.

Figure 26: WAKE-UP Signaling





Trigger Event

The AS8506C device enters into *NORMAL* mode only when a valid command is present on the **TRIG_IN** pin. There are two commands in the device.

- · Diagnosis command
- · Cell balance command

When a high pulse of width T_{diag_cmd} as shown in Figure 27, is given on **TRIG_IN** pin, the device performs the following operations.

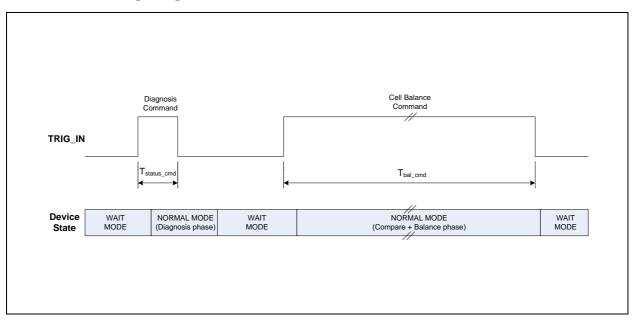
- Compares all connected cell voltages with the set lower operating voltage threshold, and if any of the cell voltage is less than lower threshold, then sets a corresponding flag in the cel_low_thsld_stat_reg register. This is indicated by high pulse on CVT_NOK_OUT pin.
- Compares all connected cell voltages with the set higher operating voltage threshold, and if any of the cell voltage is more than higher threshold, then sets a corresponding flag in the cel_high_thsld_stat_reg register. This is indicated by high pulse on CVT_NOK_OUT pin.
- Sets a corresponding flag in the temp_stat_reg register if ambient temperature or internal chip temperature is higher than respective thresholds. This is indicated by high pulse on CVT_NOK_OUT pin.
- It will enable SAR ADC and starts measuring each cell voltage, and then measures temperature channel measurement. The 12 bits digital value will be stored in corresponding registers.

Thus, on diagnosis command the device gives the cell operating voltage, ambient temperature and internal temperature status with respect to its safe operating range.

When the **TRIG_IN** pin is 'High' for longer than the status command, the device enters into Balance phase. Depending upon cell voltage status, the device starts balancing the cell voltages. The cell voltage balancing is continued till the high voltage on the **TRIG_IN** pin. As soon as **TRIG_IN** goes 'Low', the device stops balancing and enters into *WAIT* mode. Thus, the microcontroller has full control over the balancing time and stop balancing whenever required.



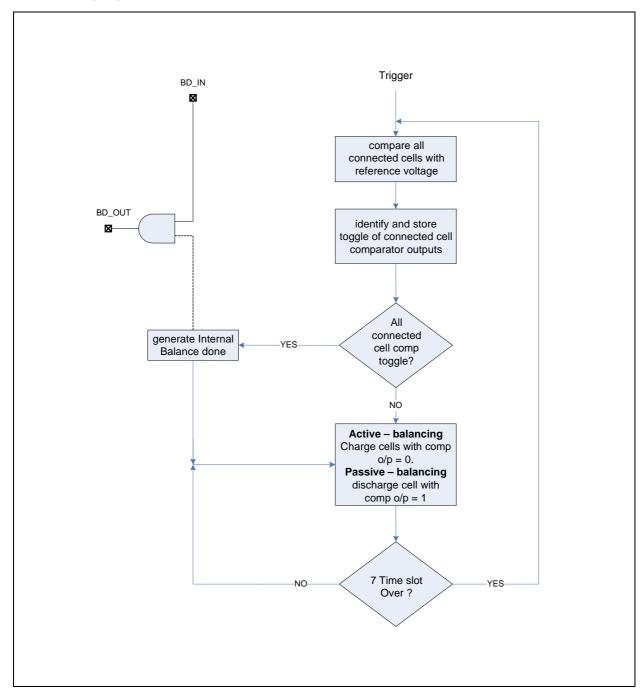
Figure 27: TRIG_IN Command Signaling





Balancing Algorithm

Figure 28: Cell Balancing Algorithm





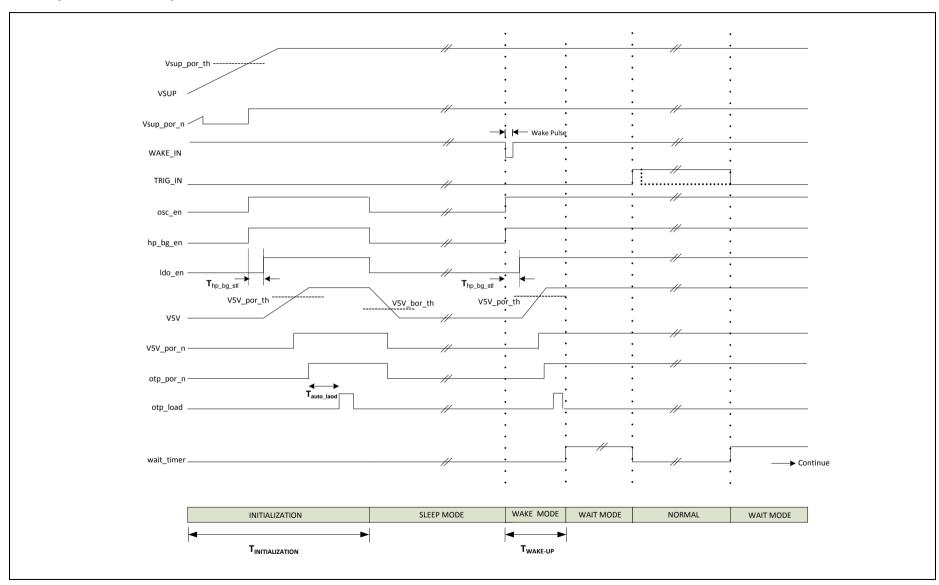
Initialization Sequence

The power-up initialization sequence diagram for AS8506C is shown in Figure 29.

- When the power supply is switched ON, initially VSUP POR output Vsup_por_n is 'Low'; hence all the digital logic will be in reset state.
- Once the VSUP crosses the Vsup_por_th, the VSUP POR output becomes 'High' enabling the oscillator and high-precision bandgap (HPBG) block.
- The digital block is now operational. It will now enable the V5V LDO and waits for V5V_por_n high signal from the V5V POR block.
- Once the V5V crosses V5V_por_th, the V5V_por_n will be 'High'. The OTP auto load command is generated by 'High' on otp_por_n signal. Now the device waits for T_{auto_load} period for OTP contents to load into digital local registers.
- After the OTP contents are loaded into digital local registers, the device power-up sequence is completed. The device enters into SLEEP mode. In SLEEP mode, the LDO, oscillator and HPBG are disabled.
- The wake-up circuit monitors the WAKE_IN pin for wake-up pulse. When a wake-up pulse is received, the oscillator and HPBG block are enabled and device enters into WAKE mode. In the WAKE mode, the device enables V5V LDO and waits for V5V_por_n high signal.
- Once the V5V crosses V5V_por_th, the V5V_por_n will be 'High' and the device enters into WAIT mode. In WAIT mode the device waits for trigger pulse on TRIG_IN pin from microcontroller. In this state, if a short or long pulse trigger signal is received on TRIG_IN within T_{wmode_tout} period, the AS8506C enters into NORMAL mode and performs required operations based on trigger pulse.



Figure 29:
Power-up Initialization Sequence





Device Interface

A 4-wire SPI is used to communicate with the device. Pins **CS**, **SCLK**, **SDI**, and **SDO** are used for SPI interface.

Serial Peripheral Interface

The Serial Peripheral Interface (SPI) provides the communication link with the microcontroller. The SPI is configured for half-duplex data transfer. The SPI in AS8506C provides access to the status registers, control registers and test registers. The SPI is also used to enter into test and OTP modes. This interface is only Slave interface and only Master can initiate the SPI operation. The SPI also supports block data transfer where sequential register data can be accessed with single SPI command.

The SPI can work on both the clock polarities. The polarity of the clock is dependent on the value of SCLK at the falling edge of CS.

At the falling edge of CS,

- If SCLK is "1", then the SPI is negative edge triggered.
- If the SCLK is "0", then SPI is positive edge triggered logic. see Figure 30 for more details.

Figure 30: SPI Clock Polarity Table

(SS	SCLK	Description
	\downarrow	Low	Serial data is transferred at rising edge and sampled at falling edge of SCLK.
	\leftarrow	High	Serial data is transferred at falling edge and sampled at rising edge of SCLK.

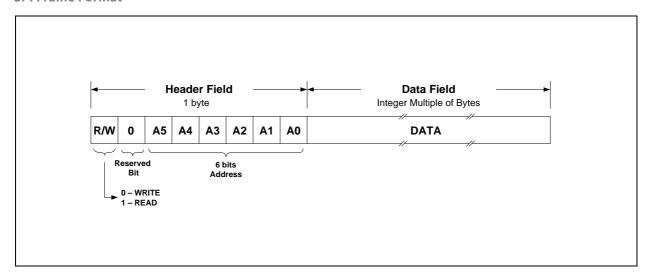


The SPI protocol frame is divided into two fields.

