Integrated Optical Sensor Module for Mobile Health

General Description

The MAX86916 is an integrated optical sensor platform with applications in bio-sensing, proximity, and color. It includes internal LEDs, photodetectors, and low-noise electronics with ambient-light-rejection circuitry. The MAX86916 helps ease design-in effort to all mobile and wearable devices.

The MAX86916 operates on a 1.8V supply voltage, with a separate 5.5V power supply for the internal LEDs. Communication to and from the module is accomplished entirely through a standard I²C-compatible interface. The module can be shut down through software with near-zero standby current, allowing the power rails to remain powered at all times.

Applications

- Smartphones/Accessories
- Tablets
- Wearable Devices
- Fitness Assistant Devices

Benefits and Features

- Miniature 3.5mm x 7.0mm x 1.5mm, 14-Pin Optical Module
- Optical-Grade Glass for Long-Term Optimal and Robust Performance
- Ultra-Low-Power Operation for Mobile Device
- Ultra-Low Shutdown Current (0.7µA, Typical)
- Built-In Low Noise Crosstalk Cancellation
- -40°C to +85°C Operating Temperature Range
- Reflective Heart Rate Monitor, Medical-Grade Pulse Oximeter, and Bio-Optical Sensor Platform

Ordering Information appears at end of data sheet.



Integrated Optical Sensor Module for Mobile Health

Absolute Maximum Ratings

VDD to GND	-0.3V to +2.2V
PGND to GND	-0.3V to +0.3V
VLED to PGND	-0.3V to +6.0V
LED_DRV1 to PGND	-0.3V to V _{LED} +0.3V
LED_DRV2 to PGND	-0.3V to V _{LED} +0.3V
LED_DRV3 to PGND	-0.3V to V _{LED} +0.3V
LED_DRV4 to PGND	-0.3V to V _{LED} +0.3V
VREF to GND	-0.3V to +2.2V
All other pins to GND	-0.3V to +6V

Output Short-Circuit Duration	Continuous
Continuous Input Current Into Any Pin	
(except LED_DRVx Pins)	±20mA
Continuous Power Dissipation	
(derate 3.25mW/°C above +70°C)	300mW
Operating Temperature Range	40°C to +85°C
Storage Temperature Range	40°C to +105°C
Soldering Temperature (reflow)	+260°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Information

PACKAGE TYPE: 14 OLGA					
Package Code	F143B7MK+1				
Outline Number	21-100325				
Land Pattern Number	90-100122				
THERMAL RESISTANCE, FOUR-LAYER BOARD:					
Junction to Ambient (θ_{JA})	125.6°C/W				
Junction to Case (θ_{JC})	123.1°C/W				

For the latest package outline information and land patterns (footprints), go to <u>www.maximintegrated.com/packages</u>. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to <u>www.maximintegrated.com/thermal-tutorial</u>.

Electrical Characteristics

 $(V_{DD} = 1.8V, V_{LED} = 5V, LED_PW = 70\mu s, SR = 1000 sps, ADC_RGE = 32\mu A, LEDx_RGE = 50mA, T_A = +25^{\circ}C, min/max are from T_A = -40^{\circ}C to +85^{\circ}C, unless otherwise noted, Note 1).$

PARAMETER	SYMBOL	CONDITIONS			TYP	MAX	UNITS
POWER SUPPLY							
Power Supply Voltage	V _{DD}	Verified during PSRF	R Test	1.7	1.8	2.0	V
LED Supply Voltage (Note 2)	V _{LED}	Verified during PSRF	R Test	3.5		5.5	V
			One LED Exposure/Sample		410		
	I _{DD}	LEDx_PA = 0x00, LED_PW = 220µS, SR = 100sps	Two LED Exposures/Sample		420		
Supply Current			Three LED Exposures/ Sample		440		μA
			Four LED Exposures/Sample		450	750	
LED Supply Current		LEDx_PA = 0x00, LED_PW = 220µS, SR = 100sps	One LED Exposure/Sample		0.2		
			Four LED Exposures/Sample		0.6	2	
	LED	LEDx_PA = 0xFF,	One LED Exposure/Sample		1300		μΑ
		LED_PW = 220µS, SR = 100sps	Four LED Exposures/Sample		5400		

Electrical Characteristics (continued)

 $(V_{DD}$ = 1.8V, V_{LED} = 5V, LED_PW = 70µs, SR = 1000sps, ADC_RGE = 32µA, LEDx_RGE = 50mA, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted, Note 1).

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Current in Shutdown	IDDSHDN	SHUTDOWN = 1			0.7	20	μA
LED Supply Current in Shutdown	ILEDSHDN	SHUTDOWN = 1			0.7	1	μA
VREF	VREF			1.195	1.210	1.220	V
OPTICAL SENSOR CHARACT	ERISTICS						
ADC Full-Scale Range	ADC FS				4, 8, 16, 32		μA
ADC Resolution	ADC RES				19		bits
Sampling Clock Frequency	CLK			31.36	32.0	32.64	kHz
Dark Current Count	LED_DCC	LEDx_PA = 0x00, LE ADC_RGE = 4µA	D_PW = 420µs, SR = 100sps,		10	128	Counts % of FS
Ambient Light Detect Noise	Amb_ Light_Det_ Noise	LEDx_PA = 0x00, LE DET = 0x1, SR = 100 T _A = +25°C	D_PW = 420μs, AMB_LIGHT_) sps, ADC FS = 4μA,		170	384	Counts
		Propriety ATE	LED4_PA = 0x5F	-15%	115k	+15%	
Blue ADC Count	BLUE _C	setup, LED_RGE = 150mA, SR = 1600sps, T _A = +25°C	LED4_PA = 0xBF	-15%	190k	+15%	
			LED4_PA = 0xFF	-15%	235k	+ 15%	
	GREEN _C	Propriety ATE setup, LED_RGE = 150mA, SR = 1600sps, $T_A = +25$ °C	LED3_PA = 0x5F	-15%	95k	+15%	_
Green ADC Count			LED3_PA = 0xBF	-15%	160k	+15%	
			LED3_PA = 0xFF	-15%	200k	+15%	Counts
		Propriety ATE setup, LED_RGE = 150mA, SR = 1600sps, T _A = +25°C	LED2_PA = 0x5F	-15%	135k	+15%	_
Red ADC Count	RED _C		LED2_PA = 0xBF	-15%	265k	+15%	
			LED2_PA = 0xFF	-15%	350k	+15%	
		Propriety ATE setup,	LED1_PA = 0x5F	-15%	160k	+15%	
IR ADC Count	IR _C	LED_RGE = 150mA, SR = 1600sps,	LED1_PA = 0xBF	-15%	310k	+15%	
		T _A = +25°C	LED1_PA = 0xFF	-15%	400k	+15%	
	DSPDupp	Propriety ATE setup,LEDx_RGE = 100mA, LEDx_PA = 0xFF	1.7V < V _{DD} < 2.0V		0.25	2	% of FS
ADC Count - PSRR (VDD)	PSRR _{VDD}	LEDx_RGE = 150mA, LED_PW = 120µs, ADC = 16µA	Frequency = DC to 100kHz, 100mV _{P-P}		30		LSB

Electrical Characteristics (continued)

 $(V_{DD}$ = 1.8V, V_{LED} = 5V, LED_PW = 70µs, SR = 1000sps, ADC_RGE = 32µA, LEDx_RGE = 50mA, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted, Note 1).

