

ADES1830/ADES1831

16-Channel Multicell Battery Monitor

FEATURES

- ▶ Measures up to 16 battery cells in series
- ▶ Maximum lifetime TME: ± 1.8 mV at 3.3 V per cell for ADES1830 and ± 5 mV for ADES1831 (-40°C to $+105^{\circ}\text{C}$)
- ▶ Simultaneous and continuous measurement of cell voltages
- ▶ Configurable integrated low-pass filtering
- ▶ Stackable architecture for high voltage battery packs
- ▶ Built-in isoSPI
 - ▶ 2 Mbps isolated serial communications
 - ▶ Uses a single twisted pair, up to 20 meters per segment
 - ▶ Low EMI susceptibility and emissions
 - ▶ Bidirectional for broken wire protection
 - ▶ Capacitor or transformer-coupled
- ▶ Hot plug tolerant without external protection
- ▶ Passive cell balancing up to 300 mA per channel with programmable PWM
- ▶ Up to 9 general-purpose analog inputs or digital I/O
 - ▶ Temperature or other sensor inputs
 - ▶ Configurable as an I²C or SPI controller
- ▶ 4 μA sleep mode supply current
- ▶ Provisions for bus bars

APPLICATIONS

- ▶ Utility energy storage
- ▶ Commercial and Industrial energy storage
- ▶ Residential energy storage
- ▶ Backup battery systems

GENERAL DESCRIPTION

The ADES1830/ADES1831 are multicell battery stack monitors that measure up to 16 series connected battery cells with a lifetime total measurement error (TME) of less than 2 mV for the ADES1830 and less than 5 mV for the ADES1831 over the full temperature range. The measurement input range of -2 V to $+5.5$ V makes the ADES1830/ADES1831 suitable for most battery chemistries and allows measurement of voltages across bus bars. Provisions are made for bypassing bus bars without dedicating any measurement channels.

All cells can be measured simultaneously and redundantly with two individual analog-to-digital converters (ADCs). The continuously operating ADCs with a high sampling rate of 4.096 MHz allow reduced external analog filtering and aliasing free measurement results. Higher noise reduction can be achieved by subsequent programmable infinite impulse response (IIR) filters.

Multiple ADES1830/ADES1831 devices can be connected in series, permitting simultaneous cell monitoring of long, high voltage battery strings. Each ADES1830/ADES1831 has an isolated serial port interface (isoSPI™) for high speed, RF immune, long distance communications. Multiple devices are connected in a daisy chain with one host processor connection. This daisy chain can be operated bidirectionally, ensuring communication integrity even in the event of a fault along the communication path.

The ADES1830/ADES1831 can be powered from the battery stack or an isolated supply. The ADES1830/ADES1831 include passive balancing with individual pulse width modulation (PWM) duty cycle control and up to 300 mA discharge current for each cell. Other features include an on-board 5 V regulator, up to 9 general-purpose inputs/outputs, and a sleep mode, where current consumption is reduced to 4 μA .

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Changes to Figure 2.....	5
Change to Internal Digital Filtering Section.....	20
Change to Using the LPCM and Discharge Timer Section.....	36
Change to Figure 42.....	77

3/2024—Revision 0: Initial Version

TYPICAL APPLICATION CIRCUIT

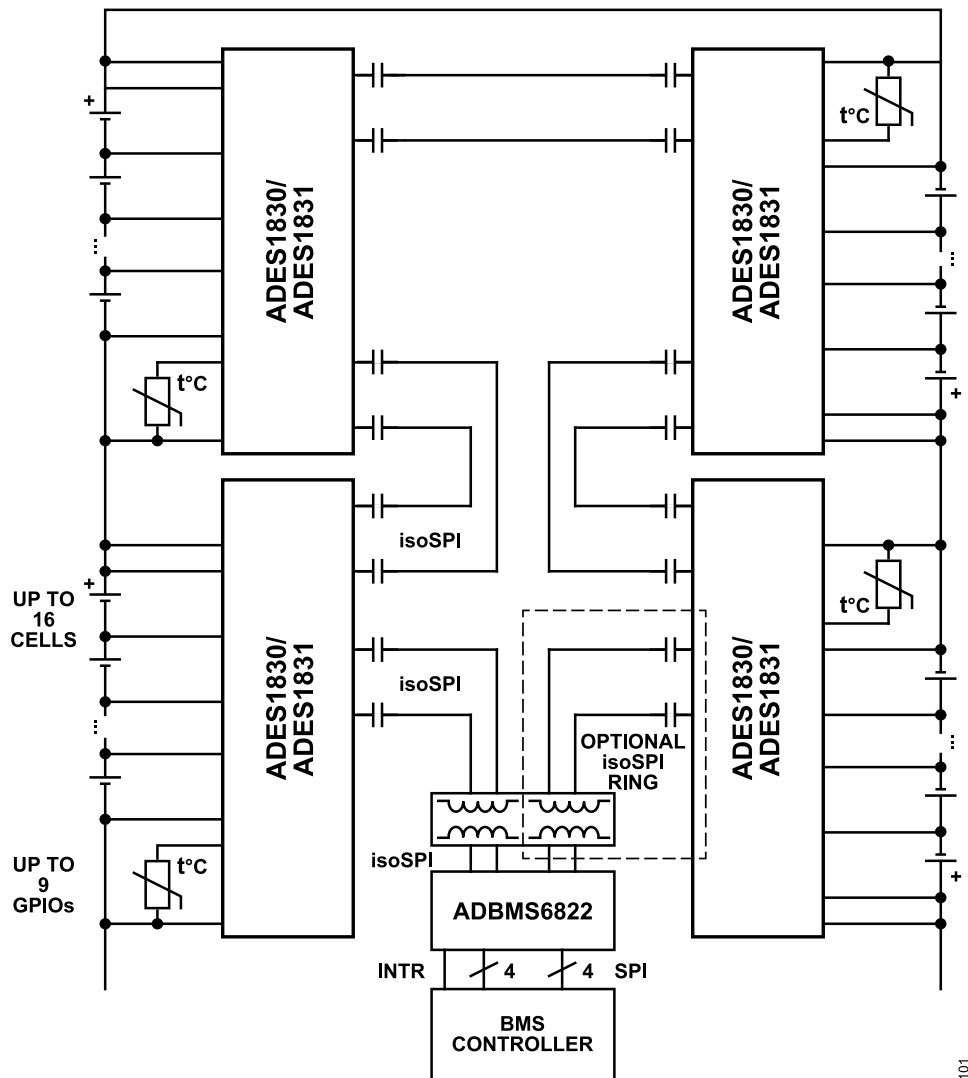


Figure 1. Typical Application Circuit

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FUNCTIONAL BLOCK DIAGRAM

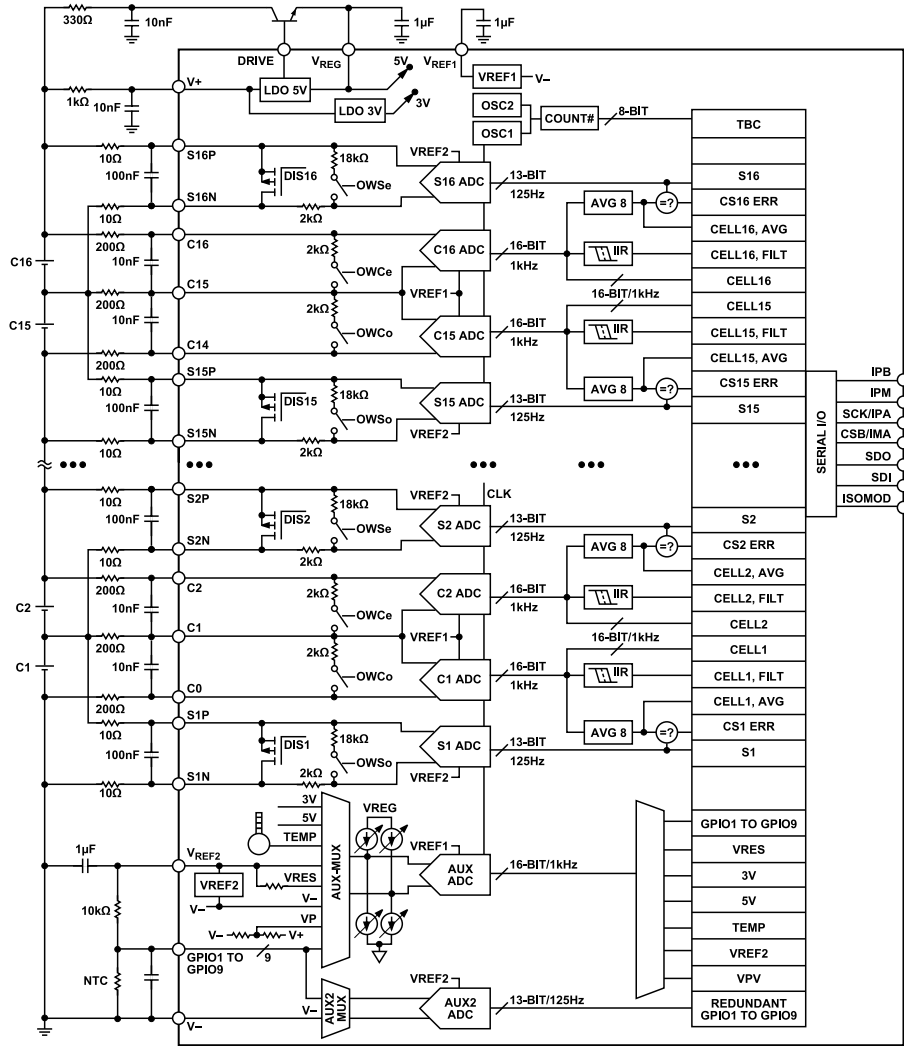


Figure 2. Functional Block Diagram

SPECIFICATIONS

Specifications apply over the full V+ operating voltage range and full operating junction temperature range ($T_J = -40^{\circ}\text{C}$ to $+105^{\circ}\text{C}$), unless otherwise noted.

Table 1. C-ADC DC Specifications

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
MEASUREMENT RESOLUTION				0.15		mV/bit
DIFFERENTIAL INPUT RANGE	V_{DIF}	$-0.1\text{ V} < (C_x \text{ to } V^-) < 80\text{ V}$	-2		+5.5	V
ADC OFFSET VOLTAGE ¹				± 0.1		mV
ADC GAIN ERROR ¹				± 0.01		%
ADC UPDATE RATE			0.9	1	1.1	kHz
ADC TRANSITION NOISE				40		$\mu\text{V rms}$
LIFETIME CELL TOTAL MEASUREMENT ERROR	C-TME	$V_{\text{DIF}} \leq \pm 2.0\text{ V}$ $V_{\text{DIF}} \leq 3.3\text{ V}$ $V_{\text{DIF}} \leq 4.5\text{ V}$ (ADES1830) $V_{\text{DIF}} \leq 4.5\text{ V}$ (ADES1831) $V_{\text{DIF}} \leq 5.5\text{ V}$			± 1.5 ± 1.8 ± 2 ± 5 ± 3	mV mV mV mV mV
INPUT LEAKAGE CURRENT		ADC off		0	± 250	nA
DIFFERENTIAL INPUT RESISTANCE	$R_{\text{IN_ADC}}$	ADC on	1.6	2.2	3	M Ω
DIFFERENTIAL INPUT RESISTANCE DURING OPEN WIRE DETECTION				1.75		k Ω
ADC SAMPLING FREQUENCY	f_s		3.7	4.1	4.5	MHz

¹ The ADC specifications are guaranteed by the total measurement error specification.

Table 2. S-ADC DC Specifications

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
MEASUREMENT RESOLUTION				1.5 ¹		mV/bit
INPUT RANGE	$V_{\text{DIF_S}}$	$-0.1\text{ V} < (S_x \text{ to } V^-) < 80\text{ V}$	-0.3		+5.5	V
ADC OFFSET VOLTAGE ²				± 0.2		mV
ADC GAIN ERROR ²				± 0.03		%
ADC UPDATE RATE			110	125	140	Hz
ADC TRANSITION NOISE				20		$\mu\text{V rms}$
S-ADC TOTAL MEASUREMENT ERROR	S-TME	$0\text{ V} \leq V_{\text{DIF_S}} \leq 4.5\text{ V}$ $V_{\text{DIF_S}} \leq 5.5\text{ V}$			± 7 ± 8	mV mV
INPUT LEAKAGE CURRENT		ADC off, $V_{\text{DIF_S}} = 5.5\text{ V}$		10	± 300	nA
DIFFERENTIAL INPUT RESISTANCE		ADC on	1	1.8	2.6	M Ω
DIFFERENTIAL INPUT RESISTANCE DURING OPEN WIRE DETECTION				20		k Ω
GAIN DURING OPEN WIRE DETECTION		No open wire fault	85	90	95	%
ADC SAMPLING FREQUENCY	f_s		3.7	4.1	4.5	MHz

¹ The S-ADC result registers are normalized to the weight of the C-ADC results, allowing to apply the same voltage conversion function. See the register description for details.

² The ADC specifications are guaranteed by the total measurement error specification.

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Table 3. Auxiliary (AUX) ADC DC Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
MEASUREMENT RESOLUTION			0.15		mV/bit
INPUT RANGE	GPIOx to V-	-0.3		V _{REG}	V
ADC OFFSET VOLTAGE ¹			-0.2		mV
ADC GAIN ERROR ¹			±0.01		%
ADC UPDATE RATE		0.9	1	1.1	kHz
ADC TRANSITION NOISE			50		µV rms
GPIOx TOTAL MEASUREMENT ERROR	0 V < GPIOx to V- ≤ 3.3 V			±2.8	mV
	3.3 V < GPIOx to V- ≤ 5 V			±4.2	mV
DIAGNOSTIC MEASUREMENTS	Internal temperature, T = maximum specified temperature		±5		°C
	V _{REG} pin		±0.1	±0.25	%
	V _{REF2} , VRES		±0.02	±0.2	%
	Digital supply voltage, V _{REGD}		±0.1	±1.6	%
	V+ to V-, V+ > 20 V	-1	±0.05	+0.5	%
	-0.1 V ≤ S1N to V- ≤ 0.1 V		±0.02	0.2	%
INPUT LEAKAGE CURRENT	AUX ADC off, GPIOx = 5 V		10	±250	nA
INPUT RESISTANCE	AUX ADC on	1.5	2.7	3.5	MΩ
INPUT CURRENT DURING OPEN WIRE DETECTION	Pull-down current: GPIOx > 1.5 V	-140	-200	-260	µA
	Pull-up current: GPIOx < V _{REG} - 1.5 V	140	200	260	µA
ADC SAMPLING FREQUENCY		3.7	4.1	4.5	MHz

¹ The ADC specifications are guaranteed by the total measurement error specification.

Table 4. AUX2 ADC DC Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
MEASUREMENT RESOLUTION			1.5 ¹		mV/bit
INPUT RANGE	GPIOx to V-	-0.3		V _{REG}	V
ADC OFFSET VOLTAGE ²			±0.2		mV
ADC GAIN ERROR ²			±0.05		%
ADC UPDATE RATE		110	125	140	Hz
ADC TRANSITION NOISE			25		µV rms
GPIOx TOTAL MEASUREMENT ERROR	0 V ≤ GPIOx to V- ≤ 3.3 V			±6	mV
	3.3 V < GPIOx to V- ≤ 5 V			±8	mV
INPUT LEAKAGE CURRENT	AUX2 ADC off, GPIOx = 5 V		10	±250	nA
INPUT RESISTANCE	AUX2 ADC on	1.5	2.7	3.5	MΩ
ADC SAMPLING FREQUENCY		3.7	4.1	4.5	MHz

¹ The AUX2 ADC result registers are normalized to the weight of the AUX ADC results, allowing to apply the same voltage conversion function. See register description for details.

² The ADC specifications are guaranteed by the total measurement error specification.

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Table 5. Voltage Reference Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
FIRST REFERENCE VOLTAGE	V _{REF1} pin, no load	3	3.2	3.3	V
FIRST REFERENCE VOLTAGE TEMPERATURE COEFFICIENT (TC)	V _{REF1} pin, no load		3		ppm/°C
FIRST REFERENCE VOLTAGE HYSTERESIS	V _{REF1} pin, no load		20		ppm
FIRST REFERENCE VOLTAGE LONG-TERM DRIFT	V _{REF1} pin, no load		20		ppm/kHr
SECOND REFERENCE VOLTAGE	V _{REF2} pin, no load	2.994	3	3.006	V
	V _{REF2} pin, 1 kΩ load to V-	2.994	3	3.006	V
OUTPUT CURRENT	ΔV _{REF2} < ± 2 mV	-0.2		+5	mA
SECOND REFERENCE VOLTAGE TC	V _{REF2} pin, no load		10		ppm/°C
SECOND REFERENCE VOLTAGE HYSTERESIS	V _{REF2} pin, no load		100		ppm
SECOND REFERENCE VOLTAGE LONG-TERM DRIFT	V _{REF2} pin, no load		60		ppm/kHr

Table 6. General DC Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
V+ SUPPLY CURRENT (See Figure 14)	Core in sleep, isoSPI in idle				
	Core in sleep, isoSPI in idle, V _{REG} = 0 V, V+ = 60 V		4	10	μA
	Core in sleep, isoSPI in idle, V _{REG} = 5 V, V+ = 60 V		2	5	μA
	Core in standby or extended balancing, V+ = 60 V	4	10	24	μA
	Core in REFUP or measure or discharge timer monitor (DTM) measure, V+ = 60 V	0.3	0.5	0.65	mA
V _{REG} SUPPLY CURRENT (See Figure 14)					
I _{REG} (CORE, MEASURE) = I _{REG} (CORE, REFUP) + I _{REG} (CORE, ADCs ON)	Core in sleep, isoSPI in idle, V _{REG} = 5 V		2.2	8	μA
	Core in standby	3	10	25	μA
	Core in REFUP	2	2.3	3	mA
	Core in measure or DTM, additional current C-ADCs on	4	4.5	5	mA
	Core in measure, additional current S-ADCs on	3	3.9	4.5	mA
	Core in measure, additional current AUX ADCs on	0.4	0.55	0.75	mA
ADDITIONAL V _{REG} SUPPLY CURRENT IF isoSPI IN READY OR ACTIVE STATE AND t _{CLK} = 0.5 μs ¹	isoSPI in idle state		0		mA
	ISOMD = 0, ready	2.6	3.2	3.9	mA
	ISOMD = 0, active	7	8.5	11.5	mA
	ISOMD = 1, ready	3.1	3.7	4.4	mA
	ISOMD = 1, active write	7.5	9	12	mA
	ISOMD = 1, active read	12.5	14	18	mA
ADDITIONAL V _{REG} SUPPLY CURRENT FROM DISCHARGING	DCT = 0 and no cell discharge enabled		0		μA
	DCT ≠ 0 and/or some cell discharges asserted	10	40	130	μA
V+ SUPPLY VOLTAGE	TME specifications met	11	40	80	V
V _{REG} SUPPLY VOLTAGE		4.5	5	5.5	V
THERMAL SHUTDOWN PROCEDURE			150		°C
DISCHARGE SWITCH ON RESISTANCE	SxN = 0 V (x = 1, 2, or 3), SxP = 6 V (x > 3)	0.5	1	4	Ω
DRIVE PIN OUTPUT					
Output Voltage (V _{DRIVE})	T _A = 25°C	5.6	5.7	5.8	V
Output Current	ΔV _{DRIVE} < ±100 mV	-0.2		+1	mA
TEMPERATURE COEFFICIENT			-1.6		mV/°C

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¹ The active state current is calculated from DC measurements. The active state current is the additional average supply current into V_{REG} when there are continuous 2 MHz communications on the isoSPI ports. Slower clock rates reduce the supply current.

Table 7. Operation Timing Specifications

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
REGULATOR START-UP TIME	t_{WAKE}	V_{REG} generated from DRIVE pin		200	500	μs
WATCHDOG OR DISCHARGE TIMER	t_{SLEEP}	DCTO[3:0] = 0000	1.8	2	2.2	sec
REFERENCE WAKE-UP TIME	t_{REFUP}	Added to the conversion time when starting from the standby state. $t_{REFUP} = 0$ when starting from other states. t_{REFUP} is independent of the number of channels measured and the ADC mode.	2.7	3.5	4.4	ms
PWM DISCHARGE PERIOD				937		ms

Table 8. Digital Pin DC Specifications

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
DIGITAL INPUT VOLTAGE HIGH	V_{IH}	CSB, SCK, SDI, ISOMD, GPIOx	2.3			V
DIGITAL INPUT VOLTAGE LOW	V_{IL}	CSB, SCK, SDI, ISOMD, GPIOx			0.8	V
DIGITAL INPUT LEAKAGE CURRENT	$I_{LEAK(DIG)}$	SDI, ISOMD, GPIOx, SDO at 5 V CSB, SCK at 5 V CSB, SCK at 3.5 V			± 1 10 1	μA μA μA
DIGITAL OUTPUT, LOW SDO, GPIOx	$V_{OL(SDO, GPIO)}$	Sinking 4 mA			0.3	V

Table 9. isoSPI Specifications

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
TRANSMITTER PULSE AMPLITUDE	V_A	$V_A = V_{IP} - V_{IM} $, termination resistance = 50 Ω	1	1.25	1.6	V
RECEIVER THRESHOLD SETTING	V_{RX}		240	300	360	mV
LEAKAGE CURRENT ON IPx AND IMx PINS	$I_{LEAK(IP/IM)}$	Idle state, V_{IP} or V_{IM} , 0 V to V_{REG}			10	μA
TRANSMITTER DRIVE CURRENT		V_{CM} set by the driver		25		mA
COMMON-MODE VOLTAGE	V_{CM}	$T_A = 25^\circ C$, IPx and IMx pins not driving		3.2		V
RECEIVER INPUT RESISTANCE	R_{IN}	ISOMD = 1, ready state IPA, IMA ISOMD = 1, ready state IPB, IMB	35 100			k Ω k Ω
DIFFERENTIAL WAKE-UP VOLTAGE	V_{WAKE}	$t_{DWELL} \geq 240$ ns	400			mV
START-UP TIME AFTER WAKE DETECTION	t_{READY}				10	μs
IDLE TIMEOUT DURATION	t_{IDLE}		4.3	5.5	6.7	ms

ISOSPI PULSE TIMING SPECIFICATIONS

Table 10. isoSPI Pulse Timing Specifications

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
CHIP SELECT						
Half Pulse Width	$t_{\frac{1}{2}PW(CS)}$	Transmitter	120	150	180	ns
Signal Filter	$t_{FILT(CS)}$	Receiver	70	90	110	ns
Pulse Inversion Delay	$t_{INV(CS)}$	Transmitter	120	155	190	ns
Valid Pulse Window	$t_{WNDW(CS)}$	Receiver	220	270	330	ns
DATA						
Half Pulse Width	$t_{\frac{1}{2}PW(D)}$	Transmitter	40	50	60	ns
Signal Filter	$t_{FILT(D)}$	Receiver	10	25	35	ns
Pulse Inversion Delay	$t_{INV(D)}$	Transmitter	40	55	65	ns
Valid Pulse Window	$t_{WNDW(D)}$	Receiver	70	90	110	ns

SPECIFICATIONS

SPI TIMING REQUIREMENTS

Table 11. SPI Timing Requirements

Symbol	Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
$t_{CLK}^{1,2}$	SCK period		0.5			μ s
t_1^2	SDI setup time before SCK rising edge		25			ns
t_2^2	SDI hold time after SCK rising edge		100			ns
t_3^2	SCK low	$t_{CLK} = t_3 + t_4 \geq 0.5 \mu$ s	100			ns
t_4^2	SCK high	$t_{CLK} = t_3 + t_4 \geq 0.5 \mu$ s	100			ns
t_5^2	CSB rising edge to CSB falling edge		2			μ s
$t_6^{1,2}$	SCK rising edge to CSB rising edge		0.5			μ s
$t_7^{1,2}$	CSB falling edge to SCK rising edge		0.5			μ s

¹ These timing specifications are dependent on the delay through the cable and include allowances for 50 ns of delay each direction. 50 ns corresponds to 10 m of Cat-5 cable (which has a velocity of propagation of 66% the speed of light). The use of longer cables requires derating these specifications by the amount of additional delay.

² This specification applies over the full operating temperature range.

ISOSPI TIMING SPECIFICATIONS

Table 12. isoSPI Timing Specifications

Symbol	Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
$t_8^{1,2}$	SCK falling edge to SDO valid				60	ns
t_9^2	SCK rising edge to short ± 1 transmit		230	265	300	ns
t_{10}^2	CSB transition to long ± 1 transmit				100	ns
$t_{11}^{1,2}$	CSB rising edge to SDO rising				200	ns
t_{RTN}^2	Data return delay		150	185	220	ns
$t_{DSY(CS)}^2$	Chip select daisy-chain delay		100	160	200	ns
$t_{DSY(D)}^2$	Data daisy-chain delay		280	330	380	ns
t_{LAG}^2	Data daisy-chain lag (vs. chip select)	$(t_{DSY(D)} + t_{\frac{1}{2}PW(D)}) - (t_{DSY(CS)} + t_{\frac{1}{2}PW(CS)})$	0	70	100	ns
$t_{5(GOV)}^2$	Chip select high to low pulse governor		0.54	0.67	0.85	μ s
$t_{6(GOV)}^2$	Data to chip select pulse governor		0.69	0.86	1.1	μ s
t_{BLOCK}^2	isoSPI port reversal blocking window		2		10	μ s

¹ These specifications do not include rise or fall time of SDO. Although fall time (typically 5 ns due to the internal pull-down transistor) is not a concern, the rising edge transition time (t_{RISE}) is dependent on the pull-up resistance and load capacitance on the SDO pin. The time constant must be chosen such that SDO meets the setup time requirements of the MCU.

² This specification applies over the full operating temperature range.

ABSOLUTE MAXIMUM RATINGS

Table 13. Absolute Maximum Ratings

Parameter	Rating
Total Supply Voltage, V+ to V-	-0.3 V to +85 V
Input Pins (Relative to V-)	
Cx (x ≤ 16)	-0.3 V to +85 V
C9N	-0.3 V to +85 V
S1N, S1P, S2N	-0.3 V to +12 V
S2P, S3N, S3P	-0.3 V to +22 V
Sx (4 ≤ x ≤ 16)	-0.3 V to +85 V
IPA ¹ , IMA ¹ , IPB, IMB	-15 V to +15 V
DRIVE	-0.3 V to +7 V
All Other Pins	-0.3 V to +6 V
Voltage Between Input Pins	
SxP to SxN	-0.3 V to +12 V
S2N to S1N	-0.3V to +12 V
Cx to Cx - 1 (x = 1...8, 10...16)	-6 V to +12 V
C9 to C9N	-6 V to +12 V
Current In and Out of Pins	
SxP to SxN (Discharge Switched Closed)	350 mA
SxN to SxP (Discharge Switch Open)	10 mA
Sx When Pulled Below V-	10 mA
IPA ¹ , IMA ¹ , IPB, IMB	40 mA
V _{REG}	30 mA
All Other Pins	10 mA
Temperature	
Operating Range	-40°C to +105°C
Junction	150°C
Storage Range	-65°C to +150°C
Lead (Soldering, 10 sec)	300°C

¹ IPA and SCK are the same pin. IMA and CSB are the same pin. The absolute maximum rating for these pins depends on whether Port A is configured for SPI mode (CSB and SCK) or isoSPI mode (IPA and IMA).

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

Thermal performance is directly linked to the printed circuit board (PCB) design and operating environment. Close attention to the PCB thermal design is required.

Table 14. Thermal Resistance

Package Type ¹	θ_{JA} ^{2,3}	θ_{JCBOT} ⁴	θ_{JCTOP} ⁵	Unit
CS-72-3	18.2	1.02	9.7	°K/W

- The exposed pad must be connected to the V- plane for proper thermal management.
- Board layout impacts thermal characteristics, such as θ_{JA} .
- θ_{JA} is the natural convection junction-to-ambient thermal resistance measured in a one cubic foot sealed enclosure.
- θ_{JCBOT} is the junction-to-case thermal resistance (bottom).
- θ_{JCTOP} is the junction-to-case thermal resistance (top).

ELECTROSTATIC DISCHARGE (ESD) RATINGS

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

Human body model (HBM) per ANSI/ESDA/JEDEC JS-001.

Charged device model (CDM) per ANSI/ESDA/JEDEC JS-002.

ESD Ratings for ADES1830/ADES1831

Table 15. ESD Ratings for ADES1830/ADES1831

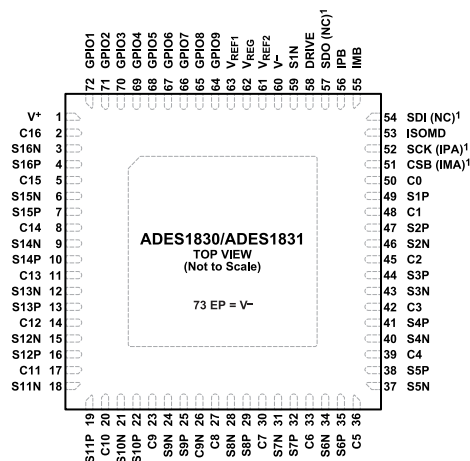
ESD Model	Withstand Threshold (V)	Class
HBM	±2000	2
CDM	±500 Corners pins: ±750	C2B

ESD CAUTION



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS



THE FUNCTION OF THESE PINS DEPENDS ON THE CONNECTION OF ISOMD:
 ISOMD TIED TO V-: CSB, SCK, SDI, SDO
 ISOMD TIED TO VREG: IPA, IMA, NC.

NOTE
 1. EXPOSED PAD. CONNECT THE EXPOSED PAD TO V-.

Figure 3. Pin Configuration, 72-Lead

Table 16. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	V+	Positive Supply Pin.
2, 5, 8, 11, 14, 17, 20, 23, 27, 30, 33, 36, 39, 42, 45, 48, 50	C16 to C1	Differential Inputs for Cell Measurement ADCs.
26	C9N	Negative Terminal of the Ninth C-Measurement Channel. See the Bus Bar Monitoring and Bypassing section for usage details.
3, 4, 6, 7, 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, 24, 25, 28, 29, 31, 32, 34, 35, 37, 38, 40, 41, 43, 44, 46, 47, 49, 59	S16P to S1P, S16N to S1N	Balance Inputs and Outputs. 16 P-channel metal-oxide semiconductor field effect transistors (P-MOSFETs) are connected between SxP and SxN. Inputs to the S-ADCs.
51, 52	IMA, IPA	Isolated 2-Wire Serial Interface Port A. IPA (plus) and IMA (minus) are a differential input/output pair.
51, 52, 54, 57	CSB, SCK, SDI, SDO	4-Wire SPI. Active low chip select (CSB), serial clock (SCK), and serial data input (SDI) are digital inputs. Serial data out (SDO) is an open-drain, N-channel metal-oxide semiconductor (NMOS) output pin. SDO requires a 1 kΩ pull-up resistor.
53	ISOMD	Serial Interface Mode. Connecting ISOMD to VREG configures the ADES1830/ADES1831 for 2-wire isolated interface (isoSPI) mode. Connecting ISOMD to V- configures the ADES1830/ADES1831 for 4-wire SPI mode.
55, 56	IMB, IPB	Isolated 2-Wire Serial Interface Port B. IPB (plus) and IMB (minus) are a differential input/output pair.
58	DRIVE	Connect the base of an external negative positive negative (NPN) transistor to this pin. Connect the collector to V+ and the emitter to VREG.
60	V-	Negative Supply Pins. The V- pins must be shorted together, external to the IC.
61	VREF2	Buffered Second Reference Voltage for Driving Multiple 10 kΩ Thermistors. Bypass with an external 1 μF capacitor.
62	VREG	5 V Regulator Input. Bypass with an external 1 μF capacitor.
63	VREF1	ADC Reference Voltage. Bypass with an external 1 μF capacitor. No DC loads allowed.
64 to 72	GPIO9 to GPIO1	General-Purpose Inputs/Outputs. Can be used as digital inputs or digital outputs, or as analog inputs with a measurement range from V- to 5 V. GPIO3 to GPIO5 can be used as an I ² C or SPI port.
	Exposed Pad	Exposed Pad. Connect the exposed pad to V-.

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, unless otherwise noted.

