Advanced Power Management Using the ALS31300 and ALS31313 3D Hall-Effect Sensor ICs with I²C Output

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Abstract

With the proliferation of human interface devices, there is a growing need for robust, non-contact sensing solutions that are low cost, low power, and low form factor. The Allegro ALS31300 and ALS31313 3D Hall-effect sensor ICs are ideally suited for trigger, pushbutton, rotation, joystick, and 2D slider joystick applications. The highly configurable power management options, including low-power duty cycle mode, sleep mode and wake on motion, make the these devices well-suited in battery-powered applications such as drones, camera gimbals, as well as console and mobile gaming controllers. This application note discusses the unique and advanced low power modes available on the ALS31300 and ALS31313 3D linear Hall-effect sensor ICs with I^2C output available from Allegro MicroSystems.

References throughout this application note to the ALS31300 also apply for the ALS31313, except that the ALS31300 is provided in a 10-contact DFN package, and the ALS31313 is provided in a TSSOP-8 package.

Introduction

The ALS31300 is a 3D linear Hall-effect sensor IC from Allegro MicroSystems. The ability to sense magnetic fields in three different axes allows the ALS31300 to be extremely versatile to sense linear motion on any axis or rotational motion using magnetic data from two axes. This application note will walk the user through application examples and device configuration tailored for specific application needs.

The ALS31300 sensor may operate on supply voltages from 2.65 to 3.5 V and features highly configurable power management to maximize efficiency. The available power modes and typical supply currents for the ALS31300 are listed in Table 1.

Table 1: ALS31300 Power Modes

Operating Mode	Mode Description	Supply Current (Typical)
Active Mode	The device continuously updates magnetic and temperature data. Supply current is constant.	$I_{CC(ACTIVE)} \approx 3.4$ mA
Sleep Mode	The device is in a near powered-off state. No magnetic or temperature data updates. Supply current is constant.	$I_{CC(SLEEP)} \approx 14$ nA
Low Power Duty Cycle Mode (LPDCM)	The device toggles between fully active and inactive state. The device periodically wakes up to refresh magnetic and temperature data.	$I_{CC(ACTIVE)} \approx 3.4$ mA $I_{CC(INACTIVE)} \approx 12$ µA

The operating mode of the ALS31300 is determined by the value in the Sleep field: address 0x27, bits 1:0. These bits may be accessed at any time and are described in Table 2.

Table 2: Sleep Register

Address	Bits	Value	Operating Mode
0x27	1:0	0	Active Mode
		1	Sleep Mode
		2	Low-Power Duty Cycle Mode (LPDCM)

Sleep Mode

In sleep mode, the ALS31300 is in a near powered-off state where it consumes the minimum amount of current (14 nA, typical). In this mode, the device will still respond to I^2C commands, but will not update magnetic or temperature data. Sleep mode is valuable in applications where the supply voltage cannot be disabled but minimal power consumption is required. The time it takes to exit sleep mode is equivalent to Power-On Delay time (t_{POD}).

Low Power Duty Cycle Mode (LPDCM)

In Low Power Duty Cycle Mode (LPDCM), the ALS31300 toggles between active and inactive states, reducing overall current consumption. The average I_{CC} for the ALS31300 during low power duty cycle mode varies based on the settings used, and may range between 12 µA to 2 mA (typical).

The diagram in Figure 1 shows the profile of I_{CC} as the ALS31300 toggles between active and inactive states during Low Power Duty Cycle Mode.

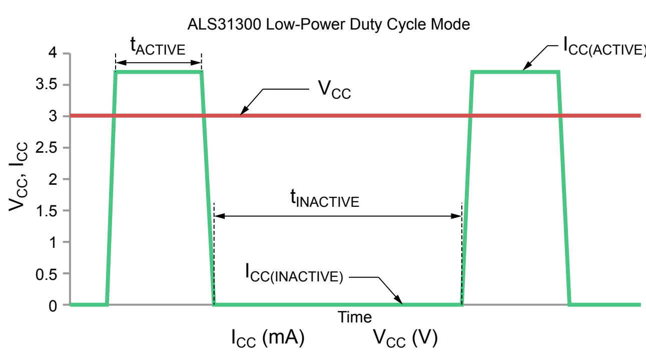

Figure 1: I_{CC} in Low Power Duty Cycle Mode

The duration $t_{INACTIVE}$ is determined by the field *Low Power Mode Count Max*: address 0x27, bits 6:4. The ALS31300 offers eight discrete time frames for $t_{INACTIVE}$.