- · The header field
- · The data field

The header field is 1 byte long; containing a read/write command bit, 1 reserved bit, and 6 address bits. The SPI frame format is shown in Figure 31. In the data phase MSB is sent first and LSB is sent last.

Figure 31: SPI Frame Format



SPI Write Operation

The SPI write operation begins with clock polarity selection at negative edge of CS (see Figure 30). Once the clock polarity is selected, the SPI write command is given by providing '0' in R/W bit of the header field in first sampling edge at **SDI** pin. The next bit in header field is reserved and set to '0'. The 6 bits address of register to be written is provided at **SDI** pin in next six consecutive sampling edges of SCLK. The data to be written is followed by last bit of header field. With each sampling edge a bit is sampled starting from MSB to LSB. During complete SPI write operation the SCSN has to be 'Low'. The SPI write operation ends with positive edge of SCSN. The waveform for SPI write operation with single data byte is shown in Figure 32 and Figure 33.



Figure 32: SPI Write Operation with Negative Clock Polarity and 1 Byte of Data Field

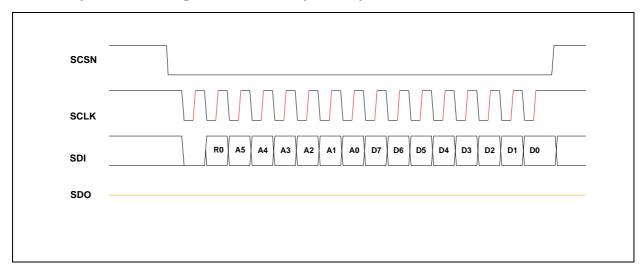
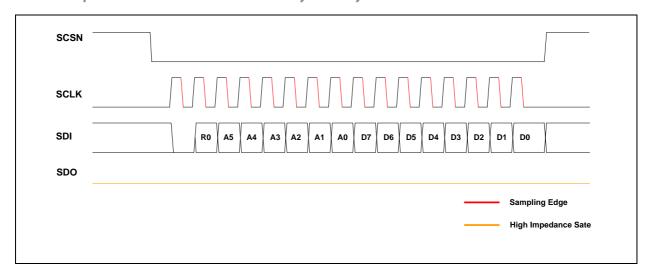


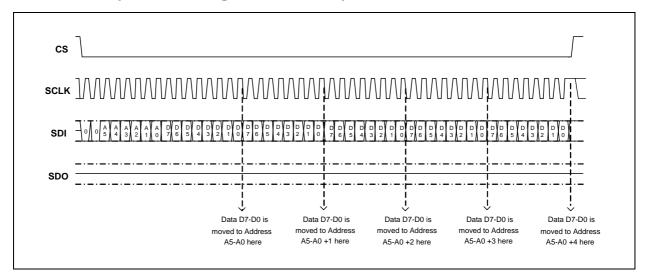
Figure 33:
SPI Write Operation with Positive Clock Polarity and 1 Byte of Data Field



In case of SPI block write operation, first data byte is written into addressed register same as single byte write operation. After first data byte, Master can send next data byte by keeping CS 'Low' and giving clock on SCLK as per polarity selection. At the end of every eighth data bit, the byte is written into next consecutive address location (internally address is incremented by one location). In this way, Master can continue writing into consecutive address locations. The waveform is shown in Figure 34.



Figure 34: SPI Block Write Operation with Negative Clock Polarity



SPI Read Operation

The SPI read operation also begins with clock polarity selection at negative edge of SCSN (see Figure 30). Once the clock polarity is selected, the SPI read command is given by providing '1' in R/W bit of the header field in first sampling edge at **SDI** pin. The next bit in header fields is reserved and set to '0'. The 6 bits address of register to be read is provided at **SDI** pin in next six consecutive sampling edges of SCLK. The read data is followed by last bit of header field on **SDO** pin. With each sampling edge a bit can be read on **SDO** pin starting from MSB to LSB. In case of multi-data bytes, MSB of next data byte can be read after the LSB of previous data byte. During complete SPI read operation the SCSN has to be 'Low'. The SPI read operation ends with positive edge of SCSN. The wave form for SPI read operation with single data byte is shown in Figure 35 and Figure 36.

Figure 35: SPI Read Operation with Negative Clock Polarity and 1 Byte of Data Field

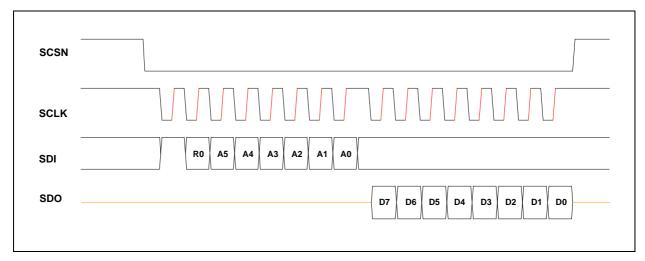
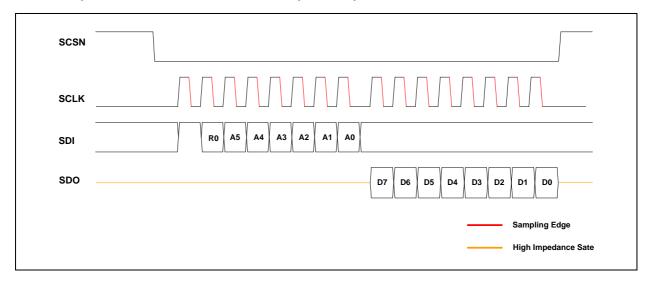


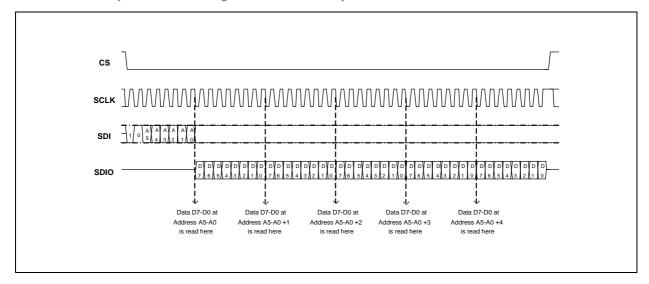


Figure 36: SPI Read Operation with Positive Clock Polarity and 1 Byte of Data Field



In case of SPI block read operation, first data byte is read from addressed register same as single byte read operation. After first data byte read, Master can read next consecutive addressed data by keeping CS 'Low' and giving clock on SCLK as per clock polarity selection. At the end of every eighth data bit, the address pointer is incremented to next consecutive address location. In this way Master can continue reading from consecutive register address locations. The waveform is shown in Figure 37.

Figure 37: SPI Block Read Operation with Negative Clock Polarity





Address Allocation Process

During the system configuration the microcontroller has to initiate the address allocation process for the AS8506C master and the stacked slave devices.

This process is started by writing the number of stacked IC's into address 0x1A (master register dadd_for_allc_reg) through the 4 wire SPI. After that the microcontroller needs to initiate the auto address allocation process by writing the datum 0x07 to master address 0x28 (register spi3_cmd_reg).

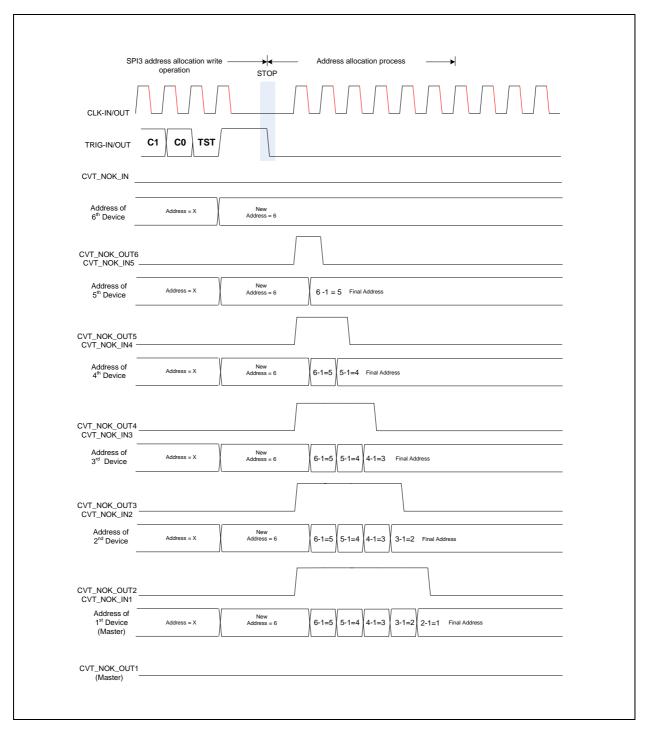
After the successful SPI3 address allocation write operation, all AS8506C devices including master will store their allocated device addresses as their address.

The device address "000000" is reserved as broadcast address seen by all devices.

The address allocation process is explained for 6 AS8506C devices (including master) in Figure 38.