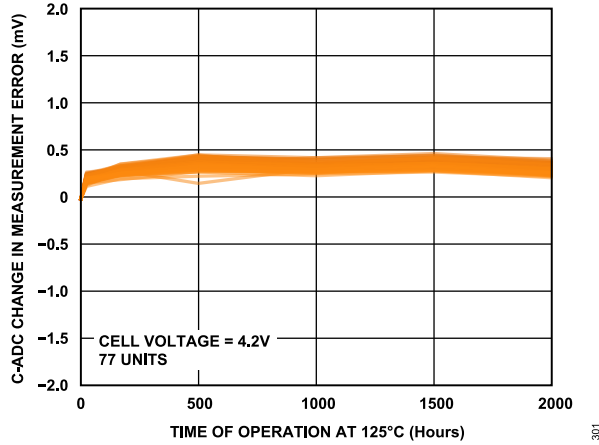


Figure 4. C-ADC Change in Measurement Error vs. Time of Operation at 125°C

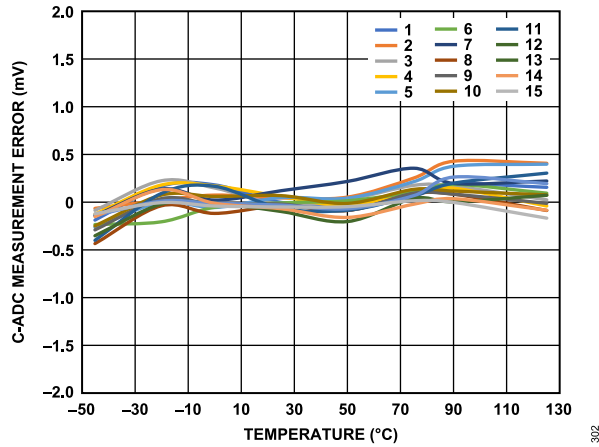


Figure 5. C-ADC Measurement Error at 4.2 V vs. Temperature for 15 Devices

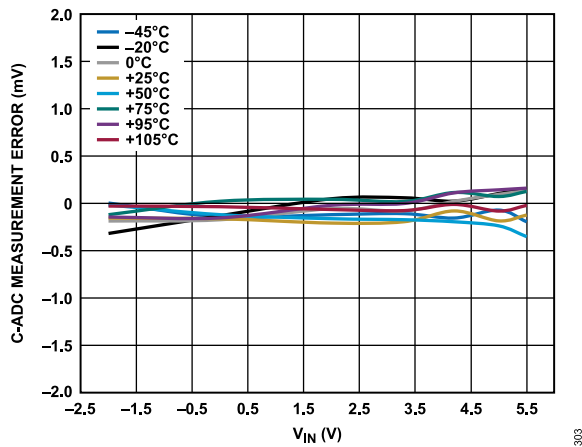


Figure 6. C-ADC Measurement Error vs. Input Voltage (V_{IN})

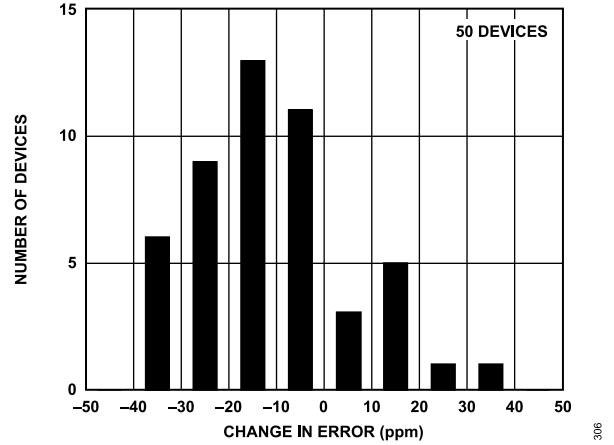


Figure 7. C-ADC Gain Error Due to IR Reflow

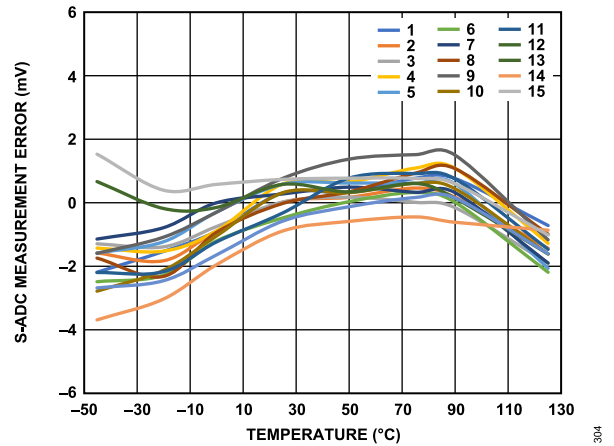


Figure 8. S-ADC Measurement Error at 4.2 V vs. Temperature for 15 Devices

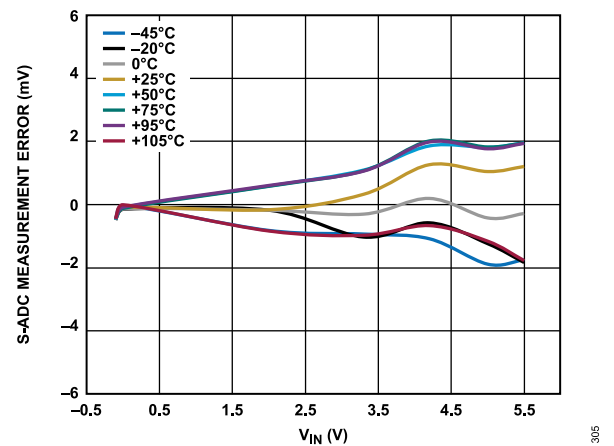


Figure 9. S-ADC Measurement Error vs. V_{IN}

TYPICAL PERFORMANCE CHARACTERISTICS

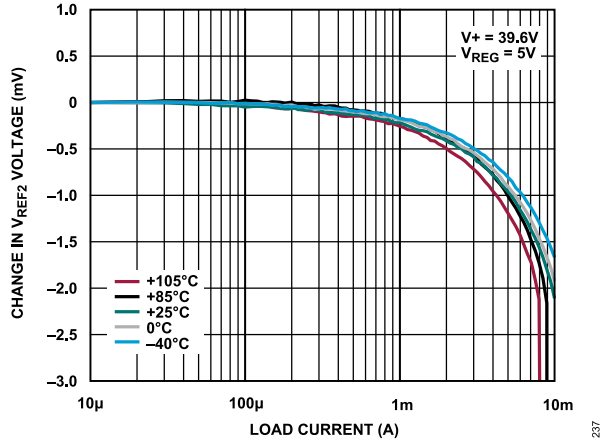


Figure 10. Change in V_{REF2} Voltage vs. Load Current

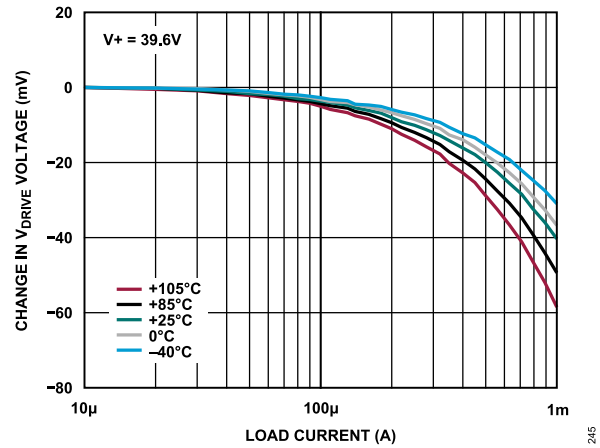


Figure 11. Change in V_{DRIVE} Voltage vs. Load Current

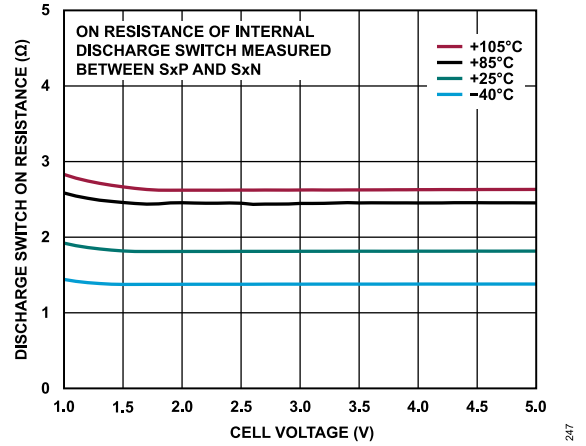


Figure 12. Discharge Switch On Resistance vs. Cell Voltage

THEORY OF OPERATION

CORE STATE DESCRIPTIONS

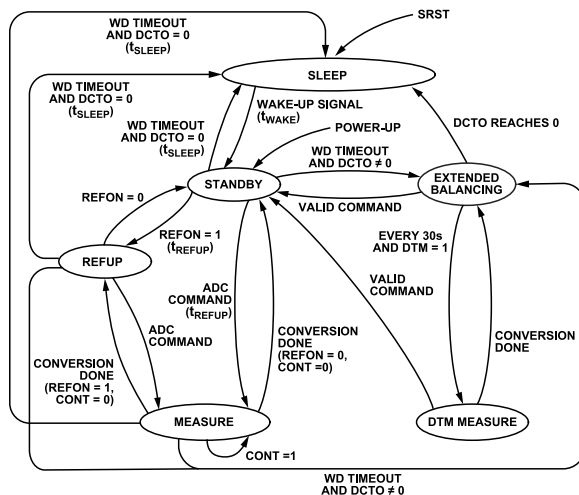


Figure 13. Core State Diagram

Standby State

At first power-up or after a power-on reset (POR), the device resets and enters the standby state. The standby state allows communicating with the ADES1830/ADES1831, and cell discharge and balancing can be enabled by writing to the PWM register group. The reference and the ADCs are off. The watchdog timer and/or the discharge timer is running. The DRIVE pin powers the V_{REG} pin to 5.2 V through an external transistor controlled by the DRIVE pin. V_{REG} can also be powered through an external source. In this case, the internal regulator must be disabled to avoid contention by floating the DRIVE pin. The IC can perform PWM discharge in the standby state.

When a valid ADC command is received, or if the REFON bit is set to 1 in the Configuration Register Group A, the IC pauses for t_{REFUP} to allow the reference to power up. Then, the IC enters either the REFUP or measure state. Otherwise, if no valid commands are received for t_{SLEEP} , the IC returns to the sleep state if $DCTO = 0$, or enters the extended balancing state if $DCTO \neq 0$.

Sleep State

When the watchdog timer times out, the ADES1830/ADES1831 enters the sleep state with minimum power consumption. The references and ADCs are powered down. The isoSPI ports are in the idle state. The DRIVE pin is 0 V. An internal 3 V regulator supplies power to detect a wake-up signal and to retain 6 bytes of user programmable data in the retention registers. All other registers are reset to their default value. If a wake-up signal is received, the ADES1830/ADES1831 enters the standby state.

REFUP State

To reach the REFUP state, the REFON bit in Configuration Register Group A must be set to 1 using the WRCFGA command. In the

REFUP state, the ADCs are off. The reference is powered up so that the ADES1830/ADES1831 can initiate ADC conversions faster than from the standby state.

When a valid ADC command is received, the IC moves to the measure state to begin the conversion. Otherwise, the ADES1830/ADES1831 returns to the standby state when the REFON bit is set to 0. If no valid commands are received for t_{SLEEP} , the IC either returns to the sleep state if $DCTO = 0$, or enters the extended balancing state if $DCTO \neq 0$.

Measure State

When receiving a valid ADC command (ADCV, ADSV, ADAX, or ADAX2), the ADES1830/ADES1831 enters the measure state to perform ADC conversions. When entering this state, the reference and ADCs are powered.

If the CONT bit in the ADC command is set to 0, the ADES1830/ADES1831 executes a single conversion cycle according to the ADC command, updates the corresponding result registers, and returns to the standby state or REFUP state.

If the CONT bit in the ADC command is set to 1, the ADES1830/ADES1831 continuously executes conversion cycles according to the ADC command, updates the corresponding result registers with a 1 kHz update rate, and feeds the ADC results to the corresponding IIR filter preconfigured according to the filter configuration register (see the [Internal Digital Filtering](#) section for more details). If a new ADCV, ADSV, ADAX, or ADAX2 command is received during the conversions, the ongoing conversions of the concerned ADCs stop, and new measurements start, allowing resynchronization of multiple ADES1830/ADES1831 devices in a stack.

THEORY OF OPERATION

Extended Balancing and DTM Measure States

In the DTM measure state, the ADES1830/ADES1831 periodically monitors cell voltages while PWM balancing and the discharge timer are active without interacting with the host controller. The host must configure the PWM balancing, clear all DCC bits, and set the DTMEN bit to enable this feature.

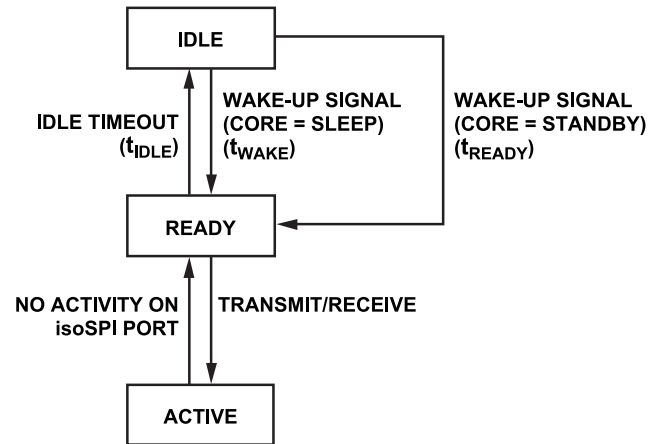
If the watchdog timer expires and the discharge timer monitor is enabled and not timed out, the ADES1830/ADES1831 enters the extended balancing state in which the configured PWM discharge continues. From this state, the ADES1830/ADES1831 transitions every 30 sec to the DTM measure state to measure the cell voltages, compare the result to the overvoltage (OV) and undervoltage (UV) thresholds, and update the OV and UV flags in the status register accordingly. When the UV threshold is reached for any cell, the ADES1830/ADES1831 discontinues the discharge of the concerned cell. If the cell voltage recovers above the UV threshold, the discharge of that cell resumes.

The discharge is not muted when cell measurements are performed in the low power cell monitoring (LPCM) heartbeat mode or DTM measure state. As a result, measurements are affected by the voltage drop of the discharge current over the cell cable resistance. The PWM discharge happens asynchronously to the ADC measurements. Therefore, it is not predictable if a measurement is altered by the voltage drop. Depending on the cable resistance and the discharge current, the intended voltage thresholds (VOV, VUV, CMT_CUV, and CMT_COV) may not be checked accurately.

The ADES1830/ADES1831 transition to the standby state upon reception of any valid command, or to the sleep state when the discharge timeout (DCTO) value expires. PWM balancing continues even when the DCTO value has not expired.

ISOSPI STATE DESCRIPTION

The ADES1830/ADES1831 has two isoSPI ports for daisy-chain communication: Port A and Port B.



NOTES

1. STATE TRANSITION DELAYS ARE DENOTED BY (t_x).

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Figure 14. isoSPI State Diagram

Idle State

In the idle state, the isoSPI ports are powered down.

When isoSPI Port A or Port B receives a wake-up signal, the isoSPI enters the ready state. This transition happens quickly (within t_{READY}) if the core is in the standby state. If the core is in the sleep state when the isoSPI receives a wake-up signal, the IC transitions to the ready state within t_{WAKE} .

Ready State

In the ready state, the isoSPI ports are ready for communication. The serial interface current in this state depends on the status of the ISOMD pin.

If there is no activity (that is, no wake-up signal) on Port A or Port B for greater than t_{IDLE} , the ADES1830/ADES1831 moves to the idle state. When the serial interface is transmitting or receiving data, the ADES1830/ADES1831 moves to the active state.

Active State

The ADES1830/ADES1831 is transmitting/receiving data using one or both of the isoSPI ports in the active state. The serial interface consumes maximum power in this state. The supply current increases with the clock frequency as the density of isoSPI pulses increases.

POWER SUPPLY

The ADES1830/ADES1831 are powered by two pins: V+ and V_{REG}. The V+ input requires a voltage greater than or equal to 11 V, independent of the voltage of the cell measurement inputs pins. V+ provides power mainly to the highly accurate Zener reference voltage. The V_{REG} input requires 5 V and provides power to the remaining core circuits and the isoSPI circuitry, and to drive the discharge switches. The V_{REG} input can be powered through an external transistor driven by the regulated DRIVE output pin. Alternatively, V_{REG} can be powered by an external supply.

The power consumption varies according to the operational states. In the sleep state, the ADES1830/ADES1831 consumes 4 µA provided either entirely by the V+ pin or partly by the V_{REG} pin if the latter is powered by an external supply. The V+ pin current depends only on the core state, whereas the V_{REG} pin current depends on both the core state and isoSPI state and can be divided into two components.

$$I_{REG} = I_{REG(Core)} + I_{REG(isoSPI)}$$

When measuring, the current drawn depends on the number of ADCs turned on to measure.

$I_{REG(Core)}$ is thus the sum of the power consumed in the REFUP state and the additional current consumed by the ADCs.

$$I_{REG} (Core, Measure) = I_{REG} (Core, REFUP) + I_{REG} (Core, ADCs on)$$

The [Specifications](#) section provides an overview of the power consumption in measure state, dependent on the number of ADCs used.

In a typical example, $I_{REG(Core)}$ can be estimated as

$$I_{REG} (Core) = I_{regREFUP} + I_{regCADC} + n_{SADC} \times t_{SADC}/t_{FDTI} \times I_{regSADC} + (n_{AUX} \times t_{AUX} + n_{AUX2} \times t_{AUX2})/t_{FDTI} \times I_{regAUX} \approx 8mA \quad (1)$$

based on the following assumptions:

- ▶ $t_{AUX} = 1$ ms, AUX conversion time
- ▶ $n_{AUX} = 18$, number of AUX conversions per fault detection time interval (FDTI) (all channels for diagnostics and all GPIOs (GPIO10 is connected to GND internally and is not available as a user accessible GPIO)).
- ▶ $t_{AUX2} = 8$ ms, AUX2 conversion time
- ▶ $n_{AUX2} = 10$, number of AUX2 conversions per FDTI (all 10 GPIOs)
- ▶ $t_{FDTI} = 100$ ms, fault detection time interval
- ▶ $t_{SADC} = 8$ ms, S-ADC conversion time
- ▶ $n_{SADC} = 3$, number of S-ADC conversions per FDTI
- ▶ $I_{regAUX} = 0.55$ mA, AUX ADC current consumption (AUX ADC and AUX2 ADC active)
- ▶ $I_{regREFUP} = 2.3$ mA, current consumption in REFUP state, which is also the base current consumption
- ▶ $I_{regCADC} = 4.5$ mA, C-ADC current consumption (for all 16)
- ▶ $I_{regSADC} = 3.9$ mA, S-ADC current consumption (for all 16)

The isoSPI draws current only from the V_{REG} pin. [Table 17](#) provides equations to approximate the isoSPI current in function of the isoSPI state.

Table 17. Power Consumption for isoSPI Communication

isoSPI State	ISOMD Logic	$I_{REG(isoSPI)}$
Idle	Not applicable	0 mA
Ready	1	3.7 mA
	0	3.2 mA
Active	1	Active write: $I_{REG(isoSPI)} (ready state) + 2 \times t_{\frac{1}{2}PW(D)}/t_{CLK} \times I_{DRV}$ Active read: $I_{REG(isoSPI)} (ready state) + 4 \times t_{\frac{1}{2}PW(D)}/t_{CLK} \times I_{DRV}$
	0	Active write/read: $I_{REG(isoSPI)} (ready state) + 2 \times t_{\frac{1}{2}PW(D)}/t_{CLK} \times I_{DRV}$

As an example, with the following assumptions:

- ▶ $I_{regRd} = 14$ mA, active read current consumption (2 Mbps, 100% SPI duty cycle).
- ▶ $I_{regWr} = 9$ mA, active write current consumption (2 Mbps, 100% SPI duty cycle).
- ▶ $I_{regRdy} = 3.7$ mA, isoSPI ready state current consumption (when not communicating and t_{DLE} not elapsed).
- ▶ duty = 0.8, SPI communication duty cycle, assuming worst case 80%.
- ▶ wrRatio = 0.3, assuming 30% of commands are write commands (for example, WRCFGA, WRCFGB, WRPWM....).
- ▶ $I_{REG(isoSPI)}$ can be estimated as

$$I_{REG(isoSPI)} = \text{duty} \times (\text{wrRatio} \times I_{regWr} + 1 - \text{wrRatio} \times I_{regRd} + 1 - \text{duty} \times I_{regRdy}) \approx 11\text{mA} \quad (2)$$

- ▶ Total I_{REG} current: 8 mA + 11 mA = 19 mA.
- ▶ For the typical application using an external NPN transistor to generate V_{REG}, this current is taken from MODULE+, to which V+ is also connected. The typical V+ current consumption in the measure state is 0.5 mA. As a result, the typical MODULE+ current consumption is < 20 mA for the assumed isoSPI communication duty cycle.

CELL VOLTAGE MEASUREMENTS

C-ADC AND S-ADC OPERATIONS AND COMMANDS

16 ADCs are dedicated to measure the 16 differential cell inputs synchronously and are therefore called C-ADCs. C-ADCs feature an input range of -2 V to $+5.5\text{ V}$ and a sampling frequency of $\sim 4\text{ MHz}$, giving out 16-bit results every 1 ms with an LSB of $150\text{ }\mu\text{V}$. Furthermore, every 8 ms an average of the last eight conversions of the ADC is provided.

16 additional ADCs are dedicated to measure the 16 differential inputs (SxP and SxN) synchronously with an input range of 0 V to 5.5 V and a sampling frequency of $\sim 4\text{ MHz}$, giving out results every 8 ms . These S-ADCs allow redundant measurement of the cell voltages using an independent measurement path from the C-ADCs.

See the [Memory Map](#) section for the memory map description for the representation of the measurement results in the respective 16-bit registers.

Two commands can trigger C-ADC and S-ADC measurements: ADCV triggers cell voltage conversions with or without redundancy, and ADSV triggers S-ADC conversions.

If a new ADCV or ADSV is received during the conversions, the ongoing conversions of the concerned ADCs stop, and new measurements start, allowing resynchronization of multiple ADES1830/ADES1831 devices in a stack. The corresponding result registers are reset upon reception of a new ADCV or ADSV.

Table 18. C-ADC and S-ADC Commands

Command Description	Name	INC ¹	CC[10:0] – Command Code										
			10	9	8	7	6	5	4	3	2	1	0
Start Cell Voltage ADC Conversion and Poll Status	ADCV	Yes	0	1	RD	CONT	1	1	DCP	0	RSTF	OW[1]	OW[0]
Start S-ADC Conversion and Poll Status	ADSV	Yes	0	0	1	CONT	1	1	DCP	1	0	OW[1]	OW[0]

¹ INC indicates whether the command counter increments for the command.

CELL VOLTAGE MEASUREMENTS

CONTINUOUS OR SINGLE SHOT MEASUREMENTS

Both C-ADCs and S-ADCs can be configured to perform a single measurement (CONT = 0) or continuous measurements (CONT = 1). In continuous mode, the result registers of the corresponding ADCs are updated at their conversion rate of 1 ms (C-ADC) and 8 ms (S-ADC). To end continuous measurement mode of the respective ADC, send an ADCV or ADSV with CONT = 0. The addressed ADC then performs a last single shot measurement before turning off.

REDUNDANT MEASUREMENTS

There are two methods to obtain redundant measurements: a direct method and an indirect method.

The direct method involves setting the redundancy bit (RD) in an ADCV command. In this case, the C-ADCs and S-ADCs are both triggered to provide redundancy. After 8 ms, the average results of the C-ADCs are compared to the results of the S-ADCs. If the results do not match within the threshold set by the CTH[2:0] in Configuration Register A, the CSxFLT flag is set in the Status Register Group C. A single shot measurement triggered with RD = 1 and CONT = 0 takes 8 ms. If an ADSV is issued with CONT = 0, no further comparison is performed, and the S-ADC performs a single shot conversion and then stops.

Note that if an ADCV with RD = 1 is issued, the open wire switches are reset (open) to ensure a proper comparison. The [Algorithm for Cell Measurement with Diagnostics](#) section describes a sequence of redundant measurements and open wire detection measurements by means of the S-ADC for high functional safety coverage.

The indirect method allows synchronizing the S-ADCs to the already running C-ADCs.

If an ADSV is issued with CONT = 1 while the C-ADCs are in continuous mode, the S-ADCs wait the current C-ADC average of 8 conversions to finish, start conversions synchronous to the CAVG8, and compare the CAVG8 and S-ADC results. When redundant measurements with subsequent result comparison are started or ongoing, the COMP bit in the status register group is set to one for latent fault coverage.

DISCHARGE DURING MEASUREMENTS

The ADES1830/ADES1831 allow interrupting PWM discharge during measurements to acquire cell voltage without voltage drop in cabling due to discharge current. The behavior is controlled through the RD, DCP, and CONT bits, as described in [Table 19](#).

Table 19. ADC Command Control Bits

Command	Inputs			PWM Discharge Status ^{1, 2}
	RD ³	DCP	CONT	
ADCV	0	0	1	Stop ongoing C-ADC conversion and restart for continuous conversion of C-ADC. PWM controlled discharge remains unaffected.
	1	0	1	PWM controlled discharge is interrupted. Stop ongoing C-ADC conversion and restart for continuous conversion of C-ADC and S-ADC to make redundant comparison. PWM discharge remains off if no further command is sent.
	1	0	0	PWM controlled discharge is interrupted. Stop ongoing C-ADC conversion and make single-shot conversion of C-ADC and S-ADC for redundant comparison. PWM discharge remains off for the duration of the redundant C-ADC and S-ADC conversion (8 ms typical).
	0	0	0	Immediately trigger single-shot conversion of C-ADC. Operation of S-ADC and PWM controlled discharge remains unaffected.
	X	1	0	Stop ongoing C-ADC conversion and make single-shot conversion of C-ADC (RD = 0) or C-ADC and S-ADC (RD = 1). No effect on PWM controlled discharge.
	X	1	1	Invalid command is ignored. Current operation remains unaffected, CC not incremented.
ADSV	X	0	1	If C-ADC is converting continuously, the S-ADC is synchronized to the C-ADC to make continuous conversion of C-ADCs and S-ADCs for redundant comparison. If C-ADC is not converting, only the S-ADC makes continuous conversions. The PWM controlled discharge is stopped.
	X	0	0	PWM controlled discharge is interrupted for single-shot conversion of S-ADC. Operation of C-ADC remains unaffected.
	X	1	0	PWM controlled discharge continues during measurement. Single-shot conversion of S-ADC. Operation of C-ADC remains unaffected.
	X	1	1	Current operation remains unaffected, CC not incremented.

¹ Discharge always continues if statically enabled through the DCC bits and not interrupted by other higher priority events such as WRCFGA, WRCFGB, mute, and thermal shutdown.

² Any ADCV interrupts the ongoing C-ADC conversions and restarts the C-ADCs. So, it is recommended to trigger redundant measurements with the ADSV command every fault tolerant time interval (FTTI) (ADSV with DCP = 0, CONT = 1).

³ X means 0 or 1.

CELL VOLTAGE MEASUREMENTS

OPEN WIRE SWITCHES

The ADES1830/ADES1831 feature current-limited switches at the cell measurement inputs, as shown in Figure 2. Activating these switches detects if the connection to the cell is broken. The open wire switches in the corresponding measurement path are controlled by the open wire bits (OW[1:0]), as shown in Table 20.

Table 20. Open Wire Switch Control Bits

OW[1]	OW[0]	Open Wire Switches
0	0	All channels: off
0	1	Even channels on (S2 and C2, S4 and C4, ...) odd channels off (S1 and C1, S3 and C3, ...)
1	0	Even channels off (S2 and C2, S4 and C4, ...) odd channels on (S1 and C1, S3 and C3, ...)
1	1	All channels on

See the Cell Open Wire Detection section for more details.

INTERNAL DIGITAL FILTERING

Figure 15 depicts the overall signal processing within the ADES1830/ADES1831. The input voltages are sampled by the S-ADCs and C-ADCs with a sampling frequency of roughly 4.1 MHz. Both S-ADCs and C-ADCs are oversampling ADCs. Whereas the C-ADCs provide a new measurement result every 1 ms, the result of the S-ADCs is updated every 8 ms. The C-ADC measurement results are then averaged over 8 ms and, if redundancy is required, compared to the synchronous results of the S-ADCs.

The 16-bit results of the C-ADCs are also fed to configurable IIR filters for further noise filtering.

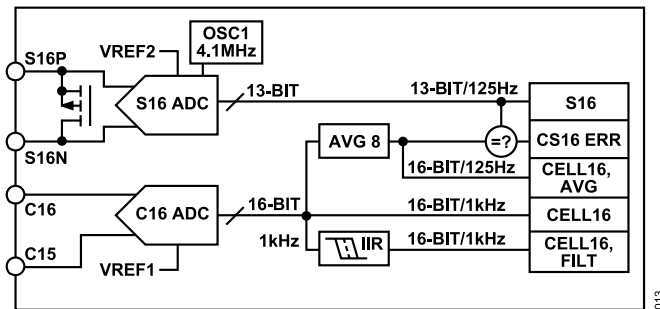


Figure 15. Integrated Digital Filters

The transfer function of the IIR filter is represented by

$$Y(n) = Y(n - 1) + (X(n) - Y(n - 1))/a \tag{3}$$

where:

X(n) represents the nth input.

Y(n) represents the nth output of the filter.

a is the filter parameter given in Table 21.

The -3 dB corner frequency can be chosen between 110 Hz and 0.625 Hz by programming the FC[2:0] bits in the Configuration Register Group A (see Table 21).

Table 21. IIR Frequency Settings

-3 dB Corner Frequency	FC[2]	FC[1]	FC[0]	Filter Parameter
Filter Disabled	0	0	0	N/A ¹
110	0	0	1	2
45	0	1	0	4
21	0	1	1	8
10	1	0	0	16
5	1	0	1	32
1.25	1	1	0	128
0.625	1	1	1	256

¹ N/A means not applicable.

If all three bits are set to zero, no IIR filtering is applied.

The filtered results are stored in the Filtered Cell Voltage Register Groups A through E. The IIR filters can be reset by either issuing a clear filtered cell voltage register group (CLRFC) command or by setting the reset filter (RSTF) bit in an ADCV command. Furthermore, the filters are reset if the filter corner frequency is changed. To speed up the settling time, the filters are preloaded with the first sample arriving after a reset. Note that any C-ADC result, whether obtained in continuous mode or in single shot mode, is added to IIR filter. Table 22 summarizes the option of digital filtering with the ADES1830/ADES1831.

Figure 16 shows the transfer function of the C-ADC results with an update rate of 1 kHz and the transfer function of their average over 8 ms, which is equivalent to the transfer function of the S-ADC and the transfer function after the additional IIR filter with the -3 dB corner frequency set to 0.625 Hz.

CELL VOLTAGE MEASUREMENTS

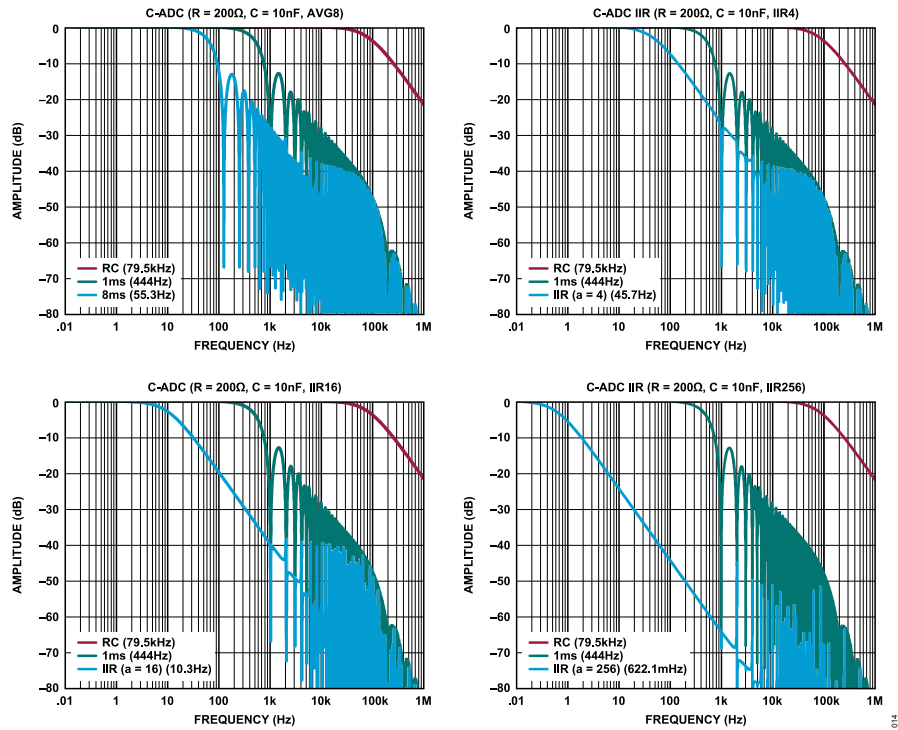


Figure 16. Filter Transfer Functions

Table 22. Digital Filtering Options

ADC	ADC Frequency (f_{ADC})	Filter Output Rate	Filter Type	Filter Function	-3 dB Corner Frequency (Hz)	Settle, Step to 0.1% of Final (sec)	Specialty
C-channel	4.1 MHz	1 kHz	IIR	1-pole low-pass filter (LPF)	110	0.010	Low frequency LPF
					45	0.025	Low frequency LPF
					21	0.052	Low frequency LPF
					10	0.108	Low frequency LPF
					5	0.218	Low frequency LPF
					1.25	0.881	Low frequency LPF
					0.625	1.765	Low frequency LPF
	125 Hz	Finite impulse response (FIR)	Average of 8 samples	56		Noise filter and 50 Hz/60 Hz	
	1 kHz	Sinc (ADC)	First order sinc	443		Fast response with good high frequency filtering	
S-channel	4.1 MHz	125 Hz	Sinc (ADC)	First order sinc	56		Matches C-channel FIR

GPIO AND DEVICE PARAMETER MEASUREMENTS

AUX ADC OPERATION AND COMMANDS

The 9 user available GPIO inputs can be measured redundantly by two separate unipolar ADCs, both preceded by a multiplexer with an input range of 0 V to 5.5 V. The main AUX ADC measures the internal supply voltages (VD and VA), a second reference (V_{REF2}), and the die temperature (ITEMP) beside the GPIO channels.

The ADAX command triggers AUX ADC measurements, and the ADAX2 command triggers AUX2 measurements.

In case of an ADAX or ADAX2 command, the CHx bits select which auxiliary input is measured, according to [Table 24](#).

If all AUX inputs must be measured (CH[4:0] = 00000), the AUX ADCs perform measurements cycling through all inputs (18 channels total) and the corresponding auxiliary registers update. Note that only GPIOs can be measured by AUX2. Therefore, CH[4] is not available in the ADAX2 command.

If the OW bit is set, the corresponding measurements are executed with open wire detection, which is performed by current sources in case of the AUX ADC. The pull-up bit decides whether pull-up (PUP

= 1) or pull-down (PUP = 0) current sources are applied during an AUX conversion (see the [GPIO Open Wire Detection](#) section for more details).

To prevent any settling errors, a soak time can be programmed that delays the start of conversion after the multiplexer has been set. The soak time is enabled by the SOAKON bit and configured by OWRNG and OWA in the Configuration Register Group A. If open wire detection is required by setting the OW bit, the current sources are switched on when setting the multiplexer setting.

Note that the execution of an ADAX or ADAX2 command with a long soak time can take longer than the watchdog timer to expire. In these cases, valid commands need to be sent to prevent the ADES1830/ADES1831 from interrupting the measurement and going to sleep.

When the ADES1830/ADES1831 receives a new ADAX or ADAX2 command during a conversion, the correspondent ADC is stopped and restarted. The corresponding result registers are not reset upon reception of a new ADAX or ADAX2 command.

Table 23. AUX Commands

Command Description	Name	INC ¹	CC[10:0] – Command Code										
			10	9	8	7	6	5	4	3	2	1	0
Start AUX ADC Conversions and Poll Status	ADAX	Yes	1	0	OW	PUP	CH[4]	0	1	CH[3]	CH[2]	CH[1]	CH[0]
Start AUX2 ADC Conversions and Poll Status	ADAX2	Yes	1	0	0	0	0	0	0	CH[3]	CH[2]	CH[1]	CH[0]

¹ INC indicates whether the command counter increments for the command.