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
		Propriety ATE setup,	For IR/RED 3.5V < V _{LED+} < 5.5V		0.05	1	% of ES
ADC Count - PSRR (VLED)	PSRR _{VLED}	LEDx_PA = 0xFF	For Green/Blue 4.5V < V _{LED+} < 5.5V		0.05	1	% UI FS
		LEDx_RGE = 150mA, LED_PW = 120µs, ADC = 16µA	Frequency = DC to 100kHz, 100mV _{P-P}		40		LSB
Max. DC Ambient Light Rejection	ALR	16 KLUX(QTH Lamp) directly on sensor, T _A = +25°C		200		uA
CROSSTALK CANCELLATION	DAC						
Crosstalk Cancellation Range	XTALK RANGE			0		1/2 ADC FS	uA
Crosstalk Cancellation Resolution	XTALK RES				5		bit
Maximum Crosstalk Cancellation Counts	XTALK COUNTS	XTALK_CANCEL = 0x1F, LED_PW = 120μs, ADC_ RGE = 16μA, LEDx_RGE = 150mA, LED1_PA = 0x70 LED2_PA = 0x80, LED3_PA = 0xF0, LED4_ PA = 0xD0			253, 952	+5%	Counts
Maximum Crosstalk Noise Contribution	XTALK NOISE	LED_PW = 120µs, SR = 400 sps, ADC_RGE = 16µA, LEDx_RGE = 150mA			0.3		dB
LED DRIVERS							
		LEDx_RGE<1:0> = 00			50, 0.15		
Maximum LED Drive Current and Headroom Voltage	I _{LED,} VLED_head- room	LEDx_RGE<1:0> = 01			100, 0.3		mA, V
		LEDx_RGE<1:0> = 10		15 0	150, 0.44		
LED Current Resolution					8		Bits
		LED_PW<1:0> = 0x0	00		70		
LED Bules Width		LED_PW<1:0> = 0x0)1		120		
		LED_PW<1:0> = 0x1	10		220		μs
		LED_PW<1:0> = 0x11			420		
IR LED CHARACTERISTICS (Note 3)						
Centroid Wavelength	λ _{centroid}	I _F = 100mA, tp = 10n	ns, T _A = +25°C	930		955	nm
Forward Voltage	V _F	I _F = 100mA, tp = 10 i	ms, T _A = +25°C		1.6	1.8	V
Radiant Power	Φe	I _F = 100mA, T _A = +25°C			60		mW
Maximum Forward Current		T _A = +25°C				100	mA
Maximum Junction Temperature	T.I					125	°C

Electrical Characteristics (continued)

 $(V_{DD}$ = 1.8V, V_{LED} = 5V, LED_PW = 70µs, SR = 1000sps, ADC_RGE = 32µA, LEDx_RGE = 50mA, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted, Note 1).

PARAMETER	SYMBOL	CONDITIONS		TYP	MAX	UNITS	
RED LED CHARACTERISTICS	6 (Note 3)	-					
Centroid Wavelength	λ _{centroid}	I _F = 50mA, T _A = +25°C	655		663	nm	
Forward Voltage	V _F	I _F = 50 mA, tp = 5 ms, T _A = +25°C	1.90	2.30	2.40	V	
Radiant Power	Φ _e	I _F = 20 mA, T _A = +25°C		6.4		mW	
Maximum Forward Current		T _A = +25°C			70	mA	
Maximum Junction Temperature	TJ				125	°C	
GREEN LED CHARACTERISTICS (Note 3)							
Centroid Wavelength	λ _{centroid}	I _F = 140mA, tp = 10 ms, T _A = +25°C	520		535	nm	
Forward Voltage	V _F	I _F = 140 mA, tp = 5 ms,, T _A = +25°C	3.1	3.5	3.9	V	
Radiant Power	Φ _e	I _F = 20mA, T _A = +25°C		6		mW	
Maximum Forward Current		T _A = +25°C			140	mA	
Maximum Junction Temperature	TJ				150	°C	
BLUE LED CHARACTERISTIC	S (Note 3)						
Centroid Wavelength		I _F = 20mA, tp = 10 ms, T _A = +25°C	455		466	nm	
Forward Voltage	V _F	I _F = 20 mA, tp = 5 ms,, T _A = +25°C	2.70	2.85	3.30	V	
Radiant Power	ΦΕ	I _F = 20 mA, T _A = +25°C		10		mW	
Maximum Forward Current		T _A = +25°C			60	mA	
Maximum Junction Temperature	TJ				125	°C	
PHOTODIODE (Note 3)							
Spectral Range of Sensitivity	L _{10%}			400 1100		nm	
Radiant Sensitive Area	A			1.51		mm ²	
Photo Diode Dark Current	IPD_DARK	Vr = 5V			5	nA	
DIGITAL CHARACTERISTICS	(SDA, SCL	, INTB)					
Output Low Voltage SDA, INTB	V _{OL}	I _{SINK} = 6mA			0.4	V	
I2C Input Voltage Low	V _{IL_I2C}	SDA, SCL			0.4	V	
I2C Input Voltage High	V _{IH_I2C}	SDA, SCL	1.4			V	
Input Hysteresis	V _{HYS}	SDA, SCL		200		mV	
Input Capacitance	C _{IN}	SDA, SCL		10		pF	
Input Lookago Current		$V_{IN} = 0\overline{V}, T_A = +25^{\circ}C \text{ (SDA, SCL, INTB)}$		0.01	1		
	IN	V_{IN} = 5.5V, T_A = +25°C (SDA, SCL, INTB)		0.01	1	μΑ	

Electrical Characteristics (continued)

 $(V_{DD} = 1.8V, V_{LED} = 5V, LED_PW = 70\mu s, SR = 1000 sps, ADC_RGE = 32\mu A, LEDx_RGE = 50mA, T_A = +25^{\circ}C, min/max are from T_A = -40^{\circ}C to +85^{\circ}C, unless otherwise noted, Note 1).$

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS		
I ² C TIMING CHARACTERISTICS (SDA, SCL) (Note 4)								
I ² C Write Address				AE		Hex		
I ² C Read Address				AF		Hex		
Serial Clock Frequency	fscl		0		400	kHz		
Bus Free Time Between STOP and START Conditions	t _{BUF}		1.3			μs		
Hold Time (Repeated) START Condition	^t HD,STA		0.6			μs		
SCL Pulse-Width Low	tLOW		1.3			μs		
SCL Pulse-Width High	thigh		0.6			μs		
Setup Time for a Repeated START Condition	^t SU,STA		0.6			μs		
Data Hold Time	^t HD,DAT		0		900	ns		
Data Setup Time	t _{SU,DAT}		100			ns		
Setup Time for STOP Condition	t _{SU,STO}		0.6			μs		
Pulse Width of Suppressed Spike	t _{SP}		0		50	ns		
Bus Capacitance	CB				400	pF		
SDA and SCL Receiving Rise Time	t _R			20 + 0.1CB	300	ns		
SDA and SCL Receiving Fall Time	t _F			20 + 0.1CB	300	ns		
SDA Transmitting Fall Time	t _F			20 + 0.1CB	300	ns		

Note 1: All devices are 100% production tested at T_A = +25°C. Specifications over temperature limits are guaranteed by Maxim Integrated's bench or proprietary automated test equipment (ATE) characterization.

Note 2: VLED should be set to accommodate the maximum LED forward voltage and the output compliance of the LED driver.

Note 3: For design guidance only. Not production tested. Tested in die only.

Note 4: For design guidance only. Not production tested.

Integrated Optical Sensor Module for Mobile Health

Typical Operating Characteristics

 V_{DD} = +1.8V, V_{LED} = +5V, T_A = +25°C, unless otherwise noted.



















100

80

60

40

20

0

400

RELATIVE POWER OUTPUT (%)

Integrated Optical Sensor Module for Mobile Health

Typical Operating Characteristics (continued)

 V_{DD} = +1.8V, V_{LED} = +5V, T_A = +25°C, unless otherwise noted.





















Integrated Optical Sensor Module for Mobile Health

Typical Operating Characteristics (continued)

 V_{DD} = +1.8V, V_{LED} = +5V, T_A = +25°C, unless otherwise noted.