Figure 38: Address Allocation Process





In the address allocation process, the

CVT_NOK_IN/CVT_NOK_OUT pins of AS8506C are used. After the successful SPI3 address allocation write operation, all AS8506C devices including Master will store the top device address (sent by Master in SPI3 address allocation write) as its address. The top device identifies itself as top most device and registers the address as its final address and at first rising edge of clock all devices force 'High' on its CVT_NOK_OUT pin. The concept of address allocation is: after the STOP of SPI3, at every falling edge of the clock each device will sample its CVT_NOK_IN pin. If CVT_NOK_IN pin is 'High', the device will decrement the assigned address by '1' and continue to force 'High' on its **CVT_NOK_OUT** pin at rising edge of clock. If **CVT_NOK_IN** is sampled to be 'Low', then the address value at register will be stored as its final device address and it stops forcing 'High' on its CVT_NOK_OUT pin and makes it 'Low' at next rising edge of clock.

In Figure 38, top most device pins are suffixed with '6' down to lower most device (Master) pins suffixed with '1' in descending order. There is no device above topmost device, CVT_NOK_IN6 is always 'Low'; therefore the address sent by Master is final address for the top device. For the fifth device the CVT_NOK_IN5 is 'Low' for one clock cycle, the address is decremented once. For the fourth device CVT_NOK_IN4 is 'Low' for two clock cycles, the address is decremented twice before registering it as final address. This procedure is continued and finally the Master device CVT_ONK_IN1 is 'Low' for 5 clock cycles, the address is decremented five times and finally address register will have value of "000001" as its final address. The microcontroller can identify the end of address allocation procedure in two ways:

- One way is by probing CVT_NOK_OUT of Master after initiating address allocation process for a pulse.
- The other method is by polling bit0 of spi3_cmd_reg register for '0' (Low) and no CRC errors.

During SPI3 address allocation write operation, if a CRC error occurs in the any of the Slaves, the Master indicates this failure of SPI3 transaction to all Slaves by driving TST bit 'High'. All Slaves should terminate the address allocation process if a 'High' TST bit is seen during start address allocation process SPI3 write operation. The Master will indicate the failure of address allocation process to μC by asserting a flag in the spi3_sts_reg register and sending interrupt pulse on its CVT_NOK_OUT pin.



Communication to Slaves

There are two modes of communication between the Master and Slaves in the AS8506C stack system:

- Broadcast Communication
- · Communication with Individual Slave

Broadcast Communication

The Broadcast of communication is used to send the reference, lower, upper threshold limit codes and timer control register values for all the slaves.

Reference and thresholds can be set by one of the two methods:

- Through the external pins
- · Through the Internal DAC

In case of the stacked system, reference and thresholds can be set by writing DAC values though broadcast SPI command.

Write the corresponding data in the registers of timer_cntl_reg, ref_dcod_lsb_reg/ref_dcod_msb_reg, hlmt_dcod_lsb_reg/hlmt_dcod_msb_reg and llmt_dcod_lsb_reg/llmt_dcod_msb_reg and command in the Command Registers spi3_cmd_reg and spop_dadd_bcmd_reg. Example:

To write DAC code of 0x0666 in the lower threshold register of all the devices, initiate a broadcast command as given in the

Figure 39:
Threshold Setting through Broadcast Command to Slaves

Command	Register Name	Address	Data
To set low threshold	llmt_dcod_lsb_reg	0x23	0x66
To section timesitoid	llmt_dcod_msb_reg	0x24	0x06
Broadcast the cell lower limit DAC code	spop_dadd_bcmd_reg	0x25	0x03
Broadcast communication command	spi3_cmd_reg	0x28	0x09

below sequence.

Each broadcast write operation takes 35 clock cycles of the communication frequency. The default communication frequency is 5KHz.

Broadcast slave register write is also possible other than above registers.

If there any specific register of all the slaves to be written with the same content of Master then this feature is useful.

Write register address in the spop_reg_add_reg.



Example:

To set the external temperature thresholds to 4.15V, initiate a broadcast command as given in the below sequence.

Figure 40: External Temperature Threshold Setting through Broadcast Command to Slaves

Command	Register Name	Address	Data
To set the external temperature threshold	tflg_tshld_setg_reg	0x1D	0xFF
Address of the register to broadcast	spop_reg_add_reg	0x26	0x1D
Broadcast communication command	spi3_cmd_reg	0x28	0x0B

Communication with Individual Slave

Communication with an individual slave is done as SPI write or read.

Write operation.

To perform the write operation to one of the slave device, corresponding data should be written in these registers spop_dadd_bcmd_reg, spop_reg_add_reg, wrop_data_reg and spi3_cmd_reg.

Example:

To set the external temperature threshold of the slave device address 0x06 to 4.15V, initiate a broadcast command as given in the below sequence.

Figure 41: Write Operation to the Individual Slave

Command	Register Name	Address	Data
Slave device address	spop_dadd_bcmd_reg	0x25	0x06
Address of the slave register	spop_reg_add_reg	0x26	0x1D
To set the external temperature threshold	wrop_data_reg	0x27	0xFF
Slave write command	spi3_cmd_reg	0x28	0x05



Read operation.

To perform the read operation to one of the slave device, corresponding data should be written in these registers spop_dadd_bcmd_reg, spop_reg_add_reg and spi3_cmd_reg.

Data from the slave device will be written in the register rdop_data_reg.

Example:

To read the temperature status register of the slave device address 0x06, initiate a broadcast command as given in the below sequence.

Figure 42: Read Operation to the Individual Slave

Command	Register Name	Address	Data
Slave device address Slave	spop_dadd_bcmd_reg	0x25	0x06
Address of the slave register	spop_reg_add_reg	0x26	0x05
write command	spi3_cmd_reg	0x28	0x03



SPI Timing Diagrams

Figure 43: Timing Diagram for Write Operation

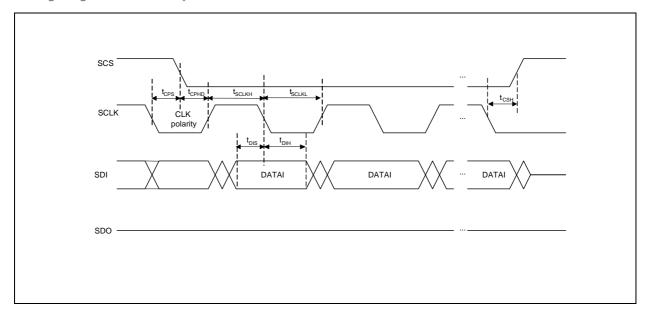
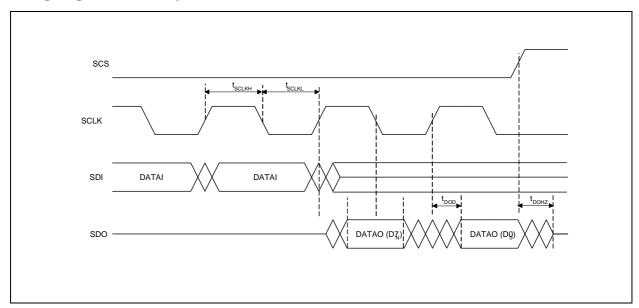


Figure 44: Timing Diagram for Read Operation





SPI Protocol

Figure 45: SPI Timing Parameters

Symbol	Parameter	Min	Тур	Max	Unit	Note						
	General											
BR _{SPI}	Bit rate			1	Mbps							
T _{SCLKH}	Clock high time	400			ns							
T _{SCLKL}	Clock low time	400			ns							
	Write Operation Parameters											
t _{DIS}	Data in setup time	20			ns							
t _{DIH}	Data in hold time	20			ns							
T _{CSH}	SCSN hold time	20			ns							
		Read C	peration P	arameter	s							
t _{DOD}	Data out delay			80	ns							
t _{DOHZ}	Data out to high impedance delay			80	ns	Time for the SPI to release the SDO bus						
	Timing	Parameter	s for SCLK	Polarity Id	lentificatio	n						
t _{CPS}	Clock setup time (CLK polarity)	20			ns	Setup time of SCLK with respect to SCSN falling edge.						
t _{CPHD}	Clock hold time (CLK polarity)	20			ns	Hold time of SCLK with respect to SCSN falling edge.						



System Timings

Figure 46: System Timings

Symbol	Parameter	Min	Тур	Max	Unit	Note					
	Wake-up Timing										
T _{wake_pulse}	Wake pulse width	100			μs						
T _{filter_delay}	Time between edge on TRIG_IN pin to trig_in_fltrd signal			4	μs						
T _{filter}	WAKE_IN pin filter specification	1		4	μs						
	Trigge	er Timing									
T _{status_cmd}	Status request command pulse	500		1000	μs						
T _{bal_cmd}	Cell balance command pulse	7000			μs						
	Wait Mode Timing										
T _{wmode_tout}	WAIT mode timeout		2000		ms						



Register Space Description

The AS8506C register space is divided into control registers and test registers. All of these registers are accessed through SPI.