Table 24. Channel Selection

Name	Function	Value					AUX Input
CH[4:0]	Selection for AUX Inputs, ADAX: CH[4:0], ADAX2: CH[3:0]	CH[4]	CH[3]	CH[2]	CH[1]	CH[0]	
		0	0	0	0	0	All
		0	0	0	0	1	GPIO1
		0	0	0	1	0	GPIO2
		0	0
		0	1	0	0	1	GPIO9
		1	0	0	0	0	VREF2
		1	0	0	0	1	VD
		1	0	0	1	0	VA
		1	0	0	1	1	ITEMP
		1	0	1	0	0	VPV
		1	0	1	0	1	VMV
		1	0	1	1	0	VRES
		1	0	1	1	1	Reserved

SYSTEM DIAGNOSTIC

CELL MEASUREMENT DIAGNOSTIC AND REPORTING

If cell measurements with redundancy are requested by sending an ADCV command with RD = 1, the S-ADC results vs. the C-ADC results are compared. In case of mismatch larger than the threshold programmed in the Control Register Group C, the ADES1830/ADES1831 sets the corresponding fault bit (CSxFLT) to 1. To avoid latent faults, the comparators are implemented redundantly, and if one of the comparators flags a mismatch, it is signaled by setting CSxFLT.

To ensure detection of faults in the IIR filters following the C-ADCs, the IIR filters are implemented redundantly and their results are

read out by two separate SPI targets whose outputs are compared (see the [Communication Diagnostic and Reporting](#) section).

CELL OPEN WIRE DETECTION

Because the ADES1830/ADES1831 measure cell voltages through two separate redundant pin pairs, a broken input connection on the PCB can be detected by comparing the measurements of the corresponding S-channel and C-channel. However, in the application, the PCB is often wired to the battery by a single cable per battery pole, as shown in [Figure 17](#).

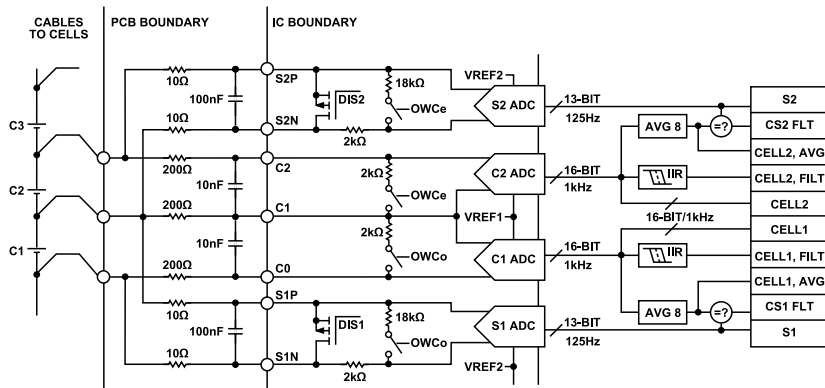


Figure 17. Open Wire Detection

SYSTEM DIAGNOSTIC

In this configuration, the break of a cable from the PCB to the battery cells cannot be detected by comparing C-ADC and S-ADC results because the inputs of both ADCs are still connected on the PCB. Therefore, the ADES1830/ADES1831 feature a safety mechanism to detect open input wires by means of differential switches with current limiting resistors between the differential inputs of each ADC, as shown in Figure 17.

Care must be taken not to activate the differential switches of the two neighborhood channels simultaneously. Otherwise, the resulting voltage divider between two cells can mask a break of the common cable between these two cells. Therefore, the ADES1830/ADES1831 activate open wire switches of odd and even channels independently.

Activating the differential switch in a C-measurement path causes the input voltage with intact wiring to reduce. This is due to the resistive divider of the external filter resistor and the internal 1.75 kΩ resistance in series with the open wire switch (to about 10/12 of the cell voltage in Figure 17). This measurement coarsely diagnoses the resistance of the external filter resistor. Furthermore, the settling of the input voltage to the new value detects the presence and coarse value of the filter capacitor. In case of a broken wire, the input capacitor is fully discharged by the open wire current.

Activating the differential switch in an S-measurement path causes the input voltage with intact wiring to reduce. This is due to the internal resistive divider of the internal 1.75 kΩ resistance and the 18 kΩ in series with the open wire switch to about 9/10 of the cell voltage. In case of a broken wire, the input capacitor is again discharged by the open wire current.

To detect open wires, an open wire switch in either the C-channel or the S-channel inputs is enough. Inserting this open wire switch in the S-ADC inputs runs open wire detection without interrupting the cell voltage measurement by the C-ADC, therefore preserving the integrity of the IIR filter result.

ALGORITHM FOR CELL MEASUREMENT WITH DIAGNOSTICS

Figure 18 shows the timing of an algorithm that performs continuous uninterrupted cell measurements by means of the C-ADC, and alternates the S-ADC between redundancy and open wire detection.

Whereas the C-ADC measures cell voltages continuously, the S-ADC is used sequentially to provide redundant measurement results and to perform open wire detection on odd and even cells.

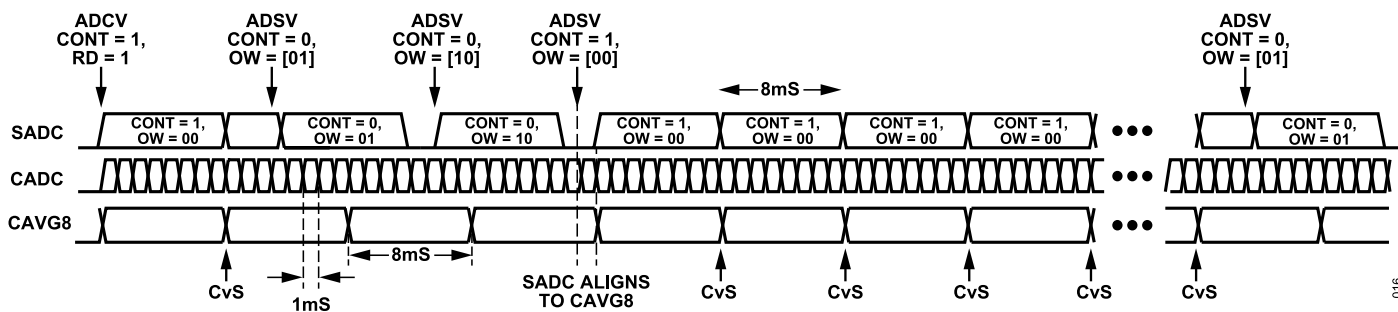


Figure 18. Cell Measurement and Diagnose Sequence

SYSTEM DIAGNOSTIC

GPIO MEASUREMENT DIAGNOSTIC

The ADES1830/ADES1831 targets high diagnostic coverage on temperature measurements if two negative temperature coefficient (NTC) thermistors are connected to two separate general-purpose inputs/outputs (GPIOs). To achieve high diagnostic coverage, the GPIOs can be measured by two redundant measurement paths formed by the AUX multiplexer and the AUX ADC, and the AUX2 multiplexer and AUX2 ADC. Because the temperature is a slow varying quantity, a command to start both measurement paths synchronously is not provided, but each ADC must be started separately by the respective command. The results of the conversion must be compared in the host controller.

GPIO OPEN WIRE DETECTION

Setting the OW bit in the ADAX command connects current sources with typically 200 μ A to the measurement channels to detect an open wire or diagnose the proper resistance of the connected NTC. The PUP bit controls whether the current sources pull the pins up or down. Results are stored in the auxiliary register groups.

The correct value of the current sources can further be verified for latent fault coverage by measuring the voltage drop over a 2.5 k Ω resistor.

When measuring all channels in round-robin (CH[4:0] set to 0 enables all channels), the activated current sources (OW set to 1) are also applied to the GPIOs, including those that may be used for the I²C/SPI controller communication (GPIO3 to GPIO5), which can disturb the serial communication.

COMMUNICATION DIAGNOSTIC AND REPORTING

Any command or data sent to or read from the ADES1830/ADES1831 are protected by a cyclic redundancy check (CRC). See the [Command PEC](#) and [Data PEC](#) sections for more details. Furthermore, registers necessary to perform redundant measurements or read their results (for example, C-ADC and S-ADC result registers) are addressed by redundant SPI targets inside the ADES1830/ADES1831 to avoid a single point of failure, and their output is bitwise compared. When a mismatch occurs, the SPIFLT bit in Status Register Group C is set.

The ADES1830/ADES1831 can diagnose that the SPIFLT diagnostic bit is not stuck by issuing an RDSTATC command with the ERR bit set to 1.

THERMAL SHUTDOWN

To protect the ADES1830/ADES1831 from overheating, a thermal shutdown circuit is included inside the IC. If the temperature detected on the die rises above approximately 150°C, the thermal shutdown circuit trips and causes a POR with the THSD bit in the STCR1 register to 1. This turns off all discharge switches. The THSD bit is cleared when the CLRFLAG command is sent, and the corresponding bit is set to 1 (see the [Clear Flag Command](#) section).

The ADES1830/ADES1831 can diagnose that the THSD diagnostic bit is not stuck. The FLAG_D[4] bit (Bit 4 in the CFGRA1 register) can be set to force the THSD bit to be set to 1. When FLAG_D[4] is written, the THSD bit flips to a 1 and must be cleared using the CLRFLAG command.

TEST MODE DETECTION

To improve diagnostic capability, the ADES1830/ADES1831 includes a TMODECHK flag in the STRC1 register that indicates that the part has entered a factory test mode. If this bit is set, do not trust the behavior of the device. The TMODECHK bit must be cleared, and if it returns to 0, the device has recovered and operation can resume.

The ADES1830/ADES1831 can diagnose that the TMODECHK diagnostic bit is not stuck. The FLAG_D[7] bit (Bit 7 in the CFGRA1 register) can be set to force the TMODECHK bit to be set to 1. When FLAG_D[7] is written, the TMODECHK bit flips to a 1 and must be cleared using the CLRFLAG command.

SLEEP STATE DETECTION

The ADES1830/ADES1831 includes a flag that indicates if the device has previously power cycled or entered the sleep state, and that the registers have reset. The SLEEP bit (RDSTATC) is useful for the system to check that all ICs in the daisy chain are entering the low power sleep state. This bit can also be used to verify that the IC has not erroneously entered the sleep state during regular operation.

SOFT RESET COMMAND

The soft reset command (SRST) quickly puts all the devices in the daisy chain into the sleep state. The soft reset command only needs sufficient time to propagate the command up the stack to the next device, after which the device enters sleep. This command achieves two functions: a quick transition to the low power state, and the ability to reset all of the switched power digital logic.

REVISION CODE

The ADES1830/ADES1831 contains a 4-bit revision code. If software detection of the device revision is necessary, contact the factory for details. Otherwise, the code can be ignored. However, in all cases, the values of all bits must be used when calculating the packet error code (PEC) on data reads.

SERIAL ID

Each ADES1830/ADES1831 is programmed at the factory with a unique 48-bit serial ID (SID) code stored in the SID register. The host can read the unique SID code for each device using the RDSID command.

SYSTEM DIAGNOSTIC

CLEAR ADC MEMORY COMMANDS

The ADES1830/ADES1831 has four clear ADC commands: CLRCELL, CLRFC, CLRAUX, and CLRSPIN. These commands clear the registers that store all ADC conversion results.

The CLRCELL command clears Cell Voltage Register A through Cell Voltage Register F and the averaged cell voltage registers. The CLRFC command clears Filtered Cell Voltage Register A through Filtered Cell Voltage Register F. The CLRSPIN command clears S-Voltage Register A through S-Voltage Register F. All bytes in these registers are set to 0x8000 by the respective clear command.

The CLRAUX command clears Auxiliary Register Group A through Auxiliary Register Group D, the Redundant Auxiliary Register Group A through Redundant Auxiliary Register Group D, and Status Register Group A and Status Register Group B. All bytes in these registers are set to 0x8000 by the CLRAUX command. Note that

this register value of 0x8000 resulting from a CLRAUX command is, for some registers, different than their default value after power-up. See the register description in the [Memory Map](#) section for their default values. Clear commands are effective in the REFUP and measure states.

CLEAR FLAG COMMAND

The CLRFLAG command resets the diagnostic flags in Status Register Group C. The CLRFLAG command requires the system to send six additional bytes to specify which fault flag is reset. [Table 25](#) describes the CLRFLAG format. The defined bits correspond to the same bit positions in Status Register Group C.

The diagnostic flags in the status register remain set until they are cleared by the user, or until the ADES1830/ADES1831 enters the sleep state.

Table 25. CLRFLAG Data Format

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CFD0	WR	CL_CS8FLT	CL_CS7FLT	CL_CS6FLT	CL_CS5FLT	CL_CS4FLT	CL_CS3FLT	CL_CS2FLT	CL_CS1FLT
CFD1	WR	CL_CS16FLT	CL_CS15FLT	CL_CS14FLT	CL_CS13FLT	CL_CS12FLT	CL_CS11FLT	CL_CS10FLT	CL_CS9FLT
CFD2	WR								
CFD3	WR								
CFD4	WR	CL_VAOV	CL_VAUV	CL_VDOV	CL_VDUV	CL_CED	CL_CMED	CL_SED	CL_SMED
CFD5	WR	CL_VDEL	CL_VDE		CL_SPIFLT	CL_SLEEP	CL_THSD	CL_TMODE	CL_OSCCHK

SYSTEM DIAGNOSTIC

CLEAR OVERVOLTAGE AND UNDERVOLTAGE COMMAND

The CLOVUV command resets the overvoltage and undervoltage flags in Status Register Group D (STATD register). The CLOVUV command requires the system to send six additional bytes to specify which fault flag is reset. [Table 26](#) describes the CLOVUV

format. The defined bits correspond to the same bit positions in Status Register Group D.

The overvoltage and undervoltage flags in the status register remain set until they are cleared by the user, or until the ADES1830/ADES1831 enters the sleep state.

Table 26. CLOVUV Command Format

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STDR0	WR	CL_C4OV	CL_C4UV	CL_C3OV	CL_C3UV	CL_C2OV	CL_C2UV	CL_C1OV	CL_C1UV
STDR1	WR	CL_C8OV	CL_C8UV	CL_C7OV	CL_C7UV	CL_C6OV	CL_C6UV	CL_C5OV	CL_C5UV
STDR2	WR	CL_C12OV	CL_C12UV	CL_C11OV	CL_C11UV	CL_C10OV	CL_C10UV	CL_C9OV	CL_C9UV
STDR3	WR	CL_C16OV	CL_C16UV	CL_C15OV	CL_C15UV	CL_C14OV	CL_C14UV	CL_C13OV	CL_C13UV
STDR4	WR								
STDR5	WR								

CELL DISCHARGE AND PWM FOR DISCHARGE

The ADES1830/ADES1831 includes internal balancing switches for each of the cell monitoring channels. The balancing switch is a low $R_{DS(on)}$ FET that allows a peak discharge current of 300 mA. To simplify discharge operation, a PWM function is available to allow for a variable discharge current on every Sx pin. The PWM runs at a period of 937 ms and the PWM duty cycle is controlled with four bits. Due to the two dedicated SxN and SxP pins per channel, the ADES1830/ADES1831 allows balancing also of neighboring channels, and therefore, a duty cycle of up to 100%.

The PWM discharge functionality is possible in the standby, REF-UP, extended balancing, and in the measure states while the discharge timeout has not expired ($DCTO \neq 0$). The ADES1830/ADES1831 interrupts the PWM discharge when an S-measurement is initiated by the ADCV or ADSV commands with $DCP = 0$. The cell discharge is not muted when cell measurements are performed in extended balancing state or in low power cell monitoring (LPCM) mode. As a result, in these cases, measurements can be affected by the voltage drop of the discharge current over the cell cable resistance.

The PWM discharge happens asynchronously to the ADC measurements. Therefore, it is not predictable if a measurement is altered by the voltage drop. Depending on the cable resistance and the discharge current, the intended voltage thresholds (VOV , VUV , CMT_CUV , and CMT_COV) may not be checked accurately.

Table 27 details the discharge priority.

SX PIN MUTING

All Sx pins may be simultaneously disabled by sending the mute command and reenabled by sending the unmute command. The mute and unmute commands do not require any subsequent data and thus the commands propagate quickly through a stack of ADES1830/ADES1831 devices. After the mute command is received, it takes 65 μ s maximum for the internal discharge switches to stop the discharge. The mute functionality allows the host to quickly disable and reenable discharging without disturbing Configuration Register Group B contents. The mute status is reported in the read-only mute bit in Configuration Register Group A.

Table 27. Discharge Priorities

Priority (7 = Highest)	Event or Feature	Behavior
7	Thermal shutdown	The final discharge control selections are gated off when thermal shutdown occurs. Also, the PWM and DCC control bits are reset.
6	Mute	All discharge is disabled while the mute feature has been activated by the mute command. Note that mute is cleared upon watchdog timeout.
5	WRCFGB	DCC and PWM and ADC discharge requests are muted during a write to the Configuration Register Group B register.
4	DCC bits	If any DCC bit is asserted, the DCC configuration takes precedence over ADC or PWM discharge controls. The DCC discharge request asserts the Sx pins if not prevented by one of the higher priority features. DCC discharge is allowed during any ADC conversion command. DCC bits are cleared by the watchdog timeout. At that time, the device transitions to PWM discharge if the $DCTO$ is not 0 and has not expired to 0.
3	ADC measurement command	During the measurement time of an ADC conversion that measures the Cx or Sx pins, PWM discharge can be muted. Some ADC commands allow the DCP bit to stop cell discharge during measurements (see the Discharge During Measurements section for details). This occurs if not prevented by one of the higher priority features (above).
2	WRPWM	PWM discharge requests are muted during a write to the PWM register group.
1	PWM	PWM discharge is the lowest priority. When PWM is enabled, by setting any of the PWM register bits to 1, it controls cell discharge only if not prevented by one of the higher priority features (above).

CELL DISCHARGE AND PWM FOR DISCHARGE

CELL DISCHARGE WITH CELL MEASUREMENTS AND DIAGNOSTICS

When the internal balancing switch between two Sx pins switches on, the S-ADC results differ from the C-ADC measurement result and their results cannot be compared for diagnostic purposes. To get continuous measurement with diagnostic coverage while discharging, the following procedure can be used.

C-ADC conversions are usually started once during initialization:

- ▶ ADCV with RD = 0, DCP = 0, CONT = 1.
 - ▶ C-ADCs run in continuous mode, deliver measurement results, and feed the IIR filter. No comparison between C-ADC and S-ADC results is performed. PWM discharge is ongoing and is not affected.

While in continuous measurement mode, conversion results are read, and balancing is controlled, as follows:

- ▶ Program desired PWM values.
- ▶ Program desired CTHx thresholds.
- ▶ Every FTTI, ADSV with DCP = 0, CONT = 1.
 - ▶ S-ADCs are switched on additionally, discharge is interrupted, and C-ADC and S-ADC results are compared.
 - ▶ Synchronous C-ADC and S-ADC conversion results are available 8 ms to 16 ms after the ADSV as it takes maximum 8 ms for the SADC to synchronize to the CADC, and an additional fixed 8 ms for the synchronous conversions.
- ▶ After getting results: ADSV with DCP = 1, CONT = 0.

- ▶ Discharge is immediately restarted, S-ADC does one more conversion, and then sleeps. C-ADC continues measuring all the time.
- ▶ An open wire check can be done right after the redundant measurement. In this case, only three ADSVs are required to make redundant measurement and open wire check, as follows:
 - ▶ ADSV with DCP = 0, CONT = 1, OW = 0 (redundant check)
 - ▶ ADSV with DCP = 0, CONT = 0, OW = 1 (even open wire check)
 - ▶ ADSV with DCP = 0, CONT = 0, OW = 2 (odd open wire check)
 - ▶ Note: discharge is enabled again automatically after the last single shot S-ADC conversion.

The timing of the redundant and open-wire measurement is as follows:

- ▶ Redundant measurement of S-ADC and C-ADC: 8 ms to 16 ms
- ▶ Odd channels open wire check: 8 ms
- ▶ Even channels open wire check: 8 ms

Thus, the whole redundant and open wire diagnostic takes 24 ms to 32 ms and limits the maximum discharge duty cycle. In average, the discharge is inhibited for $0.5 \times (32 \text{ ms} + 24 \text{ ms}) = 28 \text{ ms}$. Assuming an FTTI of 100 ms, the maximum discharge duty cycle of the ADES1830/ADES1831 are limited to 72% (even if the PWM is configured to 100%, it is limited to 72% by the diagnostic measurements).

WATCHDOG AND DISCHARGE TIMER

When there is no valid command for more than two seconds, the watchdog timer expires. If the DCTO is zero when this occurs, the ADES1830/ADES1831 transitions to the sleep state and resets all register locations to their default values. If the DCTO is non-zero when this occurs, the ADES1830/ADES1831 transitions to the extended balancing state and resets the mute function. Only the PWM discharge can continue in the extended balancing state and the DCC bits must be cleared by the host controller before entering this state. If the DCC bits are not cleared, the static discharge is disabled during extended balancing, but enabled again upon returning to the standby state. The watchdog timer is always enabled, and it resets after every valid command with matching command PEC.

When the discharge timer is enabled, the discharge controls enabled in the PWM register group continue to run for the duration programmed by the DCTO bits. To enable the discharge timer, write the DCTO value in the Configuration Register Group B to a non-zero value. The discharge timer can operate in two time ranges: 0 minutes to 63 minutes and 0 hours to 16.8 hours. The range is controlled using the DTRNG bit in the CFGBR3 register. The bit controls whether the DCTO value uses a bit weight of 1 minute per bit or 16 minutes per bit.

The status of the discharge timer can be determined by reading Configuration Register Group B using the RDCFGB command. The DCTO value indicates the time left before the discharge timer expires.

Unlike the watchdog timer, the discharge timer does not reset when there is a valid command. The discharge timer can only be reset

after writing a valid WRCFGB command to Configuration Register Group B. The discharge timer may expire in the middle of some commands.

If the discharge timer expires in the middle of the WRCFGB command, the DCC bits and mute function in Configuration Register Group B are reset. However, at the end of the valid WRCFGB command, the new data is copied to the configuration register. The new data is not lost when the discharge timer fires.

If the discharge timer expires in the middle of the RDCFGB command, the DCC bits and mute function in Configuration Register Group B reset to their default values. As a result, the readback data from bytes CFGBR4 and CFGBR5 may be corrupted.

DISCHARGE TIMER MONITOR

When the discharge timer monitor (DTMEN) bit is set in Configuration Register Group B and the ADES1830/ADES1831 has entered the extended balancing state, the ADES1830/ADES1831 continues to monitor the cell voltages every 30 seconds by a single C-ADC conversion and updates the UV flags (CxUV). The ADES1830/ADES1831 disables the discharge of a cell if its voltage falls below the UV threshold (VUV) configured in Configuration Register Group B. Once the input voltage recovers and is above the UV threshold in subsequent measurements, discharge of the concerned cell resumes. The ADES1830/ADES1831 disables all discharges if the DCTO time runs out.

LOW POWER CELL MONITORING (LPCM)

The ADES1830/ADES1831 has additional monitoring states, commands, and registers that enable monitoring of cell voltages and sensors (temperature, pressure, gas, and so on) while the battery management system (BMS) controller is asleep or inactive. In this LPCM mode, a stack of ADES1830/ADES1831 devices can be configured to power up periodically, perform measurements, compare measurements to programmed thresholds, send an isoSPI packet to the next device in the chain, and then power down. The device at the far end of the chain controls the sampling period. If any device in the chain detects an alert condition, that information is relayed to the next device.

LPCM OPERATION

An LPCM chain consists of a monitor manager (MM), one or more monitors, and a timeout monitor (TM), as shown in Figure 19. The ADES1830/ADES1831 can be configured to perform any of those functions, although in many systems an [ADBMS6821](#) (single) or [ADBMS6822](#) (dual) isoSPI transceiver is used as the timeout monitor.

The basic operation steps are as follows:

1. Ensure that no conversions are ongoing.
2. The BMS controller configures the LPCM options in the monitors and then sends the CMEN command to initiate the LPCM operation. The monitors stop accepting ADC and write commands and begin LPCM operation.
3. At the programmed heartbeat measurement interval, the MM device wakes up.
4. Cell voltages are measured by C-ADC within 1 ms (typical) and compared to thresholds.
5. GPIOs are measured by AUX-ADC with 1 ms conversion time and compared to thresholds.

6. The MM initiates a heartbeat message to the next device in the chain indicating the monitoring status (see the [LPCM Heartbeat Messages](#) section).
7. When a cell monitor receives a heartbeat message from up the daisy chain, the following occurs:
 - ▶ Cell voltages are measured and compared to thresholds.
 - ▶ GPIOs are measured and compared to thresholds.
 - ▶ The monitor sends a heartbeat message to the next device in the chain indicating the monitoring status (see the [LPCM Heartbeat Messages](#) section).
8. If the TM at the bottom of the chain receives a pass heartbeat message before timeout, the timeout counter is reset.
9. If the TM receives a fail heartbeat message or times out, it initiates a wake-up signal to the BMS controller or power-up signal to a regulator.
10. The BMS controller can use a sequence of sending the CMDIS command to end LPCM operation and resume communication with the monitors.

Note that the interrupt of the TM asserts as an initial condition when the LPCM feature is enabled. The LPCM feature assumes that, until the first heartbeat message has fully propagated through the daisy chain, there can be a fault in the system in the initial state. Regardless of the CMC_MPER configuration, the battery monitor configured as MM starts the first heartbeat sequence 31 ms after the LPCM is enabled by the CMEN command. This function allows the LPCM to quickly evaluate the daisy chain when it is enabled. The host processor can observe this behavior and use it to qualify its transition to an idle or low power state. The MCU expects the LPCM interrupt to be asserted immediately after enabling the feature and then deasserted when the first heartbeat sequence confirms a passing condition for all battery monitor devices.

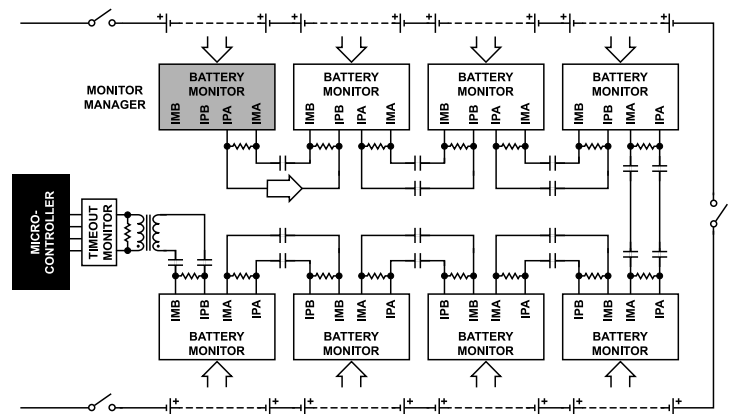


Figure 19. Basic LPCM System Configuration

LOW POWER CELL MONITORING (LPCM)

LPCM Thresholds

After taking cell and GPIO voltage measurements, the ADES1830/ADES1831 compares the results against programmed thresholds to determine whether a fault condition has occurred. The thresholds consist of the following:

- ▶ Cell undervoltage (CMT-CUV)
- ▶ Cell overvoltage (CMT-COV)
- ▶ Cell delta voltage (CMT-CDV)
- ▶ GPIO undervoltage (CMT-GUV)
- ▶ GPIO overvoltage (CMT-GOV)
- ▶ GPIO delta voltage (CMT-GDV)

Figure 20 shows the UV, OV, and DV comparisons.

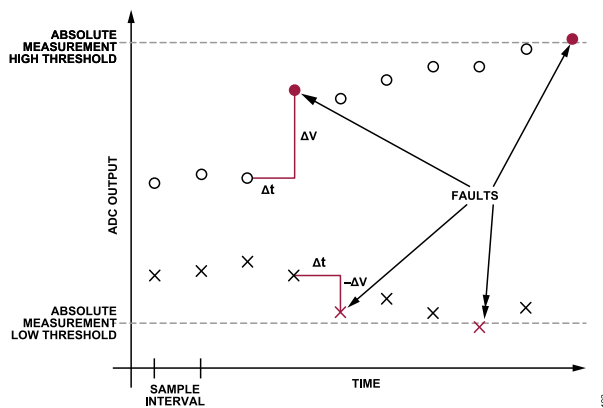


Figure 20. UV, OV, and DV Threshold Comparisons

If a fault is detected, the relevant flags are set and the ADES1830/ADES1831 transmits a heartbeat message that indicates the failure, as described in the [LPCM Heartbeat Messages](#) section.

The DV threshold comparison checks the current measurement with the previous measurement of the same input. The DV threshold is tripped for either positive or negative transitions so that a wide variety of analog and digital sensors of different output polarities can be used. Combinations of different types of sensors can be used if their thresholds are compatible. For example, thermistors can be used with an analog voltage threshold, which also trips by the transition of the digital output of a gas sensor. If a threshold type is not required in the system, the value can be set so that it cannot trip (for example, UV = 0 V, OV = 6 V, or DV = 6 V). Additionally, cell and GPIO inputs can be masked so that only the desired inputs are tested against the thresholds.

LPCM Heartbeat Messages

The LPCM feature uses smart messaging between battery monitor devices to communicate the monitoring status. The heartbeat message contains device count information about the number of devices reporting passing conditions, as well as a field of flags that indicate the types of failing conditions that may be detected.

The heartbeat message is sent as a command with PEC and data with data PEC. The usage of PEC values protects communication against faults. As the ADES1830/ADES1831 receives the heartbeat message, the command PEC and payload PEC must match, or else the ADES1830/ADES1831 ignores the command, allowing this communication fault to be detected by the timeout monitor at the end of the stack. Table 28 shows the format of the CMHB, which forms the heartbeat message. Table 29 and Table 30 describe the contents of the heartbeat message data. Note that the CMHB command is sent from the ADES1830/ADES1831 devices, not from the microcontroller.

Unlike other communication, during LPCM operation, this heartbeat message, consisting of the CMHB command, is initiated by the ADES1830/ADES1831 at the end of the daisy chain (configured as the MM) instead of being initiated by the host microprocessor. The heartbeat message is also unique in that it is not immediately propagated through the daisy chain. Upon receipt of the CMHB command, each ADES1830/ADES1831 in the chain performs the cell and auxiliary pin measurements and comparisons before re-generating the CMHB command to the next device in the chain. These actions by the ADES1830/ADES1831 create a propagation delay of approximately 5 ms to 15 ms, depending on the number of masked GPIO channels per ADES1830/ADES1831 in the daisy chain. If any of the cell or auxiliary pin measurements cause a threshold violation, a sticky flag bit is set in the CMF0 register.

In addition to being set by exceeding the corresponding OV/UV/DC thresholds, CMF0 is set to 0xFF in the event that any of the following internal diagnostics (reflected in Status Register Group C) fails during the cell or auxiliary conversions: VA_OV, VA_UV, VD_OV, VD_UV, VDE, VDEL, SPIFLT, TMODCHK, or OSCCHK.

Issue CLRFLAG of VA_OV, VA_UV, VD_OV, VD_UV, VDE, VDEL, SPIFLT, TMODCHK, and OSCCHK before entering LPCM to avoid CMF0 from being set to 0xFF in case any faults are pending.

As part of the configuration, the MM is programmed with a number equal to the number of cell monitors in the chain. The number of cell monitors is the initial value used by the MM for the heartbeat message count. If no threshold flag is asserted on the MM, it sends a number equal to the number of cell monitors minus 1. If a threshold flag is asserted, it sends a number equal to the number of cell monitors and it asserts bits in the flag field of the heartbeat message to indicate the types of error that are detected. (The code used for the number of monitors is offset by 0x42 to prevent a pass count from consisting of all 0s.)

After the MM, each cell monitor receives a count and a flag field from the previous device. After checking the thresholds, each monitor either decrements this number if no threshold is violated, or makes no change to this number if a threshold is violated, and then sends this number on to the next device. Any fault flags received from the previous device are also included in the new heartbeat message generated for the next device.

LOW POWER CELL MONITORING (LPCM)

Table 28. CMHB Command

8	8	8	8	8	8	8	8
CMD0	CMD1	PEC0	PEC1	HBD0	HBD1	DPEC0	DPEC1

Table 29. Heartbeat Message Data Format

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
HBD0	HB_DCNT[7]	HB_DCNT[6]	HB_DCNT[5]	HB_DCNT[4]	HB_DCNT[3]	HB_DCNT[2]	HB_DCNT[1]	HB_DCNT[0]
HBD1	HB_GDVP	HB_GDVN	HB_GOV	HB_GUV	HB_CDVP	HB_CDVN	HB_COV	HB_CUV

Table 30. Cell Voltage Register Group A Bit Descriptions

Byte	Bits	Bit Name	Description
HBD0	[7:0]	HB_DCNT[7] to HB_DCNT[0]	Heartbeat message device count. The MM sets the initial value for this count based on the configured CMC_NDEV value and the monitoring status of the MM device. Each monitor device in the chain decrements this value only if all monitoring comparisons pass.
HBD1	7	HB_GDVP	This sticky flag bit is asserted if a GPIO delta voltage comparison is violated in the positive direction (voltage increasing) for any device. Cleared by the CLRCMFLAG command.
HBD1	6	HB_GDVN	This sticky flag bit is asserted if a GPIO delta voltage comparison is violated in the negative direction (voltage decreasing) for any device. Cleared by the CLRCMFLAG command.
HBD1	5	HB_GOV	This sticky flag bit is asserted if a GPIO overvoltage comparison is violated for any device. Cleared by the CLRCMFLAG command.
HBD1	4	HB_GUV	This sticky flag bit is asserted if a GPIO undervoltage comparison is violated for any device. Cleared by the CLRCMFLAG command.
HBD1	3	HB_CDVP	This sticky flag bit is asserted if a cell delta voltage comparison is violated in the positive direction (voltage increasing) for any device. Cleared by the CLRCMFLAG command.
HBD1	2	HB_CDVN	This sticky flag bit is asserted if a cell delta voltage comparison is violated in the negative direction (voltage decreasing) for any device. Cleared by the CLRCMFLAG command.
HBD1	1	HB_COV	This sticky flag bit is asserted if a cell overvoltage comparison is violated for any device. Cleared by the CLRCMFLAG command.
HBD1	0	HB_CUV	This sticky flag bit is asserted if a cell undervoltage comparison is violated for any device. Cleared by the CLRCMFLAG command.

Table 31. Final Pass Value for the Heartbeat Message Data

Byte	Pass Value
HBD0	0x42
HBD1	0x00

At the bottom of the chain, the TM must receive the proper heartbeat message count that indicates no failing devices and no flags asserted. The final pass value of the heartbeat message data is shown in Table 31. Otherwise, a fault output is asserted.