The typical values for $t_{INACTIVE}$ are listed in Table 3. Typical I_{CC} during $t_{INACTIVE} \approx 12\ \mu A$.

Table 3: LPDCM Inactive Time ($t_{INACTVE}$)

Address	Bits	Value	$t_{INACTIVE}$ (typ) (ms)
0x27	6:4	0	0.5
		1	1
		2	5
		3	10
		4	50
		5	100
		6	500
		7	1000

The duration of t_{ACTIVE}, shown in Figure 1, is dependent on two settings: *BW Select* and the number of active channels.

Magnetic sensing channels on the ALS31300 are enabled independently by writing '1' to the *channel x en*, *channel y en*, and *channel z en* bits, listed in Table 4.

Table 4: Channel Enable Control

Address	Bits	Value	Description
0x02	8	1	Enables Z Sensing Channel
	7	1	Enables Y Sensing Channel
	6	1	Enables X Sensing Channel

BW Select controls the amount of filtering applied to the sampled magnetic data. Values for BW Select and corresponding update rates (typical) are listed in Table 5.

Table 5: BW Select and Update Rate

BW Select Value	1 Channel Update Rate		2 Channel Update Rate		3 Channel Update Rate		–3 dB Bandwidth
	µs	kHz	µs	kHz	µs	kHz	kHz
0	160	6	330	3	495	2	3.5
1	80	13	170	6	255	4	7
2	40	25	90	11	135	7	14
3	–	–	–	–	–	–	–
4	64	16	138	7	207	5	10
5	32	31	74	14	111	9	20
6	16	63	42	24	63	16	40
7	–	–	–	–	–	–	–

Resulting noise performance for each BW Select value is listed in Table 6.

Table 6: BW Select, Filtering Modes and Resulting Noise Performance (Input Referred)

BW Select Value	FIR Enabled	Z Channel Noise (G)	X/Y Channel Noise (G)
0	1	1.5	4
1	1	2	5
2	1	2.2	7
3	–	–	–
4	0	2	6
5	0	2.5	8
6	0	3.5	10
7	–	–	–

Configuring Low Power Duty Cycle Mode

This section will serve as a guide for configuring Low Power Duty Cycle Mode (LPDCM) based on a few top-level system requirements. Users should consider the goals of the specific application while configuring low power operation for the ALS31300. Screenshots in this section are taken from the ALS31300 Demonstration software available on Allegro's Software Portal.

LPDCM Example

Assume the ALS31300 is used in a system that requires new magnetic data from two channels, X and Y, approximately every 500 µs with full resolution.

First the X and Y magnetic channels are enabled and the Z channel is disabled under the EEPROM tab. The Bandwidth Select value is set to code '0' for full measurement resolution. Refer to the screenshot in Figure 2. Note: All channels come enabled from the Allegro factory.

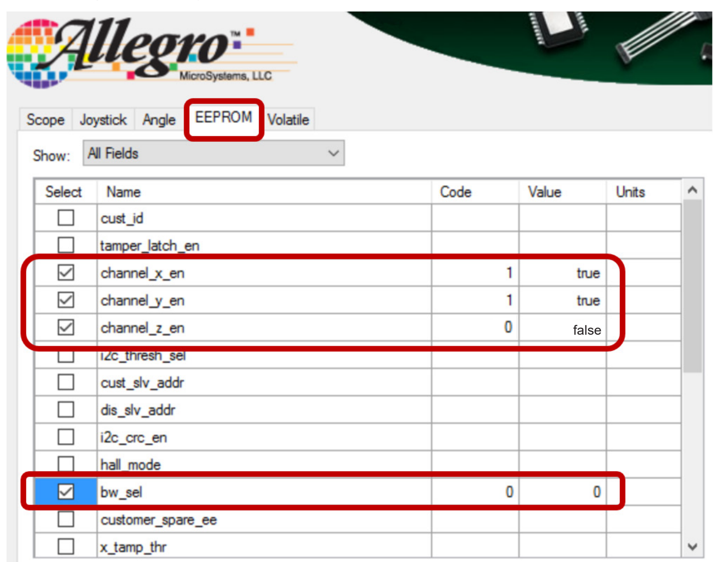

Figure 2: Setting the Active Channels

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Next, set the value for *LPM Count Max*, which controls the duration of $t_{INACTIVE}$. Referring back to Table 3, the appropriate code for $t_{INACTIVE} \approx 500$ µs is code ‘0’. With LPM Count Max set, the device may then be put into LPDCM by setting the Sleep field to a value of ‘2’. These volatile settings are shown in the screenshot in Figure 3.

