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General Description

The MAX30105 is an integrated particle-sensing module. It includes internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection. The MAX30105 provides a complete system solution to ease the design-in process of smoke detection applications including fire alarms. Due to its extremely small size, the MAX30105 can also be used as a smoke detection sensor for mobile and wearable devices.

The MAX30105 operates on a single 1.8V power supply and a separate 5.0V power supply for the internal LEDs. It communicates through a standard I^2C-compatible interface. The module can be shut down through software with zero standby current, allowing the power rails to remain powered at all times.

Applications

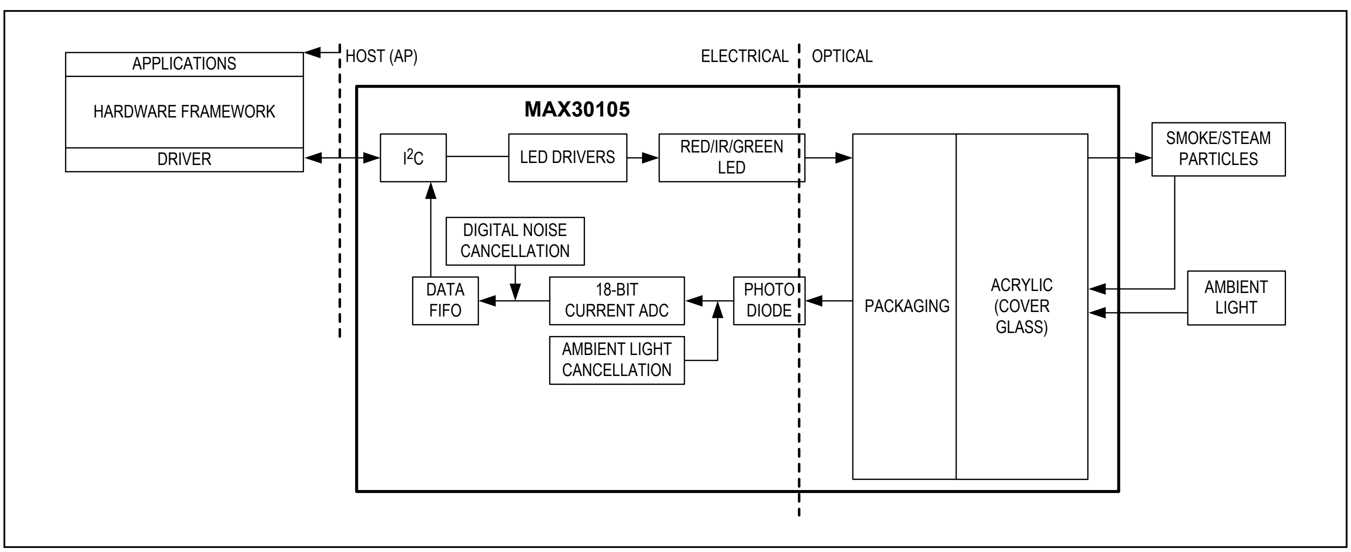
- Fire Alarms
- Smoke Detectors for Building Automation
- Smoke Detectors for Mobile Devices
- Smoke Detectors for Wearable Devices

Benefits and Features

- High Sensitivity Optical Reflective Solution for Detection of Wide Variety of Particle Sizes
- Tiny 5.6mm x 3.3mm x 1.55mm 14-Pin Optical Module
  - Integrated Cover Glass for Optimal, Robust Performance
- Ultra-Low Power Operation
  - Programmable Sample Rate and LED Current for Power Savings
  - Ultra-Low Shutdown Current (0.7µA, typ)
- Robust Motion Artifact Resilience
  - High SNR
- -40°C to +85°C Operating Temperature Range
- Capable of Operating at High Ambient Levels
- Excellent Ambient Rejection Capability

Ordering Information ***appears at end of data sheet.***

System Diagram



Absolute Maximum Ratings

V_{DD} to GND ....-0.3V to +2.2V
GND to PGND ....-0.3V to +0.3V
X_DRV, V_{LED+} to PGND.....................................-0.3V to +6.0V
All Other Pins to GND ....-0.3V to +6.0V
Output Short-Circuit Current Duration.......................Continuous
Continuous Input Current into Any Terminal ....±20mA

Continuous Power Dissipation (T_A = +70°C)
OESIP (derate 5.5mW/°C above +70°C) 440mW
Operating Temperature Range......................... -40°C to +85°C
Junction Temperature..+90°C
Soldering Temperature (reflow) ....+260°C
Storage Temperature Range........................... -40°C to +105°C

Package Thermal Characteristics (Note 1)

OESIP
Junction-to-Ambient Thermal Resistance (θ_{JA}) ....180°C/W
Junction-to-Case Thermal Resistance (θ_{JC})................150°C/W

Note 1: 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 **www.maximintegrated.com/thermal-tutorial**.

Electrical Characteristics

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY						
Power-Supply Voltage	V_{DD}	Guaranteed by RED and IR count tolerance	1.7	1.8	2.0	V
LED Supply Voltage	V_{LED+}	Guaranteed by PSRR of LED driver (R_LED+ and IR_LED+ only)	3.1	3.3	5.25	V
Supply Current	I_{DD}	Particle-sensing mode, PW = 215μs, 50sps		600	1100	μA
		IR only mode, PW = 215μS, 50sps		600	1100	
Supply Current in Shutdown	I_{SHDN}	T_A = +25°C, MODE = 0x80		0.7	2.5	μA
OPTICAL SENSOR CHARACTERISTICS						
ADC Resolution				18		bits
Red ADC Count (Note 3)	REDC	RED_PA = 0x0C, LED_PW = 0x01, SPO2_SR = 0x05, ADC_RGE = 0x00, T_A = +25°C		65536		Counts
IR ADC Count (Note 3)	IRC	IR_PA = 0x0C, LED_PW = 0x01, SPO2_SR = 0x05 ADC_RGE = 0x00, T_A = +25°C		65536		Counts
Green ADC Count (Note 3)	GRNC	GRN_PA = 0x24, LED_PW = 0x11, SPO2_SR = 0x05 ADC_RGE = 0x00, T_A = +25°C		65536		Counts
SNR IR LED	SNR_{IR}	White card loop-back, LED_PW = 0x11, ADC_RGE = 0x10, T_A = 25°C		89	300	dB
SNR Red LED	SNR_{RED}	White card loop-back, LED_PW = 0x11, ADC_RGE = 0x10, T_A = 25°C		88.9	300	dB
SNR Green LED	SNR_{GREEN}	White card loop-back, LED_PW = 0x11, ADC_RGE = 0x01, T_A = 25°C		80.4		dB