See the following examples:

- ▶ If there are six monitors in the chain, the microcontroller writes CMC_NDEV = 0x48 (6 devices plus offset of 0x42) before the microcontroller goes to sleep.
- ▶ If no threshold is violated at the MM, the MM sends HB_DCNT = 0x47 (CMC_NDEV – 1) to the next device.
- ▶ If the second device in the chain passes its fault checks, it sends HB_DCNT = 0x46 (decrement by 1) to the next device.
- ▶ If the third device in the chain fails its fault checks, it sends HB_DCNT = 0x46 (does not decrement) and asserts the appropriate flags in HBD1.
- ▶ If the third device in the chain is the only monitor that fails, the TM receives 1 as the cell monitor number, and asserts its fault output.

LPCM Interrupt Indications

The LPCM feature indicates an interrupt in the following three conditions:

- ▶ The interrupt asserts as an initial condition when the LPCM feature is enabled. The LPCM feature assumes that until the first heartbeat message has fully propagated through the daisy chain, there can be a fault in the system in the initial state. Regardless of the CMC_MPER configuration, the battery monitor configured as MM starts the first heartbeat sequence 31 ms after LPCM is enabled by the CMEN command. This allows the LPCM to quickly evaluate the daisy chain when it is enabled. The host processor can observe this behavior and use it to qualify its transition to an idle or low power state. The host expects the LPCM interrupt to be asserted immediately after enabling the feature and then deasserted when the first heartbeat sequence confirms a passing condition for all battery monitor devices. Each ADES1830/ADES1831 in the daisy chain, including the MM, first performs cell and auxiliary measurements and comparisons before generating the heartbeat message to the next device in the daisy chain. The propagation delay is approximately 6 ms per ADES1830/ADES1831 in the daisy chain. So, for example, a daisy chain of three ADES1830/ADES1831 devices waits 31 ms after CMEN to begin the heartbeat sequence and requires an additional 18 ms to propagate the heartbeat message through the three devices to the TM at the bottom of the chain. The host can expect the initial interrupt condition to end approximately 49

LOW POWER CELL MONITORING (LPCM)

- ms after the CMEN command for a daisy chain of three devices, provided no thresholds are violated.
- ▶ The interrupt asserts if there is no heartbeat message for a configurable period of time. This value can be configured by CMC_TPER in the ADES1830/ADES1831 if the bridgeless timeout monitor feature is implemented. Otherwise, it is configured for the TM device that is acting as the watchdog for LPCM heartbeat messaging.
 - ▶ The interrupt asserts when the heartbeat message contains an incorrect data payload. In this case, there is no need to wait for the configured timeout period. When the heartbeat message payload indicates wrong number of devices or a fault flag, the interrupt immediately asserts.

Clear CM Flag Command

The CLRCMFLAG command resets the flags in the CMF0 register of the CMFx register group. The CLRCMFLAG command requires the system to send two additional bytes. These two bytes must both be set to 0xFF to reset all flags.

Because the bits in CMF0 are also set to FF if any of the following internal diagnostics (reflected in Status Register Group C) fails during the cell or auxiliary conversions (VA_OV, VA_UV, VD_OV, VD_UV, VDE, VDEL, SPIFLT, TMODCHK, or OSCCHK), a CLRFLAG command must be issued before entering LPCM to clear CMF0.

LPCM BRIDGELESS TIMEOUT MONITOR

The ADES1830/ADES1831 can be set up as an LPCM TM when an isoSPI bridge transceiver is not used. In that configuration, system faults are indicated on GPIO3 and/or GPIO4. See [Figure 21](#). The bridgeless timeout monitor settings include a timeout period for receiving a pass heartbeat message from the stack. In this configuration, the TM also checks its cell and GPIO inputs against the thresholds and uses that information along with the received heartbeat message to determine the fault status.

Note that GPIO3 and GPIO4 are pull-downs only. Therefore, external pull-up resistors are required for monitor outputs.

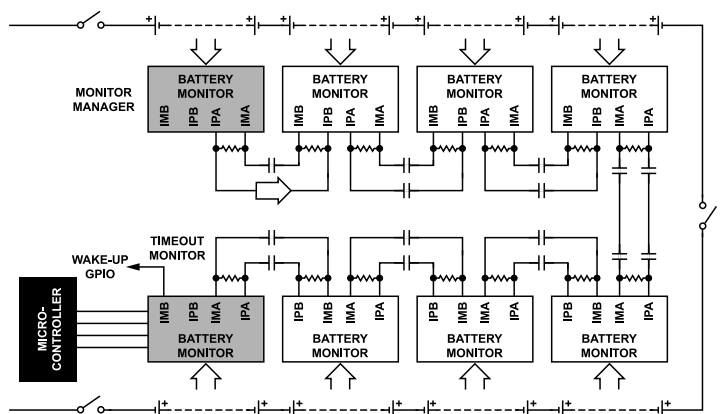


Figure 21. Bridgeless Timeout Monitor System Configuration

LOW POWER CELL MONITORING (LPCM)

LPCM WITH REVERSIBLE ISOSPI

In a system that implements a reversible isoSPI, the LPCM can be used in the forward direction, the reverse direction, or both directions simultaneously. Operating in both directions requires that

two adjacent ADES1830/ADES1831 devices be programmed to function as MMs, and the proper port must be specified using the CMC_DIR configuration bit. Two TMs must be used, one on each end. See [Figure 22](#).

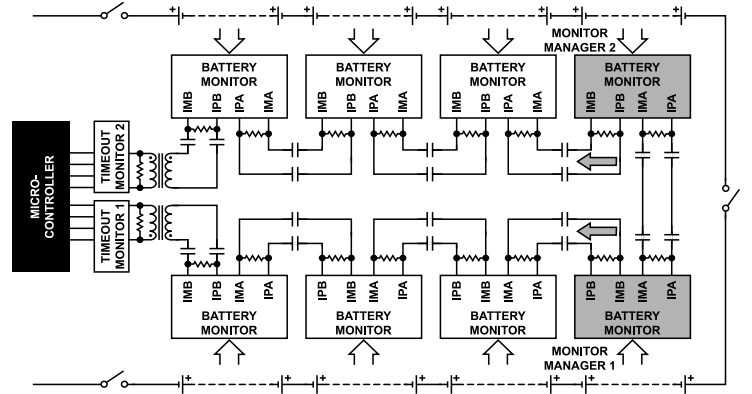


Figure 22. LPCM with Reversible isoSPI

LOW POWER CELL MONITORING (LPCM)

USING THE LPCM AND DISCHARGE TIMER

Once the BMS controller sends the CMEN command, the monitors stop accepting some commands, such as ADC and write commands. However, it is possible to enable the discharge timer feature and the LPCM feature to operate simultaneously. To do so, the BMS controller must configure the discharge timer configuration and the LPCM configuration before sending the CMEN command. The DCC bits must be cleared before sending the CMEN command, as described in the [Extended Balancing and DTM Measure States](#) and [Watchdog and Discharge Timer](#) sections. After the CMEN command, the monitors quickly transition to the extended balancing state to begin discharge and LPCM operation. If the discharge timer monitor feature is enabled (DTMEN = 1), the heartbeat conversions are used to monitor the cell voltages for discharging, rather than using the 30 second monitor period. The VUV undervoltage threshold stored in the configuration register is used to halt discharge if DTMEN = 1. The CMT_CUV undervoltage

threshold is used to determine whether an LPCM violation occurs. These two undervoltage thresholds can be programmed to different values to allow the discharge to terminate without waking the BMS controller. The cell discharge is not muted when cell measurements are performed in the LPCM and extended balancing modes. The measurements are affected by the voltage drop over the cell cable resistance due to the discharge current. The PWM discharge happens asynchronously to the ADC measurements. Therefore, it is not predictable if a measurement is altered by the cable drop. Depending on the cable resistance and the discharge current, the intended voltage thresholds may not be checked accurately.

LPCM EXPANDED STATE DIAGRAM

Figure 23 shows the standard ADES1830/ADES1831 state diagram to the left (in black), with the added ADES1830/ADES1831 states and paths to the right (in red).

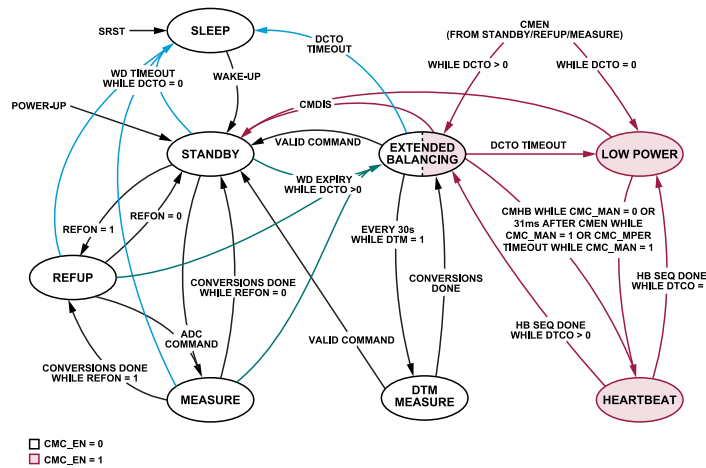


Figure 23. State Diagram with Low Power Cell Monitoring

LOW POWER CELL MONITORING (LPCM)

LPCM POWER CONSUMPTION

During LPCM operation, the ADES1830/ADES1831 consumes a quiescent current of about 10 μA during most of the measurement period. The device takes about 6.7 ms to power up, take measurements, check thresholds, send the heartbeat message over ISO-SPI, and power down. During this burst of activity, the ADES1830/ADES1831 uses approximately 70 μC of charge additionally. The measurement period (MPER) can be configured to be 1 sec, 2 sec, 4 sec, 8 sec, 12 sec, 16 sec, or 32 sec. Therefore, the average LPCM current is:

$$I_{\text{LPCM(AVG)}} \approx 70 \mu\text{C}/\text{MPER} + 10 \mu\text{A}$$

For the available measurement periods, the approximate average currents are:

1 sec $\approx 80 \mu\text{A}$ 2 sec $\approx 45 \mu\text{A}$ 4 sec $\approx 28 \mu\text{A}$ 8 sec $\approx 19 \mu\text{A}$ 12 sec $\approx 16 \mu\text{A}$ 16 sec $\approx 14 \mu\text{A}$ 32 sec $\approx 12 \mu\text{A}$

LPCM SYSTEM DIAGNOSTICS

The heartbeat message allows the system microcontroller to perform diagnostics before the controller goes to sleep. The controller can configure the monitors in such a way that one or more monitors are expected to detect a fault condition. The controller can then monitor the fault outputs and the heartbeat message to confirm that the expected faults are detected. In this way, the system can confirm proper cell voltage fault detection, GPIO fault detection, monitoring period, timeout detection, and fault output assertion.

LPCM Configuration Example

The following is an example pseudo code for configuring a stack of ADES1830/ADES1831 devices for low power cell monitoring.

```
//Wake up
repeat(NUMDEV) begin
  CSB low;
  CSB high;
  wait(500us); // 500us <= wait time < tIDLE
end

//Configure cell thresholds
CSB low;
WRCMCELLT;

//command plus command PEC
repeat(NUMDEV) begin
  write_byte (CM_CELLT_byte[0]);
  write_byte (CM_CELLT_byte[1]);
  write_byte (CM_CELLT_byte[2]);
  write_byte (CM_CELLT_byte[3]);
  write_byte (CM_CELLT_byte[4]);
  write_byte (CM_CELLT_byte[5]);
  write_byte (DPEC_byte[0]);
  write_byte (DPEC_byte[1]);
end
CSB high;
<Optional readback>

//Configure GPIO thresholds
CSB low;
WRCMGPIOT;

//command plus Command PEC
repeat(NUMDEV) begin
  write_byte (CM_GPIOT_byte[0]);
  write_byte (CM_GPIOT_byte[1]);
  write_byte (CM_GPIOT_byte[2]);
  write_byte (CM_GPIOT_byte[3]);
```

LOW POWER CELL MONITORING (LPCM)

```

write_byte (CM_GPIOT_byte[4]);
write_byte (CM_GPIOT_byte[5]);
write_byte (DPEC_byte[0]);
write_byte (DPEC_byte[1]);
end
CSB high;
<Optional readback>

```

```

//General LPCM Configurations
CSB low;
WRCMCFG;

```

```

//command plus command PEC
//TOP DEVICE IN GROUP MUST BE
//PROGRAMMED AS MANAGER
repeat(NUMDEV) begin
write_byte (CM_CFG_byte[0]);
write_byte (CM_CFG_byte[1]);
write_byte (CM_CFG_byte[2]);
write_byte (CM_CFG_byte[3]);
write_byte (CM_CFG_byte[4]);
write_byte (CM_CFG_byte[5]);
write_byte (DPEC_byte[0]);
write_byte (DPEC_byte[1]);
end
CSB high;
<Optional readback>

```

```

//Clear LPCM Flags
CSB low;
CLRCMFLAG;

```

```

//command plus command PEC
repeat(NUMDEV) begin
write_byte (8'hFF);
write_byte (8'hFF);
write_byte (DPEC_byte[0]);
write_byte (DPEC_byte[1]);
end
CSB high;
<Optional readback>

```

```

//Enable Cell Monitoring
CSB low;
CMEN;
//command plus command PEC
CSB high;

```

Below is pseudo-code for exiting LPCM mode for a stack of ADES1830/ADES1831 devices:

```

// Repeat the disable command
// until all devices have
// exited LPCM.
// The heartbeat sequence within
// one device can take ~6.6ms
// typical to execute.
// The disable command must be

```

LOW POWER CELL MONITORING (LPCM)

```
// repeated for each device
// in the stack and additionally
// for long enough to last the
// duration of a heartbeat
// sequence in progress.
// 20 repetitions of 500us wait
// allows 8ms, providing for
// possible oscillator variation
// for devices in the stack.
repeat(NUMDEV + 20) begin

// Wake up pulse
CSB low;
CSB high;
wait(500us) // 500us <= wait time < tIDLE
// Send disable command
CSB low;
CMDIS;
//command plus command PEC
CSB high;
end

//Clear the command count
CSB low;
RSTCC;

//command plus command PEC
CSB high;
```

I²C/SPI CONTROLLER USING GPIOs

The I/O ports GPIO3, GPIO4, and GPIO5 on the ADES1830/ADES1831 can be used as an I²C or SPI controller port to communicate to an I²C or SPI target. For an I²C controller, GPIO4 and GPIO5 form the SDA and SCL ports of the I²C interface, respectively. In the case of an SPI controller, GPIO3, GPIO4, and GPIO5 are the CSBM, SDIOM, and SCKM ports of the SPI, respectively. The SPI controller on the ADES1830/ADES1831 supports SPI Mode 3 (CPHA = 1, CPOL = 1).

The GPIOs are open-drain outputs. Therefore, an external pull-up resistor is required on these ports to operate as an I²C or SPI controller. It is also important to write the GPO bits to 1 in Configuration Register Group A so that these ports are not pulled low internally by the device.

COMM REGISTER

The ADES1830/ADES1831 has a 6-byte COMM register, as shown in Table 32. This register stores all data and control bits required for I²C or SPI communication to a target. The COMM register contains three bytes of data Dx[7:0] to be transmitted to or received

Table 32. COMM Register Memory Map

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
COMM0	RD/WR	ICOM0[3]	ICOM0[2]	ICOM0[1]	ICOM0[0]	FCOM0[3]	FCOM0[2]	FCOM0[1]	FCOM0[0]
COMM1	RD/WR	D0[7]	D0[6]	D0[5]	D0[4]	D0[3]	D0[2]	D0[1]	D0[0]
COMM2	RD/WR	ICOM1[3]	ICOM1[2]	ICOM1[1]	ICOM1[0]	FCOM1[3]	FCOM1[2]	FCOM1[1]	FCOM1[0]
COMM3	RD/WR	D1[7]	D1[6]	D1[5]	D1[4]	D1[3]	D1[2]	D1[1]	D1[0]
COMM4	RD/WR	ICOM2[3]	ICOM2[2]	ICOM2[1]	ICOM2[0]	FCOM2[3]	FCOM2[2]	FCOM2[1]	FCOM2[0]
COMM5	RD/WR	D2[7]	D2[6]	D2[5]	D2[4]	D2[3]	D2[2]	D2[1]	D2[0]

Table 33. Write Codes for ICOMx[3:0] and FCOMx[3:0] on I²C Controller

Control Bits	Code	Action	Description
ICOMx[3:0]	0110	Start	Generates a start signal on the I ² C port followed by data transmission.
	0001	Stop	Generates a stop signal on the I ² C port.
	0000	Blank	Proceeds directly to data transmission on I ² C port.
	0111	No transmit	Releases SDA and SCL and ignores the rest of the data.
FCOMx[3:0]	0000	Controller acknowledge	Controller generates an acknowledge signal on the ninth clock cycle.
	1000	Controller no acknowledge	Controller generates a no acknowledge signal on the ninth clock cycle.
	1001	Controller no acknowledge and stop	Controller generates a no acknowledge signal followed by a stop signal.

Table 34. Write Codes for ICOMx[3:0] and FCOMx[3:0] on SPI Controller

Control Bits	Code	Action	Description
ICOMx[3:0]	1000	CSBM low	Generates a CSBM low signal on SPI port (GPIO3).
	1010	CSBM falling edge	Drives CSBM (GPIO3) high, then low.
	1001	CSBM high	Generates a CSBM high signal on SPI port (GPIO3).
	1111	No transmit	Releases the SPI port and ignores the rest of the data.
FCOMx[3:0]	X000	CSBM low	Holds CSBM low at the end of the byte transmission.
	1001	CSBM high	Transitions CSBM high at the end of the byte transmission.

from the target device. ICOMx[3:0] specify control actions before transmitting/receiving each data byte. FCOMx[3:0] specify control actions after transmitting/receiving each data byte.

If the ICOMx[3] bit in the COMM register is set to 1, the device is an SPI controller, and if the bit is set to 0, the device is an I²C controller.

Table 33 describes the valid write codes for ICOMx[3:0] and FCOMx[3:0] and their behavior when using the device as an I²C controller.

Table 34 describes the valid write codes for ICOMx[3:0] and FCOMx[3:0] and their behavior when using the device as a SPI controller.

Note that only the codes listed in Table 33 and Table 34 are valid for ICOMx[3:0] and FCOMx[3:0]. Writing any other code not listed in Table 33 and Table 34 to ICOMx[3:0] and FCOMx[3:0] may result in unexpected behavior on the I²C or SPI port.

I²C/SPI CONTROLLER USING GPIOs

COMM COMMANDS

Three commands help accomplish I²C or SPI communication to the target device: WRCOMM, STCOMM, and RDCOMM.

The WRCOMM command writes data to the COMM register. This command writes six bytes of data to the COMM register. The PEC must be written at the end of the data. If the PEC does not match, all data in the COMM register is cleared to 0 when CSB goes high. See the [Bus Protocols](#) section for more details on the write command format.

The STCOMM command initiates I²C and SPI communication on the GPIO ports. The COMM register contains three bytes of data to be transmitted to the target. During this command, the data bytes stored in the COMM register are transmitted to the target I²C or SPI device, and the data received from the I²C or SPI device is stored in the COMM register. This command uses GPIO4 (SDA) and GPIO5 (SCL) for I²C communication or GPIO3 (CSBM), GPIO4 (SDIOM), and GPIO5 (SCKM) for SPI communication.

Follow the STCOMM with 24 clock cycles for each byte of data to be transmitted to the target device while holding CSB low. For example, to transmit three bytes of data to the target, send STCOMM command and its PEC, followed by 72 clock cycles. Pull CSB high at the end of the 72 clock cycles of STCOMM command.

During I²C or SPI communication, the data received from the target device is updated in the COMM register.

The data received from the target device can be read back from the COMM register using the RDCOMM command. The command reads back six bytes of data followed by the PEC. See the [Bus Protocols](#) section for more details on the read command format.

[Table 35](#) describes the possible read back codes for ICOMx[3:0] and FCOMx[3:0] when using the part as an I²C controller. Dx[7:0] contains the data byte transmitted by the I²C target.

Table 35. Read Codes for ICOMx[3:0] and FCOMx[3:0] on I²C Controller

Control Bits	Code	Description
ICOMx[3:0]	0110	Controller generated a start signal.
	0001	Controller generated a stop signal.
	0000	Blank, SDA held low between bytes.
	0111	Blank, SDA held high between bytes.
FCOMx[3:0]	0000	Controller generated an acknowledge signal.
	0111	Target generated an acknowledge signal.
	1111	Target generated a no acknowledge signal.
	0001	Target generated a no acknowledge signal, controller generated a stop signal.
	1001	Target generated a no acknowledge signal, controller generated a stop signal.

In case of the SPI controller, the read back codes for ICOMx[3:0] and FCOMx[3:0] are always 0111 and 1111, respectively. Dx[7:0] contains the data byte transmitted by the SPI target.

[Figure 24](#) shows the operation of the ADES1830/ADES1831 as an I²C or SPI controller using the GPIOs.

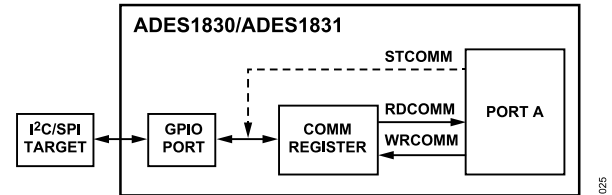


Figure 24. I²C/SPI Controller Using GPIOs

Any number of bytes can be transmitted to the target in groups of three bytes using these commands. The GPIO ports do not reset between different STCOMM commands. However, if the wait time between the commands is greater than two sec, the watchdog times out and resets the ports to their default values.

To transmit several bytes of data using an I²C controller, a start signal is only required at the beginning of the entire data stream. A stop signal is only required at the end of the data stream. All intermediate data groups can use a blank code before the data byte and an acknowledge or no acknowledge signal as appropriate after the data byte. SDA and SCL do not reset between different STCOMM commands.

To transmit several bytes of data using SPI controller, a CSBM low signal is sent at the beginning of the first data byte. CSBM can be held low or taken high for intermediate data groups using the appropriate code on FCOMx[3:0]. A CSBM high signal is sent at the end of the last byte of data. CSBM, SDIOM, and SCKM do not reset between different STCOMM commands.

[Figure 25](#) shows the 24 clock cycles following the STCOMM command for an I²C controller in different cases. Note that if ICOMx[3:0] specified a stop condition after the stop signal is sent, the SDA and SCL lines are held high and all data in the rest of the word is ignored. If ICOMx[3:0] is set for a no transmit condition, both SDA and SCL lines are released, and the rest of the data in the word is ignored. This is used when a device in the stack does not have to communicate to a target.

[Figure 26](#) shows the 24 clock cycles following a STCOMM command for an SPI controller. Like the I²C controller, if ICOMx[3:0] is set for a CSBM high or a no transmit condition, the CSBM, SCKM, and SDIOM lines of the SPI controller are released and the rest of the data in the word is ignored.

I²C/SPI CONTROLLER USING GPIOs

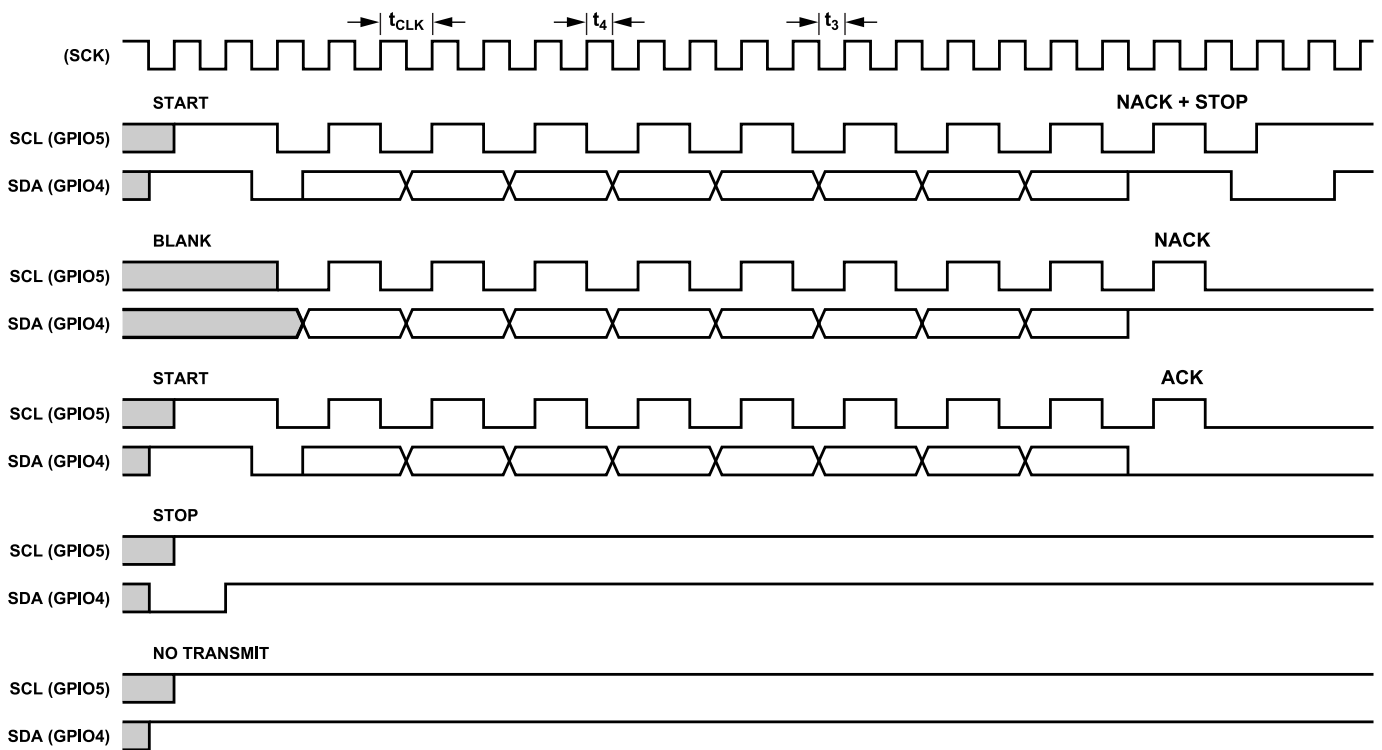


Figure 25. STCOMM Timing Diagram for an I²C Controller

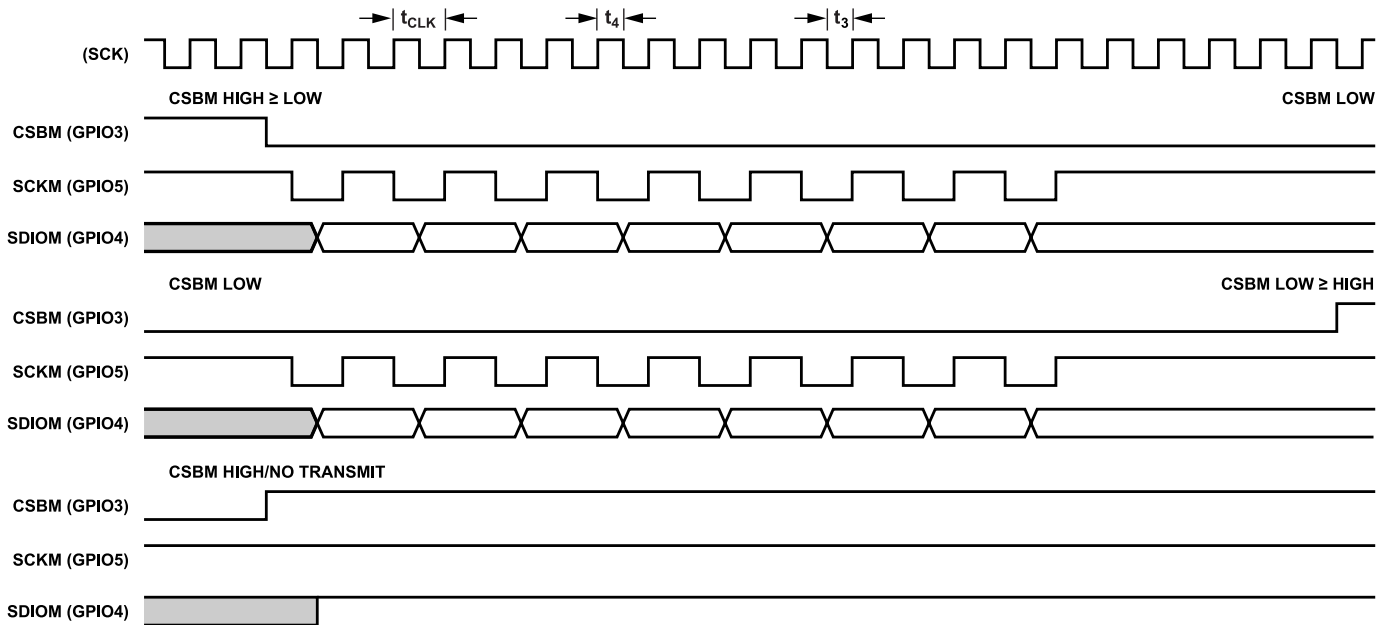


Figure 26. STCOMM Timing Diagram for an SPI Controller

I²C/SPI CONTROLLER USING GPIOsTIMING SPECIFICATIONS OF I²C AND SPI CONTROLLER

The timing of the I²C or SPI controller is controlled by the timing of the communication at the primary SPI of the ADES1830/ADES1831.

Table 36 shows the I²C controller timing relationship to the primary SPI clock. Table 37 shows the SPI controller timing specifications.

Table 36. I²C Controller Timing

I ² C Controller Parameter	Timing Relationship to Primary SPI	Timing Specifications at t _{CLK} = 0.5 ms
SCL Clock Frequency	1/(2 × t _{CLK})	Maximum 1 MHz
t _{HD;STA}	t ₃	Minimum 100 ns
t _{LOW}	t _{CLK}	Minimum 0.5 μs
t _{HIGH}	t _{CLK}	Minimum 0.5 μs
t _{SU;STA}	t _{CLK} + t ₄ ¹	Minimum 0.53 μs
t _{HD;DAT}	t ₄ ¹	Minimum 30 ns
t _{SU;DAT}	t ₃	Minimum 100 ns
t _{SU;STO}	t _{CLK} + t ₄ ¹	Minimum 0.53 μs
t _{BUF}	3 × t _{CLK}	Minimum 1.5 μs

¹ When using the isoSPI, t₄ is generated internally and is a minimum of 30 ns. Also, t₃ = t_{CLK} - t₄. When using SPI, t₃ and t₄ are the low and high times of the SCK input, each with a specified minimum of 100 ns.

Table 37. SPI Controller Timing

SPI Controller Parameter	Timing Relationship to Primary SPI	Timing Specifications at t _{CLK} = 0.5 ms
SDIOM Valid to SCKM Rising Setup	t ₃	Minimum 100 ns
SDIO Valid from SCKM Rising Hold	t _{CLK} + t ₄ ¹	Minimum 0.53 μs
SCKM Low	t _{CLK}	Minimum 0.5 μs
SCKM High	t _{CLK}	Minimum 0.5 μs
SCKM Period (SCKM Low + SCKM High)	2 × t _{CLK}	Minimum 1 μs
CSBM Pulse Width	3 × t _{CLK}	Minimum 1.5 μs
SCKM Rising to CSBM Rising	5 × t _{CLK} + t ₄ ¹	Minimum 2.53 μs
CSBM Falling to SCKM Falling	t ₃	Minimum 100 ns
CSBM Falling to SCKM Rising	t _{CLK} + t ₃	Minimum 0.6 μs
SCKM Falling to SDIOM Valid		Controller requires < t _{CLK}

¹ When using isoSPI, t₄ is generated internally and is a minimum of 30 ns. Also, t₃ = t_{CLK} - t₄. When using SPI, t₃ and t₄ are the low and high times of the SCK input, each with a specified minimum of 100 ns.

SERIAL INTERFACE OVERVIEW

There are two types of serial ports on the ADES1830/ADES1831: a standard, 4-wire SPI using CSB, SCK, SDI, and SDO, and a 2-wire isoSPI using IMA and IPA. The state of the ISOMD pin determines if the dual-function pins function as a 2-wire or 4-wire serial port. Both the 2-wire and 4-wire serial ports can communicate at 2 Mbps.

The ADES1830/ADES1831 can be used in a daisy-chain configuration either in isoSPI mode using IMA and IPA, or in SPI mode using CSB, SCK, SDI, and SDO. In a daisy-chain configuration, the second isoSPI port uses IMB and IPB.

4-WIRE SPI PHYSICAL LAYER

Connecting ISOMD to V- configures Serial Port A for 4-wire SPI. The SDO pin is an open-drain output that requires a pull-up resistor tied to the appropriate supply voltage.

The 4-wire serial port is configured to operate in an SPI system using CPHA = 0 and CPOL = 0, or in an SPI system using CPHA = 1 and CPOL = 1. Consequently, data on SDI must be stable during the rising edge of SCK. Figure 27 shows the timing. The maximum data rate is 2 Mbps. However, the device is tested at a higher data rate in production to guarantee operation at the maximum specified data rate.

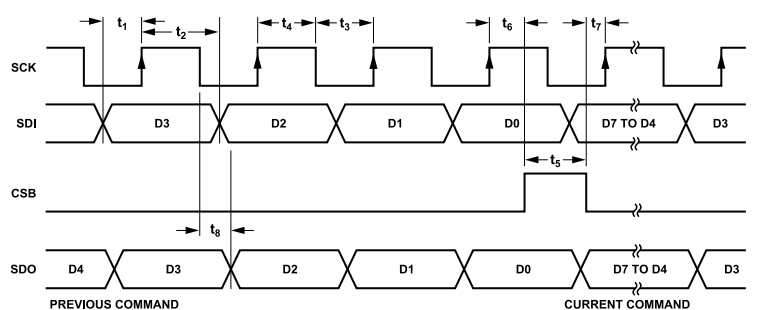


Figure 27. Timing Diagram of 4-Wire SPI

SERIAL INTERFACE OVERVIEW

REVERSIBLE 2-WIRE ISOSPI PHYSICAL LAYER

The 2-wire interface provides a means to interconnect ADES1830/ADES1831 devices using simple twisted pair cabling. The interface is designed for low packet error rates when the cabling is subjected to high RF fields. Isolation is achieved through an external transformer or external capacitors.

Standard SPI signals are encoded into differential pulses. The strength of the transmission pulses is set to 20 mA and the threshold level of the receiver is 300 mV.

External Connections

The ADES1830/ADES1831 has two serial ports: Port A and Port B. Port B is always configured as a 2-wire interface. Port A is either a 2-wire or 4-wire interface, depending on the connection of the ISOMD pin.