Figure 3: LPM Count Max and Sleep

The resulting I_{CC} profile is shown in the scope plot in Figure 4. Key parameters including inactive time ($t_{INACTIVE}$), active time (t_{ACTIVE}), $I_{CC(ACTIVE)}$, and $I_{CC(INACTIVE)}$ are highlighted.

Note that the I²C commands are still processed even while the ALS31300 returns to the inactive state. This is possible because the I²C clock (SCLK) is processed in a separate domain from the main system clock.

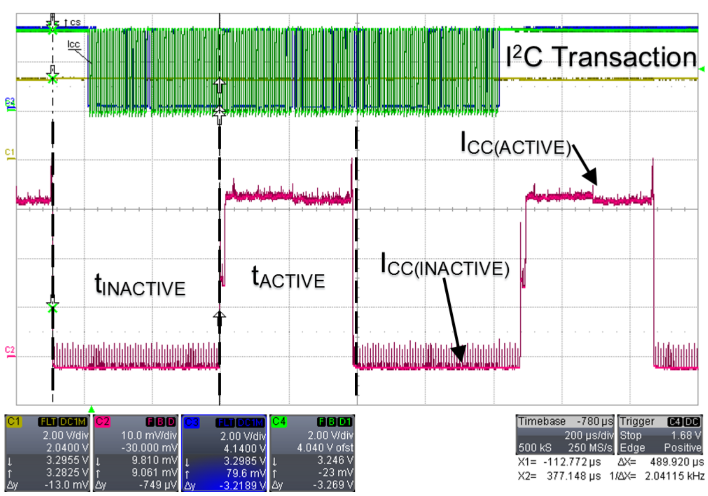

Figure 4: Measured I_{CC} profile during LPDCM

In Figure 4, I_{CC} was observed by measuring a voltage across a series resistor on VCC using an oscilloscope with a differential probe (Figure 5).

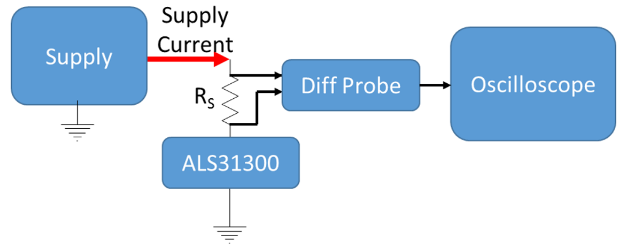

Figure 5: Bench for Observing I_{CC} during LPDCM

Estimating I_{CC} Consumption

The average current consumption can be estimated based on the scope plot in Figure 4 and the typical values for t_{ACTIVE}, $t_{INACTIVE}$, $I_{CC(ACTIVE)}$, and $I_{CC(INACTIVE)}$. Recall that the duration t_{ACTIVE} is the combination of settings for BW Select and the number of active channels.

The typical values for each of the parameters used in this example are summarized in Table 7.

Table 7: Typical Values for Key LPDCM Parameters

Parameter Name	Typical Value	Units
$t_{INACTIVE}$	500	µs
t_{ACTIVE}	390	µs
$I_{CC(ACTIVE)}$	3.4	mA
$I_{CC(INACTIVE)}$	12	µA

For a complete table on timing versus BW Select and number of active channels, refer to Table 8 in Appendix A.