Status Registers

Figure 47: Cell Detection Status Register

Address	Register Name	Feature	es and Bit Description	SPI 4	SPI 3	POR Value
		Indic	cates the detected cells.			
		D0 $0 \rightarrow \text{Cell 1 is not detected}$ $1 \rightarrow \text{Cell 1 is detected}$				
		D1	 0 → Cell 2 is not detected 1 → Cell 2 is detected 			
	cel_det_stat_reg	D2	 0 → Cell 3 is not detected 1 → Cell 3 is detected 	R	R	0000_0000 POR_V5V
0x00		D3	 0 → Cell 4 is not detected 1 → Cell 4 is detected 			
		D4	 0 → Cell 5 is not detected 1 → Cell 5 is detected 			
		D5	 0 → Cell 6 is not detected 1 → Cell 6 is detected 			
		D6	 0 → Cell 7 is not detected 1 → Cell 7 is detected 			
		D7	Reserved			



Figure 48: Diagnostic Status Register

Address	Register Name	Featu	res and Bit Description	SPI4	SPI3	POR Value
	diag_sts_reg	Diagnostic register. µC can read this register if pulse is detected on CVT_NOK_OUT pin, to diagnose cause of indication.				
		D0	1 → Low Threshold limit cross Indicator ⁽¹⁾		R	0000_0000 POR_V5V
		D1	1 → High Threshold limit cross indicator ⁽²⁾	R		
0x01		D2	1 → Over-temperature indicator			
		D3	1 → Address allocation procedure fail			
		D4	1 → SPI3 read operation fail			
		D5	1 → SPI3 write operation fail			
		D6	1 → SPI3 Broadcast operation fail			
		D7	Reserved			

Note(s) and/or Footnote(s):

- 1. This bit is only valid if all 7 cells are connected. If the cells connected are less than 7, use the cel_low_thsld_stat_reg (0x02) to detect a low threshold crossing.
- 2. This bit is only valid if all 7 cells are connected. If the cells connected are less than 7, use the cel_high_thsld_stat_reg (0x03) to detect a high threshold crossing.



Figure 49: Cell Lower Threshold Status Register

Address	Register Name		Features and Bit Description	SPI4	SPI3	POR Value
			es if a cell voltage crossed ver threshold limit set by μC.			
		D0	 0 → Cell 1 voltage is more than Low Threshold limit set 1 → Cell 1 voltage is less than Low Threshold limit set 			
		D1	 0 → Cell 2 voltage is more than Low Threshold limit set 1 → Cell 2 voltage is less than Low Threshold limit set 			
		D2	 0 → Cell 3 voltage is more than Low Threshold limit set 1 → Cell 3 voltage is less than Low Threshold limit set 			
0x02	cel_low_thsld_stat_reg	D3	 0 → Cell 4 voltage is more than Low Threshold limit set 1 → Cell 4 voltage is less than Low Threshold limit set 	R	R	0000_0000 POR_V5V
		D4	 0 → Cell 5 voltage is more than Low Threshold limit set 1 → Cell 5 voltage is less than Low Threshold limit set 			
		D5	 0 → Cell 6 voltage is more than Low Threshold limit set 1 → Cell 6 voltage is less than Low Threshold limit set 			
		D6	 0 → Cell 7 voltage is more than Low Threshold limit set 1 → Cell 7 voltage is less than Low Threshold limit set 			
		D7	Reserved			



Figure 50: Cell Higher Threshold Status Register

Address	Register Name		Features and Bit Description	SPI4	SPI3	POR Value
			ites if a cell voltage crossed wer threshold limit set by μC.			
		D0	 0 → Cell 1 voltage is less than High Threshold limit set 1 → Cell 1 voltage is more than High Threshold limit 		R	0000_0000 POR_V5V
		D1	 0 → Cell 2 voltage is less than High Threshold limit set 1 → Cell 2 voltage is more than High Threshold limit 			
	cel_high_thsld_stat_reg	D2	 0 → Cell 3 voltage is less than High Threshold limit set 1 → Cell 3 voltage is more than High Threshold limit 			
0x03		D3	 0 → Cell 4 voltage is less than High Threshold limit set 1 → Cell 4 voltage is more than High Threshold limit 	R		
		D4	 0 → Cell 5 voltage is less than High Threshold limit set 1 → Cell 5 voltage is more than High Threshold limit 			
		D5	 0 → Cell 6 voltage is less than High Threshold limit set 1 → Cell 6 voltage is more than High Threshold limit 			
		D6	 0 → Cell 7 voltage is less than High Threshold limit set 1 → Cell 7 voltage is more than High Threshold limit 			
		D7	Reserved			



Figure 51: Cell Reference Status Register

Address	Register Name	Feat	ures and Bit Description	SPI4	SPI3	POR Value	
		referen	es which cell has reached the ce value at least once. This s cleared when new reference is d.				
				D0	 0 → Cell 1 voltage is less than reference voltage 1 → Cell 1 voltage is more than reference voltage 		
		D1	 0 → Cell 2 voltage is less than reference voltage 1 → Cell 2 voltage is more than reference voltage 				
			D2	 0 → Cell 3 voltage is less than reference voltage 1 → Cell 3 voltage is more than reference voltage 			
0x04	cel_ref_stat_reg	D3	 0 → Cell 4 voltage is less than reference voltage 1 → Cell 4 voltage is more than reference voltage 	R	R	0000_0000 POR_V5V	
			D4	 0 → Cell 5 voltage is less than reference voltage 1 → Cell 5 voltage is more than reference voltage 			
		D5	 0 → Cell 6 voltage is less than reference voltage 1 → Cell 6 voltage is more than reference voltage 				
		D6	 0 → Cell 7 voltage is less than reference voltage 1 → Cell 7 voltage is more than reference voltage 	-			
		D7	Reserved				



Figure 52: Temperature Status Register

Address	Register Name	Featu	res and Bit Description	SPI4	SPI3	POR Value
0x05 temp_stat_reg		Indicates monitors	the status of temperature s.			
	D0	 0 → Ambient temperature is less than warning threshold 1 → Ambient temperature is more than warning threshold 		R	0000_0000 POR_V5V	
	D1	 0 → Internal temperature is less than warning threshold 1 → Internal temperature is more than warning threshold 				
	D2	 0 → Ambient temperature is less than maximum threshold 1 → Ambient temperature is more than maximum threshold 	R			
		D3	 0 → Internal temperature is less than maximum threshold 1 → Internal temperature is more than maximum threshold 			
		D7:D4	Reserved			



Figure 53: Zero Cross Status Register

Address	Register Name	Featu	res and Bit Description	SPI4	SPI3	POR Value	
	0x06 zero_crs_stat_reg	Indicates which cell voltage has crossed zero voltage and reached negative during sudden loading condition. This indirectly indicates the increasing status of cell internal impedance.					
					D0 O → Cell 1 voltage is normal 1 → Cell 1 voltage has crossed zero voltage towards negative direction		
		D1	 0 → Cell 2 voltage is normal 1 → Cell 2 voltage has crossed zero voltage towards negative direction 		R		
		D2	 0 → Cell 3 voltage is normal 1 → Cell 3 voltage has crossed zero voltage towards negative direction 	R			
0x06		D3	 0 → Cell 4 voltage is less than reference voltage 1 → Cell 4 voltage is more than reference voltage 				
	D4	 0 → Cell 5 voltage is normal 1 → Cell 5 voltage has crossed zero voltage towards negative direction 					
		D5	 0 → Cell 6 voltage is normal 1 → Cell 6 voltage has crossed zero voltage towards negative direction 				
		D6	 0 → Cell 7 voltage is normal 1 → Cell 7 voltage has crossed zero voltage towards negative direction 				
		D7	Reserved				



Figure 54: Cell1 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x07	cell1_volt_lsb_reg		tage measured. 8 least nt bits of 12-bit ADC code of	R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			

Figure 55: Cell1 Voltage MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x08 cell1_volt_msb_reg	Cell1 voltage measured. 4 most significant bits of 12-bit ADC code of Cell1		R	R	0000_0000	
	D3:D0	Bit11 to Bit8 of ADC code] '`	.,	POR_V5V	
	D7:D4 Reserved					

Figure 56: Cell2 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x09	Cell2_volt_lsb_reg	Cell2 voltage measured. 8 least significant bits of 12-bit ADC code of Cell2		R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			



Figure 57: Cell2 Voltage MSB Register

Address	Register Name	Featui	res and Bit Description	SPI4	SPI3	POR Value
0x0A cell2_volt_msb_reg	Cell2 voltage measured. 4 most significant bits of 12-bit ADC code of Cell2		R	R	0000_0000	
	D3:D0	Bit11 to Bit8 of ADC code] "		POR_V5V	
	D7:D4	Reserved				

Figure 58: Cell3 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x0B	cell3_volt_lsb_reg	Cell3 voltage measured. 8 least significant bits of 12-bit ADC code of Cell3		R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			

Figure 59: Cell3 Voltage MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x0C	0x0C cell3_volt_msb_reg	Cell3 voltage measured. 4 most significant bits of 12-bit ADC code of Cell3		R	R	0000_0000 POR_V5V
oxoc cens_vont_mss_reg	D3:D0	Bit11 to Bit8 of ADC code				
	D7:D4	Reserved				

Figure 60: Cell4 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x0D	cell4_volt_lsb_reg	Cell4 voltage measured. 8 least significant bits of 12-bit ADC code of Cell4		R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			