When Port A is configured as a 4-wire interface, Port A is always the target port and Port B is the controller port. Communication is always initiated on Port A of the first device in the daisy-chain configuration. The final device in the daisy chain does not use Port B, and it must be terminated. Alternatively, the Port B of the last device can be connected back to a second isoSPI port at the MCU controller side to implement a communication ring architecture. This allows a redundant communication path to all devices in the daisy chain besides the first that is configured to 4-wire interface.

Figure 28 shows the simplest port connections possible where capacitors are used to couple signals between ADES1830/ADES1831 devices.

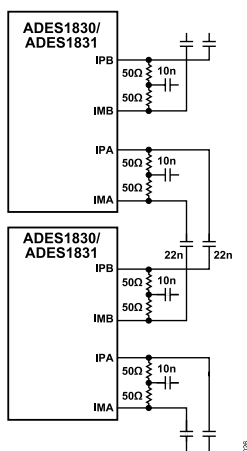


Figure 28. Capacitor Isolated isoSPI

When Port A is configured as a 2-wire interface, communication can be initiated on either Port A or Port B. If communication is initiated on Port A, the ADES1830/ADES1831 configures Port A as target and Port B as controller. Likewise, if communication is initiated on Port B, the ADES1830/ADES1831 configures Port B as target and Port A as controller. See the [Reversible isoSPI](#) section for a detailed description of reversible isoSPI.

Figure 27 is an example of a robust interconnection of multiple identical PCBs, each containing one ADES1830/ADES1831. The microprocessor is located on a separate PCB. To achieve 2-wire isolation between the microprocessor PCB and the first ADES1830/ADES1831 PCB, use the [ADBMS6821](#) or [ADBMS6822](#) support ICs.

Reversible isoSPI

Figure 29 shows a daisy-chained configuration of the ADES1830/ADES1831 using reversible isoSPI. Two [ADBMS6821](#)s or a single [ADBMS6822](#) is connected on either side of the daisy chain. Both ADBMS6821s are configured as controllers and share the same SPI to connect to the microprocessor unit (MPU). The MPU uses two different CS signals to talk to one of the two ADBMS6821s.

For example, in Figure 29, if the bottom ADBMS6821 is addressed, then ADES1830/ADES1831 Device A is the first device in the stack followed by Device B and Device C. Port A of each ADES1830/ADES1831 is configured as the target, and Port B is configured as the controller. If the top ADBMS6821 is addressed, then ADES1830/ADES1831 Device C becomes the first device in the stack followed by Device B and Device A. Port B of each ADES1830/ADES1831 is configured as a target, and Port A is configured as a controller.

The reversible isoSPI provides a redundant communication path in the event of a single point failure in the 2-wire interface.

SERIAL INTERFACE OVERVIEW

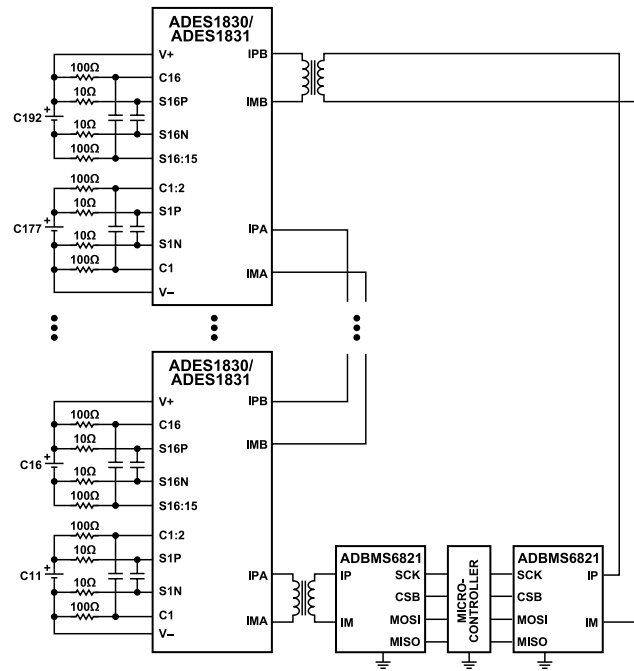


Figure 29. Multiple Devices for Reversible isoSPI

Configurable isoSPI Break

Individual ADES1830/ADES1831 devices in a daisy chain can be configured to halt any transmission of data on its controller isoSPI port. Perform this action by writing the COMM_BK bit to a 1 in Configuration Register Group A. Asserting the COMM_BK bit does not prevent the ADES1830/ADES1831 from receiving and responding to commands from either the SPI/isoSPI Port A or the isoSPI Port B. Therefore, this setup is useful in a reversible isoSPI daisy chain for increasing the effective communication bandwidth by splitting the chain in half. The host can assert the COMM_BK bits in the two center ADES1830/ADES1831 devices in the daisy chain. Then, the host can simultaneously issue commands to both ends of the daisy chain as if it is communicating to two separate daisy chains, each with half of the total chain length.

If a communication fault occurs while some ADES1830/ADES1831 devices are configured for communication break, the host can successively attempt to write COMM_BK = 0 to all devices in the chain, and in both the forward and reverse directions. This write allows the host access to all possible devices for identifying the location of the communication break.

The COMM_BK bit resets to 0 on a watchdog reset.

isoSPI Pulse Detail

Two ADES1830/ADES1831 devices can communicate by transmitting and receiving differential pulses back and forth through an isolation barrier. The transmitter can output three voltage levels: +VA, 0 V, and -VA. A positive output results from IP sourcing current and IM sinking current across the load resistor. A negative

voltage is developed by IP sinking and IM sourcing. When both outputs are off, the load resistance forces the differential output to 0 V.

To eliminate the DC signal component and enhance reliability, isoSPI pulses are defined as symmetric pulse pairs. A +1 pulse is transmitted as a positive pulse followed by a negative pulse. A -1 pulse is transmitted as a negative pulse followed by a positive pulse. The duration of each pulse is defined as $t_{1/2PW}$ because each is half of the required symmetric pair (the total isoSPI pulse duration is $2 \times t_{1/2PW}$).

Table 38. isoSPI Pulse Types

Pulse Type	First Level ($t_{1/2PW}$)	Second Level ($t_{1/2PW}$)	Ending Level
Long +1	+VA (150 ns)	-VA (150 ns)	0 V
Long -1	-VA (150 ns)	+VA (150 ns)	0 V
Short +1	+VA (50 ns)	-VA (50 ns)	0 V
Short -1	-VA (50 ns)	+VA (50 ns)	0 V

A host microcontroller does not have to generate isoSPI pulses to use this 2-wire interface. The first ADES1830/ADES1831 in the system can communicate to the microcontroller using the 4-wire SPI on its Port A, then daisy-chain to other ADES1830/ADES1831s using the 2-wire isoSPI on its Port B. Alternatively, the ADBMS6821 or ADBMS6822 can be used to translate the SPI signals into isoSPI pulses.

When the ADES1830/ADES1831 are operating with Port A as an SPI (ISOMD = V-), the SPI detects one of four communication events: CSB falling, CSB rising, SCK rising with SDI = 0, and SCK rising with SDI = 1. Each event is converted into one of four pulse types for transmission to another daisy-chained ADES1830/

SERIAL INTERFACE OVERVIEW

ADES1831. Long pulses are used to transmit CSB changes and short pulses transmit data, as explained in [Table 39](#).

Table 39. Port B (Controller) isoSPI Port Function

Communication Event (Port A SPI)	Transmitted Pulse (Port B isoSPI)
CS Rising	Long +1
CS Falling	Long -1
SCK Rising Edge, SDI = 1	Short +1
SCK Rising Edge, SDI = 0	Short -1

On the other side of the isolation barrier (that is, at the other end of the cable), the second ADES1830/ADES1831 has $ISOMD = V_{REG}$.

Table 40. Port A (Target) isoSPI Port Function

Received Pulse (Target isoSPI Port)	Internal SPI Port Action	Return Pulse
Long +1	Drive CSB high	None
Long -1	Drive CSB low	None
Short +1	Set SDI = 1 Pulse SCK	Short -1 pulse if reading 0 bits Short +1 pulse if reading 1 bit (no return pulse if not in read mode)
Short -1	Set SDI = 0 Pulse SCK	Short -1 pulse if reading 0 bits Short +1 pulse if reading a 1 bit (no return pulse if not in read mode)

Its Port A operates as a target isoSPI. It receives each transmitted pulse and reconstructs the SPI signals internally, as shown in [Table 40](#). In addition, during a read command, this port can transmit return data pulses.

The target isoSPI port (target) never transmits long (CSB) pulses. A target isoSPI port transmits short -1 pulses, a short +1 pulse when reading back a data bit. If the controller port receives a null response rather than a short +1 pulse or a short -1 pulse, it recognizes the null response as a Logic 1 bit.

SERIAL INTERFACE OVERVIEW

Timing Diagrams

Figure 31 shows the isoSPI timing diagram for a read command to daisy-chained ADES1830/ADES1831 devices. The ISOMD pin is tied to V- on the bottom device and the corresponding Port A is configured as an SPI port (CSB, SCK, SDI, and SDO). The isoSPI signals of three stacked devices are shown labeled with the port (Port A or Port B) and the device number. Note that ISO B1 and ISO A2 are the same signal but are shown on each end of the transmission cable that connects Device 1 and Device 2. Likewise, ISO B2 and ISO A3 are the same signal, but with the cable delay shown between Device 2 and Device 3.

Bit WN to Bit W0 refer to the 16-bit command code and the 16-bit PEC of a read command. At the end of Bit W0, the three devices decode the read command and begin shifting out valid data on the next rising edge of clock SCK. Bit XN to Bit X0 refer to the data shifted out by Device 1. Bit YN to Bit Y0 refer to the data shifted out by Device 2, and Bit ZN to Bit Z0 refer to the data shifted out by Device 3. All data is read back from the SDO port on Device 1 in a daisy-chained fashion.

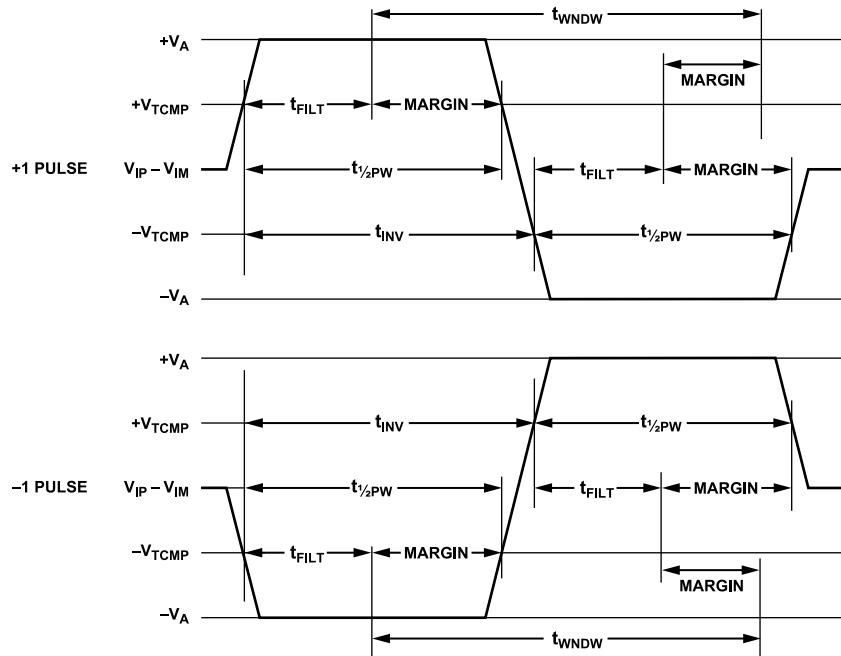


Figure 30. isoSPI Pulse Detail

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SERIAL INTERFACE OVERVIEW

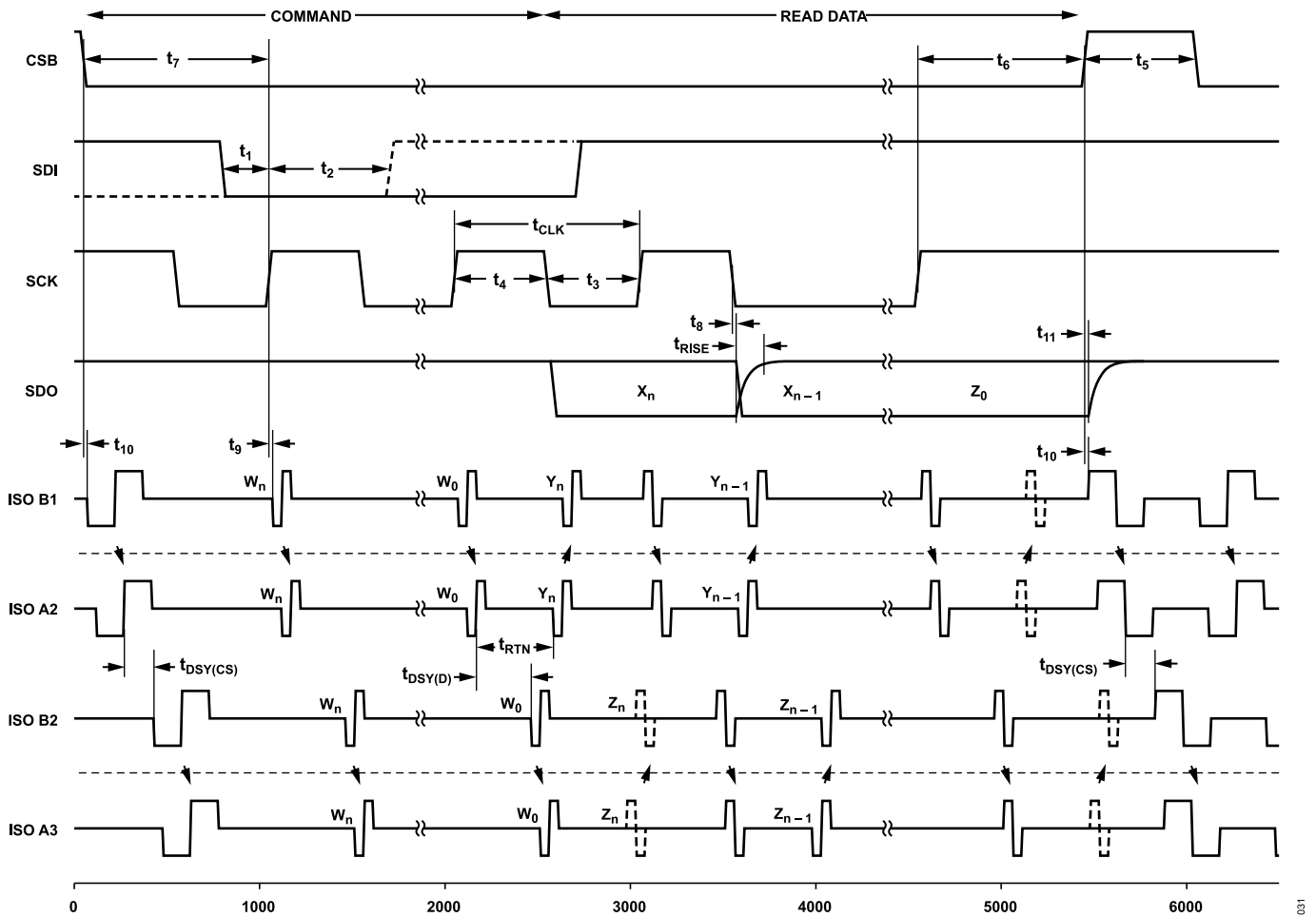


Figure 31. isoSPI Read Command Timing with Daisy-Chained Devices

Waking Up the Serial Interface

The serial ports (SPI or isoSPI) enter the low power idle state if there is no activity on Port A or Port B for a time of t_{IDLE} . The wake-up circuit monitors activity on CSB (IMA) and SCK (IPA) and activity on IMB and IPB for the ADES1830/ADES1831.

If $ISOMD = V-$, Port A is in SPI mode. Activity on the CSB pin or the SCK pin wakes up the SPI. If $ISOMD = V_{REG}$, Port A is in isoSPI mode. Differential activity on IPA to IMB wakes up the isoSPI. The ADES1830/ADES1831 is ready to communicate when the isoSPI state changes to ready within t_{WAKE} or t_{READY} , depending on the core state (see Figure 14 and the state descriptions for details).

Figure 32 shows the timing and the functionally equivalent circuit. The wake-up circuit responds to the difference between SCK (IPA) and CS (IMA). Common-mode signals do not wake up the serial interface. The interface is designed to wake up after receiving a

large signal single-ended pulse or a low amplitude symmetric pulse. The differential signal $|SCK(IPA) - CS(IMA)|$ must be at least $V_{WAKE} = 400\text{ mV}$ for a minimum duration of $t_{DWELL} = 240\text{ ns}$ to qualify as a wake-up signal that powers up the serial interface.

A robust wake-up method manually sends isoSPI traffic for enough time to wake the entire daisy chain. At a minimum, a pair of long isoSPI pulses (-1 and +1) is needed for each device, separated by more than t_{READY} or t_{WAKE} (if the core state is standby or sleep, respectively), but less than t_{IDLE} . This method allows each device to wake up and propagate the next pulse to the following device. This method works even if some devices in the chain are not in the idle state. In practice, implementing this method requires toggling the CSB pin (of the ADBMS6821 or ADBMS6822, or the bottom ADES1830/ADES1831 with $ISOMD = 0$) to generate the long isoSPI pulses. Alternatively, dummy commands (such as RDCFG) can be executed to generate the long isoSPI pulses.

SERIAL INTERFACE OVERVIEW

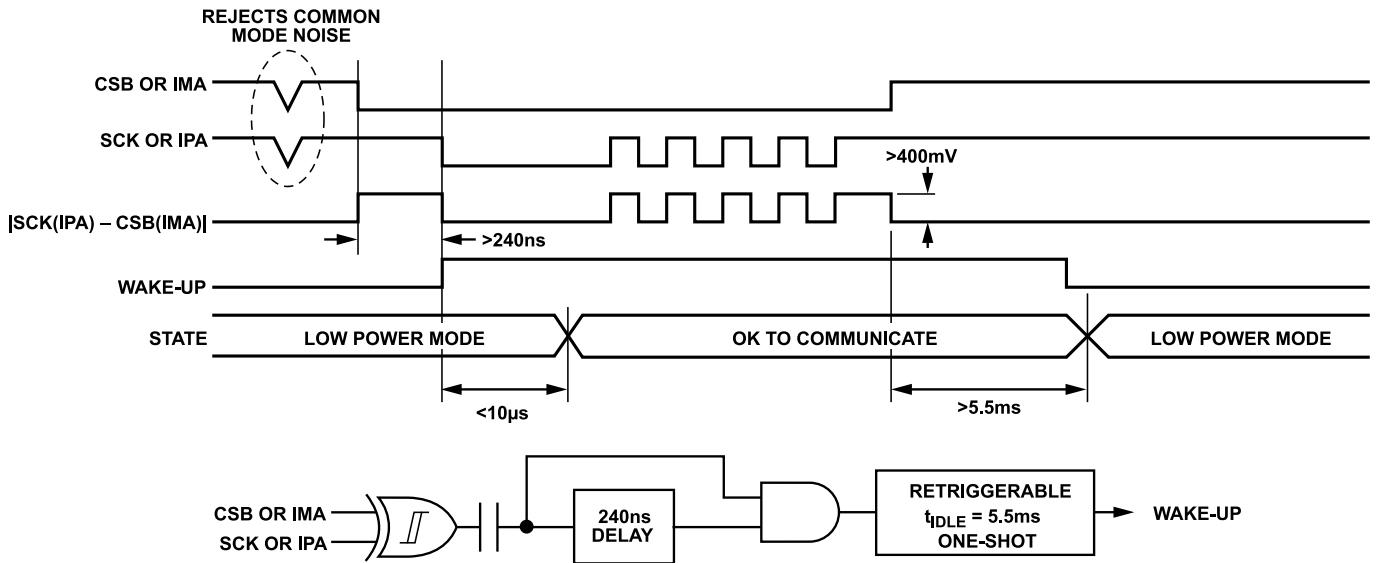


Figure 32. Wake-Up Detection and Idle Timer

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NETWORK LAYER

COMMAND PEC

The command PEC is a 15-bit cyclic redundancy check (CRC) value calculated for all 16 bits of a command, using the initial PEC value of 000000000010000 and the following characteristic polynomial: $x^{15} + x^{14} + x^{10} + x^8 + x^7 + x^4 + x^3 + 1$.

The ADES1830/ADES1831 calculates the command PEC for any command received and compares it with the PEC following the command. The command is regarded as valid only if the PEC matches. [Table 41](#) shows the format of the command PEC.

Table 41. Command PEC Format

Name	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PEC0	RD/WR	PEC[14]	PEC[13]	PEC[12]	PEC[11]	PEC[10]	PEC[9]	PEC[8]	PEC[7]
PEC1	RD/WR	PEC[6]	PEC[5]	PEC[4]	PEC[3]	PEC[2]	PEC[1]	PEC[0]	0

DATA PEC

The data PEC is a 10-bit CRC value calculated for all bits read from a register and the command counter bits. The initial PEC value is 0000010000 and the following characteristic polynomial: $x^{10} + x^7 + x^3 + x^2 + x + 1$. Data is regarded as valid only if the data PEC matches.

For write commands and the CLRFLAG command, data is sent to the ADES1830/ADES1831 followed by the data PEC. For example, when writing to the Configuration Register Group A, the data is sent in the following order: CFGAR0, ..., CFGAR5, PEC0, PEC1.

[Table 42](#) shows the format for the data PEC when writing data.

Table 42. Write Data PEC Format

Name	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PEC0	RD/WR	0	0	0	0	0	0	PEC[9]	PEC[8]
PEC1	RD/WR	PEC[7]	PEC[6]	PEC[5]	PEC[4]	PEC[3]	PEC[2]	PEC[1]	PEC[0]

COMMAND COUNTER

A command counter enhances system level software diagnostics and communication integrity. The command counter is initialized to 0 on power cycling, transition to sleep, or by the RSTCC or SRST commands. The command counter increments if the ADES1830/ADES1831 receives a command indicated by the INC column of [Table 50](#). When the command counter increments past the maximum value of 63, it rolls over to a value of 1, not 0. The 0 value is reserved for the specific reset cases listed previously. All read commands return the register data followed by the command counter and data PEC.

[Table 43](#) shows the format for the command counter and data PEC when reading data. The host can initialize the command counter in the ADES1830/ADES1831 and then verify the command counter value from the ADES1830/ADES1831 against an expected value after sending a sequence of commands.

Table 43. Read Data PEC Format

Name	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PEC0	RD/WR	CCNT[5]	CCNT[4]	CCNT[3]	CCNT[2]	CCNT[1]	CCNT[0]	PEC[9]	PEC[8]
PEC1	RD/WR	PEC[7]	PEC[6]	PEC[5]	PEC[4]	PEC[3]	PEC[2]	PEC[1]	PEC[0]

NETWORK LAYER

POLLING METHODS

The simplest method to determine ADC completion is for the controller to start an ADC conversion and wait for the specified conversion time to pass before reading the results. The ADES1830/ADES1831 also allows the use of polling to determine ADC completion.

In configurations that communicate in SPI mode (ISOMD pin tied low), there are two methods of polling. The first method is to hold CSB low after an ADC conversion command is sent. After entering a conversion command, the SDO line is driven low when the device is busy performing conversions. SDO is pulled high when the device completes conversions. However, SDO also returns high when CSB goes high even if the device has not completed the conversion (see Figure 33). A problem with this method is that the controller is not free to do other serial communication while waiting for ADC conversions to complete.

The next method overcomes this limitation. The controller can send an ADC start command, perform other tasks, and then send a polling command to determine the status of ADC conversions. The ADES1830/ADES1831 allows polling the end of conversion individually per type of ADC by four different commands, where PLCADC, PLSADC, PLAUX, and PLAUX2 poll the status of the C-ADCs, S-ADCs, AUX ADC, and AUX2 ADC, respectively. PLADC polls the status of all ADCs together, which is only meaningful, if only single shot measures are triggered, because any ADC in continuous mode prevents successful polling of the end of conversion of other ADCs. After entering a polling command, SDO goes low if the device is busy performing a related operation. SDO is pulled high at the end of the operations. However, SDO also goes high when CSBI goes high, even if the device has not completed the operation.

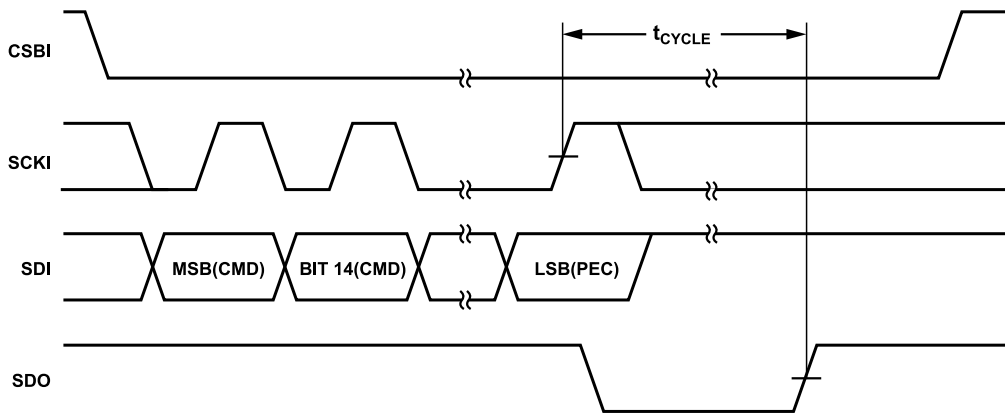


Figure 33. SDO Polling After an ADC Conversion Command

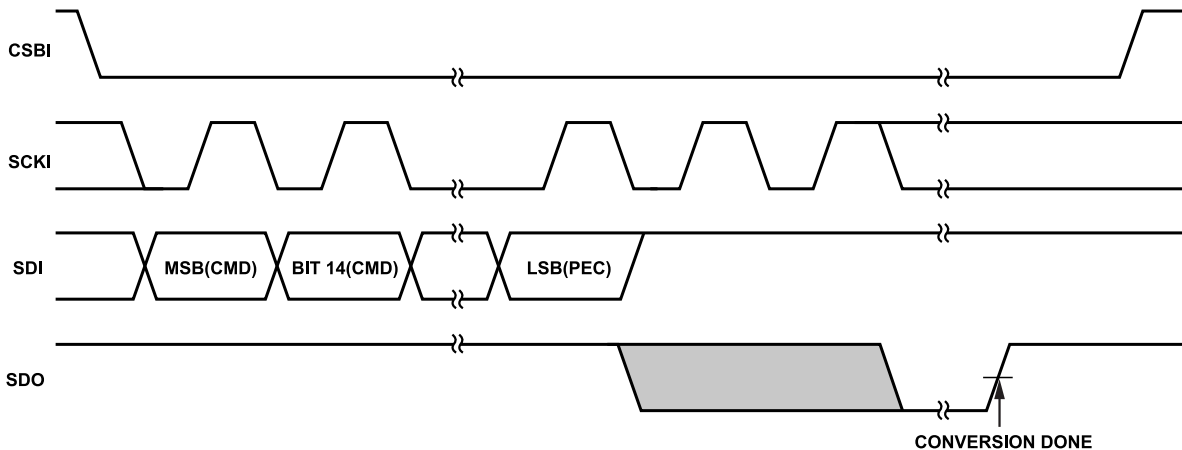


Figure 34. SDO Polling Using PLADC Command

NETWORK LAYER

In a daisy-chained configuration of x stacked devices, the same two polling methods can be used. If the bottom device communicates in SPI mode, the SDO of the bottom device indicates the operation status of the entire stack, that is, SDO remains low until all the devices in the stack complete the operations. In the first method of polling, after an ADC conversion command is sent, clock pulses are sent on SCK while keeping CSB low. The SDO status is valid only at the end of $2 \times N$ clock pulses on SCK and updates for every clock pulse that follows (see Figure 35).

In the second method, the PLADC command is sent followed by clock pulses on SCK while keeping CSB low. Similar to the first method, the SDO status is valid only after $2 \times N$ clock cycles on

SCKI and updates after every clock cycle that follows (see Figure 35).

If the bottom device communicates in isoSPI mode, isoSPI data pulses are sent to the device to update the operation status. Using the ADBMS6821 or ADBMS6822, this action can be achieved by clocking the SCK pin on the device. The operation status is valid only after the bottom ADES1830/ADES1831 device receives $2 \times N$ isoSPI data pulses and the status updates for every isoSPI data pulse that follows. The device returns a low data pulse if any of the devices in the stack are busy performing operations and returns a high data pulse if all the devices are free.

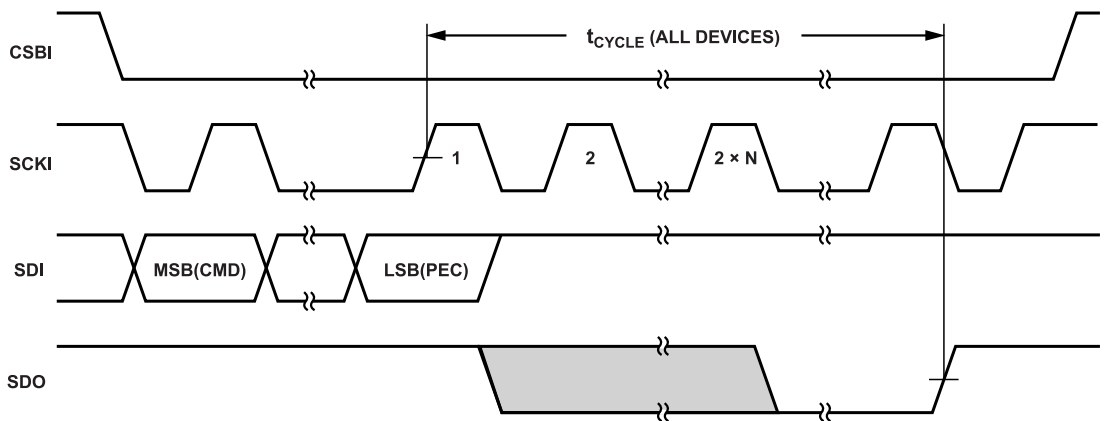


Figure 35. SDO Polling After an ADC Conversion Command (Daisy-Chain Configuration)

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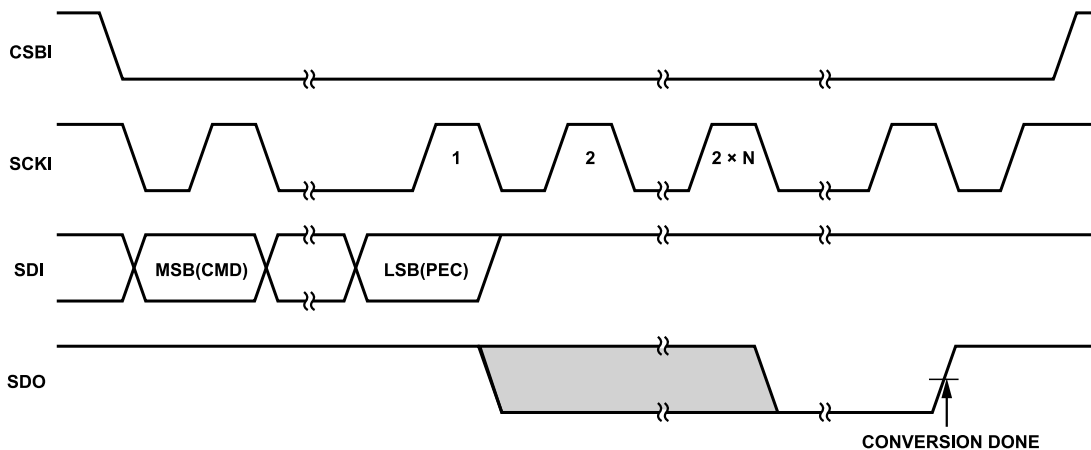


Figure 36. SDO Polling Using PLADC Command (Daisy-Chain Configuration)

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NETWORK LAYER

BUS PROTOCOLS

Table 45 through Table 47 show the protocol formats for commands. Table 44 is the key for reading the protocol diagrams.

Table 46 shows the write command sending data first to Device N, which is farthest from the host and sending data last to Device 1, which is closest to the host.

Table 47 shows the read command receiving data first from Device 1, which is closest to the host and receiving data last from Device N, which is farthest from the host.

Table 44. Protocol Key

Byte	Description
CMD0	Command Byte 0 (see Table 48)
CMD1	Command Byte 1 (see Table 48)
PEC0	Command Packet Error Code Byte 0 (see Table 41)
PEC1	Command Packet Error Code Byte 1 (see Table 41)
DPEC0	Data Packet Error Code Byte 0
DPEC1	Data Packet Error Code Byte 1
...	Continuation of protocol

Table 45. Poll Command

8	8	8	8
CMD0	CMD1	PEC0	PEC1
Poll data			

Table 46. Write Command

Data to Device N									Data to Device 1					
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
CMD0	CMD1	PEC0	PEC1	Data byte low	...	Data byte high	DPEC0	DPEC1	...	Data byte low	...	Data byte high	DPEC0	DPEC1

Table 47. Read Command

Data from Device 1									Data from Device N					
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
CMD0	CMD1	PEC0	PEC1	Data byte low	...	Data byte high	DPEC0	DPEC1	...	Data byte low	...	Data byte high	DPEC0	DPEC1

Table 48. Command Format

Name	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMD0	WR	0	0	0	0	0	CC[10]	CC[9]	CC[8]
CMD1	WR	CC[7]	CC[6]	CC[5]	CC[4]	CC[3]	CC[2]	CC[1]	CC[0]

Command Format

Table 49 shows the format for commands. Table 50 shows a list of all the command codes. The PEC for commands must be computed on the entire 16-bit command (CMD0 and CMD1).

Table 49. Command Format

Name	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMD0	WR	0	0	0	0	0	CC[10]	CC[9]	CC[8]
CMD1	WR	CC[7]	CC[6]	CC[5]	CC[4]	CC[3]	CC[2]	CC[1]	CC[0]

COMMANDS

Table 50 lists all the commands and their options. INC designates whether the command counter increments for the command.