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Dark Current Count	LED_DCC	RED_PA = IR_PA = 0x00, LED_PW = 0x03, SPO2_SR = 0x01 ADC_RGE = 0x02			30	128	Counts
					0.01	0.05	% of FS
DC Ambient Light Rejection (Note 4)	ALR	ADC counts with finger on sensor under direct sunlight (100K lux), ADC_RGE = 0x3, LED_PW = 0x03, SPO2_SR = 0x01	Red LED		2		Counts
			IR LED		2		Counts
ADC Count—PSRR (V_{DD})	$PSRRV_{DD}$	1.7V < V_{DD} < 2.0V, LED_PW = 0x00, SPO2_SR = 0x05 T_A = +25°C			0.25	1	% of FS
		Frequency = DC to 100kHz, $100mV_{P-P}$			10		LSB
ADC Count—PSRR (LED Driver Outputs)	$PSRR_{LED}$	3.6V < V_{LED+}, < 5.0V, T_A = +25°C			0.05	1	% of FS
		Frequency = DC to 100kHz, $100mV_{P-P}$			10		LSB
ADC Clock Frequency	CLK			10.2	10.48	10.8	MHz
ADC Integration Time (Note 4)	INT	LED_PW = 0x00			69		µs
		LED_PW = 0x01			118		
		LED_PW = 0x02			215		
		LED_PW = 0x03			411		
Slot Timing (Timing Between Sequential Channel Samples; e.g., Red Pulse Rising Edge To IR Pulse Rising Edge)	INT	LED_PW = 0x00			427		µs
		LED_PW = 0x01			525		
		LED_PW = 0x02			720		
		LED_PW = 0x03			1107		
COVER GLASS CHARACTERISTICS (Note 4)							
Hydrolytic Resistance Class		Per DIN ISO 719			HGB 1		
IR LED CHARACTERISTICS (Note 4)							
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C		870	880	900	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C			30		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C			1.4		V
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C			6.5		mW
RED LED CHARACTERISTICS (Note 4)							
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C		650	660	670	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C			20		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C			2.1		V

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C		9.8		mW
GREEN LED CHARACTERISTICS (Note 4)						
LED Peak Wavelength	λ_P	I_{LED} = 50mA, T_A = +25°C	530	537	545	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 50mA, T_A = +25°C		35		nm
Forward Voltage	V_F	I_{LED} = 50mA, T_A = +25°C		33		V
Radiant Power	P_O	I_{LED} = 50mA, T_A = +25°C		17.2		mW
PHOTODETECTOR CHARACTERISTICS (Note 4)						
Spectral Range of Sensitivity	Λ > 30% QE	QE: Quantum Efficiency	640		980	nm
Radiant Sensitive Area	A			1.36		mm^2
Dimensions of Radiant Sensitive Area	L x W			1.38 x 0.98		mm x mm
INTERNAL DIE TEMPERATURE SENSOR						
Temperature ADC Acquisition Time	T_T	T_A = +25°C		29		ms
Temperature Sensor Accuracy	T_A	T_A = +25°C		±1		°C
Temperature Sensor Minimum Range	T_{MIN}			-40		°C
Temperature Sensor Maximum Range	T_{MAX}			85		°C
DIGITAL INPUTS (SCL, SDA)						
Input Logic-Low Voltage	V_{IL}				0.3 x V_{DD}	V
Input Logic-High Voltage	V_{IH}		0.7 x V_{DD}			V
Input Hysteresis	V_{HYS}			0.5 x V_{DD}		V
Input Leakage Current	I_{IN}			±0.1	±1	µA
Input Capacitance	C_{IN}			10		pF
DIGITAL OUTPUTS (SDA, $\overline{INT}$)						
Output Low Voltage	V_{OL}	I_{SINK} = 3mA			0.4	V
I^2C TIMING CHARACTERISTICS						
I^2C Write Address				AE		Hex
I^2C Read Address				AF		Hex
SCL Clock Frequency	f_{SCL}	Lower limit not tested	0		400	kHz
Bus Free Time Between STOP and START Condition	t_{BUF}		1.3			µs

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Hold Time (Repeated) START Condition	$t_{HD,STA}$		0.6			µs
SCL Pulse-Width Low	t_{LOW}		1.3			µs
SCL Pulse-Width High	t_{HIGH}		0.6			µs
Setup Time for a Repeated START Condition	$t_{SU,STA}$		0.6			µs
Data Hold Time	$t_{HD;DAT}$		0		0.9	µs
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}				50	ns
Bus Capacitance	C_b				400	pF
SDA and SCL Receiving Rise Time	T_r	(Note 5)	20		300	ns
SDA and SCL Receiving Fall Time	t_{Rf}	(Note 5)	20 x V_{DD}/5.5		300	ns
SDA Transmitting Fall Time	t_{of}		20 x V_{DD}/5.5		250	ns

Note 2: 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 3: Specifications are guaranteed by Maxim Integrated's bench characterization and by 100% production test using proprietary ATE setup and conditions.
Note 4: For design guidance only. Not production tested.
Note 5: These specifications are guaranteed by design, characterization, or I²C protocol.

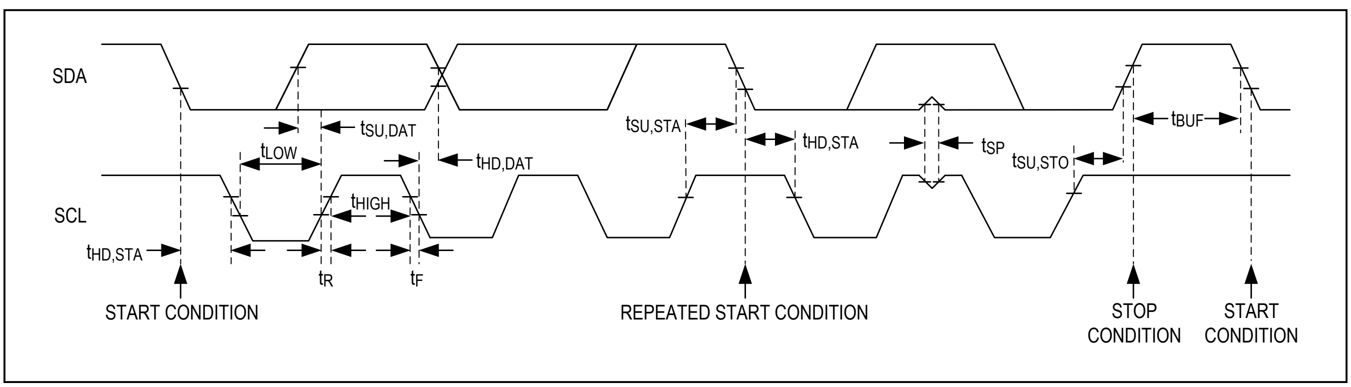
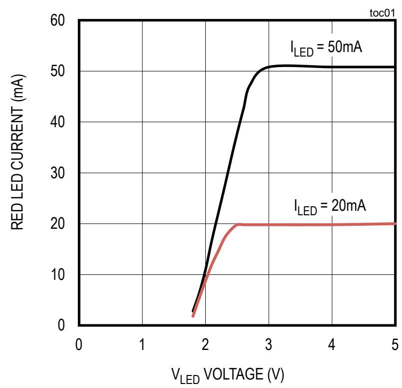


Figure 1. I²C-Compatible Interface Timing Diagram

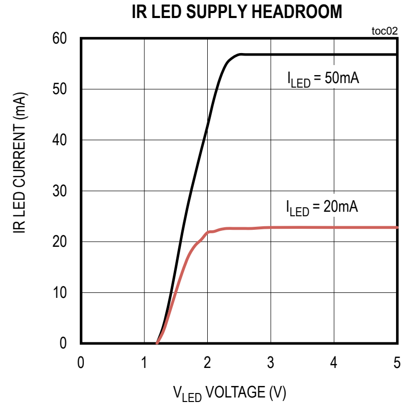
Typical Operating Characteristics

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = +25°C, unless otherwise noted.)