Pin Configuration



Pin Description

PIN	NAME	FUNCTION
POWER		
6	V _{DD}	Main Power Supply. Connect to externally-regulated supply. Bypass with a $0.1\mu F$ capacitor as close as possible to pad and a $4.7\mu F$ capacitor to GND.
5	GND	Main Power Return. Connect to GND.
4, 2	V_{LED}	LED Power Supply Input. Connect to external voltage supply. Bypass with a 0.1μ F capacitor as close as possible to pad and a 10μ F capacitor to GND.
3	PGND	LED Power Return. Connect to GND.
CONTROL IN	TERFACE	
10	SDA	SDA Input/Output. I ² C data I/O
9	SCL	SCL Input. I ² C clock input
11	INTB	Interrupt. Programmable open-drain interrupt output signal (active-low).
REFERENCE		
8	VREF	Internal Reference Decoupling Point. Bypass with a 1µF capacitor to GND.
N.C.		
1, 12, 13, 14	N.C.	No Connection. Internally connected to LEDx cathode (x = 1–4). Leave N.C. unconnected.
7	N.C.	No Connection. Internally connected. Leave N.C. unconnected.

Functional Diagrams



Detailed Description

The MAX86916 is an optical sensor module designed for the demanding requirements of mobile devices. The MAX86916 maintains a very small total solution size without sacrificing optical or electrical performance. Minimal external hardware components are necessary for integration into a mobile device. The MAX86916 is fully adjustable through software registers, and the digital output data is stored in a 32-deep FIFO within the device. The FIFO allows the MAX86916 to be connected to a microcontroller or processor on a shared bus, where the data is not being read continuously from the MAX86916 registers.

Photo Diode Receiver

The receive path in the MAX86916 is composed of an ambient-light-cancellation (ALC) circuit, a continuous-time sigma-delta ADC, and proprietary digital filter that rejects slow-changing ambient light, including 100Hz/120Hz interference from artificial lights. The ALC uses a track-and-hold to cancel ambient light. The internal ADC is a continuous time oversampling sigma delta converter with

19-bit resolution. The ADC output data rate can be programmed from 50sps (samples per second) to 3200sps.

The optical subsystem in MAX86916 is features a proprietary ambient-light-cancellation (ALC) circuit. This ALC scheme is designed to cancel ambient-light-generated photo diode current up to 200μ A, allowing the sensor to work in high ambient light conditions.

When the ambient light cancellation function has reached its maximum limit due to overflow from strong ambient light, the output of the ADC could be affected. In this case, Ambient Light Cancellation Overflow interrupt (ALC_OVF) can be used to detect the condition. This interrupt can be enabled by setting Ambient Light Cancellation Overflow Interrupt enable (ALC_OVF_EN).

By default, ALC is enabled. But if a measurement of direct ambient light is needed, ALC can be disabled. This can be done by enabling "Ambient Light Detection Mode" (AMB_ LIGHT_DET = 1). In this mode, the filtering scheme used for ALC will be disabled. To measure ambient light correctly, LED Current Pulse Amplitude (LEDx_PA) should also be set to 0x0.

LED Driver

The MAX86916 integrates four LED drivers and BLUE, GREEN, RED, and INFRARED LEDs. The LED current can be programmed from 0mA to 150mA with proper VLED supply voltage. The LED pulse width can be programmed from 70 μ s to 420 μ s to allow the algorithm to optimize data acquisition accuracy and power consumption based on use cases.

Proximity Function

The MAX86916 includes a proximity function to save power and reduce visible light emission when the user's finger is not on the sensor. The proximity function is enabled by setting PROX INT EN to 1. When the programmed data acquisition is initiated, the LED1 is turned on in proximity mode with a driver current set by the PILOT PA register. When an object is detected and ADC count exceeds the Proximity Mode Threshold. PROX INT interrupt is asserted, FIFO DATA is flushed and the part transitions automatically to the programmed data acquisition mode based on settings in MODE register. When the ADC count is detected below the Proximity Mode Threshold, the proximity function will be re-entered automatically without triggering the PROX INT interrupt. The Proximity Mode threshold is defined by register PROX INT THRESH multiplied by 2048.

The proximity function can be disabled by resetting PROX_INT_EN to 0. In that case, when the programmed data acquisition mode is initiated in the FIFO Data Control registers, the data acquisition begins immediately.

Cross Talk Cancellation

MAX86916 features a Cross-Talk Cancellation DAC to improve the robustness of optical system design. The DAC code is used to subtract a DC component of the received optical signal at the photodetector that is coherent with the LED pulse. The intent of this feature is to cancel out the cross-talk caused by the system level optical design, especially when high reflective or translucent cover glass is used. The final optical system design will need to be characterized to set the code for XTALK_DACx.



Figure 1. Proximity Function Flow Diagram

Integrated Optical Sensor Module for Mobile Health

FIFO Configuration

The FIFO can hold up to 32 samples of data, each sample can be comprised of up to 4 data items (time slots). Each data item is 3 bytes. The content of each data item is programmed through registers LEDC1 to LEDC4 (LED sequence registers). These data items are ADC counts from the analog front-end of this device. The FIFO supports the following features:

- Maximum 32 samples (depth)
- Supports up to four data items in each sample
- FIFO roll-on-full
- Different interrupt modes based on watermark

There are seven registers that control how the FIFO is configured and read out. These registers are illustrated on Table 1.

LED Sequence Register, LEDCx

LED sequence registers are only effective when the MODE[1:0] is set to 0x03 (Flex LED mode). The data format in the FIFO, as well as the sequencing of exposures, are controlled by the LED sequence registers through LEDC1–LEDC4. There are four data items available, each holding up to 32 samples. The exposure sequence cycles through the LED sequence registers, starting from LEDC1 to LEDC4. The first LED sequence field set to NONE (0000) ends the sequence. Table 2 shows all the available data item types.

The LED sequence registers LEDC1, LEDC2, LEDC3, and LEDC4 control the turn-on and sequencing of the LED drivers. For settings 0x1 to 0x4, the PA setting for the enabled LED driver is read as normal from the corresponding LEDx_ PA register but for settings 0x5 to 0x8 the PA is used from the PILOT_PA register.

ADDRESS	REGISTER NAME	DEFAULT VALUE	B7	B6	В5	B4	В3	B2	B1	В0
0x04	FIFO Write Pointer	00	-	-	-	FIFO_WR_PTR[4:0]				
0x05	Overflow Counter	00	-	-	-	OVF_COUNTER[4:0]				
0x06	FIFO Read Pointer	00	-	-	-	FIFO_RD_PTR[4:0]				
0x07	FIFO Data Register	00	FIFO_DATA[7:0]							
0x08	FIFO Configuration	0F	SMP_AVE[2:0] FIFO_RO			FIFO_RO		FIFO_A_	FULL[3:0]	
0x13	LED Sequence Register 1	00	LEDC2[3:0]				LEDC	:1[3:0]		
0x14	LED Sequence Register 2	00	LEDC4[3:0]					LEDC	3[3:0]	

Table 1. FIFO Information, Control and Configuration Registers

Table 2. LED Sequence Data Item Types

LEDCX[3:0], X = 1, 2, 3, 4	DATA ITEM TYPE
0000	OFF
0001	LED1
0010	LED2
0011	LED3
0100	LED4

LEDCX[3:0], X = 1, 2, 3, 4	DATA ITEM TYPE
0101	PILOT LED1
0110	PILOT LED2
0111	PILOT LED3
1000	PILOT LED4
1001 to 1111	OFF (Reserved)

Write Pointer, FIFO_WR_PTR[4:0]

FIFO_WR_PTR[4:0] points to the FIFO location where the next sample will be written. This pointer advances for each sample pushed on to the FIFO by the internal conversion process. The write pointer is a 5-bit counter and will wrap around to count 0x00 on the next sample after count 0x1F.