Figure 61: Cell4 Voltage MSB Register

Address	Register Name	Featur	es and Bit Description	SPI4	SPI3	POR Value
0x0F	0x0E cell4_volt_msb_reg	Cell4 voltage measured. 4 most significant bits of 12-bit ADC code of Cell4		R	R	0000_0000
OXOL		D3:D0	Bit11 to Bit8 of ADC code			POR_V5V
	D7:D4	Reserved				

Figure 62: Cell5 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x0F	cell5_volt_lsb_reg	Cell5 voltage measured. 8 least significant bits of 12-bit ADC code of Cell5		R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			

Figure 63: Cell5 Voltage MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x10	0x10 cell5_volt_msb_reg	Cell5 voltage measured. 4 most significant bits of 12-bit ADC code of Cell5		R	R	0000_0000 POR_V5V
oxio cana_ionnaz_neg	D3:D0	Bit11 to Bit8 of ADC code				
	D7:D4 Reserved					

Figure 64: Cell6 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x11	cell6_volt_lsb_reg	Cell6 volta significan Cell6	R	R	0000_0000 POR_V5V	
		D7:D0	Bit7 to Bit0 of ADC code			



Figure 65: Cell6 Voltage MSB Register

Address	Register Name	Featu	res and Bit Description	SPI4	SPI3	POR Value
0x12	0x12 cell6_volt_msb_reg	Cell6 voltage measured. 4 most significant bits of 12-bit ADC code of Cell6		R	R	0000_0000
OXIZ		D3:D0	Bit11 to Bit8 of ADC code] "		POR_V5V
	D7:D4 Reserved					

Figure 66: Cell7 Voltage LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x13	cell7_volt_lsb_reg		age measured. 8 least t bits of 12-bit ADC code of	R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			

Figure 67: Cell7 Voltage MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x14	0x14 cell7 volt msb reg		Cell7 voltage measured. 4 most significant bits of 12-bit ADC code of Cell7		R	0000_0000
	oxii cen/_voit_mss_reg	D3:D0	Bit11 to Bit8 of ADC code			POR_V5V
		D7:D4 Reserved				

Figure 68: Temperature Input1 LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x15	temp_in1_lsb_reg	Temperature sensor input1 measured. 8 least significant bits of 12-bit ADC code of temperature input1.		R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			



Figure 69: Temperature Input1 MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x16	temp_in1_msb_reg	Temperature sensor input1 measured. 4 most significant bits of 12-bit ADC code of temperature input1.		R	R	0000_0000 POR V5V
		D3:D0	Bit11 to Bit8 of ADC code			101(_\$\$\$
	D7:D4 Reserved					

Figure 70: Temperature Input2 LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x17	temp_in2_lsb_reg	Temperature sensor input2 measured. 8 least significant bits of 12-bit ADC code of temperature input1.		R	R	0000_0000 POR_V5V
		D7:D0	Bit7 to Bit0 of ADC code			

Figure 71: Temperature Input2 MSB Register

Address	Register Name	Featur	res and Bit Description	SPI4	SPI3	POR Value
0x18	0x18 temp_in2_msb_reg	Temperature sensor input 2 measured. 4 most significant bits of 12-bit ADC code of temperature input 2.		R	R	0000_0000
oxio		D3:D0	Bit11 to Bit8 of ADC code			POR_V5V
	D7:D4 Reserved					



Figure 72: SPI3 Status Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
		_	This register has status of the latest SPI3 operation.			
	D0	 0 → No CRC error. 1 → CRC error for data from Master to Slave 				
0x19	0x19 spi3_sts_reg	D1	 0 → No CRC error. 1 → CRC error for data from Slave to Master 	R	R	0000_0000 POR_V5V
		D2	 0 → Start address allocation process write pass 1 → Start address allocation process write fail 			
		D7:D3	Reserved			



Configuration and 3-Wire SPI Interface Related Registers

Figure 73:
Device Address for Address Allocation Register

Address	Register Name	Features a	SPI4	SPI3	POR Value	
0x1A	dadd_for_allc_reg	The device address for address allocation. In the address allocation process the µC writes top device address in this register. Address "00000" is reserved as broadcast address.		R/W	R/W	0000_0000 POR_VSUP
	D5:D0	D5:D0 Device address				
		D7:D6	Reserved			

Figure 74:
Allocated Device Address Register

Address	Register Name	Features a	SPI4	SPI3	POR Value	
		Final device ac			0000 0000	
0x1B	0x1B allcd_dev_add_reg	D5:D0	Device address	R	R	POR_VSUP
		D7:D6	Reserved			

Figure 75:
Device Configuration Setting Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
		Selects SPI3 fr	requency of operation.			
0x1C	dev_cnfg_setg_reg	D1:D0	00 → 5 KHz 01 → 20 KHz 10 → 40 KHz 11 → Reserved	R/W	-	0000_0000 POR_VSUP
		D7:D2	Reserved			



Figure 76: Temperature Threshold Setting Register

Address	Register Name	F	Features and Bit Description SPI4 SPI3	POR Value
Address 0x1D		Sets ove	r-temperature warning flag and vn flag threshold. Over temperature warning flag threshold selection Code Value Code Value Code Value V	
			Code Value Code Value Code Value 0000 3.165 0110 3.561 1100 3.957 0001 3.231 0111 3.627 1101 4.023 0010 3.297 1000 3.693 1110 4.089 0011 3.363 1001 3.759 1111 4.155 0100 3.429 1010 3.825 - 0101 3.495 1011 3.891 -	



Figure 77: Timer Control Register

Address	Register Name	Features	s and Bit Description	SPI4	SPI3	POR Value
	0x1E timer_cntl_reg	D2:D0	$000 \rightarrow 25\%$ duty cycle $001 \rightarrow 15\%$ duty cycle $010 \rightarrow 20\%$ duty cycle $011 \rightarrow 30\%$ duty cycle $100 \rightarrow 35\%$ duty cycle $101 \rightarrow 40\%$ duty cycle $110 \rightarrow 45\%$ duty cycle $111 \rightarrow 50\%$ duty cycle	R/W	R/W	0000_0000 POR_VSUP
0x1E		D4:D3	$00 \rightarrow 1s$ time slot $01 \rightarrow 8s$ time slot $10 \rightarrow 16s$ time slot $11 \rightarrow 32s$ time slot			
		D6:D5	00 → 100 KHz 01 → 25 KHz 10 → 50 KHz 11 → 200 KHz			
		D7	 0 → 5 clock cycles for comparator 1 → 15 clock cycles for comparator 			

Figure 78: Reference DAC Code LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x1F	0x1F ref_dcod_lsb_reg	Least Significa code for settin	R/W	R/W	0000_0000	
OXII		D7:D0	Bit7 to Bit0 of DAC code	10,00	10,00	POR_VSUP



Figure 79: Reference DAC Code MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
		Most Signific				
0x20	0x20 ref_dcod_msb_reg		Bit11 to Bit8 of DAC code	R/W	R/W	0000_0000 POR_VSUP
		D7:D4	Reserved			

Figure 80: Higher Limit DAC Code LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x21	0x21 hlmt_dcod_lsb_reg	Least Significa code for settin	R/W	R/W	0000_0000	
UNZI		D7:D0	Bit7 to Bit0 of DAC code	R/W R/W		POR_VSUP

Figure 81: Higher Limit DAC Code MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
	Most Signifi code for set					
0x22	0x22 hlmt_dcod_msb_reg	D3:D0	Bit11 to Bit8 of DAC code	R/W	R/W	0000_0000 POR_VSUP
		D7:D4	Reserved			

Figure 82: Lower Limit DAC Code LSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x23	0x23 llmt_dcod_lsb_reg	Least Significa code for settin	R/W	R/W	0000_0000	
UAZJ		D7:D0	Bit7 to Bit0 of DAC code	10,00	17, 44	POR_VSUP

ams Datasheet: 2014-Jun-23 [v1-00]



Figure 83: Lower Limit DAC Code MSB Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
		Most Significant byte of 12-bit DAC code for setting low limit voltage.				
0x24	0x24 Ilmt_dcod_msb_reg	D3:D0	Bit11 to Bit8 of DAC code	R/W	R/W	0000_0000 POR_VSUP
		D7:D4	Reserved			

Figure 84:
Device Address and Broadcast Command SPI Operation Register

Address	Register Name	Feat	ures and Bit Description	SPI4	SPI3	POR Value
		Device a register	ddress/ broadcast command			
			If spi3_cmd_reg [D3-D1] = 001/010 Address of Device to be accessed. (000000 address is broadcast address)			
0x25	spop_dadd_bcmd _reg	D5:D0	If spi3_cmd_reg [D3-D1] = 100 Broadcast communication commands. 000000 → No operation 000011 → Timer control register write 000010 → Cell reference DAC code write 000011 Cell lower limit DAC code write 000100 → Cell higher limit DAC code write	R/W	-	0000_0000 POR_V5V
			If spi3_cmd_reg [D3-D1] = 101 000000 → Data of register wrop_data_reg is written to address stored in spop_reg_add_reg in all devices.			
		D7:D6	Reserved (accessible only in Master mode)			