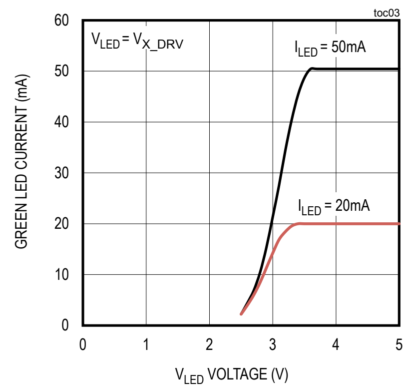
RED LED SUPPLY HEADROOM



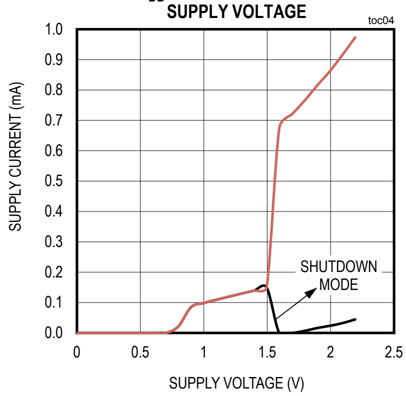
IR LED SUPPLY HEADROOM



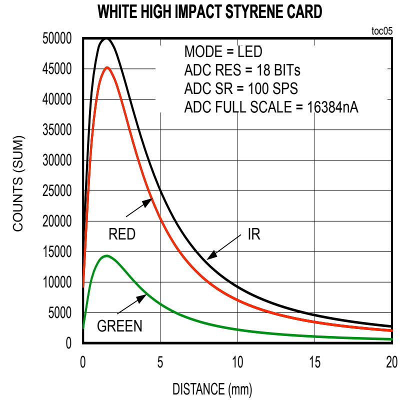
GREEN LED SUPPLY HEADROOM



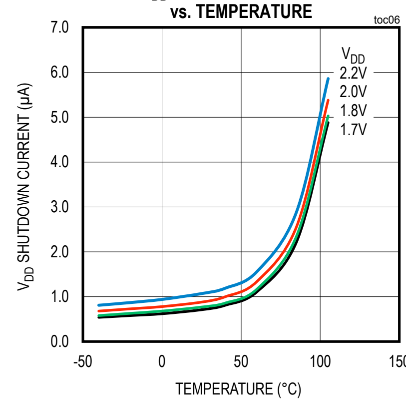
V_{DD} SUPPLY CURRENT vs. SUPPLY VOLTAGE



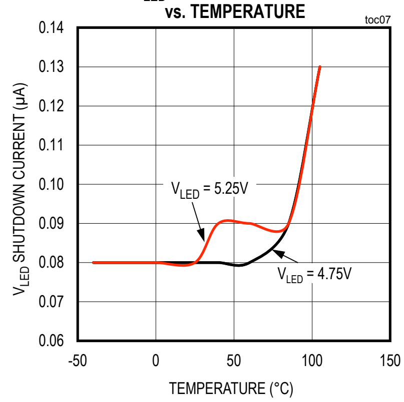
DC COUNTS vs. DISTANCE FOR WHITE HIGH IMPACT STYRENE CARD



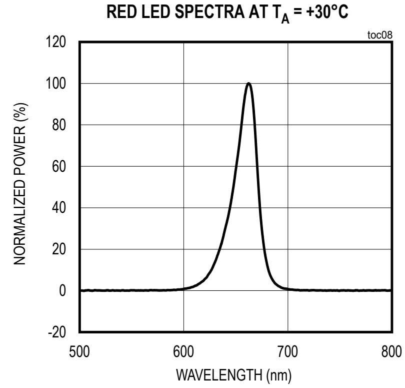
V_{DD} SHUTDOWN CURRENT vs. TEMPERATURE



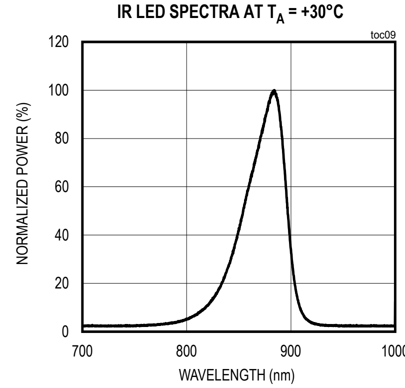
V_{LED} SHUTDOWN CURRENT vs. TEMPERATURE



RED LED SPECTRA AT T_A = +30°C



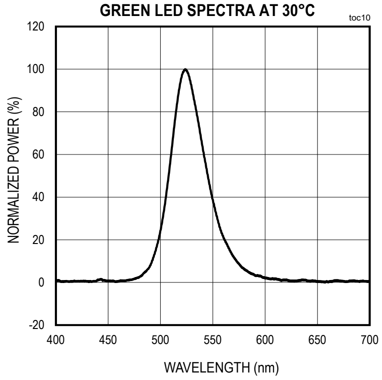
IR LED SPECTRA AT T_A = +30°C



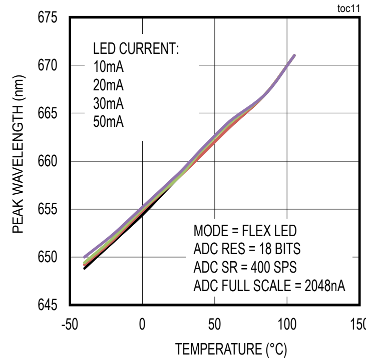
Typical Operating Characteristics (continued)

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = +25°C, unless otherwise noted.)

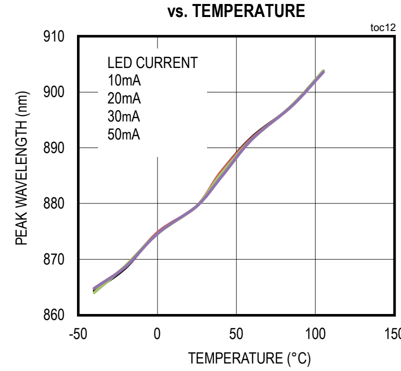
GREEN LED SPECTRA AT 30°C



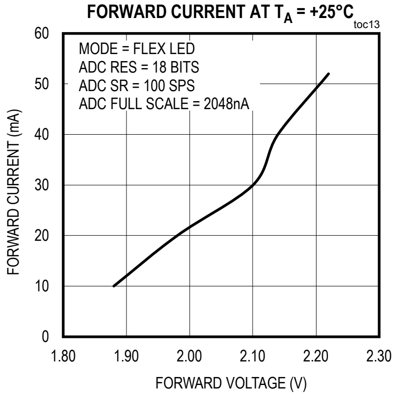
RED LED PEAK WAVELENGTH vs. TEMPERATURE



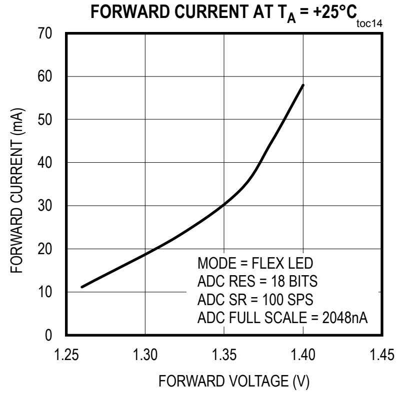
IR LED PEAK WAVELENGTH vs. TEMPERATURE



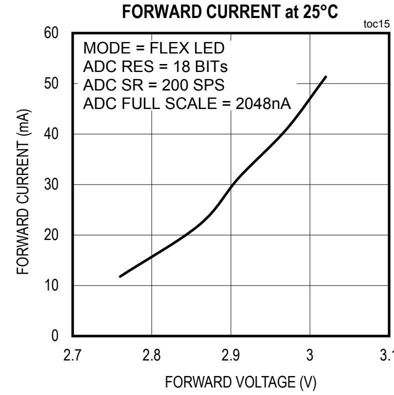
RED LED FORWARD VOLTAGE vs. FORWARD CURRENT AT T_A = +25°C