Overflow Counter, OVF_COUNTER[4:0]

OVF_COUNTER[4:0] logs the number of samples lost if the FIFO is not read in a timely fashion. This counter holds at count value 0x1F. When a complete sample is popped from the FIFO (when the read pointer advances), the OVF_COUNTER is reset to zero. This counter is essentially a debug tool. It should be read immediately before reading the FIFO in order to check if an overflow condition has occurred.

Read Pointer, FIFO_RD_PTR[4:0]

FIFO_RD_PTR[4:0] points to the location from where the next sample from the FIFO will be read through the interface. This advances each time a sample is read from the FIFO. The read pointer can be both read and written to. This allows a sample to be reread from the FIFO if it has not already been overwritten. The read pointer is updated from a 5-bit counter and will wrap around to count 0x00 from count 0x1F.

FIFO Data, FIFO_DATA[7:0]

FIFO_DATA[7:0] is a read-only register used to retrieve data from the FIFO. The format and data type of the data stored in the FIFO is determined by the LED Sequence register. Readout from the FIFO follows a progression defined by LED Sequence register as well. This configuration is best illustrated by a few examples.

Assume it is desired to perform a measurement with three LEDs sequentially as shown in <u>Figure 2</u>. The time for the LED to settle (t_{LED_STLNG}) is 20µs. To perform this measurement, configure the following registers:

Mode Configuration field

MODE[1:0] = 0x3	(FLEX LED Mode)
LED Sequence field	
LEDC1[3:0] = 0x1	(LED1)
LEDC2[3:0] = 0x2	(LED2)
LEDC3[3:0] = 0x3	(LED3)
LEDC4[3:0] = 0x0	(OFF)
Configuration	

Configuration

ADC_RGE[1:0]	(Gain Range Control)
SR[3:0]	(Sample Rate Control)
LED_PW[1:0] (Integration Time)



Figure 2. LED Sequence Timing Diagram with 3 Data Items Sampling.

Integrated Optical Sensor Module for Mobile Health

LED Pulse Amplitude

LED1_PA[7:0]	(LED1 Current Pulse Amplitude)
LED2_PA[7:0]	(LED2 Current Pulse Amplitude)
LED3_PA[7:0]	(LED3 Current Pulse Amplitude)

When done so the sample sequence and the data format in the FIFO will follow the following time/location sequence.

LED1 sample 1

LED2 sample 1

LED3 sample 1

LED1 sample 2

LED2 sample 2

LED3 sample 2

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.

LED1 sample n

LED2 sample n

LED3 sample n

where:

LED1 sample x = ADC count exposure data from LED1 for the sample x

LED2 sample x = ADC count exposure data from LED2 for the sample x

LED3 sample x = ADC count exposure data from LED3 for the sample x

n is the number of samples in the FIFO, which can be up to 32 samples.

The number of active data samples in the FIFO is directly readable by subtracting the FIFO_RD_PTR[4:0] from

the FIFO_WR_PTR[4:0], and taking wrap around of the pointers into consideration. It is typically controlled in the system by generating an interrupt on the INTB line when the FIFO reaches a watermark level computed from the FIFO_A_FULL[3:0] field in the FIFO Configuration register (0x08). In this case when the active data samples in the FIFO reach a level given by 32 - FIFO_A_FULL[3:0] an A_FULL interrupt is generated.

To calculate the number of active samples when the INTB signal is asserted, execute the following pseudo-code:

read the OVF_COUNTER register

read the FIFO_WR_PTR register

read the FIFO_RD_PTR register

```
if (OVF_COUNTER == 0) then //no overflow occurred
```

if (FIFO_WR_PTR > FIFO_RD_PTR) then

```
NUM_AVAILABLE_SAMPLES = FIFO_WR_
PTR - FIFO_RD_PTR
```

else

NUM_AVAILABLE_SAMPLES = FIFO_WR_ PTR + 32 - FIFO_RD_PTR

endif

else

```
NUM_AVAILABLE_SAMPLES = 32 // overflow occurred and data has been lost
```

endif

Optical data, whether ambient corrected LED exposure, ambient corrected proximity or direct ambient sampled data is as shown in the <u>Table 3</u>. The ADC data is left-justified at FIFO_DATA[18] and the MSBs (FIFO_DATA[23:18]) are don't care and should be masked as shown in <u>Table 3</u>. In other words, the MSB bit of the ADC data is always in the bit 18 position.

Table 3. Integration Pulse Width, Resulting ADC Resolution and FIFO Data Format

		FIFO DATA FORMAT (FIFO_DATA[23:0])																						
ADC		ADC Value																						
Res	F23	F22	F21	F20	F19	F18	F17	F16	F15	F14	F13	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1	F0
19-bits	Х	Х	Х	Х	Х	O18	017	O16	O15	014	013	012	011	O10	09	08	07	06	O5	04	O3	02	01	O0

FIFO Almost Full (Watermark)

The FIFO_A_FULL[3:0] register in the FIFO_Configuration register (0x08) determines when the A_FULL bit in the Interrupt_Status 1 register (0x00) gets asserted. The FIFO is almost full when it has 32 minus FIFO_A_FULL[3:0] samples. Then, if A_FULL_EN mask bit in the Interrupt_Enable 1 register (0x02) is set, the A_FULL bit in the Interrupt Status 1 will be set and routed to the INTB pin on the MAX86916 interface. This condition prompts the Application Processor to read samples from the FIFO before it gets filled. The A_FULL bit is cleared and INTB is deasserted when the status register is read.

When the Application Processor receives an interrupt, there are at least 32 minus FIFO_A_FULL[3:0] samples available in the FIFO. It is not necessary to read the FIFO_WR_PTR and FIFO_RD_PTR registers. The Application Processor may read all the available samples in the FIFO, or only a portion of it. At high sample rates, it is recommended that only a portion of the available samples are read on an A_FULL interrupt, to ensure that FIFO reading does not happen when the next sample conversion is in progress. The remaining samples will be read on the next interrupt.

If the A_FULL interrupt is not enabled, the Application Processor has to read the FIFO in polling mode. In this mode the Application Processor has to read the FIFO_ WR_PTR and FIFO_RD_PTR registers to calculate the number of samples available in the FIFO, and then decide how many samples to read. However, polling mode is not recommended, because in this mode an interface transaction will inevitably overlap an optical sample, potentially adding noise to the optical data. Because of this concern, the interface transaction should occur during the dead time between optical samples to avoid adding additional noise.

FIFO_RO (FIFO Roll Over)

The FIFO_RO bit in the FIFO_Configuration register (0x08) determines whether samples get pushed on to the FIFO when it is full. If push is enabled when FIFO is full, old samples are lost. If FIFO_RO is not set, the new sample is dropped and the FIFO is not updated.

I²C/SMBus Compatible Serial Interface

The MAX86916 features an I²C/SMBus compatible, 2-wire serial interface consisting of a serial data line (SDA) and a serial clock line (SCL). SDA and SCL facilitate communication between the MAX86916 and the master at clock rates up to 400kHz. The master generates SCL and initiates data transfer on the bus. The master device writes data to the MAX86916 by transmitting the proper slave address followed by the register address and then the data word. Each transmit sequence is framed by a START (S) or REPEATED START (Sr) condition and a STOP (P) condition. Each word transmitted to the MAX86916 is 8-bits long and is followed by an acknowledge clock pulse. A master reading data from the MAX86916 transmits the proper slave address followed by a series of nine SCL pulses. The MAX86916 transmits data on SDA in sync with the master-generated SCL pulses. The master acknowledges receipt of each byte of data. Each read sequence is framed by a START (S) or REPEATED START (Sr) condition, a not acknowledge, and a STOP (P) condition. SDA operates as both an input and an open-drain output. A pullup resistor is required on SDA. SCL operates only as an input. A pullup resistor is required on SCL if there are multiple masters on the bus, or if the single master has an open-drain SCL output. Series resistors in line with SDA and SCL are optional. Series resistors protect the digital inputs of the MAX86916 from high voltage spikes on the bus lines, and minimize crosstalk and undershoot of the bus signals.