Figure 85: SPI Operation Register Address Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
		Address of register to be accessed during 3-wire read/write operation in the device selected in spop_dadd_bcmd_reg				0000 0000
0x26	0x26 spop_reg_add_reg		Address of Register to be accessed (R/W)	R/W	-	0000_0000 POR_V5V
			Reserved (accessible only in Master mode)			

Figure 86: SPI Write Operation Data Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x27	wrop_data_reg	Data to be written in the register addressed by spop_reg_add_reg of device selected in spop_dadd_bcmd_reg during SPI3 write operation.		R/W	-	0000_0000 POR V5V
OAZ/ Wop_data_reg		D7:D0	Bit7 to Bit0 of accessed register (accessible only in Master mode)			



Figure 87: SPI3 Command Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
	3-wire SPI c cleared onc done.					
	D0	 0 → No SPI3 operation 1 → Start SPI3 operation corresponding to command code 				
0x28	spi3_cmd_reg	D3:D1	000 → Reserved 001 → Slave register Read 010 → Slave register Write 011 → Start address allocation process 100 → Broadcast configuration command 101 → Broadcast Slave register Write 110 → Reserved 111 → Reserved	R/W	-	0000_0000 POR_V5V
		D7:D4	Reserved			

Figure 88: SPI Read Operation Data Register

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x29	rdop_data_reg	Read data from the register addressed by spop_reg_add_reg of device selected in spop_dadd_bcmd_reg during SPI3 read operation.		R/W	R/W	0000_0000 POR VSUP
		D7:D0	Bit7 to Bit0 of accessed register (accessible only in Master mode)			. 5.1 \$361



Figure 89: Feature Selection Register 1

Address	Register Name	Features	Features and Bit Description		SPI3	POR Value
		Feature sele	ction register1.			
		D0	1 → Zero cross detection enable			
		D2:D1	Zero cross detection filter setting $00 \rightarrow 8\mu s$ $01 \rightarrow 6\mu s$ $10 \rightarrow 4\mu s$ $11 \rightarrow 2\mu s$			
		D3	Reserved			
0x2A	feat_sel_reg_1	D4	1 → External resistor divider enable	R/W	R/W	0000_0000
		D5	 0 → Cell reference is generated from DAC 1 → Cell reference is supplied externally on VREF_IN pin 			POR_VSUP
		D6	 0 → Cell Lower/Higher limit is generated from DAC 1 → Cell Lower/Higher limit is supplied externally on CELL_THL and CELL_THU pins 			
		D7	Reserved			



Figure 90: Feature Selection Register 2

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
		Feature sele	ction register2.			
0x2B	feat_sel_reg_2	D1:D0	FD_OUT pad configuration 10 → Optocoupler driver 11 → Normal Pad	R/W	-	0000_0010 POR_V5V
		D7:D2	Reserved			

Note(s) and/or Footnote(s):

1. Registers from address 0x2C to 0x2F are 'Reserved'.

OTP Reflection Registers

Figure 91: OTP Reflection Register 1

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x30	otp_refln_reg_1	D7:D0	OTP bits [0:7] Chip ID [0:7]	R	R	0000_0000 POR_V5V

Figure 92: OTP Reflection Register 2

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x31	otp_refln_reg_2	D7:D0	OTP bits [8:15] Chip ID [8:15]	R	R	0000_0000 POR_V5V



Figure 93: OTP Reflection Register 3

Addres	s Register Name	Feature	Features and Bit Description		SPI3	POR Value
0x32	otp_refln_reg_3	D7:D0	OTP bits [16:23] Chip ID [16:18], OTP bits [19:23]	R	R	0000_0000 POR_V5V

Figure 94: OTP Reflection Register 4

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x33	otp_refln_reg_4	D7:D0	OTP bits [24:31]	R	R	0000_0000 POR_V5V

Figure 95: OTP Reflection Register 5

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x34	otp_refln_reg_5	D7:D0	OTP bits [32:39]	R	R	0000_0000 POR_V5V

Figure 96: OTP Reflection Register 6

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x35	otp_refln_reg_6	D7:D0	OTP bits [40:47]	R	R	0000_0000 POR_V5V



Figure 97: OTP Reflection Register 7

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x36	otp_refln_reg_7	D7:D0	OTP bits [48:55]	R	R	0000_0000 POR_V5V

Figure 98: OTP Reflection Register 8

Address	Register Name	Features and Bit Description		SPI4	SPI3	POR Value
0x37	otp_refln_reg_8	D7:D0	OTP bits [56:63]	R	R	0000_0000 POR_V5V

Note(s) and/or Footnote(s):

- 1. Registers from address 0x38 to 0x39 are 'Reserved'.
- 2. Registers from address 0x3A to 0x4E are OTP and Test registers. These are for factory use.



Application Information

Figure 99:
Application Schematic with Single Device

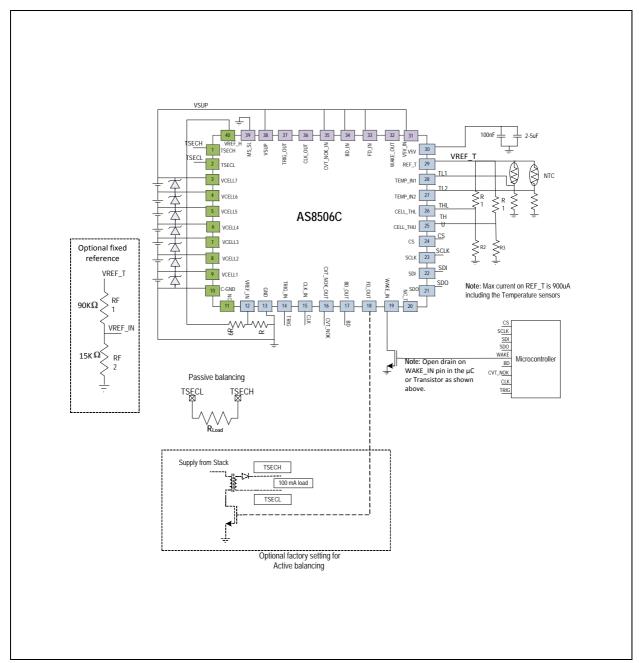




Figure 100:
Application Schematic with Single Device Passive Balancing-Option 1

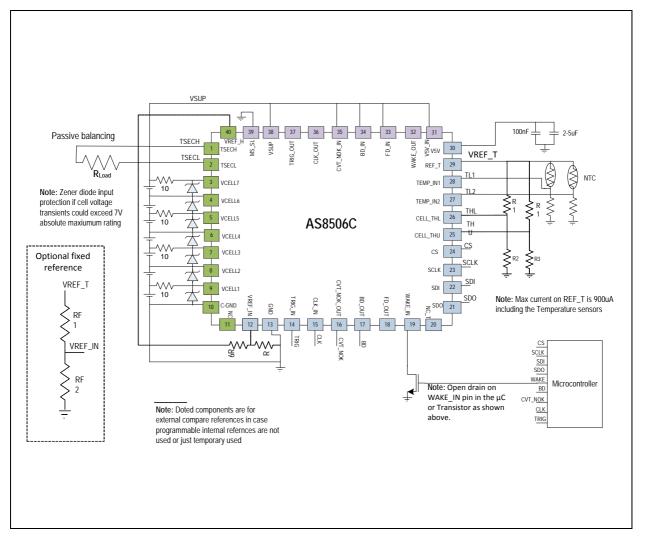
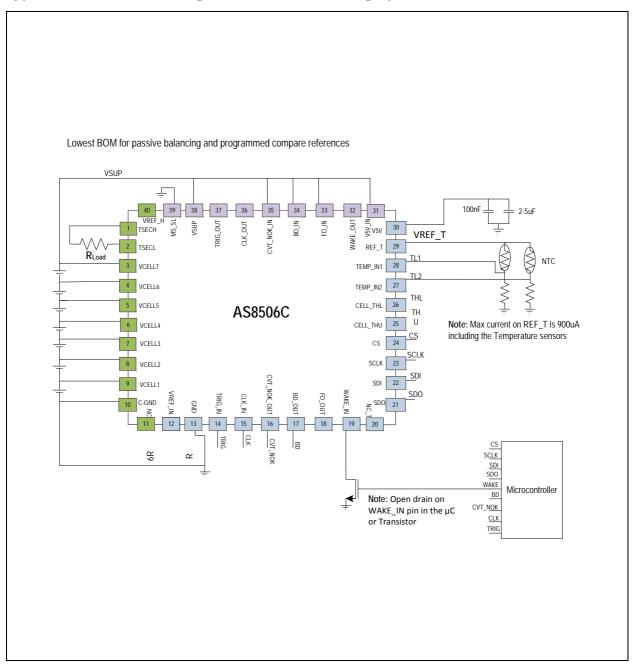




Figure 101:
Application Schematic with Single Device Passive Balancing-Option 2





Passive balance

Passive balance is to dissipate the energy from the cell with the higher cell voltage to the reference value (average of the stack e.g. max cell voltage in constant voltage charge phase or mean cell voltage as generated by resitor divider).

Resistor value should be selected based on the cell chemistry and voltage limits. Maximum current capability of internal shuttle switch is 100mA. Internal resistance of the shuttle switch typically is 5Ω ..