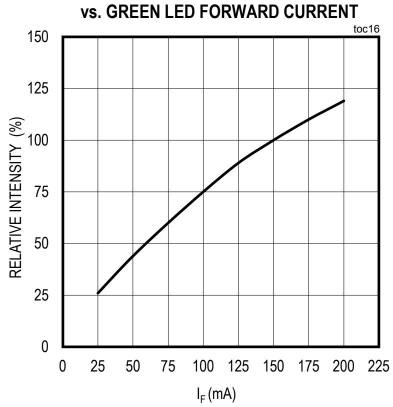
IR LED FORWARD VOLTAGE vs. FORWARD CURRENT AT T_A = +25°C



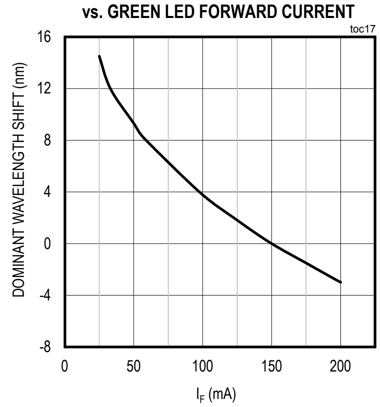
GREEN LED FORWARD VOLTAGE vs. FORWARD CURRENT at 25°C



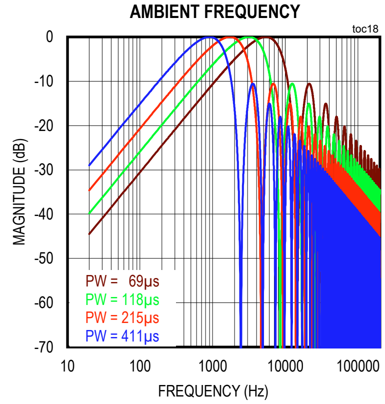
RELATIVE INTENSITY vs. GREEN LED FORWARD CURRENT



DOMINANT WAVELENGTH SHIFT vs. GREEN LED FORWARD CURRENT

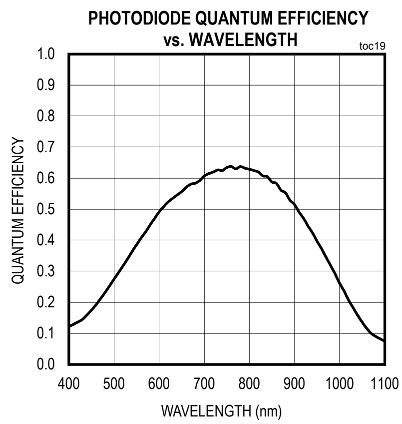


AMBIENT REJECTION vs. AMBIENT FREQUENCY

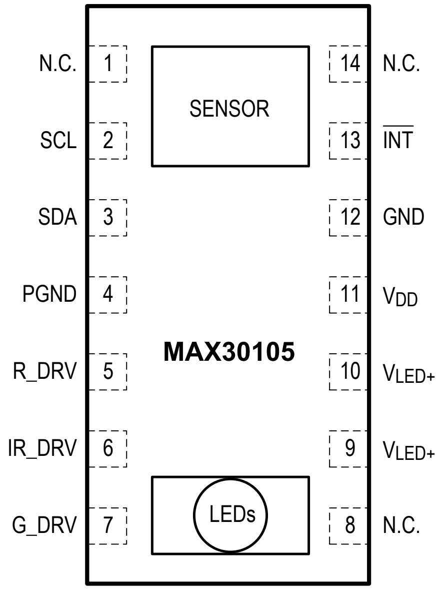


Typical Operating Characteristics (continued)

(V_{DD} = 1.8V, V_{LED+} = 5.0V, T_A = +25°C, unless otherwise noted.)



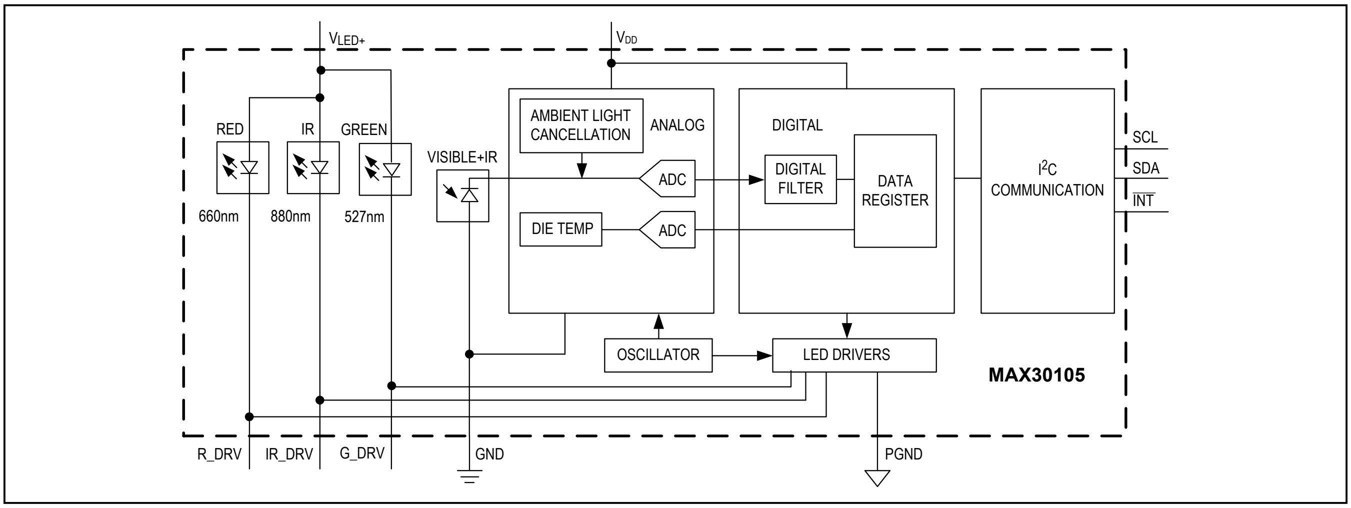
Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1, 8, 14	N.C.	No Connection. Connect to PCB pad for mechanical stability.
2	SCL	I^2C Clock Input
3	SDA	I^2C Clock Data, Bidirectional (Open-Drain)
4	PGND	Power Ground of the LED Driver Blocks
5	R_DRV	Red LED Driver
6	IR_DRV	IR LED Driver
7	G_DRV	Green LED Driver
9	V_{LED+}	LED Power Supply (anode connection). Use a bypass capacitor to PGND for best performance.
10	V_{LED+}	
11	V_{DD}	Analog Power Supply Input. Use a bypass capacitor to GND for best performance.
12	GND	Analog Ground
13	$\overline{INT}$	Active-Low Interrupt (Open-Drain). Connect to an external voltage with a pullup resistor.

Functional Diagram



Detailed Description

The MAX30105 is a complete particle detection sensor system solution module. The MAX30105 maintains a very small solution size without sacrificing optical/electrical performance. Minimal external hardware components are required for integration into a smoke detection system.

The MAX30105 is fully adjustable through software registers, and the digital output data can be stored in a 32-deep FIFO within the IC. The FIFO allows the MAX30105 to be connected to a microcontroller or processor on a shared bus, where the data is not being read continuously from the MAX30105's registers.