Detailed I²C Timing Diagram

The detailed timing diagram of various electrical characteristics is shown in Figure 3.

Bit Transfer

One data bit is transferred during each SCL cycle. The data on SDA must remain stable during the high period of the SCL pulse. Changes in SDA while SCL is high are control signals (see the <u>START and STOP Conditions</u> section).

START and STOP Conditions

SDA and SCL idle high when the bus is not in use. A master initiates communication by issuing a START condition. A START condition is a high-to-low transition on SDA with SCL high. A STOP condition is a low-to-high transition on SDA while SCL is high (Figure 4). A START condition from the master signals the beginning of a transmission to the MAX86916. The master terminates transmission, and frees the bus, by issuing a STOP condition. The bus remains active if a REPEATED START condition is generated instead of a STOP condition.

Integrated Optical Sensor Module for Mobile Health



Figure 3. Detailed I²C Timing Diagram



Figure 4: I²C START, STOP, and REPEATED START Conditions

Early STOP Conditions

The MAX86916 recognizes a STOP condition at any point during data transmission unless the STOP condition occurs in the same high pulse as a START condition. For proper operation, do not send a STOP condition during the same SCL high pulse as the START condition.

Slave Address

The slave address is defined as the seven most significant bits (MSBs) followed by the read/write bit. For the MAX86916 the seven most significant bits are 0b1010111. For read mode, set the read/write bit to 1. For write mode, set the read/write bit to 0. The address is the first byte of information sent to the IC after the START condition.

Acknowledge Bit

The acknowledge bit (ACK) is a clocked 9th bit that the MAX86916 uses to handshake receipt each byte of data when in write mode (Figure 5). The MAX86916 pulls down SDA during the entire master-generated 9th clock pulse if the previous byte is successfully received. Monitoring ACK allows for detection of unsuccessful data transfers. An unsuccessful data transfer occurs if a receiving device is busy or if a system fault has occurred. In the event of an unsuccessful data transfer, the bus master will retry communication. The master pulls down SDA during the 9th clock cycle to acknowledge receipt of data when the MAX86916 is in read mode. An acknowledge is sent by the master after each read byte to allow data transfer to continue. A not-acknowledge is sent when the master reads the final byte of data from the MAX86916, followed by a STOP condition.

I²C Write Data Format

A write to the MAX86916 includes transmission of a START condition, the slave address with the R/W bit set to 0, one byte of data to configure the internal register address pointer, one or more bytes of data, and a STOP condition. Figure 6 illustrates the proper frame format for writing one byte of data to the MAX86916. Figure 7 illustrates the frame format for writing n-bytes of data to the MAX86916.

The slave address with the R/W bit set to 0 indicates that the master intends to write data to the MAX86916. The MAX86916 acknowledges receipt of the address byte during the master-generated 9th SCL pulse.

The second byte transmitted from the master configures the MAX86916's internal register address pointer. The pointer tells the MAX86916 where to write the next byte of data. An acknowledge pulse is sent by the MAX86916 upon receipt of the address pointer data.

The third byte sent to the MAX86916 contains the data that will be written to the chosen register. An acknowledge pulse from the MAX86916 signals receipt of the data byte. The address pointer auto increments to the next register address after each received data byte. This autoincrement feature allows a master to write to sequential registers within one continuous frame. The master signals the end of transmission by issuing a STOP condition. The auto_increment feature is disabled when there is an attempt to write to the FIFO_DATA register.



Figure 5. I²C Acknowledge Bit

Integrated Optical Sensor Module for Mobile Health

I²C Read Data Format

Send the slave address with the R/W bit set to 1 to initiate a read operation. The MAX86916 acknowledges receipt of its slave address by pulling SDA low during the 9th SCL clock pulse. A START command followed by a read command resets the address pointer to register 0x00.

The first byte transmitted from the MAX86916 will be the contents of register 0x00. Transmitted data is valid on the rising edge of SCL. The address pointer auto-increments after each read data byte. This auto-increment feature allows all registers to be read sequentially within one continuous frame. The auto_increment feature is disabled when there is an attempt to read from the FIFO_DATA register. A STOP condition can be issued after any number of read data bytes. If a STOP condition is issued followed by another read operation, the first data byte to be read will be from register 0x00.

The address pointer can be preset to a specific register before a read command is issued. The master presets the address pointer by first sending the MAX86916 slave address with the R/\overline{W} bit set to 0 followed by the register address. A REPEATED START condition is then sent followed by the slave address with the R/\overline{W} bit set to 1. The MAX86916 then transmits the contents of the specified register. The address pointer auto-increments after transmitting the first byte.

The master acknowledges receipt of each read byte during the acknowledge clock pulse. The master must acknowledge all correctly received bytes except the last byte. The final byte must be followed by a not acknowledge from the master and then a STOP condition. Figure 8 illustrates the frame format for reading one byte from the MAX86916. Figure 9 illustrates the frame format for reading multiple bytes from the MAX86916.



Figure 6. I²C Single Byte Write Transaction

Integrated Optical Sensor Module for Mobile Health



Figure 7. I²C Multi-Byte Write Transaction



Figure 8. I²C Single Byte Read Transaction

Integrated Optical Sensor Module for Mobile Health



Figure 9. I²C Multi-Byte Read Transaction

Register Map

User Register Map

ADDRESS	NAME	MSB							LSB
STATUS R	EGISTERS				1	1			1
0x00	Interrupt Status 1[7:0]	A_FULL	SMP_RDY	ALC_OVF	PROX_INT	-	-	-	PWR_RDY
0x01	RESERVED[7:0]	-	-	-	_	_	_	-	-
0x02	Interrupt Enable 1[7:0]	A_FULL_ EN	SMP_ RDY_EN	ALC_OVF_ EN	PROX_ INT_EN	_	_	_	-
0x03	RESERVED[7:0]	_	-	-	_	_	_	-	_
FIFO REG	STERS			·					
0x04	FIFO Write Pointer[7:0]	-	-	-		FIFC		[4:0]	
0x05	Over Flow Counter[7:0]	-	-	-		OVF		R[4:0]	
0x06	FIFO Read Pointer[7:0]	-	-	-		FIF	D_RD_PTR	[4:0]	
0x07	FIFO Data Register[7:0]				FIFO_D	ATA[7:0]			
CONFIGU	RATION								
0x08	FIFO Configuration[7:0]	S	MP_AVE[2:	0]	FIFO_RO		FIFO_A_	FULL[3:0]	
0x09	Mode Configuration 1[7:0]	SHUT- DOWN	RESET	_	RE- SERVED	RE- SERVED	RE- SERVED DET MOD		E[1:0]
0x0A	Mode Configuration 2[7:0]	RE- SERVED	ADC_F	GE[1:0]		SR[2:0]		LED_F	PW[1:0]
0x0B	RESERVED[7:0]	-	-	-	_	_	_	-	-
LED PULS	EAMPLITUDE								
0x0C	LED1 PA[7:0]				LED1_	PA[7:0]			
0x0D	LED2 PA[7:0]				LED2_	PA[7:0]			
0x0E	LED3 PA[7:0]				LED3_	PA[7:0]			
0x0F	LED4 PA[7:0]				LED4_	PA[7:0]			
0x11	LED Range[7:0]	LED4_RGE[1:0] LED3_RGE[1:0] LED2_RGE[1:0] LED1_RGE[1:					RGE[1:0]		
0x12	Pilot PA[7:0]	PILOT_PA[7:0]							
LED SEQU	IENCE CONTROL								
0x13	LED Sequence Register 1[7:0]	LEDC2[3:0] LEDC1[3:0]							
0x14	LED Sequence Register 2[7:0]	LEDC4[3:0] LEDC3[3:0]							