Table 50. Command Codes

Command Description	Name	INC	CC[10:0] – Command Code											
			10	9	8	7	6	5	4	3	2	1	0	
Write Configuration Register Group A	WRCFGA	Yes ¹	0	0	0	0	0	0	0	0	0	0	0	1
Write Configuration Register Group B	WRCFGB	Yes ¹	0	0	0	0	0	0	1	0	0	1	0	0
Read Configuration Register Group A	RDCFGA		0	0	0	0	0	0	0	0	0	0	1	0
Read Configuration Register Group B	RDCFGB		0	0	0	0	0	0	1	0	0	1	1	0
Read Cell Voltage Register Group A	RDCVA		0	0	0	0	0	0	0	0	0	1	0	0
Read Cell Voltage Register Group B	RDCVB		0	0	0	0	0	0	0	0	0	1	1	0
Read Cell Voltage Register Group C	RDCVC		0	0	0	0	0	0	0	0	1	0	0	0
Read Cell Voltage Register Group D	RDCVD		0	0	0	0	0	0	0	0	1	0	1	0
Read Cell Voltage Register Group E	RDCVE		0	0	0	0	0	0	0	0	1	0	0	1
Read Cell Voltage Register Group F	RDCVF		0	0	0	0	0	0	0	0	1	0	1	1
Read All Cell Results	RDCVALL		0	0	0	0	0	0	0	0	1	1	0	0
Read Averaged Cell Voltage Register Group A	RDACA		0	0	0	0	0	1	0	0	0	1	0	0
Read Averaged Cell Voltage Register Group B	RDACB		0	0	0	0	0	1	0	0	0	1	1	0
Read Averaged Cell Voltage Register Group C	RDACC		0	0	0	0	0	1	0	0	1	0	0	0
Read Averaged Cell Voltage Register Group D	RDACD		0	0	0	0	0	1	0	0	1	0	1	0
Read Averaged Cell Voltage Register Group E	RDACE		0	0	0	0	0	1	0	0	1	0	0	1
Read Averaged Cell Voltage Register Group F	RDACF		0	0	0	0	0	1	0	0	1	0	1	1
Read All Avg Cell Results	RDACALL		0	0	0	0	0	1	0	0	1	1	0	0
Read S Voltage Register Group A	RDSVA		0	0	0	0	0	0	0	0	0	0	1	1
Read S Voltage Register Group B	RDSVB		0	0	0	0	0	0	0	0	0	1	0	1
Read S Voltage Register Group C	RDSVC		0	0	0	0	0	0	0	0	0	1	1	1
Read S Voltage Register Group D	RDSVD		0	0	0	0	0	0	0	0	1	1	0	1
Read S Voltage Register Group E	RDSVE		0	0	0	0	0	0	0	0	1	1	1	0
Read S Voltage Register Group F	RDSVF		0	0	0	0	0	0	0	0	1	1	1	1
Read All S Results	RDSALL		0	0	0	0	0	0	0	1	0	0	0	0
Read all C and S Results	RDCSALL		0	0	0	0	0	0	0	1	0	0	0	1
Read all Average C and S Results	RDACSALL		0	0	0	0	0	1	0	1	0	0	0	1
Read Filter Cell Voltage Register Group A	RDFCA		0	0	0	0	0	0	0	1	0	0	1	0
Read Filter Cell Voltage Register Group B	RDFCB		0	0	0	0	0	0	0	1	0	0	1	1
Read Filter Cell Voltage Register Group C	RDFCC		0	0	0	0	0	0	0	1	0	1	0	0
Read Filter Cell Voltage Register Group D	RDFCD		0	0	0	0	0	0	0	1	0	1	0	1
Read Filter Cell Voltage Register Group E	RDFCE		0	0	0	0	0	0	0	1	0	1	1	0
Read Filter Cell Voltage Register Group F	RDFCF		0	0	0	0	0	0	0	1	0	1	1	1
Read All Filter Cell Results	RDFCALL		0	0	0	0	0	0	0	1	1	0	0	0
Read Auxiliary Register Group A	RDAUXA		0	0	0	0	0	0	0	1	1	0	0	1
Read Auxiliary Register Group B	RDAUXB		0	0	0	0	0	0	0	1	1	0	1	0
Read Auxiliary Register Group C	RDAUXC		0	0	0	0	0	0	0	1	1	0	1	1
Read Auxiliary Register Group D	RDAUXD		0	0	0	0	0	0	0	1	1	1	1	1
Read Redundant Auxiliary Register Group A	RDRAXA		0	0	0	0	0	0	0	1	1	1	0	0
Read Redundant Auxiliary Register Group B	RDRAXB		0	0	0	0	0	0	0	1	1	1	0	1
Read Auxiliary Redundant Register Group C	RDRAXC		0	0	0	0	0	0	0	1	1	1	1	0
Read Auxiliary Redundant Register Group D	RDRAXD		0	0	0	0	0	0	1	0	0	1	0	1
Read Status Register Group A	RDSTATA		0	0	0	0	0	0	1	1	0	0	0	0
Read Status Register Group B	RDSTATB		0	0	0	0	0	0	1	1	0	0	0	1
Read Status Register Group C	RDSTATC		0	0	0	0	0	ERR	1	1	0	0	1	0
Read Status Register Group D	RDSTATD		0	0	0	0	0	0	1	1	0	0	1	1

COMMANDS

Table 50. Command Codes (Continued)

Command Description	Name	INC	CC[10:0] – Command Code										
			10	9	8	7	6	5	4	3	2	1	0
Read Status Register Group E	RDSTATE		0	0	0	0	0	1	1	0	1	0	0
Read all AUX/Status Registers	RDASALL		0	0	0	0	0	1	1	0	1	0	1
Write PWM Register Group A	WRPWMA	Yes ¹	0	0	0	0	0	1	0	0	0	0	0
Read PWM Register Group A	RDPWMA		0	0	0	0	0	1	0	0	0	1	0
Write PWM Register Group B	WRPWMB	Yes ¹	0	0	0	0	0	1	0	0	0	0	1
Read PWM Register Group B	RDPWMB		0	0	0	0	0	1	0	0	0	1	1
LPCM Disable	CMDIS	Yes	0	0	0	0	1	0	0	0	0	0	0
LPCM Enable	CMEN	Yes	0	0	0	0	1	0	0	0	0	0	1
LPCM Heartbeat	CMHB ²		0	0	0	0	1	0	0	0	0	1	1
Write LPCM Configuration Register	WRCMCFG	Yes ¹	0	0	0	0	1	0	1	1	0	0	0
Read LPCM Configuration Register	RDCMCFG		0	0	0	0	1	0	1	1	0	0	1
Write LPCM Cell Threshold	WRCMCELLT	Yes ¹	0	0	0	0	1	0	1	1	0	1	0
Read LPCM Cell Threshold	RDCMCELLT		0	0	0	0	1	0	1	1	0	1	1
Write LPCM GPIO Threshold	WRCMGPLOT	Yes ¹	0	0	0	0	1	0	1	1	1	0	0
Read LPCM GPIO Threshold	RDCMGPLOT		0	0	0	0	1	0	1	1	1	0	1
Clear LPCM Flags	CLRCMFLAG	Yes ¹	0	0	0	0	1	0	1	1	1	1	0
Read LPCM Flags	RDCMFLAG		0	0	0	0	1	0	1	1	1	1	1
Start Cell Voltage ADC Conversion and Poll Status	ADCV	Yes	0	1	RD	CONT	1	1	DCP	0	RSTF	OW[1]	OW[0]
Start S-ADC Conversion and Poll Status	ADSV	Yes	0	0	1	CONT	1	1	DCP	1	0	OW[1]	OW[0]
Start AUX ADC Conversions and Poll Status	ADAX	Yes	1	0	OW	PUP	CH[4]	0	1	CH[3]	CH[2]	CH[1]	CH[0]
Start AUX2 ADC Conversions and Poll Status	ADAX2	Yes	1	0	0	0	0	0	0	CH[3]	CH[2]	CH[1]	CH[0]
Clear Cell Voltage Register Groups	CLRCELL	Yes	1	1	1	0	0	0	1	0	0	0	1
Clear Filtered Cell Voltage Register Groups	CLRFC	Yes	1	1	1	0	0	0	1	0	1	0	0
Clear Auxiliary Register Groups	CLRAUX	Yes	1	1	1	0	0	0	1	0	0	1	0
Clear S-Voltage Register Groups	CLRSPIN	Yes	1	1	1	0	0	0	1	0	1	1	0
Clear Flags	CLRFLAG	Yes ¹	1	1	1	0	0	0	1	0	1	1	1
Clear OVUV	CLOVUV	Yes ¹	1	1	1	0	0	0	1	0	1	0	1
Poll Any ADC Status	PLADC	Yes	1	1	1	0	0	0	1	1	0	0	0
Poll C-ADC	PLCADC	Yes	1	1	1	0	0	0	1	1	1	0	0
Poll S-ADC	PLSADC	Yes	1	1	1	0	0	0	1	1	1	0	1
Poll AUX ADC	PLAUX	Yes	1	1	1	0	0	0	1	1	1	1	0
Poll AUX2 ADC	PLAUX2	Yes	1	1	1	0	0	0	1	1	1	1	1
Write COMM Register Group	WRCOMM	Yes ¹	1	1	1	0	0	1	0	0	0	0	1
Read COMM Register Group	RDCOMM		1	1	1	0	0	1	0	0	0	1	0
Start I2C/SPI Communication	STCOMM	Yes	1	1	1	0	0	1	0	0	0	1	1
Mute Discharge	MUTE	Yes	0	0	0	0	0	1	0	1	0	0	0
Unmute Discharge	UNMUTE	Yes	0	0	0	0	0	1	0	1	0	0	1
Read Serial ID Register Group	RDSID		0	0	0	0	0	1	0	1	1	0	0
Reset Command Counter	RSTCC		0	0	0	0	0	1	0	1	1	1	0
Snapshot	SNAP	Yes	0	0	0	0	0	1	0	1	1	0	1
Release Snapshot	UNSNAP	Yes	0	0	0	0	0	1	0	1	1	1	1
Soft Reset	SRST		0	0	0	0	0	1	0	0	1	1	1
Unlock Retention Register	ULRR	Yes	0	0	0	0	0	1	1	1	0	0	0
Write Retention Registers	WRRR	Yes ¹	0	0	0	0	0	1	1	1	0	0	1
Read Retention Registers	RDRR		0	0	0	0	0	1	1	1	0	1	0

COMMANDS

- ¹ A valid data packet, including valid data PEC, must be received on the positive edge of CSB for the command counter to increment.
- ² CMHB is usually initiated by the LPCM MM device. The microprocessor can initiate CMHB for diagnostics or some limited application configurations but requires LPCM mode active for the command to be processed.

Table 51. Command Bit Descriptions

Name	Function	Value					AUX Input
CH[4:0]	Selection for AUX Inputs ADAX: CH[4:0]. ADAX2: CH[3:0]	CH[4]	CH[3]	CH[2]	CH[1]	CH[0]	
		0	0	0	0	0	ALL
		0	0	0	0	1	GPIO1
		0	0	0	1	0	GPIO2
		0	0
		0	1	0	0	1	GPIO9
		1	0	0	0	0	VREF2
		1	0	0	0	1	VD
		1	0	0	1	0	VA
		1	0	0	1	1	ITEMP
		1	0	1	0	0	VPV
		1	0	1	0	1	VMV
1	0	1	1	0	RES		
1	0	1	1	1	Reserved		

Table 52. Command Bit Description Continued

Name	Function	Values	Description
CONT	Continuous	0	Single measurement, then standby
		1	Continuous measurement
OW[1:0]	Open wire on C-ADCS and S-ADCS	00	Open wire detection off on all channels
		01	Open wire detection on for even channels, off for odd channels
		10	Open wire detection on for odd channels, off for even channels
		11	Open wire detection on for all channels
OW	Open wire on AUX ADCs	0	Off
		1	On
PUP	Pull-up and pull-down current for open wire conversions	0	Pull-down current during AUX conversions (if OW = 1)
		1	Pull-up current during AUX conversions (if OW = 1)
DCP	Discharge permitted	0	Discharge not permitted during S-ADC measurements (see the Discharge During Measurements section for details)
		1	Discharge permitted during S-ADC measurements (see the Discharge During Measurements section for details)
RSTF	Reset filter	0	Do not reset IIR filter
		1	Reset IIR filter
ERR	Inject error in SPI read- out	0	Reading Status Register C without error injection
		1	Reading Status Register C with error injection for latent fault detection, Bit SPIFLT must be set

COMMANDS

READ ALL AND SNAPSHOT COMMANDS

Most of the read commands of the ADES1830/ADES1831 allow the device to read a single register group composed by 6 bytes followed by the PEC. Therefore, successive readings of two register groups may not provide coherent data. Coherent data reading is possible by either using the read all commands (for single IC applications only) or by using the snap (and unsnap) command (supported in all applications), as described in the [Read All Commands](#) section.

READ ALL COMMANDS

The ADES1830/ADES1831 supports the ability to read an entire group of measurement registers for single IC applications. Note that unused bytes in a register group are not transmitted.

The RDCVALL command allows a controller to read Cell Voltage Register Group A through Cell Voltage Register Group F (32 data bytes for the ADES1830/ADES1831) by issuing a single command, followed by a single 2-byte PEC for the entire readback packet.

The RDACALL command allows a controller to read Averaged Cell Voltage Register Group A through Averaged Cell Voltage Register Group F (32 data bytes for the ADES1830/ADES1831) by issuing a single command, followed by a single 2-byte PEC for the entire readback packet.

The RDFCALL command allows a controller to read Filtered Cell Voltage Register Group A through Filtered Cell Voltage Register Group F (32 data bytes for the ADES1830/ADES1831) by issuing a single command, followed by a single 2-byte PEC for the entire readback packet.

The RDSALL command allows a controller to read S Voltage Register Group A through S Voltage Register Group F (32 data bytes for the ADES1830/ADES1831) by issuing a single command, followed by a single 2-byte PEC for the entire readback packet.

The RDCSALL command allows a controller to read Cell Voltage Register Group A through Cell Voltage Register Group F followed by S Voltage Register Group A through S Voltage Register Group F (64 data bytes for the ADES1830/ADES1831), by issuing a single command, followed by a single 2-byte PEC for the entire readback packet.

The RDACSALL command allows a controller to read Average Cell Voltage Register Group A through Average Cell Voltage Register Group F followed by S Voltage Register Group A through S Voltage Register Group F (64 data bytes for the ADES1830/ADES1831), by issuing a single command, followed by a single 2-byte PEC for the entire readback packet.

The RDASALL command reads Auxiliary Register Group A through Auxiliary Register Group D in the ADES1830/ADES1831, followed by Redundant Auxiliary Register Group A through Redundant Auxiliary Register Group D, followed by Status Register Group A through Status Register Group E by issuing a single command, followed by

a single 2-byte PEC for the entire readback packet. The RDASALL command returns 68 bytes of data because STCR2 and STCR3 of Status Register C are not included.

SNAPSHOT COMMANDS

To enable reading of coherent data in the daisy-chain operation, the snap command allows the device to freeze all result and status registers at a given time, and read them at convenience before releasing the freeze by an unsnap command. During the freeze of the results registers, the ADC results add to the IIR filter in continuous mode. If redundancy is enabled, the comparison between S-ADC and C-ADC measurement is still performed. Furthermore, the ADES1830/ADES1831 keeps track of any (alert) flag during the freeze and updates the status registers accordingly after an unsnap command. Note that sending additional snap commands while the result registers are already frozen does not have any effect. Upon reception of a snap or unsnap command, the command counter increments. The following registers are subject to the snap protocol:

- ▶ Cell Voltage Register Group A through Cell Voltage Register Group F
- ▶ S Voltage Register Group A through S Voltage Register Group F
- ▶ Average Cell Voltage Register Group A through Average Cell Voltage Register Group F
- ▶ Filtered Cell Voltage Register Group A through Filtered Cell Voltage Register Group F
- ▶ STCR0 to STCR3 from Status Register Group C and STDR0 to STDR4 of Status Register Group D

Polling end of ADC conversions is not supported while in freeze state.

RETENTION REGISTER COMMANDS

The ADES1830/ADES1831 retains 6 bytes of data in the retention registers even during sleep mode. To write to the retention register group, send an unlock retention register (ULRR) command followed by a write retention register (WRRR) command with 6 bytes of RR data followed by the data PEC bytes. Even if the two bytes of data PEC do not match the 6 bytes of data payload, the WRRR command is executed anyway. Any other command sent after a ULRR command locks the writing to the retention register group. The data in the retention registers can be read through a read retention register (RDRR) command.

MEMORY MAP

Note: Reserved bits can be either 0 or 1 and are part of the PEC calculation.

Table 53. Serial ID Register Group (RDSID)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Default
SIDR0	Read	SID[7]	SID[6]	SID[5]	SID[4]	SID[3]	SID[2]	SID[1]	SID[0]	0xXX
SIDR1	Read	SID[15]	SID[14]	SID[13]	SID[12]	SID[11]	SID[10]	SID[9]	SID[8]	0xXX
SIDR2	Read	SID[23]	SID[22]	SID[21]	SID[20]	SID[19]	SID[18]	SID[17]	SID[16]	0xXX
SIDR3	Read	SID[31]	SID[30]	SID[29]	SID[28]	SID[27]	SID[26]	SID[25]	SID[24]	0xXX
SIDR4	Read	SID[39]	SID[38]	SID[37]	SID[36]	SID[35]	SID[34]	SID[33]	SID[32]	0xXX
SIDR5	Read	SID[47]	SID[46]	SID[45]	SID[44]	SID[43]	SID[42]	SID[41]	SID[40]	0xXX

Table 54. Serial ID Register Group Bit Descriptions

Register	Bits	Bit Name	Description
SIDR0 to SIDR5	[7:0]	SID[x]	Serial ID Bits. Read only access is provided to the unique ID.
SIDR1	[6:1]	SID[x]	Device ID = 00 0011 for the ADES1830/ADES1831.

Table 55. Configuration Register Group A (RDCFGA, WRCFGA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CFGAR0	RD/WR	REFON	0	0	0	0	CTH[2]	CTH[1]	CTH[0]
CFGAR1	RD/WR	FLAG_D[7]	FLAG_D[6]	FLAG_D[5]	FLAG_D[4]	FLAG_D[3]	FLAG_D[2]	FLAG_D[1]	FLAG_D[0]
CFGAR2	RD/WR	SOAKON	OWRNG	OWA[2]	OWA[1]	OWA[0]	0	0	0
CFGAR3	RD/WR	GPO[8]	GPO[7]	GPO[6]	GPO[5]	GPO[4]	GPO[3]	GPO[2]	GPO[1]
CFGAR4	RD/WR	0	0	0	0	0	0	GPO[10]	GPO[9]
CFGAR5	RD/WR	0	0	SNAP_ST	MUTE_ST	COMM_BK	FC[2]	FC[1]	FC[0]

Table 56. Configuration Register Group B (RDCFGB, WRCFGB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CFGBR0	RD/WR	VUV[7]	VUV[6]	VUV[5]	VUV[4]	VUV[3]	VUV[2]	VUV[1]	VUV[0]
CFGBR1	RD/WR	VOV[3]	VOV[2]	VOV[1]	VOV[0]	VUV[11]	VUV[10]	VUV[9]	VUV[8]
CFGBR2	RD/WR	VOV[11]	VOV[10]	VOV[9]	VOV[8]	VOV[7]	VOV[6]	VOV[5]	VOV[4]
CFGBR3	RD/WR	DTMEN	DTRNG	DCTO[5]	DCTO[4]	DCTO[3]	DCTO[2]	DCTO[1]	DCTO[0]
CFGBR4	RD/WR	DCC[8]	DCC[7]	DCC[6]	DCC[5]	DCC[4]	DCC[3]	DCC[2]	DCC[1]
CFGBR5	RD/WR	DCC[16]	DCC[15]	DCC[14]	DCC[13]	DCC[12]	DCC[11]	DCC[10]	DCC[9]

Table 57. Cell Voltage Register Group A (RDCVA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVAR0	RD	C1V[7]	C1V[6]	C1V[5]	C1V[4]	C1V[3]	C1V[2]	C1V[1]	C1V[0]
CVAR1	RD	C1V[15]	C1V[14]	C1V[13]	C1V[12]	C1V[11]	C1V[10]	C1V[9]	C1V[8]
CVAR2	RD	C2V[7]	C2V[6]	C2V[5]	C2V[4]	C2V[3]	C2V[2]	C2V[1]	C2V[0]
CVAR3	RD	C2V[15]	C2V[14]	C2V[13]	C2V[12]	C2V[11]	C2V[10]	C2V[9]	C2V[8]
CVAR4	RD	C3V[7]	C3V[6]	C3V[5]	C3V[4]	C3V[3]	C3V[2]	C3V[1]	C3V[0]
CVAR5	RD	C3V[15]	C3V[14]	C3V[13]	C3V[12]	C3V[11]	C3V[10]	C3V[9]	C3V[8]

Table 58. Cell Voltage Register Group B (RDCVB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVBR0	RD	C4V[7]	C4V[6]	C4V[5]	C4V[4]	C4V[3]	C4V[2]	C4V[1]	C4V[0]
CVBR1	RD	C4V[15]	C4V[14]	C4V[13]	C4V[12]	C4V[11]	C4V[10]	C4V[9]	C4V[8]
CVBR2	RD	C5V[7]	C5V[6]	C5V[5]	C5V[4]	C5V[3]	C5V[2]	C5V[1]	C5V[0]
CVBR3	RD	C5V[15]	C5V[14]	C5V[13]	C5V[12]	C5V[11]	C5V[10]	C5V[9]	C5V[8]
CVBR4	RD	C6V[7]	C6V[6]	C6V[5]	C6V[4]	C6V[3]	C6V[2]	C6V[1]	C6V[0]

MEMORY MAP

Table 58. Cell Voltage Register Group B (RDCVB) (Continued)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVBR5	RD	C6V[15]	C6V[14]	C6V[13]	C6V[12]	C6V[11]	C6V[10]	C6V[9]	C6V[8]

Table 59. Cell Voltage Register Group C (RDCVC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVCR0	RD	C7V[7]	C7V[6]	C7V[5]	C7V[4]	C7V[3]	C7V[2]	C7V[1]	C7V[0]
CVCR1	RD	C7V[15]	C7V[14]	C7V[13]	C7V[12]	C7V[11]	C7V[10]	C7V[9]	C7V[8]
CVCR2	RD	C8V[7]	C8V[6]	C8V[5]	C8V[4]	C8V[3]	C8V[2]	C8V[1]	C8V[0]
CVCR3	RD	C8V[15]	C8V[14]	C8V[13]	C8V[12]	C8V[11]	C8V[10]	C8V[9]	C8V[8]
CVCR4	RD	C9V[7]	C9V[6]	C9V[5]	C9V[4]	C9V[3]	C9V[2]	C9V[1]	C9V[0]
CVCR5	RD	C9V[15]	C9V[14]	C9V[13]	C9V[12]	C9V[11]	C9V[10]	C9V[9]	C9V[8]

Table 60. Cell Voltage Register Group D (RDCVD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVDR0	RD	C10V[7]	C10V[6]	C10V[5]	C10V[4]	C10V[3]	C10V[2]	C10V[1]	C10V[0]
CVDR1	RD	C10V[15]	C10V[14]	C10V[13]	C10V[12]	C10V[11]	C10V[10]	C10V[9]	C10V[8]
CVDR2	RD	C11V[7]	C11V[6]	C11V[5]	C11V[4]	C11V[3]	C11V[2]	C11V[1]	C11V[0]
CVDR3	RD	C11V[15]	C11V[14]	C11V[13]	C11V[12]	C11V[11]	C11V[10]	C11V[9]	C11V[8]
CVDR4	RD	C12V[7]	C12V[6]	C12V[5]	C12V[4]	C12V[3]	C12V[2]	C12V[1]	C12V[0]
CVDR5	RD	C12V[15]	C12V[14]	C12V[13]	C12V[12]	C12V[11]	C12V[10]	C12V[9]	C12V[8]

Table 61. Cell Voltage Register Group E (RDCVE)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVER0	RD	C13V[7]	C13V[6]	C13V[5]	C13V[4]	C13V[3]	C13V[2]	C13V[1]	C13V[0]
CVER1	RD	C13V[15]	C13V[14]	C13V[13]	C13V[12]	C13V[11]	C13V[10]	C13V[9]	C13V[8]
CVER2	RD	C14V[7]	C14V[6]	C14V[5]	C14V[4]	C14V[3]	C14V[2]	C14V[1]	C14V[0]
CVER3	RD	C14V[15]	C14V[14]	C14V[13]	C14V[12]	C14V[11]	C14V[10]	C14V[9]	C14V[8]
CVER4	RD	C15V[7]	C15V[6]	C15V[5]	C15V[4]	C15V[3]	C15V[2]	C15V[1]	C15V[0]
CVER5	RD	C15V[15]	C15V[14]	C15V[13]	C15V[12]	C15V[11]	C15V[10]	C15V[9]	C15V[8]

Table 62. Cell Voltage Register Group F (RDCVF)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CVFR0	RD	C16V[7]	C16V[6]	C16V[5]	C16V[4]	C16V[3]	C16V[2]	C16V[1]	C16V[0]
CVFR1	RD	C16V[15]	C16V[14]	C16V[13]	C16V[12]	C16V[11]	C16V[10]	C16V[9]	C16V[8]
CVFR2	RD	1	1	1	1	1	1	1	1
CVFR3	RD	1	1	1	1	1	1	1	1
CVFR4	RD	1	1	1	1	1	1	1	1
CVFR5	RD	1	1	1	1	1	1	1	1

Table 63. Averaged Cell Voltage Register Group A (RDACA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACVAR0	RD	AC1V[7]	AC1V[6]	AC1V[5]	AC1V[4]	AC1V[3]	AC1V[2]	AC1V[1]	AC1V[0]
ACVAR1	RD	AC1V[15]	AC1V[14]	AC1V[13]	AC1V[12]	AC1V[11]	AC1V[10]	AC1V[9]	AC1V[8]
ACVAR2	RD	AC2V[7]	AC2V[6]	AC2V[5]	AC2V[4]	AC2V[3]	AC2V[2]	AC2V[1]	AC2V[0]
ACVAR3	RD	AC2V[15]	AC2V[14]	AC2V[13]	AC2V[12]	AC2V[11]	AC2V[10]	AC2V[9]	AC2V[8]
ACVAR4	RD	AC3V[7]	AC3V[6]	AC3V[5]	AC3V[4]	AC3V[3]	AC3V[2]	AC3V[1]	AC3V[0]
ACVAR5	RD	AC3V[15]	AC3V[14]	AC3V[13]	AC3V[12]	AC3V[11]	AC3V[10]	AC3V[9]	AC3V[8]

MEMORY MAP

Table 64. Averaged Cell Voltage Register Group B (RDACB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACVBR0	RD	AC4V[7]	AC4V[6]	AC4V[5]	AC4V[4]	AC4V[3]	AC4V[2]	AC4V[1]	AC4V[0]
ACVBR1	RD	AC4V[15]	AC4V[14]	AC4V[13]	AC4V[12]	AC4V[11]	AC4V[10]	AC4V[9]	AC4V[8]
ACVBR2	RD	AC5V[7]	AC5V[6]	AC5V[5]	AC5V[4]	AC5V[3]	AC5V[2]	AC5V[1]	AC5V[0]
ACVBR3	RD	AC5V[15]	AC5V[14]	AC5V[13]	AC5V[12]	AC5V[11]	AC5V[10]	AC5V[9]	AC5V[8]
ACVBR4	RD	AC6V[7]	AC6V[6]	AC6V[5]	AC6V[4]	AC6V[3]	AC6V[2]	AC6V[1]	AC6V[0]
ACVBR5	RD	AC6V[15]	AC6V[14]	AC6V[13]	AC6V[12]	AC6V[11]	AC6V[10]	AC6V[9]	AC6V[8]

Table 65. Averaged Cell Voltage Register Group C (RDACC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACVACR0	RD	AC7V[7]	AC7V[6]	AC7V[5]	AC7V[4]	AC7V[3]	AC7V[2]	AC7V[1]	AC7V[0]
ACVACR1	RD	AC7V[15]	AC7V[14]	AC7V[13]	AC7V[12]	AC7V[11]	AC7V[10]	AC7V[9]	AC7V[8]
ACVACR2	RD	AC8V[7]	AC8V[6]	AC8V[5]	AC8V[4]	AC8V[3]	AC8V[2]	AC8V[1]	AC8V[0]
ACVACR3	RD	AC8V[15]	AC8V[14]	AC8V[13]	AC8V[12]	AC8V[11]	AC8V[10]	AC8V[9]	AC8V[8]
ACVACR4	RD	AC9V[7]	AC9V[6]	AC9V[5]	AC9V[4]	AC9V[3]	AC9V[2]	AC9V[1]	AC9V[0]
ACVACR5	RD	AC9V[15]	AC9V[14]	AC9V[13]	AC9V[12]	AC9V[11]	AC9V[10]	AC9V[9]	AC9V[8]

Table 66. Averaged Cell Voltage Register Group D (RDACD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACVDR0	RD	AC10V[7]	AC10V[6]	AC10V[5]	AC10V[4]	AC10V[3]	AC10V[2]	AC10V[1]	AC10V[0]
ACVDR1	RD	AC10V[15]	AC10V[14]	AC10V[13]	AC10V[12]	AC10V[11]	AC10V[10]	AC10V[9]	AC10V[8]
ACVDR2	RD	AC11V[7]	AC11V[6]	AC11V[5]	AC11V[4]	AC11V[3]	AC11V[2]	AC11V[1]	AC11V[0]
ACVDR3	RD	AC11V[15]	AC11V[14]	AC11V[13]	AC11V[12]	AC11V[11]	AC11V[10]	AC11V[9]	AC11V[8]
ACVDR4	RD	AC12V[7]	AC12V[6]	AC12V[5]	AC12V[4]	AC12V[3]	AC12V[2]	AC12V[1]	AC12V[0]
ACVDR5	RD	AC12V[15]	AC12V[14]	AC12V[13]	AC12V[12]	AC12V[11]	AC12V[10]	AC12V[9]	AC12V[8]

Table 67. Averaged Cell Voltage Register Group E (RDACE)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACVER0	RD	AC13V[7]	AC13V[6]	AC13V[5]	AC13V[4]	AC13V[3]	AC13V[2]	AC13V[1]	AC13V[0]
ACVER1	RD	AC13V[15]	AC13V[14]	AC13V[13]	AC13V[12]	AC13V[11]	AC13V[10]	AC13V[9]	AC13V[8]
ACVER2	RD	AC14V[7]	AC14V[6]	AC14V[5]	AC14V[4]	AC14V[3]	AC14V[2]	AC14V[1]	AC14V[0]
ACVER3	RD	AC14V[15]	AC14V[14]	AC14V[13]	AC14V[12]	AC14V[11]	AC14V[10]	AC14V[9]	AC14V[8]
ACVER4	RD	AC15V[7]	AC15V[6]	AC15V[5]	AC15V[4]	AC15V[3]	AC15V[2]	AC15V[1]	AC15V[0]
ACVER5	RD	AC15V[15]	AC15V[14]	AC15V[13]	AC15V[12]	AC15V[11]	AC15V[10]	AC15V[9]	AC15V[8]

Table 68. Averaged Cell Voltage Register Group F (RDACF)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACVFR0	RD	AC16V[7]	AC16V[6]	AC16V[5]	AC16V[4]	AC16V[3]	AC16V[2]	AC16V[1]	AC16V[0]
ACVFR1	RD	AC16V[15]	AC16V[14]	AC16V[13]	AC16V[12]	AC16V[11]	AC16V[10]	AC16V[9]	AC16V[8]
ACVFR2	RD	1	1	1	1	1	1	1	1
ACVFR3	RD	1	1	1	1	1	1	1	1
ACVFR4	RD	1	1	1	1	1	1	1	1
ACVFR5	RD	1	1	1	1	1	1	1	1

Table 69. Filtered Cell Voltage Register Group A (RDFCA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVAR0	RD	FC1V[7]	FC1V[6]	FC1V[5]	FC1V[4]	FC1V[3]	FC1V[2]	FC1V[1]	FC1V[0]
FCVAR1	RD	FC1V[15]	FC1V[14]	FC1V[13]	FC1V[12]	FC1V[11]	FC1V[10]	FC1V[9]	FC1V[8]

MEMORY MAP

Table 69. Filtered Cell Voltage Register Group A (RDFCA) (Continued)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVAR2	RD	FC2V[7]	FC2V[6]	FC2V[5]	FC2V[4]	FC2V[3]	FC2V[2]	FC2V[1]	FC2V[0]
FCVAR3	RD	FC2V[15]	FC2V[14]	FC2V[13]	FC2V[12]	FC2V[11]	FC2V[10]	FC2V[9]	FC2V[8]
FCVAR4	RD	FC3V[7]	FC3V[6]	FC3V[5]	FC3V[4]	FC3V[3]	FC3V[2]	FC3V[1]	FC3V[0]
FCVAR5	RD	FC3V[15]	FC3V[14]	FC3V[13]	FC3V[12]	FC3V[11]	FC3V[10]	FC3V[9]	FC3V[8]

Table 70. Filtered Cell Voltage Register Group B (RDFCB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVBR0	RD	FC4V[7]	FC4V[6]	FC4V[5]	FC4V[4]	FC4V[3]	FC4V[2]	FC4V[1]	FC4V[0]
FCVBR1	RD	FC4V[15]	FC4V[14]	FC4V[13]	FC4V[12]	FC4V[11]	FC4V[10]	FC4V[9]	FC4V[8]
FCVBR2	RD	FC5V[7]	FC5V[6]	FC5V[5]	FC5V[4]	FC5V[3]	FC5V[2]	FC5V[1]	FC5V[0]
FCVBR3	RD	FC5V[15]	FC5V[14]	FC5V[13]	FC5V[12]	FC5V[11]	FC5V[10]	FC5V[9]	FC5V[8]
FCVBR4	RD	FC6V[7]	FC6V[6]	FC6V[5]	FC6V[4]	FC6V[3]	FC6V[2]	FC6V[1]	FC6V[0]
FCVBR5	RD	FC6V[15]	FC6V[14]	FC6V[13]	FC6V[12]	FC6V[11]	FC6V[10]	FC6V[9]	FC6V[8]

Table 71. Filtered Cell Voltage Register Group C (RDFCC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVFCR0	RD	FC7V[7]	FC7V[6]	FC7V[5]	FC7V[4]	FC7V[3]	FC7V[2]	FC7V[1]	FC7V[0]
FCVFCR1	RD	FC7V[15]	FC7V[14]	FC7V[13]	FC7V[12]	FC7V[11]	FC7V[10]	FC7V[9]	FC7V[8]
FCVFCR2	RD	FC8V[7]	FC8V[6]	FC8V[5]	FC8V[4]	FC8V[3]	FC8V[2]	FC8V[1]	FC8V[0]
FCVFCR3	RD	FC8V[15]	FC8V[14]	FC8V[13]	FC8V[12]	FC8V[11]	FC8V[10]	FC8V[9]	FC8V[8]
FCVFCR4	RD	FC9V[7]	FC9V[6]	FC9V[5]	FC9V[4]	FC9V[3]	FC9V[2]	FC9V[1]	FC9V[0]
FCVFCR5	RD	FC9V[15]	FC9V[14]	FC9V[13]	FC9V[12]	FC9V[11]	FC9V[10]	FC9V[9]	FC9V[8]