Particle-Sensing Subsystem

The particle-sensing subsystem contains ambient light cancellation (ALC), a continuous-time sigma-delta ADC, and proprietary discrete time filter. The ALC has an internal Track/Hold circuit to cancel ambient light and increase the effective dynamic range. The particle-sensing ADC has a programmable full-scale range from 2μA to 16μA. The ALC can cancel up to 200μA of ambient current.

The internal ADC is a continuous time oversampling sigma-delta converter with 18-bit resolution. The ADC sampling rate is 10.24MHz. The ADC output data rate can be programmed from 50sps (samples per second) to 3200sps.

Temperature Sensor

The MAX30105 has an on-chip temperature sensor for calibrating the temperature dependence of the particle-sensing subsystem. The temperature sensor has an inherent resolution 0.0625°C.

LED Driver

The MAX30105 integrates red, green, and IR LED drivers to modulate LED pulses for particle-sensing measurements. The LED current can be programmed from 0 to 50mA with proper supply voltage. The LED pulse width can be programmed from 69μs to 411μs to allow the algorithm to optimize particle-sensing accuracy and power consumption based on use cases.

Proximity Function

When the particle-sensing function is initiated (by writing the MODE register), the IR LED is activated in proximity mode with a drive current set by the PILOT_PA register. When an object is detected by exceeding the IR ADC count threshold (set in the PROX_INT_THRESH register), the part transitions automatically to the normal particle-sensing Mode. To reenter proximity mode, the MODE register must be rewritten (even if the value is the same).

The proximity function can be disabled by resetting PROX_INT_EN to 0. In this case, the particle-sensing mode begins immediately.

Register Maps and Descriptions

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
STATUS											
Interrupt Status 1	A_FULL	DATA_RDY	ALC_OVF	PROX_INT				PWR_RDY	0x00	0X00	R
Interrupt Status 2							DIE_TEMP_RDY		0x01	0x00	R
Interrupt Enable 1	A_FULL_EN	DATA_RDY_EN	ALC_OVF_EN	PROX_INT_EN					0x02	0X00	R/W
Interrupt Enable 2							DIE_TEMP_RDY_EN		0x03	0x00	R/W
FIFO											
FIFO Write Pointer				FIFO_WR_PTR[4:0]					0x04	0x00	R/W
Overflow Counter				OVF_COUNTER[4:0]					0x05	0x00	R/W
FIFO Read Pointer				FIFO_RD_PTR[4:0]					0x06	0x00	R/W
FIFO Data Register	FIFO_DATA[7:0]								0x07	0x00	R/W
CONFIGURATION											
FIFO Configuration	SMP_AVE[2:0]			FIFO_ROLL OVER_EN	FIFO_A_FULL[3:0]				0x08	0x00	R/W
Mode Configuration	SHDN	RESET				MODE[2:0]			0x09	0x00	R/W
SpO_2 Configuration	0 (Reserved)	ADC_RGE [1:0]		SR[2:0]			LED_PW[1:0]		0x0A	0x00	R/W
RESERVED									0x0B	0x00	R/W
LED Pulse Amplitude	LED1_PA[7:0]								0x0C	0x00	R/W
	LED2_PA[7:0]								0x0D	0x00	R/W
	LED3_PA[7:0]								0x0E	0x00	R/W
RESERVED									0x0F	0x00	R/W
Proximity Mode LED Pulse Amplitude	PILOT_PA[7:0]								0x10	0x00	R/W
Multi-LED Mode Control Registers		SLOT2[2:0]				SLOT1[2:0]			0x11	0x00	R/W
		SLOT4[2:0]				SLOT3[2:0]			0x12	0x00	R/W

Register Maps and Descriptions (continued)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
RESERVED									0x13–0x17	0xFF	R/W
RESERVED									0x18-0x1E	0x00	R
DIE TEMPERATURE											
Die Temp Integer	TINT[7:0]								0x1F	0x00	R
Die Temp Fraction					TFRAC[3:0]				0x20	0x00	R
Die Temperature Config								TEMP _EN	0x21	0x00	R
RESERVED									0x22–0x2F	0x00	R/W
PROXIMITY FUNCTION											
Proximity Interrupt Threshold	PROX_INT_THRESH[7:0]								0x30	0x00	R/W
PART ID											
Revision ID	REV_ID[7:0]								0xFE	0xXX*	R
Part ID	PART_ID[7]								0xFF	0x15	R

**XX denotes a 2-digit hexadecimal number (00 to FF) for part revision identification. Contact Maxim Integrated for the revision ID number assigned for your product.*

Interrupt Status (0x00–0x01)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Interrupt Status 1	A_FULL	DATA_ RDY	ALC_OVF	PROX_ INT				PWR_ RDY	0x00	0X00	R
Interrupt Status 2							DIE_ TEMP_RDY		0x01	0x00	R

Whenever an interrupt is triggered, the MAX30105 pulls the active-low interrupt pin into its low state until the interrupt is cleared.

A_FULL: FIFO Almost Full Flag

In particle-sensing mode, this interrupt triggers when the FIFO write pointer has a certain number of free spaces remaining. The trigger number can be set by the FIFO_A_FULL[3:0] register. The interrupt is cleared by reading the Interrupt Status 1 register (0x00).

DATA_RDY: New FIFO Data Ready

In particle-sensing mode, 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: Ambient Light Cancellation Overflow

This interrupt triggers when the ambient light cancellation function of the particle-sensing photodiode has reached its maximum limit, 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: Proximity Threshold Triggered

The proximity interrupt is triggered when the proximity threshold is reached, and particle-sensing mode has begun. This lets the host processor know to begin running the particle-sensing algorithm and collect data. The interrupt is cleared by reading the Interrupt Status 1 register (0x00).

PWR_RDY: Power Ready Flag

On power-up or after a brownout condition, when the supply voltage V_{DD} transitions from below the undervoltage-lockout (UVLO) voltage to above the UVLO voltage, a power-ready interrupt is triggered to signal that the module is powered-up and ready to collect data.

DIE_TEMP_RDY: Internal Temperature Ready Flag

When an internal die temperature conversion is finished, this interrupt is triggered so the processor can read the temperature data registers. The interrupt is cleared by reading either the Interrupt Status 2 register (0x01) or the TFRAC register (0x20).

The interrupts are cleared whenever the interrupt status register is read, or when the register that triggered the interrupt is read. For example, if the particle-sensing sensor triggers an interrupt due to finishing a conversion, reading either the FIFO data register or the interrupt register clears the interrupt pin (which returns to its normal HIGH state). This also clears all the bits in the interrupt status register to zero.

Interrupt Enable (0x02–0x03)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Interrupt Enable 1	A_ FULL_ EN	DATA_ RDY_EN	ALC_ OVF_EN	PROX_ INT_EN					0x02	0X00	R/W
Interrupt Enable 2							DIE_TEMP_ RDY_EN		0x03	0x00	R/W

Each source of hardware interrupt, with the exception of power ready, can be disabled in a software register within the MAX30105 IC. The power-ready interrupt cannot be disabled because the digital state of the module is reset upon a brownout condition (low power supply voltage), and the default condition is that all the interrupts are disabled. Also, it is important for the system to know that a brownout condition has occurred, and the data within the module is reset as a result.

The unused bits should always be set to zero for normal operation.