Integrated Optical Sensor Module for Mobile Health

Register Map (continued)

ADDRESS	NAME	MSB							LSB
RESERVE	D				·				<u> </u>
0x1F	RESERVED[7:0]	_	_	_	-	_	_	-	_
0x20	RESERVED[7:0]	_	_	_	-	_	_	-	_
0x21	RESERVED[7:0]	_	_	_	_	_	_	_	_
RESERVE	D				· · · · · ·				
0x22	RESERVED[7:0]	-	-	-	-	-	-	-	-
0x23	RESERVED[7:0]	-	-	-	-	-	-	-	-
0x24	RESERVED[7:0]	-	-	-	-	_	-	-	-
0x25	RESERVED[7:0]	-	-	-	-	_	-	-	-
CROSSTA	LK DAC								
0x26	DAC1 Crosstalk Code[7:0]	-	-	_		XTA	ALK_DAC1[4:0]	
0x27	DAC2 Crosstalk Code[7:0]	-	-	-		XTA	ALK_DAC2[4:0]	
0x28	DAC3 Crosstalk Code[7:0]	-	-	-		XTA	ALK_DAC3[4:0]	
0x29	DAC4 Crosstalk Code[7:0]	-	-	-		XTA	ALK_DAC4[4:0]	
PROXIMIT	YMODE								
0x30	Proximity Interrrupt Threshold[7:0]			Р	ROX_INT_1	HRESH[7:	0]		
LED CONN	IECTIVITY TEST								
0x31	LED Comparator Enable[7:0]	LED_ TEST_EN4	LED_ TEST_EN3	LED_ TEST_EN2	LED_ TEST_EN1	-	-	-	COMP
0x32	LED Comparator Status[7:0]					COMP_ OUT4	COMP_ OUT3	COMP_ OUT2	COMP_ OUT1
RESERVE	D								
0x51	RESERVED[7:0]	-	-	-	-	-	-	-	-
0x52	RESERVED[7:0]	-	-	-	-	-	-	-	-
0x53	RESERVED[7:0]	-	-	-	-	-	-	-	-
0x54	RESERVED[7:0]						_		
PART ID									
0xFE	Revision ID[7:0]				REV_I	D[7:0]			
0xFF	Part ID[7:0]	PART_ID[7:0]							

Integrated Optical Sensor Module for Mobile Health

Register Details

Interrupt Status 1 (0x00)

BIT	7	6	5	4	3	2	1	0
Field	A_FULL	SMP_RDY	ALC_OVF	PROX_INT	-	-	-	PWR_RDY
Reset	0x0	0x0	0x0	0x0	_	-	-	0x1
Access Type	Read Only	Read Only	Read Only	Read Only	_	-	-	Read Only

A_FULL

VALUE	ENUMERATION	DECODE
0	OFF	Normal Operation
1	ON	Indicates that the FIFO buffer will overflow the threshold set by FIFO_A_FULL[3:0] on the next sample. The interrupt is cleared by reading the Interrupt Status 1 register (0x00).

SMP_RDY

VALUE	ENUMERATION	DECODE
0	OFF	Normal Operation
1	ON	This interrupt triggers when there is a new sample in the data FIFO. The interrupt is cleared by reading the Interrupt Status 1 register (0x00), or by reading the FIFO_DATA register.

ALC_OVF

VALUE	ENUMERATION	DECODE
0	OFF	Normal Operation
1	ON	This interrupt triggers when the ambient light cancellation function of the photodiode has reached its maximum limit due to overflow, and therefore, ambient light is affecting the output of the ADC. The interrupt is cleared by reading the Interrupt Status 1 register (0x00).

PROX_INT

See Proximity Function for more details.

VALUE	ENUMERATION	DECODE
0	OFF	Normal Operation
1	ON	Indicates that the proximity threshold has been crossed when in proximity mode. If PROX_INT is masked by setting PROX_INT_EN to 0, then the proximity mode is disabled and the selected operating MODE begins immediately. The interrupt is cleared by reading the Interrupt Status 1 register (0x00).

PWR_RDY

VALUE	ENUMERATION	DECODE
0	OFF	Normal Operation
1	ON	Indicates that VDD went below the UVLO (< 1.55V, typ.) threshold. This bit is not set to 1 by a soft reset. The interrupt is cleared by reading the Interrupt Status 1 register (0x00).

Integrated Optical Sensor Module for Mobile Health

Interrupt Enable 1 (0x02)

BIT	7	6	5	4	3	2	1	0
Field	A_FULL_EN	SMP_RDY_ EN	ALC_OVF_ EN	PROX_INT_ EN	-	-	-	-
Reset	0x0	0x0	0x0	0x0	-	-	-	-
Access Type	Write, Read	Write, Read	Write, Read	Write, Read	_	_	-	_

A_FULL_EN

VALUE	ENUMERATION	DECODE
0	OFF	A_FULL interrupt is disabled
1	ON	A_FULL interrupt is enabled

SMP_RDY_EN

VALUE	ENUMERATION	DECODE
0	OFF	SMP_RDY interrupt is disabled
1	ON	SMP_RDY interrupt is enabled.

ALC_OVF_EN

VALUE	ENUMERATION	DECODE
0	OFF	ALC_OVF interrupt is disabled
1	ON	ALC_OVF interrupt is enabled

PROX_INT_EN

When the sensor is initiated with PROX_INT_EN = 1, the LED1 is turned on in proximity mode with a drive current set by the PILOT_PA register. When an object is detected by exceeding the Proximity Mode Threshold (set in the PROX_INT_ THRESH register), PROX_INT interrupt is asserted and the part transitions automatically to the programmed configuration set is MODE.

See Proximity Function for more details.

VALUE	ENUMERATION	DECODE
0	OFF	PROX_INT interrupt is disabled
1	ON	PROX_INT interrupt is enabled

FIFO Write Pointer (0x04)

BIT	7	6	5	4	3	2	1	0	
Field	_	_	-	FIFO_WR_PTR[4:0]					
Reset	_	_	-		0x00				
Access Type	-	-	-	Read Only					

FIFO_WR_PTR

This points to the location where the next sample will be written. This pointer advances for each sample pushed on to the FIFO.

See *FIFO Configuration* for more details.

Overflow Counter (0x05)

BIT	7	6	5	4	3	2	1	0	
Field	-	-	-	OVF_COUNTER[4:0]					
Reset	-	-	-		0x00				
Access Type	_	_	_	Read Only					

OVF_COUNTER

When FIFO is full any new samples will result in new or old samples getting lost depending on FIFO_RO. OVF_COUNTER counts the number of samples lost. It saturates at 0x1F. It gets reset to 0 when a sample is read from the FIFO.

See FIFO Configuration for more details.

FIFO Read Pointer (0x06)

BIT	7	6	5	4	3	2	1	0	
Field	_	_	-	FIFO_RD_PTR[4:0]					
Reset	_	_	-		0x00				
Access Type	-	-	-	Write, Read					

FIFO_RD_PTR

The FIFO Read Pointer points to the location from where the processor gets the next sample from the FIFO via the I²C interface. This advances each time a sample is popped from the FIFO. The processor may also write to this pointer after reading the samples. This allows rereading (or retrying) samples from the FIFO.

See FIFO Configuration for more details.

FIFO Data Register (0x07)

BIT	7	6	5	4	3	2	1	0		
Field		FIFO_DATA[7:0]								
Reset		0x00								
Access Type				Read	Only					

FIFO_DATA

This is a read-only register and is used to get data from the FIFO.

See FIFO Configuration for more details.

FIFO Configuration (0x08)

BIT	7	6	5	4	3	2	1	0	
Field	SMP_AVE[2:0]			FIFO_RO	FIFO_A_FULL[3:0]				
Reset	0x0			0x0		0xF			
Access Type	Write, Read			Write, Read		Write,	Read		

SMP_AVE

Adjacent samples (of each individual LED) can be internally averaged to reduce the amount of data throughput. Each LED channel will be averaged individually and output sequentially as programmed in the LED Seruence Registers.