Current consumption may be estimated by the following equation, Average I_{CC} in LPDCM:

$$I_{CC\,(AVG)} = \frac{(I_{CC\,(ACTIVE)} \times t_{ACTIVE}) + (I_{CC\,(INACTIVE)} \times t_{INACTIVE})}{t_{ACTIVE} + t_{INACTIVE}} \quad (1)$$

Replacing the symbols in this equation with their typical values, I_{CC} may be estimated as:

$$I_{CC\,(AVG)} = \frac{(3.4\ mA \times 390\ \mu s) + (12\ \mu A \times 500\ \mu s)}{390\ \mu s + 500\ \mu s} = 1.5\ mA$$

Advanced Low Power Management Using the Interrupt Feature on ALS31300

The interrupt feature on the ALS31300 enables further system level power savings for applications requiring long battery life. This technique allows a system’s microcontroller to enter a low power state and wait for an interrupt from the ALS31300.

Assume that a system is monitoring for the presence of an applied magnetic field. For example, an electricity power meter may become inaccurate in the presence of large external magnetic fields. Assume this meter is sensitive to magnetic fields greater than 300 gauss (30 mT). Finally, assume there is a need for maximum current reduction in the system while on battery power due to a power blackout. A simplified block diagram is outlined in Figure 6.

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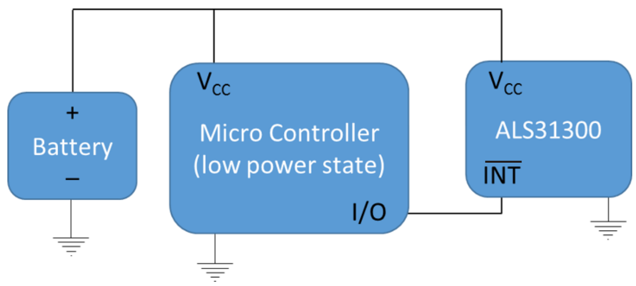

Figure 6: Simplified Tamper Detection Block Diagram

Initialize Interrupt Conditions and Configure Device for LPDCM

The ALS31300 interrupt thresholds may be configured independently for all three axes (X, Y, and Z). For this example, each axes threshold will be set to a value equivalent to 300 gauss.

During normal operation of the meter, the ALS31300 will be used in its full active mode, Sleep = 0, since power consumption is not as much of a concern. In this mode, the device is consuming its typical $I_{CC(ACTIVE)}$ at all times and continuously updating magnetic and temperature data.

Assume that the electricity meter detects a loss of power from the grid and reverts to battery backup, but it is still necessary to monitor for tampering events or large external fields. Since these events are interesting but not dangerous, we may choose to put the ALS31300 in its most efficient LPDCM.

First, set BW Select to the fastest state, code 7.

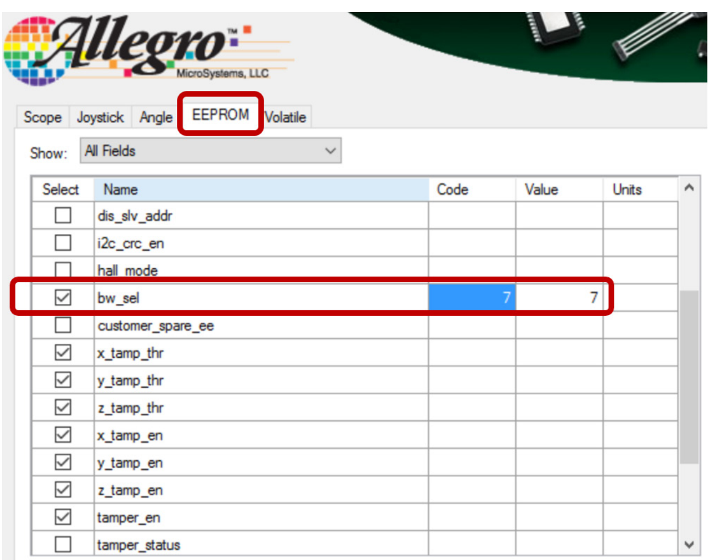

Figure 7: Fastest BW Select Code = 7

Next, configure the ALS31300 for one of its longest $t_{INACTIVE}$ times by setting LPM Count Max to code 6. Referring back to Table 3, we can see code 6 corresponds to a $t_{INACTIVE}$ time of 500 ms.

Average I_{CC} consumption is again estimated in this mode using Equation 1 and substituting the symbols with typical values.