FIFO (0x04–0x07)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
FIFO Write Pointer				FIFO_WR_PTR[4:0]					0x04	0x00	R/W
Over Flow Counter				OVF_COUNTER[4:0]					0x05	0x00	R/W
FIFO Read Pointer				FIFO_RD_PTR[4:0]					0x06	0x00	R/W
FIFO Data Register	FIFO_DATA[7:0]								0x07	0x00	R/W

FIFO Write Pointer

The FIFO Write Pointer points to the location where the MAX30105 writes the next sample. This pointer advances for each sample pushed on to the FIFO. It can also be changed through the I^2C interface when MODE[2:0] is 010, 011, or 111.

FIFO Overflow Counter

When the FIFO is full, samples are not pushed on to the FIFO, samples are lost. OVF_COUNTER counts the number of samples lost. It saturates at 0xF. When a complete sample is “popped” (i.e., removal of old FIFO data and shifting the samples down) from the FIFO (when the read pointer advances), OVF_COUNTER is reset to zero.

FIFO Read Pointer

The FIFO Read Pointer points to the location from where the processor gets the next sample from the FIFO through the I^2C interface. This advances each time a sample is popped from the FIFO. The processor can also write to this pointer after reading the samples to allow rereading samples from the FIFO if there is a data communication error.

FIFO Data Register

The circular FIFO depth is 32 and can hold up to 32 samples of data. The sample size depends on the number of LED channels configured as active. As each channel signal is stored as a 3-byte data signal, the FIFO width can be 3 bytes, 6 bytes, 9 bytes, or 12 bytes in size.

The FIFO_DATA register in the I2C register map points to the next sample to be read from the FIFO. FIFO_RD_PTR points to this sample. Reading the FIFO_DATA register does not automatically increment the I2C register address. Burst reading this register reads the same address over and over. Each sample is 3 bytes of data per channel (i.e., 3 bytes for RED, 3 bytes for IR, etc.).

The FIFO registers (0x04–0x07) can all be written and read, but in practice only the FIFO_RD_PTR register should be written to in operation. The others are automatically incremented or filled with data by the MAX30105. When starting a new particle-sensing conversion, it is recommended to first clear the FIFO_WR_PTR, OVF_COUNTER, and FIFO_RD_PTR registers to all zeroes (0x00) to ensure the FIFO is empty and in a known state. When reading the MAX30105 registers in one burst-read I2C transaction, the register address pointer typically increments so that the next byte of data sent is from the next register, etc. The exception to this is the FIFO data register, register 0x07. When reading this register, the address pointer does not increment, but the FIFO_RD_PTR does. So the next byte of data sent represents the next byte of data available in the FIFO.

Entering and exiting the proximity mode (when PROX_INT_EN = 1) clears the FIFO by setting the write and read pointers equal to each other.

Reading from the FIFO

Normally, reading registers from the I2C interface autoincrements the register address pointer, so that all the registers can be read in a burst read without an I2C start event. In the MAX30105, this holds true for all registers except for the FIFO_DATA register (register 0x07).

Reading the FIFO_DATA register does not automatically increment the register address. Burst reading this register reads data from the same address over and over. Each sample comprises multiple bytes of data, so multiple bytes should be read from this register (in the same transaction) to get one full sample.

The other exception is 0xFF. Reading more bytes after the 0xFF register does not advance the address pointer back to 0x00, and the data read is not meaningful.

FIFO Data Structure

The data FIFO consists of a 32-sample memory bank that can store GREEN, IR, and RED ADC data. Since each sample consists of three channels of data, there are 9 bytes of data for each sample, and therefore 288 total bytes of data can be stored in the FIFO.

The FIFO data is left-justified as shown in Table 1; in other words, the MSB bit is always in the bit 17 data position regardless of ADC resolution setting. See Table 2 for a visual presentation of the FIFO data structure.

Table 1. FIFO Data is Left-Justified

ADC Resolution	FIFO_DATA[17]	FIFO_DATA[16]	...	FIFO_DATA[12]	FIFO_DATA[11]	FIFO_DATA[10]	FIFO_DATA[9]	FIFO_DATA[8]	FIFO_DATA[7]	FIFO_DATA[6]	FIFO_DATA[5]	FIFO_DATA[4]	FIFO_DATA[3]	FIFO_DATA[2]	FIFO_DATA[1]	FIFO_DATA[0]
18-bit																
17-bit																
16-bit																
15-bit																

FIFO Data Contains 3 Bytes per Channel

The FIFO data is left-justified, meaning that the MSB is always in the same location regardless of the ADC resolution setting. FIFO DATA[18] – [23] are not used. Table 2 shows the structure of each triplet of bytes (containing the 18-bit ADC data output of each channel).

Each data sample in particle-sensing mode comprises two data triplets (3 bytes each), To read one sample, requires an I^2C read command for each byte. Thus, to read one sample in particle-sensing mode requires 6 I^2C byte reads. To read one sample with three LED channels requires 9 I^2C byte reads. The FIFO read pointer is automatically incremented after the first byte of each sample is read.

Write/Read Pointers

Write/Read pointers are used to control the flow of data in the FIFO. The write pointer increments every time a new sample is added to the FIFO. The read pointer is incremented every time a sample is read from the FIFO. To reread a sample from the FIFO, decrement its value by one and read the data register again.

The FIFO write/read pointers should be cleared (back to 0x00) upon entering particle-sensing mode, so that there is no old data represented in the FIFO. The pointers are automatically cleared if V_{DD} is power-cycled or V_{DD} drops below its UVLO voltage.

Table 2. FIFO Data (3 Bytes per Channel)

BYTE 1							FIFO_ DATA[17]	FIFO_ DATA[16]
BYTE 2	FIFO_ DATA[15]	FIFO_ DATA[14]	FIFO_ DATA[13]	FIFO_ DATA[12]	FIFO_ DATA[11]	FIFO_ DATA[10]	FIFO_ DATA[9]	FIFO_ DATA[8]
BYTE 3	FIFO_ DATA[7]	FIFO_ DATA[6]	FIFO_ DATA[5]	FIFO_ DATA[4]	FIFO_ DATA[3]	FIFO_ DATA[2]	FIFO_ DATA[1]	FIFO_ DATA[0]

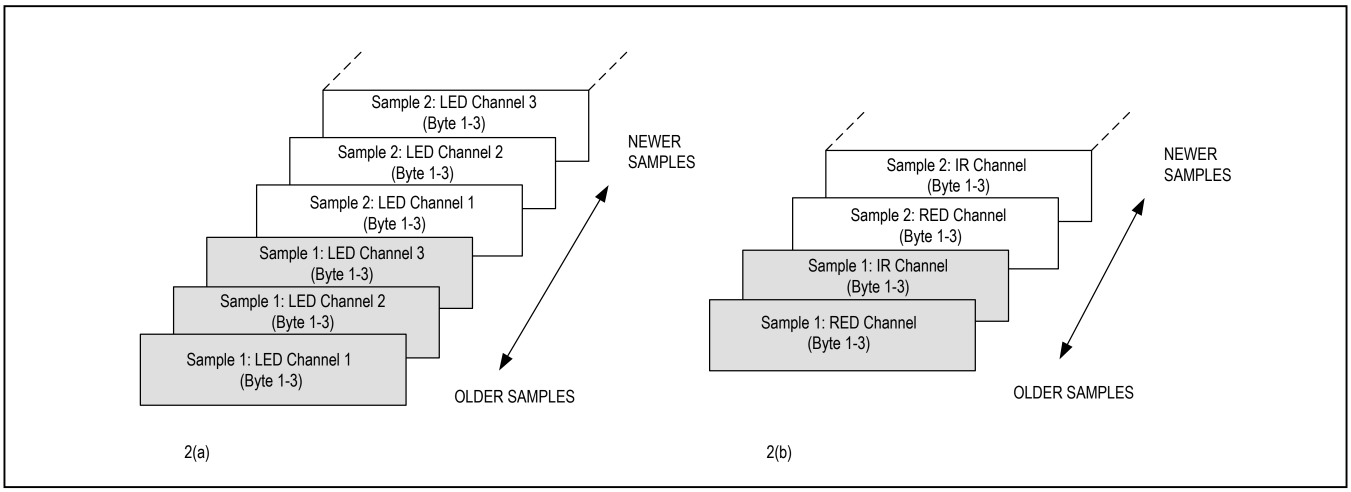


Figure 2a and 2b. Graphical Representation of the FIFO Data Register. The left shows three LEDs in multi-LED mode, and the right shows IR and Red only in particle-sensing Mode.