Active balance

In the active balance device charge the cells which are lower than the reference voltage. This is a method of charge transfer from the stack to the cell.

Flyback converter is used for this charge transfer. Active balancing mode need to be enabled by factory setting. It is not available for the default ASSP.

Flyback Converter (with external Transformer)

The high-efficiency, high-voltage, DC-DC Flyback converter delivers current of 100mA to the lithium ion cell when the secondary side of the Flyback transformer is connected to the cell terminals. This also gives the isolation between the primary supply and the load cell. The Flyback converter is designed to charge the lithium-ion battery cells during the balancing mode of the IC. It consists of a PWM waveform generator with variable duty cycle and a driver. This driver can drive an external MOSFET, (or) the optocoupler, (or) an isolation device based on the requirement. During the ON-state of the PWM waveform, the primary side of the Flyback transformer conducts and stores the energy. In the other phase the stored energy in the secondary is transferred to the cell which will be connected to the secondary side of the transformer. The converter always works in discontinuous current mode (DCM).

The advantages of this type of control system can be summarized as following:

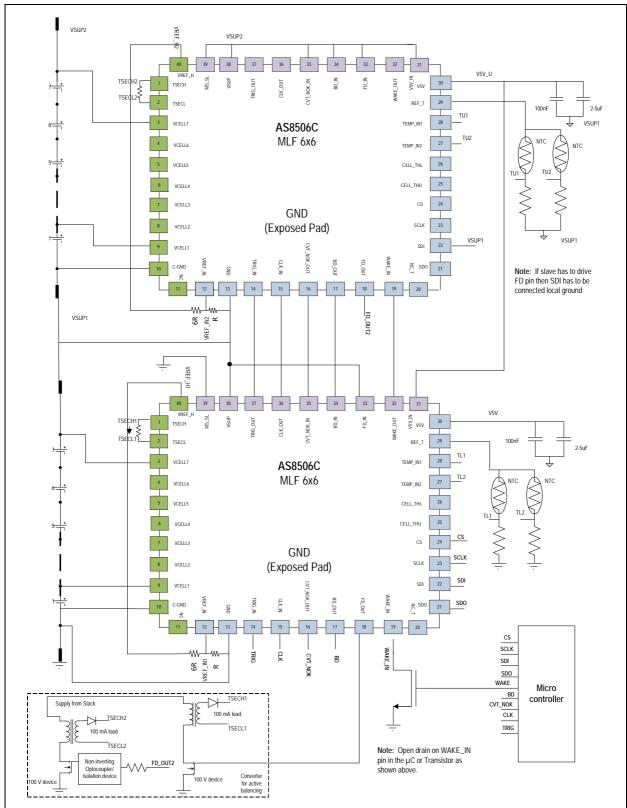
- · High-efficiency even at light load
- Intrinsically stable
- Simplicity

Figure 102: External Components

Component	Manufacturer Part Number	Manufacturer
Transformer	WE-FLEX 749196111	WURTH ELECTRONICS
Optocoupler	ACPL-M72T-000E	AVAGO TECHNOLOGIES

amii

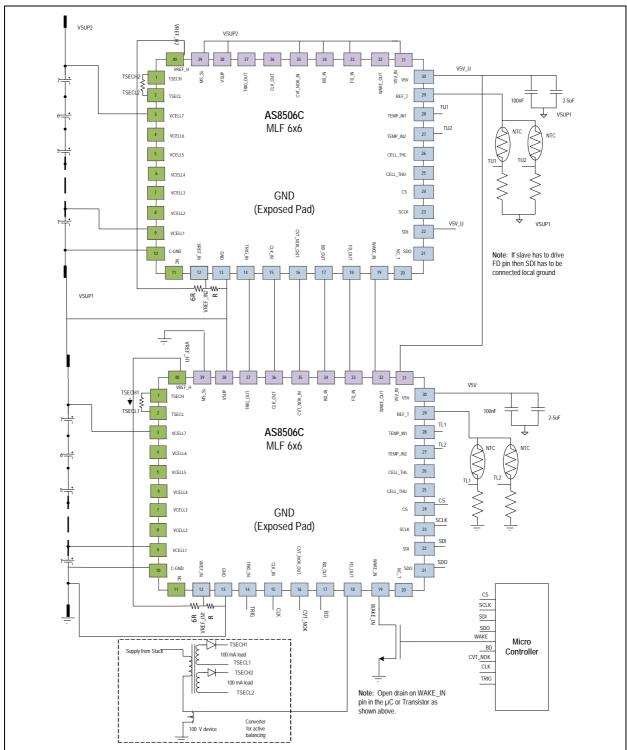
Figure 103:
Application with Opto-Coupler/ Isolation Device



Caution: In the application it's recommended to connect the AS8506C devices stacked first and connect the battery stack from bottom to top in sequence to avoid any possible damage of the system. While removing the battery pack its strictly recommended to remove the battery pack from the top. Removing the battery pack from bottom will damage the system.



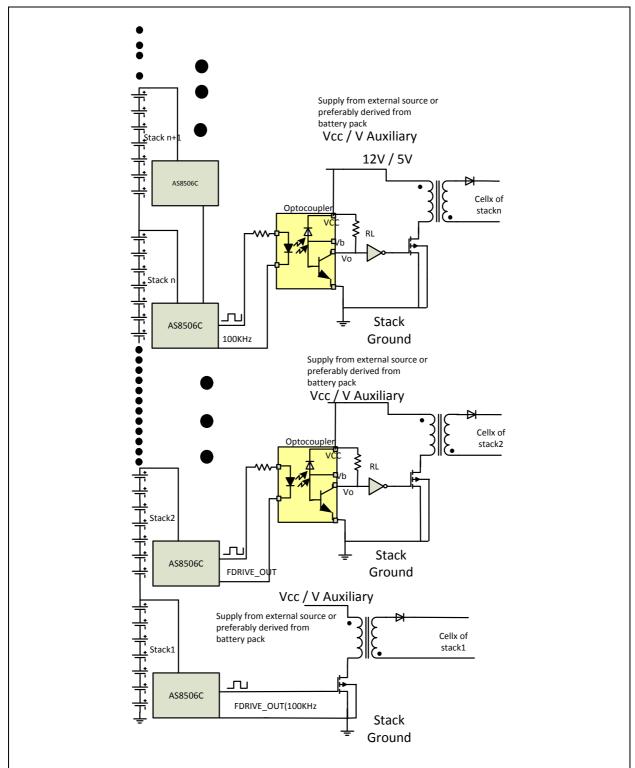
Figure 104:
Application Schematic



Caution: In the application it's recommended to connect the AS8506C devices stacked first and connect the battery stack from bottom to top in sequence to avoid any possible damage of the system. While removing the battery pack its strictly recommended to remove the battery pack from the top. Removing the battery pack from bottom will damage the system.



Figure 105:
Application with Opto-Coupler Device Stackable to Higher Numbers

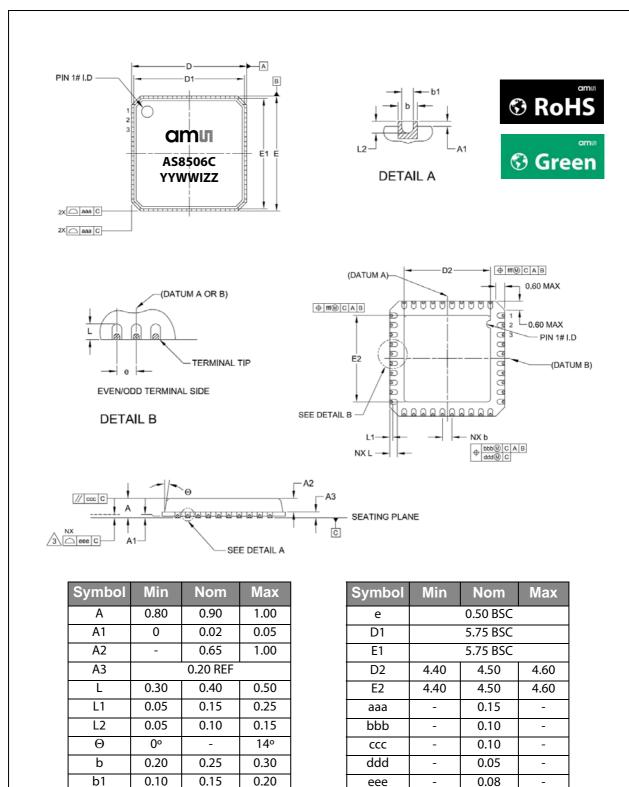


Caution:: In the application it's recommended to connect the AS8506C devices stacked first and connect the battery stack from bottom to top in sequence to avoid any possible damage of the system. While removing the battery pack its strictly recommended to remove the battery pack from the top. Removing the battery pack from bottom will damage the system.



Package Drawings & Markings The AS8506C device is available in a 40-pin MLF (6x6) package.