Typical value for $t_{INACTIVE}$ with 3 channels enabled and BW Select = 7 can be found in Table 8 in Appendix A.

$$I_{CC\,(AVG)} = \frac{(3.4\ mA \times 89\ \mu s) + (12\ \mu A \times 500\ ms)}{89\ \mu s + 500\ ms} = 12.6\ \mu A$$

The system's microcontroller may now be put into a deeper sleep state where it will be woken up by an active low by an active low Interrupt signal from the ALS31300 in the presence of field > 300 gauss.

The resulting I_{CC} profile is shown in the scope plot in Figure 8. The duration of t_{ACTIVE} is so small in comparison to $t_{INACTIVE}$ that it appears as two small slits on the oscilloscope. I^2C transactions still occur during LPDCM.

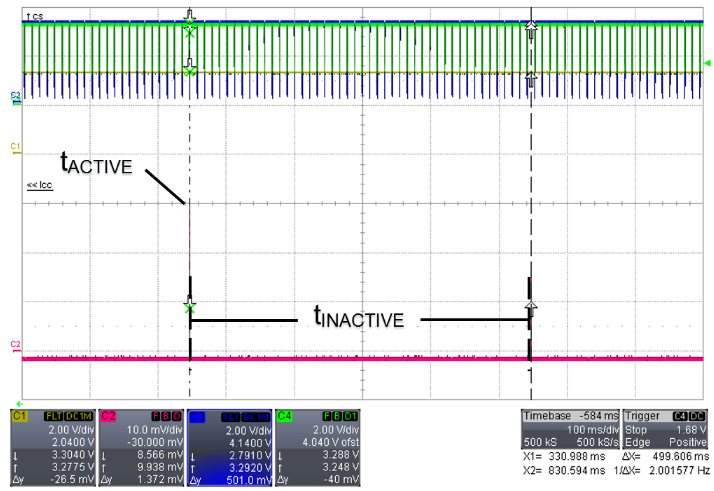

Figure 8: I_{CC} Profile During LPDCM

The scope plot in Figure 9 shows the Interrupt pin of the ALS3100 responding to an applied magnetic field > 300 gauss. The $\overline{INT}$ signal may be used as a wake up event for the meter's micro, alerting the system to handle the tampering event.

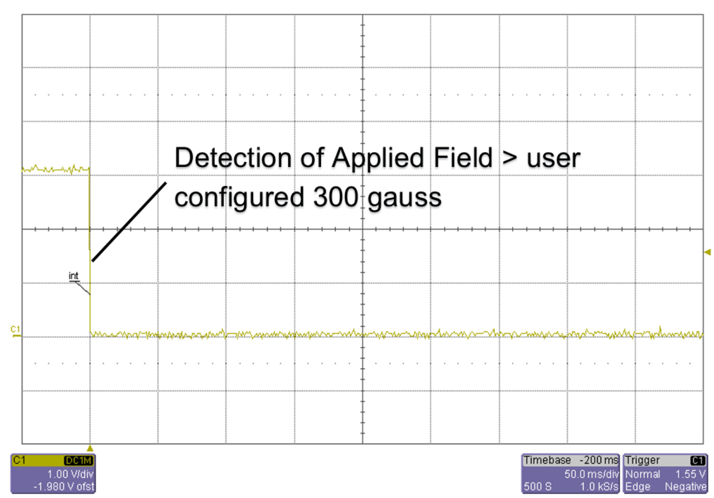

Figure 9: ALS31300 $\overline{INT}$ Pin Responding to Field > 300 G

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APPENDIX A

The full table of typical values for active time (t_{ACTIVE}) based on BW SELECT settings and the number of active channels are shown in Table 8.

Table 8: Typical Active Times (t_{ACTIVE}) vs. Number of Active Channels and BW Select Values

BW SELECT	Active Channels	Active Time (t_{ACTIVE}) (μs)
0	3	592
	2	390
	1	218
1	3	313
	2	224
	1	135
2	3	188
	2	141
	1	114
3	–	–
	–	–
	–	–
4	3	263
	2	191
	1	119
5	3	164
	2	125
	1	84
6	3	114
	2	91
	1	69
7	–	–
	–	–
	–	–

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Revision History

Number	Date	Description
–	August 3, 2017	Initial release
1	August 23, 2017	Revised Abstract (page 1)
2	August 8, 2018	Added ALS31313 part references
3	August 16, 2019	Minor editorial updates

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