Table 72. Filtered Cell Voltage Register Group D (RDFCD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVDR0	RD	FC10V[7]	FC10V[6]	FC10V[5]	FC10V[4]	FC10V[3]	FC10V[2]	FC10V[1]	FC10V[0]
FCVDR1	RD	FC10V[15]	FC10V[14]	FC10V[13]	FC10V[12]	FC10V[11]	FC10V[10]	FC10V[9]	FC10V[8]
FCVDR2	RD	FC11V[7]	FC11V[6]	FC11V[5]	FC11V[4]	FC11V[3]	FC11V[2]	FC11V[1]	FC11V[0]
FCVDR3	RD	FC11V[15]	FC11V[14]	FC11V[13]	FC11V[12]	FC11V[11]	FC11V[10]	FC11V[9]	FC11V[8]
FCVDR4	RD	FC12V[7]	FC12V[6]	FC12V[5]	FC12V[4]	FC12V[3]	FC12V[2]	FC12V[1]	FC12V[0]
FCVDR5	RD	FC12V[15]	FC12V[14]	FC12V[13]	FC12V[12]	FC12V[11]	FC12V[10]	FC12V[9]	FC12V[8]

Table 73. Filtered Cell Voltage Register Group E (RDFCE)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVER0	RD	FC13V[7]	FC13V[6]	FC13V[5]	FC13V[4]	FC13V[3]	FC13V[2]	FC13V[1]	FC13V[0]
FCVER1	RD	FC13V[15]	FC13V[14]	FC13V[13]	FC13V[12]	FC13V[11]	FC13V[10]	FC13V[9]	FC13V[8]
FCVER2	RD	FC14V[7]	FC14V[6]	FC14V[5]	FC14V[4]	FC14V[3]	FC14V[2]	FC14V[1]	FC14V[0]
FCVER3	RD	FC14V[15]	FC14V[14]	FC14V[13]	FC14V[12]	FC14V[11]	FC14V[10]	FC14V[9]	FC14V[8]
FCVER4	RD	FC15V[7]	FC15V[6]	FC15V[5]	FC15V[4]	FC15V[3]	FC15V[2]	FC15V[1]	FC15V[0]
FCVER5	RD	FC15V[15]	FC15V[14]	FC15V[13]	FC15V[12]	FC15V[11]	FC15V[10]	FC15V[9]	FC15V[8]

Table 74. Filtered Cell Voltage Register Group F (RDFCF)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVFR0	RD	FC16V[7]	FC16V[6]	FC16V[5]	FC16V[4]	FC16V[3]	FC16V[2]	FC16V[1]	FC16V[0]
FCVFR1	RD	FC16V[15]	FC16V[14]	FC16V[13]	FC16V[12]	FC16V[11]	FC16V[10]	FC16V[9]	FC16V[8]
FCVFR2	RD	1	1	1	1	1	1	1	1
FCVFR3	RD	1	1	1	1	1	1	1	1
FCVFR4	RD	1	1	1	1	1	1	1	1

MEMORY MAP

Table 74. Filtered Cell Voltage Register Group F (RDFCF) (Continued)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FCVFR5	RD	1	1	1	1	1	1	1	1

Table 75. S-Voltage Register Group A (RDSVA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SVAR0	RD	S1V[7]	S1V[6]	S1V[5]	S1V[4]	S1V[3]	S1V[2]	S1V[1]	S1V[0]
SVAR1	RD	S1V[15]	S1V[14]	S1V[13]	S1V[12]	S1V[11]	S1V[10]	S1V[9]	S1V[8]
SVAR2	RD	S2V[7]	S2V[6]	S2V[5]	S2V[4]	S2V[3]	S2V[2]	S2V[1]	S2V[0]
SVAR3	RD	S2V[15]	S2V[14]	S2V[13]	S2V[12]	S2V[11]	S2V[10]	S2V[9]	S2V[8]
SVAR4	RD	S3V[7]	S3V[6]	S3V[5]	S3V[4]	S3V[3]	S3V[2]	S3V[1]	S3V[0]
SVAR5	RD	S3V[15]	S3V[14]	S3V[13]	S3V[12]	S3V[11]	S3V[10]	S3V[9]	S3V[8]

Table 76. S-Voltage Register Group B (RDSVB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SVBR0	RD	S4V[7]	S4V[6]	S4V[5]	S4V[4]	S4V[3]	S4V[2]	S4V[1]	S4V[0]
SVBR1	RD	S4V[15]	S4V[14]	S4V[13]	S4V[12]	S4V[11]	S4V[10]	S4V[9]	S4V[8]
SVBR2	RD	S5V[7]	S5V[6]	S5V[5]	S5V[4]	S5V[3]	S5V[2]	S5V[1]	S5V[0]
SVBR3	RD	S5V[15]	S5V[14]	S5V[13]	S5V[12]	S5V[11]	S5V[10]	S5V[9]	S5V[8]
SVBR4	RD	S6V[7]	S6V[6]	S6V[5]	S6V[4]	S6V[3]	S6V[2]	S6V[1]	S6V[0]
SVBR5	RD	S6V[15]	S6V[14]	S6V[13]	S6V[12]	S6V[11]	S6V[10]	S6V[9]	S6V[8]

Table 77. S-Voltage Register Group C (RDSVC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SVCR0	RD	S7V[7]	S7V[6]	S7V[5]	S7V[4]	S7V[3]	S7V[2]	S7V[1]	S7V[0]
SVCR1	RD	S7V[15]	S7V[14]	S7V[13]	S7V[12]	S7V[11]	S7V[10]	S7V[9]	S7V[8]
SVCR2	RD	S8V[7]	S8V[6]	S8V[5]	S8V[4]	S8V[3]	S8V[2]	S8V[1]	S8V[0]
SVCR3	RD	S8V[15]	S8V[14]	S8V[13]	S8V[12]	S8V[11]	S8V[10]	S8V[9]	S8V[8]
SVCR4	RD	S9V[7]	S9V[6]	S9V[5]	S9V[4]	S9V[3]	S9V[2]	S9V[1]	S9V[0]
SVCR5	RD	S9V[15]	S9V[14]	S9V[13]	S9V[12]	S9V[11]	S9V[10]	S9V[9]	S9V[8]

Table 78. S-Voltage Register Group D (RDSVD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SVDR0	RD	S10V[7]	S10V[6]	S10V[5]	S10V[4]	S10V[3]	S10V[2]	S10V[1]	S10V[0]
SVDR1	RD	S10V[15]	S10V[14]	S10V[13]	S10V[12]	S10V[11]	S10V[10]	S10V[9]	S10V[8]
SVDR2	RD	S11V[7]	S11V[6]	S11V[5]	S11V[4]	S11V[3]	S11V[2]	S11V[1]	S11V[0]
SVDR3	RD	S11V[15]	S11V[14]	S11V[13]	S11V[12]	S11V[11]	S11V[10]	S11V[9]	S11V[8]
SVDR4	RD	S12V[7]	S12V[6]	S12V[5]	S12V[4]	S12V[3]	S12V[2]	S12V[1]	S12V[0]
SVDR5	RD	S12V[15]	S12V[14]	S12V[13]	S12V[12]	S12V[11]	S12V[10]	S12V[9]	S12V[8]

Table 79. S-Voltage Register Group E (RDSVE)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SVER0	RD	S13V[7]	S13V[6]	S13V[5]	S13V[4]	S13V[3]	S13V[2]	S13V[1]	S13V[0]
SVER1	RD	S13V[15]	S13V[14]	S13V[13]	S13V[12]	S13V[11]	S13V[10]	S13V[9]	S13V[8]
SVER2	RD	S14V[7]	S14V[6]	S14V[5]	S14V[4]	S14V[3]	S14V[2]	S14V[1]	S14V[0]
SVER3	RD	S14V[15]	S14V[14]	S14V[13]	S14V[12]	S14V[11]	S14V[10]	S14V[9]	S14V[8]
SVER4	RD	S15V[7]	S15V[6]	S15V[5]	S15V[4]	S15V[3]	S15V[2]	S15V[1]	S15V[0]
SVER5	RD	S15V[15]	S15V[14]	S15V[13]	S15V[12]	S15V[11]	S15V[10]	S15V[9]	S15V[8]

MEMORY MAP

Table 80. S-Voltage Register Group F (RDSVF)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SVFR0	RD	S16V[7]	S16V[6]	S16V[5]	S16V[4]	S16V[3]	S16V[2]	S16V[1]	S16V[0]
SVFR1	RD	S16V[15]	S16V[14]	S16V[13]	S16V[12]	S16V[11]	S16V[10]	S16V[9]	S16V[8]
SVFR2	RD	1	1	1	1	1	1	1	1
SVFR3	RD	1	1	1	1	1	1	1	1
SVFR4	RD	1	1	1	1	1	1	1	1
SVFR5	RD	1	1	1	1	1	1	1	1

Table 81. Auxiliary Register Group A (RDAUXA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GPARG0	RD	G1V[7]	G1V[6]	G1V[5]	G1V[4]	G1V[3]	G1V[2]	G1V[1]	G1V[0]
GPARG1	RD	G1V[15]	G1V[14]	G1V[13]	G1V[12]	G1V[11]	G1V[10]	G1V[9]	G1V[8]
GPARG2	RD	G2V[7]	G2V[6]	G2V[5]	G2V[4]	G2V[3]	G2V[2]	G2V[1]	G2V[0]
GPARG3	RD	G2V[15]	G2V[14]	G2V[13]	G2V[12]	G2V[11]	G2V[10]	G2V[9]	G2V[8]
GPARG4	RD	G3V[7]	G3V[6]	G3V[5]	G3V[4]	G3V[3]	G3V[2]	G3V[1]	G3V[0]
GPARG5	RD	G3V[15]	G3V[14]	G3V[13]	G3V[12]	G3V[11]	G3V[10]	G3V[9]	G3V[8]

Table 82. Auxiliary Register Group B (RDAUXB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GPBR0	RD	G4V[7]	G4V[6]	G4V[5]	G4V[4]	G4V[3]	G4V[2]	G4V[1]	G4V[0]
GPBR1	RD	G4V[15]	G4V[14]	G4V[13]	G4V[12]	G4V[11]	G4V[10]	G4V[9]	G4V[8]
GPBR2	RD	G5V[7]	G5V[6]	G5V[5]	G5V[4]	G5V[3]	G5V[2]	G5V[1]	G5V[0]
GPBR3	RD	G5V[15]	G5V[14]	G5V[13]	G5V[12]	G5V[11]	G5V[10]	G5V[9]	G5V[8]
GPBR4	RD	G6V[7]	G6V[6]	G6V[5]	G6V[4]	G6V[3]	G6V[2]	G6V[1]	G6V[0]
GPBR5	RD	G6V[15]	G6V[14]	G6V[13]	G6V[12]	G6V[11]	G6V[10]	G6V[9]	G6V[8]

Table 83. Auxiliary Register Group C (RDAUXC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GPCR0	RD	G7V[7]	G7V[6]	G7V[5]	G7V[4]	G7V[3]	G7V[2]	G7V[1]	G7V[0]
GPCR2	RD	G7V[15]	G7V[14]	G7V[13]	G7V[12]	G7V[11]	G7V[10]	G7V[9]	G7V[8]
GPCR3	RD	G8V[7]	G8V[6]	G8V[5]	G8V[4]	G8V[3]	G8V[2]	G8V[1]	G8V[0]
GPCR4	RD	G8V[15]	G8V[14]	G8V[13]	G8V[12]	G8V[11]	G8V[10]	G8V[9]	G8V[8]
GPCR5	RD	G9V[7]	G9V[6]	G9V[5]	G9V[4]	G9V[3]	G9V[2]	G9V[1]	G9V[0]
GPCR6	RD	G9V[15]	G9V[14]	G9V[13]	G9V[12]	G9V[11]	G9V[10]	G9V[9]	G9V[8]

Table 84. Auxiliary Register Group D (RDAUXD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GPDR0	RD	G10V[7]	G10V[6]	G10V[5]	G10V[4]	G10V[3]	G10V[2]	G10V[1]	G10V[0]
GPDR1	RD	G10V[15]	G10V[14]	G10V[13]	G10V[12]	G10V[11]	G10V[10]	G10V[9]	G10V[8]
GPDR2	RD	VMV[7]	VMV[6]	VMV[5]	VMV[4]	VMV[3]	VMV[2]	VMV[1]	VMV[0]
GPDR3	RD	VMV[15]	VMV[14]	VMV[13]	VMV[12]	VMV[11]	VMV[10]	VMV[9]	VMV[8]
GPDR4	RD	VPV[7]	VPV[6]	VPV[5]	VPV[4]	VPV[3]	VPV[2]	VPV[1]	VPV[0]
GPDR5	RD	VPV[15]	VPV[14]	VPV[13]	VPV[12]	VPV[11]	VPV[10]	VPV[9]	VPV[8]

Table 85. Redundant Auxiliary Register Group A (RDAXA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RGPAR0	RD	R_G1V[7]	R_G1V[6]	R_G1V[5]	R_G1V[4]	R_G1V[3]	R_G1V[2]	R_G1V[1]	R_G1V[0]
RGPAR1	RD	R_G1V[15]	R_G1V[14]	R_G1V[13]	R_G1V[12]	R_G1V[11]	R_G1V[10]	R_G1V[9]	R_G1V[8]

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Table 85. Redundant Auxiliary Register Group A (RDRAXA) (Continued)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RGPAR2	RD	R_G2V[7]	R_G2V[6]	R_G2V[5]	R_G2V[4]	R_G2V[3]	R_G2V[2]	R_G2V[1]	R_G2V[0]
RGPAR3	RD	R_G2V[15]	R_G2V[14]	R_G2V[13]	R_G2V[12]	R_G2V[11]	R_G2V[10]	R_G2V[9]	R_G2V[8]
RGPAR4	RD	R_G3V[7]	R_G3V[6]	R_G3V[5]	R_G3V[4]	R_G3V[3]	R_G3V[2]	R_G3V[1]	R_G3V[0]
RGPAR5	RD	R_G3V[15]	R_G3V[14]	R_G3V[13]	R_G3V[12]	R_G3V[11]	R_G3V[10]	R_G3V[9]	R_G3V[8]

Table 86. Redundant Auxiliary Register Group B (RDRAXB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RGPBR0	RD	R_G4V[7]	R_G4V[6]	R_G4V[5]	R_G4V[4]	R_G4V[3]	R_G4V[2]	R_G4V[1]	R_G4V[0]
RGPBR1	RD	R_G4V[15]	R_G4V[14]	R_G4V[13]	R_G4V[12]	R_G4V[11]	R_G4V[10]	R_G4V[9]	R_G4V[8]
RGPBR2	RD	R_G5V[7]	R_G5V[6]	R_G5V[5]	R_G5V[4]	R_G5V[3]	R_G5V[2]	R_G5V[1]	R_G5V[0]
RGPBR3	RD	R_G5V[15]	R_G5V[14]	R_G5V[13]	R_G5V[12]	R_G5V[11]	R_G5V[10]	R_G5V[9]	R_G5V[8]
RGPBR4	RD	R_G6V[7]	R_G6V[6]	R_G6V[5]	R_G6V[4]	R_G6V[3]	R_G6V[2]	R_G6V[1]	R_G6V[0]
RGPBR5	RD	R_G6V[15]	R_G6V[14]	R_G6V[13]	R_G6V[12]	R_G6V[11]	R_G6V[10]	R_G6V[9]	R_G6V[8]

Table 87. Redundant Auxiliary Register Group C (RDRAXC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RGPCR0	RD	R_G7V[7]	R_G7V[6]	R_G7V[5]	R_G7V[4]	R_G7V[3]	R_G7V[2]	R_G7V[1]	R_G7V[0]
RGPCR1	RD	R_G7V[15]	R_G7V[14]	R_G7V[13]	R_G7V[12]	R_G7V[11]	R_G7V[10]	R_G7V[9]	R_G7V[8]
RGPCR2	RD	R_G8V[7]	R_G8V[6]	R_G8V[5]	R_G8V[4]	R_G8V[3]	R_G8V[2]	R_G8V[1]	R_G8V[0]
RGPCR3	RD	R_G8V[15]	R_G8V[14]	R_G8V[13]	R_G8V[12]	R_G8V[11]	R_G8V[10]	R_G8V[9]	R_G8V[8]
RGPCR4	RD	R_G9V[7]	R_G9V[6]	R_G9V[5]	R_G9V[4]	R_G9V[3]	R_G9V[2]	R_G9V[1]	R_G9V[0]
RGPCR5	RD	R_G9V[15]	R_G9V[14]	R_G9V[13]	R_G9V[12]	R_G9V[11]	R_G9V[10]	R_G9V[9]	R_G9V[8]

Table 88. Redundant Auxiliary Register Group D (RDRAXD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RGPDR0	RD	R_G10V[7]	R_G10V[6]	R_G10V[5]	R_G10V[4]	R_G10V[3]	R_G10V[2]	R_G10V[1]	R_G10V[0]
RGPDR1	RD	R_G10V[15]	R_G10V[14]	R_G10V[13]	R_G10V[12]	R_G10V[11]	R_G10V[10]	R_G10V[9]	R_G10V[8]
RGPDR2	RD	1	1	1	1	1	1	1	1
RGPDR3	RD	1	1	1	1	1	1	1	1
RGPDR4	RD	1	1	1	1	1	1	1	1
RGPDR5	RD	1	1	1	1	1	1	1	1

Table 89. Status Register Group A (RDSTATA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STAR0	RD	VREF2[7]	VREF2[6]	VREF2[5]	VREF2[4]	VREF2[3]	VREF2[2]	VREF2[1]	VREF2[0]
STAR1	RD	VREF2[15]	VREF2[14]	VREF2[13]	VREF2[12]	VREF2[11]	VREF2[10]	VREF2[9]	VREF2[8]
STAR2	RD	ITMP[7]	ITMP[6]	ITMP[5]	ITMP[4]	ITMP[3]	ITMP[2]	ITMP[1]	ITMP[0]
STAR3	RD	ITMP[15]	ITMP[14]	ITMP[13]	ITMP[12]	ITMP[11]	ITMP[10]	ITMP[9]	ITMP[8]
STAR4	RD	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
STAR5	RD	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

Table 90. Status Register Group B (RDSTATB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STBR0	RD	VD[7]	VD[6]	VD[5]	VD[4]	VD[3]	VD[2]	VD[1]	VD[0]
STBR1	RD	VD[15]	VD[14]	VD[13]	VD[12]	VD[11]	VD[10]	VD[9]	VD[8]
STBR2	RD	VA[7]	VA[6]	VA[5]	VA[4]	VA[3]	VA[2]	VA[1]	VA[0]
STBR3	RD	VA[15]	VA[14]	VA[13]	VA[12]	VA[11]	VA[10]	VA[9]	VA[8]
STBR4	RD	VRES[7]	VRES[6]	VRES[5]	VRES[4]	VRES[3]	VRES[2]	VRES[1]	VRES[0]

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Table 90. Status Register Group B (RDSTATB) (Continued)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STBR5	RD	VRES[15]	VRES[14]	VRES[13]	VRES[12]	VRES[11]	VRES[10]	VRES[9]	VRES[8]

Table 91. Status Register Group C (RDSTATC)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STCR0	RD	CS8FLT	CS7FLT	CS6FLT	CS5FLT	CS4FLT	CS3FLT	CS2FLT	CS1FLT
STCR1	RD	CS16FLT	CS15FLT	CS14FLT	CS13FLT	CS12FLT	CS11FLT	CS10FLT	CS9FLT
STCR2	RD	0	0	0	CT[10]	CT[9]	CT[8]	CT[7]	CT[6]
STCR3	RD	CT[5]	CT[4]	CT[3]	CT[2]	CT[1]	CT[0]	CTS[1]	CTS[0]
STCR4	RD	VA_OV	VA_UV	VD_OV	VD_UV	CED	CMED	SED	SMED
STCR5	RD	VDEL	VDE	COMP	SPIFLT	SLEEP	THSD	TMODCHK	OSCHK

Table 92. Status Register Group D (RDSTATD)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STDR0	RD	C4OV	C4UV	C3OV	C3UV	C2OV	C2UV	C1OV	C1UV
STDR1	RD	C8OV	C8UV	C7OV	C7UV	C6OV	C6UV	C5OV	C5UV
STDR2	RD	C12OV	C12UV	C11OV	C11UV	C10OV	C10UV	C9OV	C9UV
STDR3	RD	C16OV	C16UV	C15OV	C15UV	C14OV	C14UV	C13OV	C13UV
STDR4	RD	1	1	1	1	1	1	1	1
STDR5	RD	OC_CNTR[7]	OC_CNTR[6]	OC_CNTR[5]	OC_CNTR[4]	OC_CNTR[3]	OC_CNTR[2]	OC_CNTR[1]	OC_CNTR[0]

Table 93. Status Register Group E (RDSTATE)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
STER0	RD	1	1	1	1	1	1	1	1
STER1	RD	1	1	1	1	1	1	1	1
STER2	RD	1	1	1	1	1	1	1	1
STER3	RD	1	1	1	1	1	1	1	01
STER4	RD	GPI[8]	GPI[7]	GPI[6]	GPI[5]	GPI[4]	GPI[3]	GPI[2]	GPI[1]
STER5	RD	REV[3]	REV[2]	REV[1]	REV[0]	0	0	GPI[10]	GPI[9]

Table 94. COMM Register Group (WRCOMM, RDCOMM)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
COMM0	RD/WR	ICOM0[3]	ICOM0[2]	ICOM0[1]	ICOM0[0]	FCOM0[3]	FCOM0[2]	FCOM0[1]	FCOM0[0]
COMM1	RD/WR	D0[7]	D0[6]	D0[5]	D0[4]	D0[3]	D0[2]	D0[1]	D0[0]
COMM2	RD/WR	ICOM1[3]	ICOM1[2]	ICOM1[1]	ICOM1[0]	FCOM1[3]	FCOM1[2]	FCOM1[1]	FCOM1[0]
COMM3	RD/WR	D1[7]	D1[6]	D1[5]	D1[4]	D1[3]	D1[2]	D1[1]	D1[0]
COMM4	RD/WR	ICOM2[3]	ICOM2[2]	ICOM2[1]	ICOM2[0]	FCOM2[3]	FCOM2[2]	FCOM2[1]	FCOM2[0]
COMM5	RD/WR	D2[7]	D2[6]	D2[5]	D2[4]	D2[3]	D2[2]	D2[1]	D2[0]

Table 95. PWM Register Group A (WRPWMA, RDPWMA)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PWMR0	RD/WR	PWM2[3]	PWM2[2]	PWM2[1]	PWM2[0]	PWM1[3]	PWM1[2]	PWM1[1]	PWM1[0]
PWMR1	RD/WR	PWM4[3]	PWM4[2]	PWM4[1]	PWM4[0]	PWM3[3]	PWM3[2]	PWM3[1]	PWM3[0]
PWMR2	RD/WR	PWM6[3]	PWM6[2]	PWM6[1]	PWM6[0]	PWM5[3]	PWM5[2]	PWM5[1]	PWM5[0]
PWMR3	RD/WR	PWM8[3]	PWM8[2]	PWM8[1]	PWM8[0]	PWM7[3]	PWM7[2]	PWM7[1]	PWM7[0]
PWMR4	RD/WR	PWM10[3]	PWM10[2]	PWM10[1]	PWM10[0]	PWM9[3]	PWM9[2]	PWM9[1]	PWM9[0]
PWMR5	RD/WR	PWM12[3]	PWM12[2]	PWM12[1]	PWM12[0]	PWM11[3]	PWM11[2]	PWM11[1]	PWM11[0]

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Table 96. PWM Register Group B (WRPWMB, RDPWMB)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PSR0	RD/WR	PWM14[3]	PWM14[2]	PWM14[1]	PWM14[0]	PWM13[3]	PWM13[2]	PWM13[1]	PWM13[0]
PSR1	RD/WR	PWM16[3]	PWM16[2]	PWM16[1]	PWM16[0]	PWM15[3]	PWM15[2]	PWM15[1]	PWM15[0]
PSR2	RD/WR	1	1	1	1	1	1	1	1
PSR3	RD/WR	1	1	1	1	1	1	1	1
PSR4	RD/WR	1	1	1	1	1	1	1	1
PSR5	RD/WR	1	1	1	1	1	1	1	1

Table 97. LPCM Configuration Register Group (WRCMCFG, RDCMCFG)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMCF0	RD/WR	CMC_MAN	CMC_MPER[2]	CMC_MPER[1]	CMC_MPER[0]	CMC_BTM	CMC_TPER[2]	CMC_TPER[1]	CMC_TPER[0]
CMCF1	RD/WR	CMC_NDEV[7]	CMC_NDEV[6]	CMC_NDEV[5]	CMC_NDEV[4]	CMC_NDEV[3]	CMC_NDEV[2]	CMC_NDEV[1]	CMC_NDEV[0]
CMCF2	RD/WR	CMM_C[8]	CMM_C[7]	CMM_C[6]	CMM_C[5]	CMM_C[4]	CMM_C[3]	CMM_C[2]	CMM_C[1]
CMCF3	RD/WR	CMM_C[16]	CMM_C[15]	CMM_C[14]	CMM_C[13]	CMM_C[12]	CMM_C[11]	CMM_C[10]	CMM_C[9]
CMCF4	RD/WR	CMM_G[2]	CMM_G[1]	CMC_DIR	CMC_GOE[2]	CMC_GOE[1]	CMC_GOE[0]	CMM_C[18]	CMM_C[17]
CMCF5	RD/WR	CMM_G[10]	CMM_G[9]	CMM_G[8]	CMM_G[7]	CMM_G[6]	CMM_G[5]	CMM_G[4]	CMM_G[3]

Table 98. LPCM Cell Thresholds Register Group (WRCMCELLT, RDCMCELLT)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMTC0	RD/WR	CMT_CUV[7]	CMT_CUV[6]	CMT_CUV[5]	CMT_CUV[4]	CMT_CUV[3]	CMT_CUV[2]	CMT_CUV[1]	CMT_CUV[0]
CMTC1	RD/WR	CMT_COV[3]	CMT_COV[2]	CMT_COV[1]	CMT_COV[0]	CMT_CUV[11]	CMT_CUV[10]	CMT_CUV[9]	CMT_CUV[8]
CMTC2	RD/WR	CMT_COV[11]	CMT_COV[10]	CMT_COV[9]	CMT_COV[8]	CMT_COV[7]	CMT_COV[6]	CMT_COV[5]	CMT_COV[4]
CMTC3	RD/WR	CMT_CDV[7]	CMT_CDV[6]	CMT_CDV[5]	CMT_CDV[4]	CMT_CDV[3]	CMT_CDV[2]	CMT_CDV[1]	CMT_CDV[0]
CMTC4	RD/WR	0	0	0	0	CMT_CDV[11]	CMT_CDV[10]	CMT_CDV[9]	CMT_CDV[8]
CMTC5	RD/WR	0	0	0	0	0	0	0	0

Table 99. LPCM GPIO Threshold Register Group (WRCMGPLOT, RDCMGPLOT)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMTG0	RD/WR	CMT_GUV[7]	CMT_GUV[6]	CMT_GUV[5]	CMT_GUV[4]	CMT_GUV[3]	CMT_GUV[2]	CMT_GUV[1]	CMT_GUV[0]
CMTG1	RD/WR	CMT_GOV[3]	CMT_GOV[2]	CMT_GOV[1]	CMT_GOV[0]	CMT_GUV[11]	CMT_GUV[10]	CMT_GUV[9]	CMT_GUV[8]
CMTG2	RD/WR	CMT_GOV[11]	CMT_GOV[10]	CMT_GOV[9]	CMT_GOV[8]	CMT_GOV[7]	CMT_GOV[6]	CMT_GOV[5]	CMT_GOV[4]
CMTG3	RD/WR	CMT_GDV[7]	CMT_GDV[6]	CMT_GDV[5]	CMT_GDV[4]	CMT_GDV[3]	CMT_GDV[2]	CMT_GDV[1]	CMT_GDV[0]
CMTG4	RD/WR	0	0	0	0	CMT_GDV[11]	CMT_GDV[10]	CMT_GDV[9]	CMT_GDV[8]
CMTG5	RD/WR	0	0	0	0	0	0		

Table 100. LPCM Flags Register Group (RDCMFLAG)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMF0	RD/WR	CMF_GDVP	CMF_GDVN	CMF_GOV	CMF_GUV	CMF_CDVP	CMF_CDVN	CMF_COV	CMF_CUV
CMF1	RD/WR	CMC_EN	0	0	0	0	0	CMF_BTMWD	CMF_BTMCMP
CMF2	RD/WR	0	0	0	0	0	0	0	0
CMF3	RD/WR	0	0	0	0	0	0	0	0
CMF4	RD/WR	0	0	0	0	0	0	0	0
CMF5	RD/WR	0	0	0	0	0	0	0	0

Table 101. Retention Register Group (ULRR, WRRR, RDRR)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RRR0	RD/WR	RR[47]	RR[46]	RR[45]	RR[44]	RR[43]	RR[42]	RR[41]	RR[40]
RRR1	RD/WR	RR[39]	RR[38]	RR[37]	RR[36]	RR[35]	RR[34]	RR[33]	RR[32]

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Table 101. Retention Register Group (ULRR, WRRR, RDRR) (Continued)

Register	RD/WR	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RRR2	RD/WR	RR[31]	RR[30]	RR[29]	RR[28]	RR[27]	RR[26]	RR[25]	RR[24]
RRR3	RD/WR	RR[23]	RR[22]	RR[21]	RR[20]	RR[19]	RR[18]	RR[17]	RR[16]
RRR4	RD/WR	RR[15]	RR[14]	RR[13]	RR[12]	RR[11]	RR[10]	RR[9]	RR[8]
RRR5	RD/WR	RR[7]	RR[6]	RR[5]	RR[4]	RR[3]	RR[2]	RR[1]	RR[0]

Table 102. Configuration Register A Bit Descriptions

Name	Description	Values	Default
REFON	Reference powered up.	1 = reference remains powered up until watchdog timeout. 0 = reference shuts down after conversions (default).	0
CTH[2:0]	C-ADC vs. S-ADC comparison voltage threshold.	000: 5.1 mV 001: 8.1 mV (default) 010: 9 mV 011: 10.05 mV 100: 15 mV 101: 19.95 mV 110: 25.05 mV 111: 40.05 mV	001
FLAG_Dx	Asserts various flags in Status Register C for latent fault detection.	Asserting flags in status register for latent fault diagnostic does not cause the ADES1830/ADES1831 to behave as if the flag is set by the actual diagnostic mechanism. For example, setting THSD (thermal shutdown) through FLAG_D[4] does not cause a power-on reset. FLAG_D[0]: 1 = forces oscillator counter fast. FLAG_D[1]: 1 = forces oscillator counter slow. FLAG_D[2]: 1 = forces supply error detection (ED). FLAG_D[3]: 1 = selects supply OV and delta detection. 0 = selects UV. FLAG_D[4]: 1 = sets THSD. FLAG_D[5]: 1 = forces nonvolatile memory (NVM) error detection (ED). Sets CED and SED. FLAG_D[6]: 1 = forces NVM multiple error detection (MED). Sets CMED and SMED. FLAG_D[7]: 1 = forces TMODCHK.	0
SOAKON	Enables soak on AUX ADCs.	1 = enables soak time for all commands. 0 = disables soak time.	0
OWRNG	Soak time range.	1 = long soak time range. 0 = short soak time range.	0
OWA	Open wire soak times.	For AUX commands. If OWRNG = 0, soak time = $2^{(6 + OWA[2:0])}$ clocks (32 us to 4.1 ms). If OWRNG = 1, soak time = $2^{(13 + OWA[2:0])}$ clocks (4.1 ms to 524 ms).	0
GPOx	GPIOx pin control.	0 = GPIOx pin pull-down on. 1 = GPIOx pin pull-down off (default).	1
FC[2:0]	IIR filter parameter.	See Table 21.	000
COMM_BK	Communication break.	1 = asserts the communication break feature that prevents the devices from propagation communication further through the daisy chain.	0
MUTE_ST	Mute status.	1 = mute is activated and discharging is disabled. 0 = mute is deactivated.	0
SNAP_ST	Snapshot status.	1 = snapshot is activated, result registers are frozen. 0 = snapshot is deactivated.	0

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Table 103. Configuration Register B Bit Descriptions

Name	Description	Values	Default
VUV	UV comparison voltage.	Cell undervoltage threshold = $VUV \times 16 \times 150 \mu V + 1.5 V$.	0x800
VOV	OV comparison voltage.	Cell overvoltage threshold = $VOV \times 16 \times 150 \mu V + 1.5 V$.	0x7FF
DTMEN	Enable discharge timer monitor.	1 = enables the discharge timer monitor function if the devices transition to the extended balancing state. 0 = disables the discharge timer monitor function.	0
DTRNG	Discharge timer range setting.	1 = 0 to 16.8 hours in 16 minute increments. 0 = 0 to 63 minutes in 1 minute increments.	0
DCTO	Discharge timeout value.	Write = set new value, 16-minute or 1-minute increments according to DTRNG read. Read = remaining value, 16-minute or 1-minute increments according to DTRNG read. 1 = less than or equal to 1 increment remaining. 0 = timeout has occurred or DCTO not set.	0
DCCx	Discharge Cell x.	1 = continuously turns on shorting switch for Cell x. 0 = continuously turns off shorting switch for Cell x (default).	0