Pseudo-Code Example of Reading Data from FIFO

First transaction: Get the FIFO_WR_PTR:

```
START;
Send device address + write mode
Send address of FIFO_WR_PTR;
REPEATED_START;
Send device address + read mode
Read FIFO_WR_PTR;
STOP;
```

The central processor evaluates the number of samples to be read from the FIFO:

```
NUM_AVAILABLE_SAMPLES = FIFO_WR_PTR – FIFO_RD_PTR
(Note: pointer wrap around should be taken into account)
NUM_SAMPLES_TO_READ = < less than or equal to NUM_AVAILABLE_SAMPLES >
```

Second transaction: Read `NUM_SAMPLES_TO_READ` samples from the FIFO:

```
START;
Send device address + write mode
Send address of FIFO_DATA;
REPEATED_START;
Send device address + read mode
for (i = 0; i < NUM_SAMPLES_TO_READ; i++) {
Read FIFO_DATA;
Save LED1[23:16];
Read FIFO_DATA;
Save LED1[15:8];
Read FIFO_DATA;
Save LED1[7:0];
Read FIFO_DATA;
Save LED2[23:16];
Read FIFO_DATA;
Save LED2[15:8];
Read FIFO_DATA;
Save LED2[7:0];
Read FIFO_DATA;
Save LED3[23:16];
Read FIFO_DATA;
Save LED3[15:8];
Read FIFO_DATA;
Save LED3[7:0];
Read FIFO_DATA;
}
STOP;
```

```
START;
Send device address + write mode
Send address of FIFO_RD_PTR;
Write FIFO_RD_PTR;
STOP;
```

Third transaction: Write to FIFO_RD_PTR register. If the second transaction was successful, FIFO_RD_PTR points to the next sample in the FIFO, and this third transaction is not necessary. Otherwise, the processor updates the FIFO_RD_PTR appropriately, so that the samples are reread.

FIFO Configuration (0x08)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
FIFO Configuration	SMP_AVE[2:0]			FIFO_ROLLOVER_EN	FIFO_A_FULL[3:0]				0x08	0x00	R/W

Bits 7:5: Sample Averaging (SMP_AVE)

To reduce the amount of data throughput, adjacent samples (in each individual channel) can be averaged and decimated on the chip by setting this register.

Table 3. Sample Averaging

SMP_AVE[2:0]	NO. OF SAMPLES AVERAGED PER FIFO SAMPLE
000	1 (no averaging)
001	2
010	4
011	8
100	16
101	32
110	32
111	32

Bit 4: FIFO Rolls on Full (FIFO_ROLLOVER_EN)

This bit controls the behavior of the FIFO when the FIFO becomes completely filled with data. If FIFO_ROLLOVER_EN is set (1), the FIFO Address rolls over to zero and the FIFO continues to fill with new data. If the bit is not set (0), then the FIFO is not updated until FIFO_DATA is read or the WRITE/READ pointer positions are changed.

Bits 3:0: FIFO Almost Full Value (FIFO_A_FULL)

This register sets the trigger for the FIFO_A_FULL interrupt. For example, if set to 0x0F, the interrupt triggers when there are 15 empty space left (17 data samples), and so on.

FIFO_A_FULL[3:0]	NO. OF SAMPLES IN THE FIFO
0x0h	32
0x1h	31
0x2h	30
0x3h	29
…	…
0xFh	17

Mode Configuration (0x09)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Mode Configuration	SHDN	RESET				MODE[2:0]			0x09	0x00	R/W

Bit 7: Shutdown Control (SHDN)

The part can be put into a power-save mode by setting this bit to one. While in power-save mode, all registers retain their values, and write/read operations function as normal. All interrupts are cleared to zero in this mode.

Bit 6: Reset Control (RESET)

When the RESET bit is set to one, all configuration, threshold, and data registers are reset to their power-on-state through a power-on reset. The RESET bit is cleared automatically back to zero after the reset sequence is completed.

Note: Setting the RESET bit does not trigger a PWR_RDY interrupt event.

Bits 2:0: Mode Control

These bits set the operating state of the MAX30105. Changing modes does not change any other setting, nor does it erase any previously stored data inside the data registers.

Table 4. Mode Control

MODE[2:0]	MODE	ACTIVE LED CHANNELS
000	Do not use	
001	Do not use	
010	Particle-sensing mode using 1 LED	Red only
011	Particle-sensing mode using 2 LEDs	Red and IR
100–110	Do not use	
111	Multi-LED mode	Green, Red, and/or IR

Particle-Sensing Configuration (0x0A)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
SpO_2 Configuration		ADC_RGE<1:0>		SR[2:0]			LED_PW[2:0]		0x0A	0x00	R/W

Bits 6:5: Particle-Sensing ADC Range Control

This register sets the particle-sensing sensor ADC's full-scale range as shown in Table 5.

Table 5. Particle-Sensing ADC Range Control (18-Bit Resolution)

ADC_RGE[1:0]	LSB SIZE (pA)	FULL SCALE (nA)
00	7.81	2048
01	15.63	4096
02	31.25	8192
03	62.5	16384

Bits 4:2: Particle-Sensing Sample Rate Control (Using 2 LEDs)

These bits define the effective sampling rate with one sample consisting of one IR pulse/conversion and one RED pulse/conversion.

The sample rate and pulse width are related in that the sample rate sets an upper bound on the pulse width time. If the user selects a sample rate that is too high for the selected LED_PW setting, the highest possible sample rate is programmed instead into the register.

Table 6. Particle-Sensing Sample Rate Control

SR[2:0]	SAMPLES PER SECOND
000	50
001	100
010	200
011	400
100	800
101	1000
110	1600
111	3200

See Table 11 and Table 12 for Pulse Width vs. Sample Rate information.

Bits 1:0: LED Pulse Width Control and ADC Resolution

These bits set the LED pulse width (the IR, Red, and Green have the same pulse width), and therefore, indirectly sets the integration time of the ADC in each sample. The ADC resolution is directly related to the integration time.

Table 7. LED Pulse Width Control

LED_PW[1:0]	PULSE WIDTH (µs)	ADC RESOLUTION (bits)
00	69 (68.95)	15
01	118 (117.78)	16
10	215 (215.44)	17
11	411 (410.75)	18

LED Pulse Amplitude (0x0C–0x10)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
LED Pulse Amplitude	LED1_PA[7:0]								0x0C	0x00	R/W
	LED2_PA[7:0]								0x0D	0x00	R/W
LED Pulse Amplitude	LED3_PA[7:0]								0x0E	0x00	R/W
RESERVED									0x0F	0x00	R/W
Proximity Mode LED Pulse Amplitude	PILOT_PA[7:0]								0x10	0x00	R/W

These bits set the current level of each LED as shown in Table 8.