These bits set the number of samples that are averaged on chip before being written to the FIFO. The effective output sample rate is the sample rate programmed in SR divided by the Sample Average value based on the table below:

SMP_AVE[2:0]	SAMPLE AVERAGE
000	1
001	2
010	4
011	8
100	16
101	32
110	32
111	32

FIFO_RO

Push enable when FIFO is full:

This bit controls the behavior of the FIFO when the FIFO becomes completely filled with data.

Push to FIFO is enabled when FIFO is full if FIFO_RO = 1. In this mode old samples are overwritten. FIFO_WR_PTR increments for each sample. FIFO_RD_PTR also increments for each sample pushed to the FIFO.

Push to FIFO is disabled when FIFO is full if FIFO_RO = 0. In this mode old samples are not overwritten and new samples are discarded . FIFO_WR_PTR and FIFO_RD_PTR do not increment for each sample after the FIFO is full.

When the device is in proximity mode, push to FIFO is enabled independent of FIFO_RO setting. The FIFO is flushed when the PROX_INT is triggered.

See *Proximity Function* for more details.

VALUE	ENUMERATION	DECODE
0	OFF	The FIFO stops on full.
1	ON	The FIFO automatically rolls over on full.

Integrated Optical Sensor Module for Mobile Health

FIFO_A_FULL

These bits indicate how many unread samples are in the FIFO when the interrupt is asserted. For example, if set to 0xF, the interrupt triggers when there are 17 data samples in the FIFO (15 empty spaces lefts).

See FIFO Configuration for more details.

FIFO_A_ FULL[3:0]	FREE SPACE AT INTERRUPT	# OF SAMPLES IN FIFO
0000	0	32
0001	1	31
0010	2	30
0011	3	29
	—	—
1110	14	18
1111	15	17

Mode Configuration 1 (0x09)

BIT	7	6	5	4	3	2	1	0
Field	SHUTDOWN	RESET	-	RESERVED	RESERVED	AMB_LIGHT_DET	MODE[1:0]	
Reset	0x0	0x0	-	0x0	0x0	0x0	0x0	
Access Type	Write, Read	Write, Read	-	Write, Read	Write, Read	Write, Read	Write, Read	

SHUTDOWN

Shutdown Control

VALUE	ENUMERATION	DECODE
0x0	0	Normal Operation
0x1	1	The part can be put into a power-save mode by writing a '1' to this bit. While in this mode all configuration and control registers remain accessible and retain their data. All interrupts are cleared. In this mode the oscillator is shutdown and the part draws minimum current.

RESET

Software Reset

VALUE	ENUMERATION	DECODE
0x0	0	Normal operation
0x1	1	The part under-goes a forced power-on-reset sequence. All the registers, except PWR_RDY, are reset to their power-on-reset state. The RESET bit then automatically resets to 0 after the reset sequence is completed.

AMB_LIGHT_DET

Ambient Light Detection Mode Enable. ALC and digital filter are disabled when AMB_LIGHT_DET = 1.

VALUE	ENUMERATION	DECODE			
0x0	0	Normal Operation			
0x1	1	Ambient Light Detection Mode disabled.			

MODE

These bits set the operating mode

MODE[1:0]	MODE
00	Disabled
01	LED1 Enabled. Only one ADC conversion for LED1 (IR LED)
10	LED1 and LED2 Enabled. Two ADC conversions sequencitally for LED1 (IR LED) and LED2 (RED LED)
11	Flex LED Mode. Number of ADC conversions and the LED types are programmed in the LED Sequence Reg- isters.

Mode Configuration 2 (0x0A)

BIT	7	6	5	4	3	2	1	0	
Field	RESERVED	ADC_RGE[1:0]		SR[2:0]			LED_PW[1:0]		
Reset	0x0	0	x0	0x0		0:	x0		
Access Type	Write, Read	Write,	Read	Write, Read		Write,	Read		

ADC_RGE

These bits set the ADC range of the sensor as shown in the table below.

ADC_ RGE[1:0]	LSB (PA)	FULL SCALE (NA)
00	7.81	4096
01	15.63	8192
10	31.25	16384
11	62.50	32768

SR

These bits set the sampling rate of the optical sensor as shown in the table below.

SR[2:0]	SAMPLE PER SECOND				
0	50				
1	100				
2	200				
3	400				
4	800				
5	1000				
6	1600				
7	3200				

Integrated Optical Sensor Module for Mobile Health

Maximum Sample rates (Hz) supported for all the Pulse Widths and Number of Conversions:

	LED_PW[1:0]						
NUMBER OF LEDS FIRING PER SAMPLE	0x0	0x1	0x2	0x3			
1	3200	1600	1000	400			
2	1600	1000	400	200			
3	1000	400	400	200			
4	800	400	200	100			

LED_PW

These bits set the pulse width of the LED drivers and the integration time of ADC as shown in the table below.

LED_PW[1:0]	PULSE WIDTH [µs]	INTEGRATION TIME [µs]	RESOLUTION [BITS]
00	70	50	19
01	120	100	19
10	220	200	19
11	420	400	19

LED1 PA (0x0C)

BIT	7	6	5	4	3	2	1	0		
Field		LED1_PA[7:0]								
Reset		0x00								
Access Type				Write,	Read					

LED1_PA

These bits set the nominal current pulse amplitude of LEDx (x = 1 to 4) as shown in the table below.

LEDX_RGE[1:0]	0X0	0X1	0X2	0X3
LEDx_PA[7:0], (x = 1 to 4), PILOT_PA	LED CURRENT[mA]	LED CURRENT[mA]	LED CURRENT[mA]	LED CURRENT[mA]
0000 0000	0	0	0	0
0000 0001	0.2	0.4	0.6	0.8
0000 0010	0.4	0.8	1.2	1.6
0000 0011	0.6	1.2	1.8	2.4
1111 1100	49.8	99.6	149.4	199.2
1111 1101	50	100	150	200
1111 1110	50.2	100.4	150.6	200.8
1111 1111	50.4	100.8	151.2	201.6
LSB	0.2	0.4	0.6	0.8

Integrated Optical Sensor Module for Mobile Health

LED2 PA (0x0D)

BIT	7	6	5	4	3	2	1	0
Field		LED2_PA[7:0]						
Reset		0x00						
Access Type		Write, Read						

LED2_PA

See description under LED1_PA.

LED3 PA (0x0E)

BIT	7	6	5	4	3	2	1	0
Field		LED3_PA[7:0]						
Reset		0x00						
Access Type		Write, Read						

LED3_PA

See description under LED1_PA.

LED4 PA (0x0F)

BIT	7	6	5	4	3	2	1	0	
Field		LED4_PA[7:0]							
Reset		0x00							
Access Type	Write, Read								

LED4_PA

See description under LED1_PA.

LED Range (0x11)

BIT	7	6	5	4	3	2	1	0
Field	LED4_F	RGE[1:0]	LED3_RGE[1:0]		LED2_RGE[1:0]		LED1_RGE[1:0]	
Reset	0>	x0	0x0		0x0		0x0	
Access Type	Write,	Read	Write, Read		Write, Read		Write, Read	

Integrated Optical Sensor Module for Mobile Health

LED4_RGE

Range selection of the LED current. Please refer to LED1_PA[7:0] for more details.

LEDX_RGE[1:0] (X = 1 TO 4)	LED CURRENT [mA]
00	50
01	100
10	150
11	200

LED3_RGE

See description under LED4_RGE.

LED2_RGE

See description under LED4_RGE.

LED1_RGE

See description under LED4_RGE.

Pilot PA (0x12)

BIT	7	6	5	4	3	2	1	0
Field		PILOT_PA[7:0]						
Reset		0x0						
Access Type		Write, Read						

PILOT_PA

PILOT_PA is used for driving the LED when PILOT_LED1-4 is configured in LEDCx register.