Table 104. Result Registers Bit Descriptions

Name	Description	Values	Default
CxV	Cell x voltage.	x = 1 to 16: 16-bit ADC measurement value for Cell x. Cell voltage for Cell x = $CxV \times 150 \mu V + 1.5 V$. CxV is reset to 0x8000 on power-up and after clear command (CLRCELL).	0x8000
ACxV	Averaged Cell x voltage.	x = 1 to 16: 16-bit average of 8 conversions results for value for Cell x. Averaged cell voltage for Cell x = $CxV \times 150 \mu V + 1.5 V$. ACxV is reset to 0x8000 on power-up and after clear command (CLRCELL).	0x8000
FCxV	Filtered Cell x voltage.	x = 1 to 16: 16-bit IIR filtered measurement value for Cell x. Filtered cell voltage for Cell x = $CxV \times 150 \mu V + 1.5 V$. FCxV is reset to 0x8000 on power-up and after clear command (CLRFC).	0x8000
SxV	Sx Pin x voltage.	16-bit ADC measurement value for Sx pin from ADSV or ADCV commands. Spin voltage for Channel x = $SxV \times 150 \mu V + 1.5 V$. SxV is reset to 0x8000 on power-up and after clear command (CLRSPIN).	0x8000
GxV, R_GxV	Redundant GPIOx voltage.	x = 1 to 9: 16-bit ADC measurement value for (redundant) GPIOx voltage for GPIOx = $GxV \times 150 \mu V + 1.5 V$.	0x8000
VPV	V+ to V- measurement.	16-bit ADC measurement value of V+ to V- = $25 \times (VPV \times 150 \mu V + 1.5 V)$. Reset to 0x8000 after power-up, sleep, or clear command (CLRAUX).	0x8000
VMV	S1N to V- measurement.	16-bit ADC measurement value of S1N to V- = $VMV \times 150 \mu V + 1.5 V$. Reset to 0x8000 after power-up, sleep, or clear command (CLRAUX).	0x8000

Table 105. Status Register A Bit Descriptions

Name	Description	Values	Default
VREF2	Second reference voltage.	16-bit ADC measurement value for second reference voltage for second reference = $V_{REF2} \times 150 \mu V + 1.5 V$. Normal range is within 2.988 V to 3.012 V considering data sheet limits, thermal hysteresis, and long-term drift. Reset to 0x8000 after power-up, sleep, or clear command (CLRAUX).	0x8000
ITMP	Internal die temperature.	16-bit ADC measurement value of Internal Die temperature. Temperature measurement voltage = $(ITMP \times 150 \mu V + 1.5 V) / 7.5 mV/^\circ C - 273^\circ C$. Reset to 0x7FFF after power-up, sleep, and to 0x8000 after clear command (CLRAUX).	0x7FFF

Table 106. Status Register B Bit Descriptions

Name	Description	Values	Default
VD	Digital power supply voltage. VD is off in sleep.	16-bit ADC measurement value of digital power supply voltage. Digital power supply voltage = $VD \times 150 \mu V + 1.5 V$. Normal range is within 2.7 V to 3.6 V. Reset to 0x7FFF after power-up, sleep, and to 0x8000 after clear command (CLRAUX).	0x7FFF
VA	Analog power supply voltage = voltage at the V_{REG} pin. VA is off in sleep.	16-bit ADC measurement value of analog power supply voltage. Analog power supply voltage = $VA \times 150 \mu V + 1.5 V$. The value of VA is set by external components and must be in the range of 4.5 V to 5.5 V for normal operation. Reset to 0x7FFF after power-up, sleep, and to 0x8000 after clear command (CLRAUX).	0x7FFF

MEMORY MAP

Table 106. Status Register B Bit Descriptions (Continued)

Name	Description	Values	Default
VRES	VREF2 across resistor.	16-bit ADC value of VREF2 with series resistor for open wire check. Voltage = VRES × 150 μV + 1.5 V. Reset to 0x7FFF after power-up, sleep, and to 0x8000 after clear command (CLRAUX).	0x7FFF

Table 107. Register Format Overview

Register Names	Width	LSB	Offset	Unit	Min	Zero	Max
CxV, SxV, ACxV, FCxV, GxV, R_GxV, VREF2, VD, VA, VRES, VMV	16	0.00015	1.5	V	Analog: -3.4152 Hex: 0x8000	Analog: 1.5 Hex: 0x0000	Analog: 6.41505 Hex: 0x7FFF
VUV, VOV, CMT_CUV, CMT_COV, CMT_GUV, CMT_GOV	12	0.0024	1.5	V	Analog: -3.4152 Hex: 0x0800	Analog: 1.5 Hex: 0x0000	Analog: 6.4128 Hex: 0x07FF
CMT_CDV, CMT_GDV	12	0.0012	0	V	Analog: 0 Hex: 0x000	Analog: 0 Hex: 0x000	Analog: 4.914 Hex: 0xFFF
VPV	16	0.00375	37.5	V	Analog: -85.38 Hex: 0x8000	Analog: 37.5 Hex: 0x0000	Analog: 160.37625 Hex: 0x7FFF
ITMP	16	0.02	-73.0	°C	Analog: -728.36 Hex: 0x8000	Analog: -73.0 Hex: 0x0000	Analog: 582.34 Hex: 0x7FFF

Table 108. Status Register C Bit Descriptions

Name	Description	Values	Default
CSxFLT	C-ADC vs. S-ADC fault of Channel X.	Read: 1 = a mismatch between C-ADC and S-ADC measurement on Channel X occurred. Read: 0 = no mismatch between C-ADC and S-ADC measurement on Channel X occurred.	0xFFFF
VA_OV	5 V analog rail OV.	This bit can be cleared to 0 by using the CLRFLAG command with CL_VAOV = 1. Read: 1 = overvoltage event detected on the main 5 V analog power rail during an ADC operation. Read: 0 = no overvoltage event detected on the analog power rail.	1
VA_UV	5 V analog rail UV.	This bit can be cleared to 0 by using the CLRFLAG command with CL_VAUV = 1. Because VA is derived from V _{REG} , VA_UV is set when entering standby from sleep. Read: 1 = undervoltage event detected on the main 5 V analog power rail during an ADC operation. Read: 0 = no undervoltage event detected on the analog power rail.	1
VD_OV	3 V digital rail OV.	This bit can be cleared to 0 by using the CLRFLAG command with CL_VDOV = 1. Read: 1 = overvoltage event detected on the digital power rail during an ADC operation. Read: 0 = no overvoltage event detected on the digital power rail.	1
VD_UV	3 V digital rail UV.	This bit can be cleared to 0 by using the CLRFLAG command with CL_VDUV = 1. Because VD is derived from V _{REG} , VD_UV is set when entering standby from sleep. Read: 1 = undervoltage event detected on the digital power rail during an ADC operation. Read: 0 = no undervoltage event detected on the digital power rail.	1
CED	C-trim error detection.	The ADES1830/ADES1831 can correct single trim errors. Read: 1 = trim error detected in C-NVM. Read: 0 = no trim error detected in C-NVM.	1
CMED	C-trim multiple error detection.	Multiple trim errors can lead to parameters out of specification. Read: 1 = multiple trim errors detected in C-NVM. Read: 0 = no multiple trim errors detected in C-NVM	1
SED	S-trim error detection.	The ADES1830/ADES1831 can correct single trim errors. Read: 1 = trim error detected in S-NVM. Read: 0 = no trim error detected in S-NVM.	1
SMED	S-trim multiple error detection.	Multiple trim errors can lead to parameters out of specification. Read: 1 = multiple trim errors detected in S-NVM. Read: 0 = no multiple trim errors detected in S-NVM.	1
VDE	Supply rail delta.	This bit can be cleared to 0 by using the CLRFLAG command with CL_VDE = 1. Read: 1 = any of the 5 V supplies differ from V _{REG} by more than 0.5 V.	1

MEMORY MAP

Table 108. Status Register C Bit Descriptions (Continued)

Name	Description	Values	Default
		Read: 0 = no delta of 5 V supplies detected.	
VDEL	Supply rail delta latent.	This bit can be cleared to 0 by using the CLRFLAG command with CL_VDEL = 1. VDEL allows to check supply rail monitors for latent faults. Read: 1 = all the 5 V supplies differed from V _{REG} by more than 0.5 V. Read: 0 = not all the 5 V supplies differed from V _{REG} by more than 0.5 V.	1
COMP	Comparison.	Indicates that comparison between C-ADC and S-ADC results is active. 1 = C-ADC vs. S-ADC comparison active. 0 = C-ADC vs. S-ADC comparison off.	0
SPIFLT	SPI fault.	Read: 1 = a mismatch between redundant SPI target outputs occurred. Read: 0 = no mismatch between redundant SPI target outputs occurred.	1
SLEEP	Sleep mode detection.	This bit can be cleared to 0 by using the CLRFLAG command with CL_SLEEP = 1. Read: 1 = the device has previously power cycled or entered sleep mode. Read: 0 = the device has not power cycled or entered sleep mode.	1
THSD	Thermal shutdown status.	THSD bit cleared to 0 by using the CLRFLAG command with CL_THSD = 1. Read: 0 = thermal shutdown did not occur. Read: 1 = thermal shutdown occurred.	0
TMODCHK	Test mode detection.	This bit can be cleared to 0 by using the CLRFLAG command with CL_TMODE = 1. Read: 1 = the device has previously activated a test mode. Read: 0 = the device has not activated a test mode.	1
OSCCHK	Oscillator check.	This bit can be cleared to 0 by using the CLRFLAG command with CL_OSCCHK = 1. 1 = an out of range oscillator count is detected during an ADC operation. 0 = no out of range oscillator counts are detected.	1
CT[10:0]	Conversions counter.	Free running C-ADC conversion counter. Resets with every ADCV command. Rolls over after maximum value.	0
CTS[1:0]	Conversions subcounter.	Free running C-ADC subsample conversion counter. 4 increments per sample. Resets with every ADCV command. Rolls over after maximum value. CT[10:0], CTS[1:0] can be treated as a 13-bit counter CCTS[12:0] that increments 4 times per sample. Can be read coherently to CADC results using the SNAP command to identify new or old samples. Coherency to SADC results is guaranteed only when CCTS is not 31, 32, 63, 64,	0

Table 109. Status Register D Bit Descriptions

Name	Description	Values	Default
CxOV	Cell x OV flag.	x = 1 to 16: C-ADC 1 ms cell voltage measurement result compared to VOV comparison voltage. 0 = Cell x not flagged for overvoltage condition. 1 = Cell x flagged.	1
CxUV	Cell x UV flag.	x = 1 to 16: C-ADC 1 ms cell voltage measurement result compared to VUV comparison voltage. 0 = Cell x not flagged for undervoltage condition. 1 = Cell x flagged.	1
OC_CNTR[7:0]	Oscillator check counter.	Stores the results of the oscillator counter check. If no OSCCHK failure occurs, this stores the most recently acquired oscillator count. If OSCCHK failure occurs, this stores the first failing counter value. Passing range is 52 to 71.	0

Table 110. Status Register E Bit Descriptions

Name	Description	Values	Default
GPiX	GPIOx pin state.	(Read only) 0 = GPIOx pin at Logic 0. 1 = GPIOx pin at Logic 1.	0
REV	Revision code.	Device Revision Code.	
RSVD	Reserved bits.	Read: read back value can be 1 or 0.	
RSVD0	Reserved bits.	Read: read back value is always 0.	0
RSVD1	Reserved bits.	Read: read back value is always 1.	1

MEMORY MAP

Table 111. PWM Register Bit Descriptions

Name	Description	Values	Default
PWMCx	PWM configuration.	4'b1111 = 100% duty cycle 4'b0001 = 6.6% duty cycle 4'b0000 = disabled (default)	4'b000

Table 112. LPCM Configuration Register Bit Descriptions

Name	Description	Values	Default
CMC_NDEV	Number of devices.	Set to number of devices + 0x42.	8'h00
CMC_MAN	Fault monitoring manager.	1 = enables manager function for this device. 0 = disables manager function for this device.	0
CMC_MPER	Fault monitoring measure (heartbeat) period.	000 = 1 second 001 = 2 seconds 010 = 4 seconds 011 = 8 seconds 100 = 12 seconds 101 = 16 seconds 110 = 32 seconds 111 = 1 second	000
CMC_BTM	Fault monitoring bridgeless LPCM timeout monitor.	1 = enables bridgeless LPCM timeout monitor for this device. 0 = disables bridgeless LPCM timeout monitor for this device.	0
CMC_TPER	Fault monitoring bridgeless timeout period.	000 = 1.5 seconds 001 = 3 seconds 010 = 6 seconds 011 = 12 seconds 100 = 18 seconds 101 = 24 seconds 110 = 48 seconds 111 = 1.5 seconds	000
CMC_DIR	Manager Tx direction.	Determines whether the manager device sends data from Port A or Port B. Does not care for other devices. 1 = manager sends CMHB out on Port A. 0 = manager sends CMHB out on Port B.	0
CMC_GOE	LPCM interrupt to GPIO.	Allows configuration of GPIO(s) as interrupt outputs. If bridgeless LPCM is enabled, interrupt is asserted based on timer or bad heartbeat final count. If not, bridgeless LPCM is based on this device's status. When used as interrupts, host must configure CMM_G[4:3] accordingly to mask the selected GPIO against use as an analog input. GPIOs are open-drain and require an external pull-up resistor. 000 = no GPIO outputs enabled. 001 = GPIO3 active low (interrupt asserts low). 010 = GPIO3 active high (interrupt asserts high). 011 = GPIO4 active low. 100 = GPIO4 active high. 101 = GPIO4 active low, GPIO3 active low. 110 = GPIO4 active low, GPIO3 active high. 111 = GPIO4 active high, GPIO3 active low.	000

MEMORY MAP

Table 112. LPCM Configuration Register Bit Descriptions (Continued)

Name	Description	Values	Default
CMM_C	Cell mask.	Mask/ignore individual cell results for setting the interrupt.	18'h0_000 0
CMM_G	GPIO mask.	Mask/ignore individual GPIO results for setting the interrupt. Note: masked GPIO channels are skipped during conversion sequencing.	10'h000

Table 113. LPCM Cell Threshold Register Bit Descriptions

Name	Description	Values	Default
CMT_CUV	Cell UV threshold.	12-bit, signed, LSB = 2.4 mV, offset = 1.5 V. For example, threshold = 2.5 V → CMT_CUV = (2.5 V - 1.5 V)/2.4 mV = 0x1A1.	12'h000
CMT_COV	Cell OV threshold.	12-bit, signed, LSB = 2.4 mV, offset = 1.5 V.	12'h000
CMT_CDV	Cell DV threshold.	12-bit, unsigned, LSB = 1.2 mV, offset = 0 V. For example, threshold = 0.2 V → CMT_CDV = 0.2 V/1.2 mV = 0x0A7.	12'h000

Table 114. LPCM GPIO Threshold Register Bit Descriptions

Name	Description	Values	Default
CMT_GUV	GPIO UV threshold.	12-bit, signed, LSB = 2.4 mV, offset = 1.5 V.	12'h000
CMT_GOV	GPIO OV threshold.	12-bit, signed, LSB = 2.4 mV, offset = 1.5 V.	12'h000
CMT_GDV	GPIO DV threshold.	12-bit, unsigned, LSB = 1.2 mV, offset = 0 V.	12'h000

Table 115. LPCM Flags Register Bit Descriptions

Name	Description ¹	Values	Default
CMC_EN	LPCM enabled status.	Reflect status of LPCM. Set through CMEN command, cleared through CMDIS command or POR. 0 = LPCM inactive. 1 = LPCM active.	0
CMF_BTWARD	Bridgeless watchdog flag.	Bridgeless LPCM timeout monitor interrupt due to watchdog timeout.	1
CMF_BTMCMP	Bridgeless message flag.	Bridgeless LPCM timeout monitor interrupt due to threshold comparison failure, indicated by either the heartbeat message or local comparisons.	1
CMF_CUV	LPCM cell UV flag.	Any nonmasked Cellx < CMT_CUV.	0
CMF_COV	LPCM cell OV flag.	Any nonmasked Cellx > CMT_COV.	0
CMF_CDVP	LPCM cell DVP flag.	Any nonmasked Cellx(n) to Cellx(n-1) > CMT_CDV.	0
CMF_CDVN	LPCM cell DVN flag.	Any nonmasked Cellx(n-1) to Cellx(n) > CMT_CDV.	0
CMF_GUV	LPCM GPIO UV flag.	Any nonmasked GPIOx < CMT_GUV.	0
CMF_GOV	LPCM GPIO OV flag.	Any nonmasked GPIOx > CMT_GOV.	0
CMF_GDVP	LPCM GPIO DVP flag.	Any nonmasked GPIOx(n) to GPIOx(n-1) > CMT_GDV.	0
CMF_GDVN	LPCM GPIO DVN flag.	Any nonmasked GPIOx(n-1) to GPIOx(n) > CMT_GDV.	0

¹ LPCM flags generated outside the LPCM operation are not to be considered.

Table 116. Communication Register Bit Descriptions

Name	Description	Values
ICOMx	Initial communication control bits.	Write for I ² C communication: 0110 = start. 0001 = stop. 0000 = blank. 0111 = no transmit. Read for SPI communication: 1000 = CSB low. 1010 = CSB falling edge. 1001 = CSB high.

MEMORY MAP

Table 116. Communication Register Bit Descriptions (Continued)

Name	Description	Values
Dx	I ² C/SPI communication data byte. Read data transmitted/ received) to or from I ² C/SPI target device.	1111 = no transmit. Read for I ² C communication: 0110 = start from controller. 0001 = stop from controller. 0000 = SDA low between bytes. 0111 = SDA high between bytes. Read for SPI communication: 0111 = all cases.
FCOMx	Final communication control bits.	Write for I ² C communication: 0000 = controller ACK. 1000 = controller NACK. 1001 = controller NACK + stop. Read for SPI communication: x000 = CSB low. 1001 = CSB high. Read for I ² C communication: 0000 = ACK from controller. 0111 = ACK from target. 1111 = NACK from target. 0001 = ACK from target + stop from controller. 1001 = NACK from target + stop from controller.

APPLICATIONS INFORMATION

PROVIDING POWER BY LINEAR REGULATOR

The primary supply pin for the ADES1830/ADES1831 are the 5 V ± 0.5 V V_{REG} input pin. The DRIVE pin can be used to form a discrete regulator with the addition of a few external components, as shown in Figure 37. The DRIVE pin provides a 5.7 V output, capable of sourcing 1 mA. When buffered with an NPN transistor, this configuration provides a stable 5 V over temperature. Choose the NPN transistor to have a sufficient beta value over temperature (>40) to supply the necessary supply current. The peak V_{REG} current requirement of the ADES1830/ADES1831 approaches 30 mA when simultaneously communicating over the isoSPI and while making ADC conversions. If the V_{REG} pin is required to support any additional load, a transistor with a higher beta value may be required.

The NPN collector can be powered from any voltage source that is a minimum 6 V above V₋, including the cells being monitored, or an unregulated power supply. A 330 Ω, 10 nF RC decoupling network is recommended for the collector power connection to protect the NPN from transients. Filter the DRIVE pin by adding a 10 Ω, 10 nF RC to the base of the NPN. The emitter must have a ferrite bead in series with a 1 μF reservoir capacitor required to bypass the V_{REG} pin. Avoid a larger capacitance because it increases the wake-up time of the ADES1830/ADES1831. Choose a transistor with adequate thermal dissipation. In most systems, it is good practice to choose a device with greater than 1 W because there can be significant power dissipation with a high collector voltage.

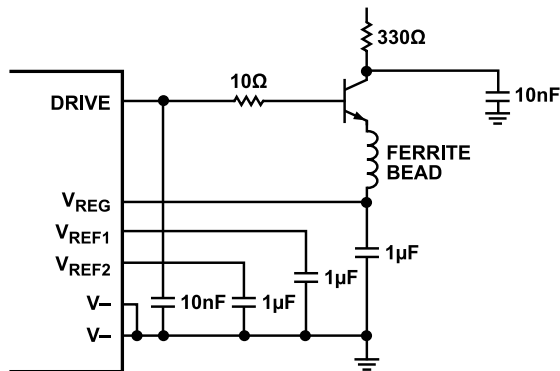


Figure 37. V_{REG} Power Source Using NPN Pass Transistor

INPUT FILTERING

The ADES1830/ADES1831 uses dedicated ADCs per cell without a multiplexer to measure cell voltages. Due to oversampling, Δ-Σ ADCs relax the input filtering requirements. Only fast transient noise around and above the sampling frequency of about 4 MHz must be filtered out by adding RC low pass decoupling to each ADC.

When converting cell voltages, the ADES1830/ADES1831 C-ADCs present a differential input impedance of 2.2 MΩ, leading to a differential input current of around 1.6 μA for a cell voltage around 4 V. The input current of neighboring channels cancels out if the

filter resistor is shared between two channels (Figure 38). For those channels, where the filter resistor is not shared with a neighboring channel, the introduced voltage drop over the filter resistor leads to a gain error in the C-ADC measurement. This gain error is calibrated out at a final test for a total of 200 Ω of filter resistance. Therefore, 200 Ω resistors must be placed in the cell inputs that are not shared between channels, as shown in Figure 38. Using 10 nF of differential capacitance leads to a cutoff frequency of around 80 kHz and provides >30 dB of damping at f_s~4 MHz.

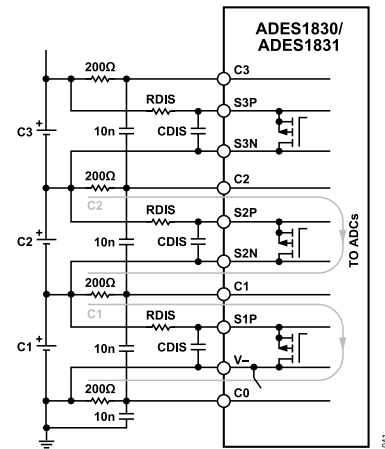


Figure 38. Input Filtering and Balancing Network

If a value different than 200 Ω is used for a filter resistor (R_{FILT}) that is not shared between two neighboring channels, the introduced measurement error of this channel due to the nominal input resistance and sampling offset current of the ADC can be calculated as follows:

$$V_{ERROR} = -V_{CELL} \times \frac{R_{FILT} - 200 \Omega}{2.2 M\Omega} - (R_{FILT} - 200 \Omega) \times 300 nA \tag{4}$$

For example, using a filter resistor of 470 Ω causes a measurement error of roughly V_{ERROR} = -0.5 mV.

The error due to a filter resistor different from 200 Ω can be compensated by applying the following formula:

$$V_{CELL_CORR} = V_{CELL} + V_{CELL} \times \frac{R_{FILT} - 200 \Omega}{2.2 M\Omega} + (R_{FILT} - 200 \Omega) \times 300 nA \tag{5}$$

where:

V_{CELL} is the ADC reading of the corresponding cell voltage.
R_{FILT} is the used filter resistor.

Because the input resistance and sampling offset current may deviate from their typical values according to the C-ADC specifications (see Table 1), a residual error after correction may occur. Figure 39 shows the maximum and minimum residual error after compensation for filter resistances of R_{FILT} = 470 Ω and R_{FILT} = 1 kΩ in function of the cell voltage.

APPLICATIONS INFORMATION

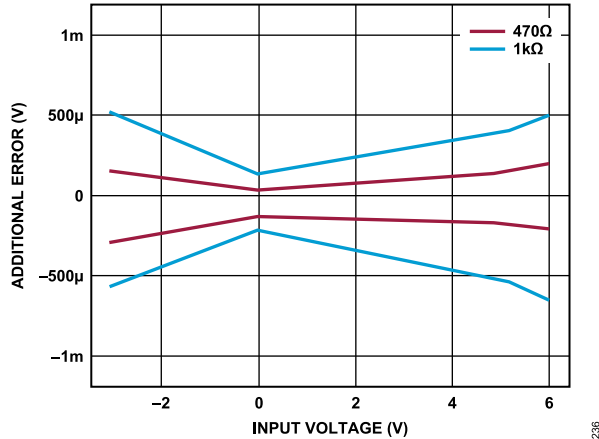


Figure 39. Cell Voltage Residual Error After Compensation

Only resistors not shared between two cell measurement channels and different from 200 Ω can cause an error to be compensated (concerns only the highest and lowest used measurement channels in a stack).

CELL BALANCING

The ADES1830/ADES1831 includes signals (the Sx pins) that can be used to balance cells with internal or external discharge. Cells can be discharged using the internal MOSFETs at the Sx pins, or the Sx pins can act as digital outputs to drive external transistors.

Cell Balancing with Internal MOSFETs

With passive balancing, if one cell in a series stack is overcharged, an Sx output can slowly discharge this cell by connecting it to a resistor. Each Sx output is connected to an internal MOSFET with a maximum on resistance of 4 Ω. Connect an external resistor in series with these MOSFETs to limit the discharge current and allow most of the heat to be dissipated outside of the ADES1830/ADES1831 package, as shown in Figure 38.

The internal discharge switches can be used to passively balance cells with a balancing current of 300 mA or less. Balancing currents larger than 300 mA is not recommended for the internal switches. When discharging cells with the internal discharge switches, monitor the die temperature.

To ensure valid comparison of C-ADC vs. S-ADC results, the time constant of the filter network on the Sx pins (RDIS and CDIS) must be chosen close to the time constant of the filter network on the Cx pins (200 Ω and 10 nF).

Cell Balancing with External Transistors

For applications that require balancing currents above 300 mA, the Sx outputs can be used to control external transistors. The Sx pins can act as digital outputs suitable for driving the gate of an external MOSFET. See Figure 40.

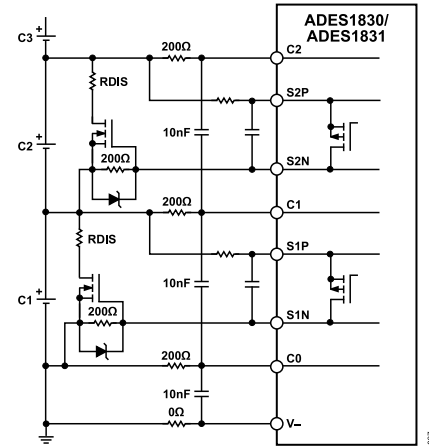


Figure 40. Cell Balancing with External Transistors

CELL DEPOPULATION

The ADES1830/ADES1831 can be used in applications using fewer than the maximum of 16 cells to be monitored. The minimum of cells that can be monitored is given by the minimum supply voltage at V+ of 11 V.

Cell Depopulation with ADES1830/ADES1831

The ADES1830/ADES1831 uses charge pumps to drive the gates of the PMOS balancing FET of Channels S1, S2, and S3 to ensure enough gate drive even at low input voltage of these channels. Therefore S1, S2, and S3 must not be depopulated if cell balancing on the next higher channel is required. Therefore, it is recommended to start depopulating from the top, as shown in Figure 41.

The first used channel suffers from the voltage drop caused by the input current over the filter resistor, which is not compensated by the return current from the next higher cell. This error can be compensated by the following formula:

$$V_{CELL_CORR} = V_{CELL} + V_{CELL} \times \frac{R_{FILT}}{2.2 \text{ M}\Omega}$$

As an example, the uncompensated error is typically in the order of:

$$V_{ERROR_UNCOMP} = -V_{CELL} \times \frac{R_{FILT}}{2.2 \text{ M}\Omega} = -4 \text{ V} \times \frac{200 \text{ }\Omega}{2.2 \text{ M}\Omega} = -320 \text{ }\mu\text{V}$$

APPLICATIONS INFORMATION

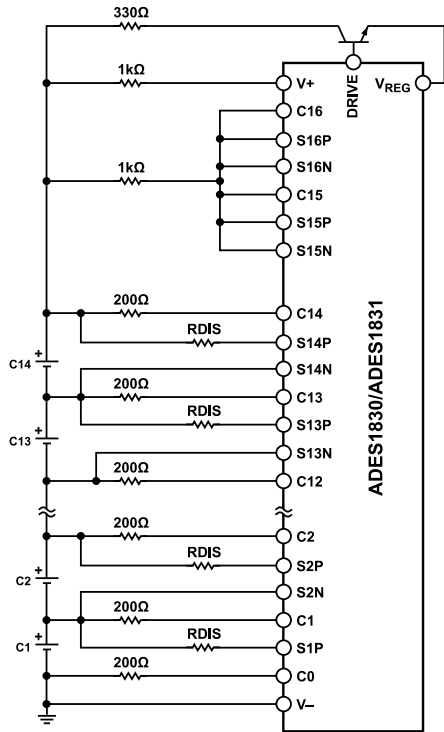


Figure 41. Cell Depopulation

BUS BAR MONITORING AND BYPASSING

All ADES1830/ADES1831 cell measurement channels can measure negative voltages down to -2 V and can thus be used to measure the voltage drop over bus bars. The Sx pins must be

disconnected or shorted to either side of the bus bar to avoid current through the body diode of the PMOS.

If the voltage over a bus bar does not need to be measured, a bus bar bypass is possible between Channel 8 and Channel 9 for the ADES1830/ADES1831.

If a channel is used to measure a bus bar, the currents through the filter resistor shared with a neighborhood channel do not cancel out because the bus bar voltage is typically much lower than a cell voltage.

This causes an error in measurement of the neighborhood channels, with which the bus bar channel shares the filter resistors. The introduced error is typically in the range of:

$$V_{ERROR_UNCOMP} = -V_{CELL} \times \frac{R_{FILT}}{2.2 \text{ M}\Omega} = -4 \text{ V} \times \frac{200 \text{ }\Omega}{2.2 \text{ M}\Omega} = -320 \text{ }\mu\text{V}$$

and can be compensated by applying the following correction to the cell voltage reading of the concerned channels:

$$V_{CELL_CORR} = V_{CELL} + V_{CELL} \times \frac{R_{FILT}}{2.2 \text{ M}\Omega}$$

When connecting a bus bar to a measurement channel, the Sx pins need to be disconnected from the inputs to avoid current through the body diode of the PMOS in case of negative voltages. It is also possible to connect the shorted Sx pins to one side of the bus bar connector. Do not connect the shorted Sx pins directly to one of the Cx pins as this could cause measurement errors due to additional leakage on the Cx pin measurement path.

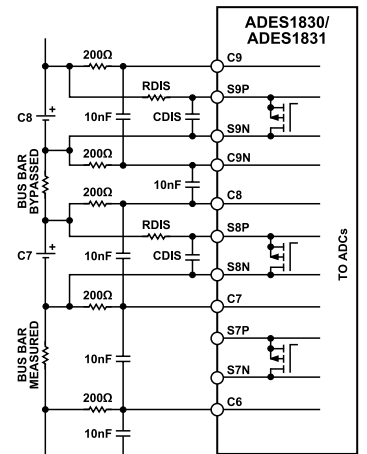


Figure 42. Measuring or Bypassing Bus Bars

APPLICATIONS INFORMATION

INTERNAL PROTECTION

The ADES1830/ADES1831 incorporates various ESD safeguards to ensure robust performance. Figure 43 shows an equivalent circuit with the specific protection structure. Zener like suppressors are shown with their nominal clamp voltage.

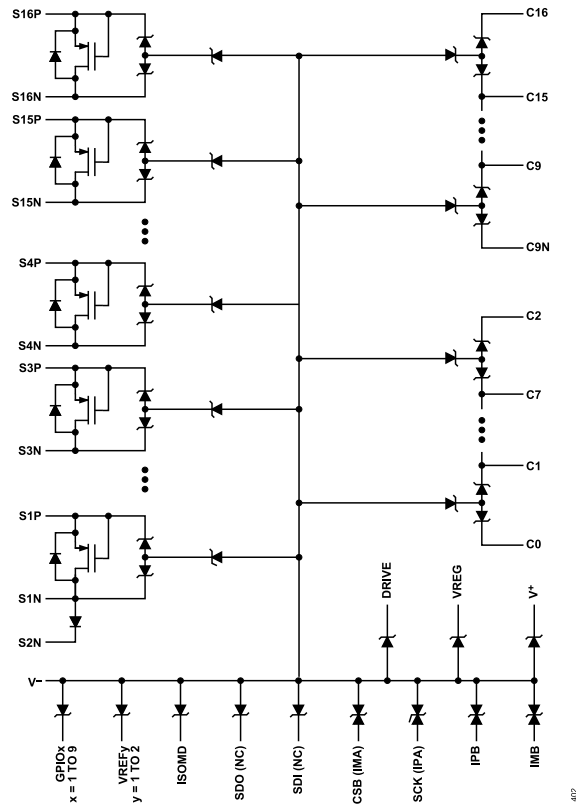


Figure 43. Internal ESD Protection Structures of the ADES1830/ADES1831

CURRENT MEASUREMENT CAPABILITIES

One of the ADES1830/ADES1831 auxiliary inputs can be utilized as a current measuring channel with a high accuracy of $\pm 0.2\%$ through the use of a shunt and internal ADC. A recommended Analog Devices ADC is the ADA4051-1, which is a zero drift operational amplifier featuring rail-to-rail input/output swing and an extremely low offset voltage of $15 \mu\text{V}$ maximum while operating from a 1.8 V to 5.5 V power supply and a typical supply current of $13 \mu\text{A}$ per amplifier.

Figure 44 shows an example circuit from Analog Devices of a high accuracy current measurement system providing a gain of 50 V/V while utilizing the low sense shunt measurement capabilities.

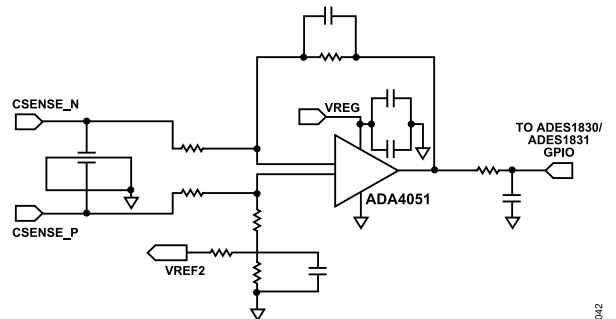


Figure 44. Typical Application of Current Measurement Capabilities

OUTLINE DIMENSIONS

Package Drawing (Option)	Package Type	Package Description
CS-72-3	LFCSP_SS	72-Lead 10 mm × 10 mm Body, with Side Solderable Leads

For the latest package outline information and land patterns (footprints), go to [Package Index](#).

Updated: March 08, 2024

ORDERING GUIDE

Model ¹	Temperature Range	Package Description	Packing Quantity	Package Option
ADES1830CCSZ	-40°C to +105°C	72-lead LFCSP-CS (10 mm x 10 mm x 0,75 mm)		CS-72-3
ADES1830CCSZ-RL	-40°C to +105°C	72-lead LFCSP-CS (10 mm x 10 mm x 0,75 mm)	Reel, 2000	CS-72-3
ADES1831CCSZ	-40°C to +105°C	72-lead LFCSP-CS (10 mm x 10 mm x 0,75 mm)		CS-72-3
ADES1831CCSZ-RL	-40°C to +105°C	72-lead LFCSP-CS (10 mm x 10 mm x 0,75 mm)	Reel, 2000	CS-72-3

¹ Z = RoHS Compliant Part.

EVALUATION BOARD

Model ¹	Package Description
EV-ADES1830CCSZ	Evaluation Board for ADES1830

¹ Z = RoHS Compliant Part.