Figure 106: AS8506C Package Drawings and Dimensions



fff

Ν

_

0.10

40

D

Ε

6.00 BSC

6.00 BSC



Note(s) and/or Footnote(s):

- 1. Dimensions and toleranceing conform to ASME Y14.5M. 1994.
- 2. All dimensions are in millimeters (angles in degrees).
- 3. Bilateral coplanarity zone applies to the exposed pad as well as the terminal.
- 4. Radius on terminal is optional.
- 5. N is the number of terminals.

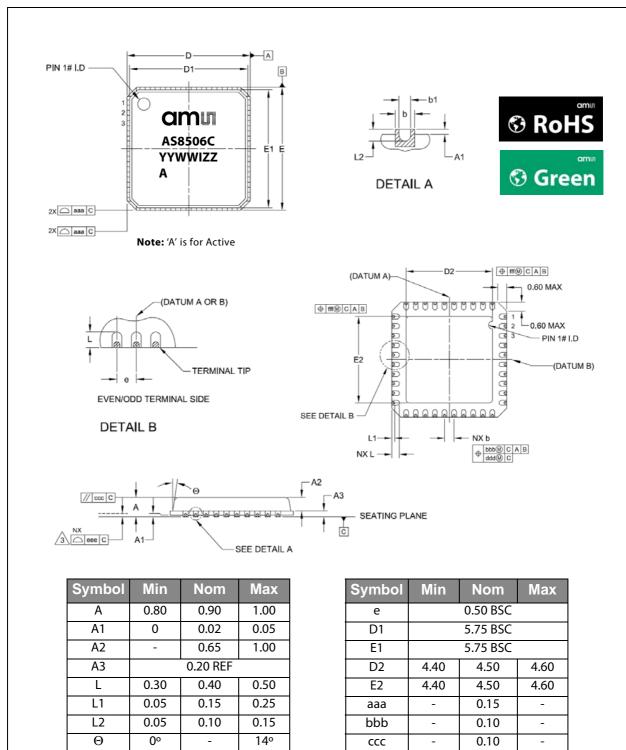
Figure 107:

AS8506C Packaging Code YYWWXZZ

YY	ww	1	ZZ
Last two digits of the year	Manufacturing week	Plant identifier	Assembly traceability code



Figure 108: **AS8506C A Package Drawings and Dimensions**



Symbol	Min	Nom	Мах
е	0.50 BSC		
D1	5.75 BSC		
E1	5.75 BSC		
D2	4.40	4.50	4.60
E2	4.40	4.50	4.60
aaa	-	0.15	-
bbb	-	0.10	-
ccc	-	0.10	-
ddd	-	0.05	-
eee	-	0.08	-
fff	-	0.10	-
N		40	

b

b1

D

Ε

0.20

0.10

0.25

0.15

6.00 BSC

6.00 BSC

0.30

0.20



Note(s) and/or Footnote(s):

- 1. Dimensions and toleranceing conform to ASME Y14.5M. 1994.
- 2. All dimensions are in millimeters (angles in degrees).
- 3. Bilateral coplanarity zone applies to the exposed pad as well as the terminal.
- 4. Radius on terminal is optional.
- 5. N is the number of terminals.

Figure 109:

AS8506C A Packaging Code YYWWXZZ

YY	ww	-	ZZ
Last two digits of the year	Manufacturing week	Plant identifier	Assembly traceability code



Ordering & Contact Information

The devices are available as the standard products shown in Ordering Information.

Figure 110: Ordering Information

Ordering Code	Description	Delivery Form	Package	Reel Size
AS8506C-BQFP	Monitor and Balancer IC (1)	Tape and Reel	40-Pin MLF (6x6)	4000
AS8506C-BQFM	Monitor and Balancer IC (1)	Tape and Reel	40-Pin MLF (6x6)	1000
AS8506C-BQFP-A	Monitor and Balancer IC (2)	Tape and Reel	40-Pin MLF (6x6)	4000
AS8506C-BQFM-A	Monitor and Balancer IC (2)	Tape and Reel	40-Pin MLF (6x6)	1000

Note(s) and/or Footnote(s):

- 1. For Passive balancing.
- 2. For Active balancing.

Buy our products or get free samples online at:

www.ams.com/ICdirect

Technical Support is available at:

www.ams.com/Technical-Support

For further information and requests, e-mail us at:

ams_sales@ams.com

For sales offices, distributors and representatives, please visit:

www.ams.com/contact

Headquarters

ams AG Tobelbaderstrasse 30 8141 Unterpremstaetten Austria, Europe

Tel: +43 (0) 3136 500 0

Website: www.ams.com



RoHS Compliant & ams Green Statement

RoHS: The term RoHS compliant means that ams AG products fully comply with current RoHS directives. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes.

ams Green (RoHS compliant and no Sb/Br): ams Green defines that in addition to RoHS compliance, our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

Important Information: The information provided in this statement represents ams AG knowledge and belief as of the date that it is provided. ams AG bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. ams AG has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. ams AG and ams AG suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.



Copyrights & Disclaimer

Copyright ams AG, Tobelbader Strasse 30, 8141 Unterpremstaetten, Austria-Europe. Trademarks Registered. All rights reserved. The material herein may not be reproduced, adapted, merged, translated, stored, or used without the prior written consent of the copyright owner.

Devices sold by ams AG are covered by the warranty and patent indemnification provisions appearing in its General Terms of Trade. ams AG makes no warranty, express, statutory, implied, or by description regarding the information set forth herein. ams AG reserves the right to change specifications and prices at any time and without notice. Therefore, prior to designing this product into a system, it is necessary to check with ams AG for current information. This product is intended for use in commercial applications. Applications requiring extended temperature range, unusual environmental requirements, or high reliability applications, such as military, medical life-support or life-sustaining equipment are specifically not recommended without additional processing by ams AG for each application. This product is provided by ams AG "AS IS" and any express or implied warranties, including, but not limited to the implied warranties of merchantability and fitness for a particular purpose are disclaimed.

ams AG shall not be liable to recipient or any third party for any damages, including but not limited to personal injury, property damage, loss of profits, loss of use, interruption of business or indirect, special, incidental or consequential damages, of any kind, in connection with or arising out of the furnishing, performance or use of the technical data herein. No obligation or liability to recipient or any third party shall arise or flow out of ams AG rendering of technical or other services.



Document Status

Document Status	Product Status	Definition
Product Preview	Pre-Development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice
Preliminary Datasheet	Pre-Production	Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice
Datasheet	Production	Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade
Datasheet (discontinued)	Discontinued	Information in this datasheet is based on products which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs



Revision Information

Initial released version 1-00



Content Guide

1 General Description

- 2 Key Benefits & Features
- 2 Applications
- 3 Block Diagram

4 Pin Assignment

8 Absolute Maximum Ratings

10 Typical Operating Characteristics

11 Electrical Characteristics

- 11 Device Level Specifications
- 12 Low Dropout Regulator (5V Output LDO)
- 13 High-precision Bandgap Reference
- 13 Digital to Analog Converter
- 14 Analog to Digital Converter
- 14 Pre-Regulator
- 15 PWM Driver
- 16 PWM Oscillator
- 16 Oscillator for Digital Circuit
- 17 External Temperature Thresholds
- 18 Ron of the Shuttle Switches (Internal Switch for Charging/Discharging)
- 18 Over-Temperature Measurement
- 19 Weak Cell Detection (Voltage Comparator)
- 19 Power on Voltage Detection
- 20 Electrical Characteristics for Digital Inputs and Outputs

23 Detailed Description

- 23 Voltage Regulator (LDO_5V)
- 23 High Precision Bandgap (HPBG)
- 23 External Temperature Monitor and Measurement
- 24 Internal Temperature Monitor
- 24 PWM Generator
- 24 RC Oscillator
- 24 DAC for the Reference Generation
- 25 SAR ADC
- 25 Pre-Regulator
- 25 Cell Threshold
- 25 Weak Cell Detection
- 25 External Resister Divider Control
- 26 PORs on Different Supplies
- 27 AS8506C System Operation
- 29 Functional State Diagram
- 30 Operating Modes
- 30 NORMAL Mode
- 30 Diagnosis Phase
- 31 Compare and Balance Phase
- 32 Sleep Mode
- 32 Wait Mode
- 32 Wake Mode
- 33 Wake-up Event
- 34 Trigger Event
- 36 Balancing Algorithm
- 37 Initialization Sequence



- 39 Device Interface
- 39 Serial Peripheral Interface
- 40 SPI Write Operation
- 42 SPI Read Operation
- 44 Address Allocation Process
- 47 Communication to Slaves
- 47 Broadcast Communication
- 48 Communication with Individual Slave
- 48 Write operation.
- 49 Read operation.
- 50 SPI Timing Diagrams
- 51 SPI Protocol
- 52 System Timings
- 53 Register Space Description
- 53 Status Registers
- 66 Configuration and 3-Wire SPI Interface Related Registers
- 74 OTP Reflection Registers

77 Application Information

- 80 Passive balance
- 80 Active balance
- 80 Flyback Converter (with external Transformer)
- 84 Package Drawings & Markings
- 88 Ordering & Contact Information
- 89 RoHS Compliant & ams Green Statement
- 90 Copyrights & Disclaimer
- 91 Document Status
- 92 Revision Information