See description under LED1_PA.

LED Sequence Register 1 (0x13)

BIT	7	6	5	4	3	2	1	0	
Field		LEDC	2[3:0]		LEDC1[3:0]				
Reset		0:	x0		0x0				
Access Type		Write,	Read		Write, Read				

Integrated Optical Sensor Module for Mobile Health

LEDC2

When Mode[1:0] = 0x3 the LED Sequence Registers LEDC1, LEDC2, LEDC3, and LEDC4 control the turn on and sequencing of the LED drivers. For settings 0x1 to 0x4, the LEDx_PA setting for the enabled LED driver is used, but for settings 0x5 to 0x8 the PA setting for the PILOT_PA is used. PILOT LED is generally used by setting a different PA settings for all LED channels. It is generally used with lower PA settings for a lower power mode.

The LED Sequence Registers also sets the data type of element x of the sample in the FIFO.

See FIFO Configuration for more details.

LEDCX[3:0], X = 1, 2, 3, 4	LED
0000	OFF
0001	LED1
0010	LED2
0011	LED3
0100	LED4
0101	PILOT LED1
0110	PILOT LED2
0111	PILOT LED3
1000	PILOT LED4
1001 to 1111	OFF (Reserved)

LEDC1

See description under LEDC2.

LED Sequence Register 2 (0x14)

BIT	7	6	5	4	3	2	1	0	
Field		LEDC	24[3:0]		LEDC3[3:0]				
Reset		0:	x0		0x0				
Access Type		Write,	Read		Write, Read				

LEDC4

See description under LEDC2.

LEDC3

See description under LEDC2.

DAC1 Crosstalk Code (0x26)

BIT	7	6	5	4	3	2	1	0
Field	-	-	-	XTALK_DAC1[4:0]				
Reset	_	-	_	0x00				
Access Type	_	-	-			Write, Read		

XTALK_DAC1

XTALK_DACx[4:0] (x = 1 to 4) sets the crosstalk cancellation DAC code used in ADC. The DAC code is used to subtract a DC component of the received optical signal at the photodetector that is coherent with the LED pulse. The intent of this feature is to cancel out the crosstalk caused by the system level optical design, especially when high reflective or translucent cover glass is used. The final optical system design will need to be characterized to set the code for XTALK_DACx. The FULL RANGE of the DAC code is dependent of setting used in ADC_RGE[1:0], as shown in the following table.

Crosstalk cancellation is disabled when $XTALK_DACx[4:0]$ (x = 1 to 4) code is 0.

	XTALK_DACX[4:0] (X = 1 TO 4)				
ADC_RGE[1:0]	LSB (nA)	FULL SCALE (nA)			
00	64	1984			
01	128	3968			
10	256	7936			
11	512	15872			

DAC2 Crosstalk Code (0x27)

BIT	7	6	5	4	3	2	1	0
Field	_	_	_	XTALK_DAC2[4:0]				
Reset	-	-	-	0x00				
Access Type	-	-	-	Write, Read				

XTALK_DAC2

See description under XTALK_DAC1.

DAC3 Crosstalk Code (0x28)

BIT	7	6	5	4	3	2	1	0
Field	-	-	-	XTALK_DAC3[4:0]				
Reset	-	-	_	0x00				
Access Type	-	-	-	Write, Read				

XTALK_DAC3

See description under XTALK_DAC1.

DAC4 Crosstalk Code (0x29)

BIT	7	6	5	4	3	2	1	0
Field	-	-	-	XTALK_DAC4[4:0]				
Reset	_	_	-	0x00				
Access Type	-	-	-	Write, Read				

XTALK_DAC4

See description under XTALK_DAC1.

Proximity Interrrupt Threshold (0x30)

BIT	7	6	5	4	3	2	1	0
Field		PROX_INT_THRESH[7:0]						
Reset		0x0						
Access Type				Write,	Read			

PROX_INT_THRESH

This register sets the LED1 ADC count value that will trigger the transition between proximity mode to normal mode. The threshold is defined as the 8 MSB bits of the ADC count. For example, if PROX_INT_THRESH[7:0] = 0x01, then an ADC value of 2048 (decimal) or higher triggers the PROX interrupt. If PROX_INT_THRESH[7:0] = 0xFF, then only a saturated ADC triggers the interrupt.

Please see the *Proximity Function* section in the detailed description for more details on the operation of proximity mode.

LED Comparator Enable (0x31)

BIT	7	6	5	4	3	2	1	0
Field	LED_TEST_ EN4	LED_TEST_ EN3	LED_TEST_ EN2	LED_TEST_ EN1	-	-	-	COMP
Reset	0x0	0x0	0x0	0x0	-	-	-	0x0
Access Type	Write, Read	Write, Read	Write, Read	Write, Read	-	_	_	Write, Read

LED_TEST_EN4

When COMP[0] = 0x1, this bit is dedicated to force LED4 enable to check LED4 failure. This test should check one LED driver at a time.

VALUE	ENUMERATION	DECODE
0	OFF	Disable LED4
1	ON	Enable LED4

LED_TEST_EN3

When COMP[0] = 0x1, this bit is dedicated to force LED3 enable to check LED3 failure. This test should check one LED driver at a time.

VALUE	ENUMERATION	DECODE
0	OFF	Disable LED3
1	ON	Enable LED3

LED_TEST_EN2

When COMP[0] = 0x1, this bit is dedicated to force LED2 enable to check LED2 failure. This test should check one LED driver at a time.

VALUE	ENUMERATION	DECODE
0	OFF	Disable LED2
1	ON	Enable LED2

LED_TEST_EN1

When COMP[0] = 0x1, this bit is dedicated to force LED1 enable to check LED1 failure. This test should check one LED driver at a time.

VALUE	ENUMERATION	DECODE
0	OFF	Disable LED1
1	ON	Enable LED1

COMP

This bit enables LED comparator to check LEDx failure.

VALUE	ENUMERATION	DECODE
0	OFF	Disable comparator
1	ON	Enable comparator

LED Comparator Status (0x32)

BIT	3	2	1	0
Field	COMP_ OUT4	COMP_ OUT3	COMP_ OUT2	COMP_ OUT1
Reset	0x0	0x0	0x0	0x0
Access Type	Read Only	Read Only	Read Only	Read Only

COMP_OUT4

This bit stores LED4's comparator output.

VALUE	ENUMERATION	DECODE
0		Normal
1		LED4 is open

COMP_OUT3

This bit stores LED3's comparator output.

VALUE	ENUMERATION	DECODE
0		Normal
1		LED3 is open

COMP_OUT2

This bit stores LED2's comparator output.

VALUE	ENUMERATION	DECODE
0		Normal
1		LED2 is open

COMP_OUT1

This bit stores LED1's comparator output.

VALUE	ENUMERATION	DECODE
0		Normal
1		LED1 is open.

Revision ID (0xFE)

BIT	7	6	5	4	3	2	1	0
Field	REV_ID[7:0]							
Reset	0xXX							
Access Type	Read Only							

REV_ID

This register stores revision ID which varies from 00(Hex) to FF(Hex). Contact Maxim Integrated for the revision ID number assigned for your product.

Part ID (0xFF)

BIT	7	6	5	4	3	2	1	0
Field	PART_ID[7:0]							
Reset	0x2B							
Access Type	Read Only							

PART_ID

This register stores the Part identifier for the chip.

Typical Application Circuit



Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE		
MAX86916EFD+T	-40°C to + 85°C	14-Lead OLGA		

+Denotes a lead(Pb)-free/RoHS-compliant package. T = Tape and reel.

Integrated Optical Sensor Module for Mobile Health

Revision History

REVISION	REVISION	DESCRIPTION	PAGES
NUMBER	DATE		CHANGED
0	10/19	Initial release	—

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