Table 8. LED Current Control

LEDx_PA [7:0]	TYPICAL LED CURRENT (mA)*
0x00h	0.0
0x01h	0.2
0x02h	0.4
…	…
0x0Fh	3.1
…	…
0x1Fh	6.4
…	…
0x3Fh	12.5
…	…
0x7Fh	25.4
…	…
0xFFh	50.0

**Actual measured LED current for each part can vary significantly due to the trimming methodology.*

The purpose of PILOT_PA[7:0] is to set the LED power during the proximity mode, as well as in Multi-LED mode.

Multi-LED Mode Control Registers (0x11–0x12)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Multi-LED Mode Control Registers		SLOT2[2:0]				SLOT1[2:0]			0x11	0x00	R/W
		SLOT4[2:0]				SLOT3[2:0]			0x12	0x00	R/W

In multi-LED mode, each sample is split into up to four time slots, SLOT1 through SLOT4. These control registers determine which LED is active in each time slot, making for a very flexible configuration.

Table 9. Multi-LED Mode Control Registers

SLOTx[2:0] Setting	WHICH LED IS ACTIVE	LED PULSE AMPLITUDE SETTING
000	None (time slot is disabled)	N/A (Off)
001	LED1 (RED)	LED1_PA[7:0]
010	LED2 (IR)	LED2_PA[7:0]
011	LED3 (GREEN)	LED3_PA[7:0]
100	None	N/A (Off)
101	LED1 (Red)	PILOT_PA[7:0]
110	LED2 (IR)	PILOT_PA[7:0]
111	LED3 (GREEN)	PILOT_PA[7:0]

Each slot generates a 3-byte output into the FIFO. One sample comprises all active slots, for example if SLOT1 and SLOT2 are non-zero, then one sample is 2 x 3 = 6 bytes. If SLOT1 through SLOT3 are all non-zero, then one sample is 3 x 3 = 9 bytes.

The slots should be enabled in order (i.e., SLOT1 should not be disabled if SLOT2 or SLOT3 are enabled).

Temperature Data (0x1F–0x21)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Temp_Integer	TINT[7]								0x1F	0x00	R/W
Temp_Fraction					TFRAC[3:0]				0x20	0x00	R/W
Die Temperature Config								TEMP_EN	0x21	0x00	R

Temperature Integer

The on-board temperature ADC output is split into two registers, one to store the integer temperature and one to store the fraction. Both should be read when reading the temperature data, and the equation below shows how to add the two registers together:

$$T_{MEASURED} = T_{INTEGER} + T_{FRACTION}$$

This register stores the integer temperature data in 2's complement format, where each bit corresponds to 1°C.

Table 10. Temperature Integer

REGISTER VALUE (hex)	TEMPERATURE (°C)
0x00	0
0x00	+1
...	...
0x7E	+126
0x7F	+127
0x80	-128
0x81	-127
...	...
0xFE	-2
0xFF	-1

Temperature Fraction

This register stores the fractional temperature data in increments of 0.0625°C. If this fractional temperature is paired with a negative integer, it still adds as a positive fractional value (e.g., -128°C + 0.5°C = -127.5°C).

Temperature Enable (TEMP_EN)

This is a self-clearing bit which, when set, initiates a single temperature reading from the temperature sensor. This bit clears automatically back to zero at the conclusion of the temperature reading when the bit is set to one in particle-sensing mode.

Proximity Mode Interrupt Threshold (0x30)

REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	REG ADDR	POR STATE	R/W
Proximity Interrupt Threshold	PROX_INT_THRESH[7:0]								0x30	0x00	R/W

This register sets the IR ADC count that will trigger the beginning of particle-sensing mode. The threshold is defined as the 8 MSBs of the ADC count. For example, if PROX_INT_THRESH[7:0] = 0x01, then an ADC value of 1023 (decimal) or higher triggers the PROX interrupt. If PROX_INT_THRESH[7:0] = 0xFF, then only a saturated ADC triggers the interrupt.

Applications Information

Sampling Rate and Performance

The maximum sample rate for the ADC depends on the selected pulse width, which in turn, determines the ADC resolution. For instance, if the pulse width is set to 69μs then the ADC resolution is 15 bits, and all sample rates are selectable. However, if the pulse width is set to 411μs, then the samples rates are limited. The allowed sample rates for both particle-sensing modes are summarized in Table 11 and Table 12.

Power Considerations

The LED waveforms and their implication for power supply design are discussed in this section.

The LEDs in the MAX30105 are pulsed with a low duty cycle for power savings, and the pulsed currents can cause ripples in the V_{LED+} power supply. To ensure these pulses do not translate into optical noise at the LED outputs, the power supply must be designed to handle these. Ensure that the resistance and inductance from the power supply (battery, DC/DC converter, or LDO) to the pin is much smaller than 1Ω, and that there is at least 1μF of power supply bypass capacitance to a good ground plane. The capacitance should be located as close as physically possible to the IC.

Table 11. Particle-Sensing Mode Using 2 LEDs (Allowed Settings)

SAMPLES PER SECOND	PULSE WIDTH (μs)			
	69	118	215	411
50	O	O	O	O
100	O	O	O	O
200	O	O	O	O
400	O	O	O	O
800	O	O	O	
1000	O	O		
1600	O			
3200				
Resolution (bits)	15	16	17	18

Table 12. Particle-Sensing Mode Using 1 LEDs (Allowed Settings)

SAMPLES PER SECOND	PULSE WIDTH (μs)			
	69	118	215	411
50	O	O	O	O
100	O	O	O	O
200	O	O	O	O
400	O	O	O	O
800	O	O	O	O
1000	O	O	O	O
1600	O	O	O	
3200	O			
Resolution (bits)	15	16	17	18

Particle-Sensing Temperature Compensation

The MAX30105 has an accurate on-board temperature sensor that digitizes the IC's internal temperature upon command from the I2C master.

Table 13 shows the correlation of red LED wavelength versus the temperature of the LED. Since the LED die heats up with a very short thermal time constant (tens of microseconds), the LED wavelength should be calculated according to the current level of the LED and the temperature of the IC. Use Table 13 to estimate the temperature.

Red LED Current Settings vs. LED Temperature Rise

Add estimated temperature rise to the module temperature reading to estimate the LED temperature and output wavelength. The LED temperature estimate is valid even with very short pulse widths, due to the fast thermal time constant of the LED.

Interrupt Pin Functionality

The active-low interrupt pin pulls low when an interrupt is triggered. The pin is open-drain, which means it normally requires a pullup resistor or current source to an external voltage supply (up to +5V from GND). The interrupt pin is not designed to sink large currents, so the pullup resistor value should be large, such as 4.7kΩ.

Table 13. RED LED Current Settings vs. LED Temperature Rise

RED LED CURRENT SETTING	RED LED DUTY CYCLE (% OF LED PULSE WIDTH TO SAMPLE TIME)	ESTIMATED TEMPERATURE RISE (ADD TO TEMP SENSOR MEASUREMENT) (°C)
0001 (0.2mA)	8	0.1
1111 (50mA)	8	2
0001 (0.2mA)	16	0.3
1111 (50mA)	16	4
0001 (0.2mA)	32	0.6
1111 (50mA)	32	8