

# AS7221

## Calibrated XYZ Chromatic Manager for Network Enabled Smart Lighting

### General Description

The AS7221 Smart Lighting Manager device is part of the ams Cognitive Lighting™ family of products that enable lights to be “aware” and adapt to their surroundings, autonomously adapting to human lighting and energy conservation needs. The device is equipped with an advanced Cognitive Lighting Engine (CLE) to optimize, chromatic white/color tuning, daylight harvesting and lumen maintenance via a combination of PWM and/or 0-10V controls with dimming ballasts. Direct connection to a local sensor network (LSN), enables connectivity with standard occupancy sensors, dimmers or communications bridges.

AS7221 XYZ chromatic white/color sensing provides mapping to x, y (z) of the CIE 1931 2-dimensional color gamut coordinates and scales the coordinates to the CIE 1976 u'v' coordinate system. The AS7221 integrates standard observer filters into standard silicon via nano-optic deposited interference filters which deliver high-stability over time and temperature. The LGA package includes a built in aperture to control light entering the sensor array. Integrated intelligence enables lifetime CCT calibration to within 2-4 Macadam steps.

The AS7221 connects to standard 0-10V dimmers inputs and drives 0-10V dimming ballasts/drivers to enable a highly cost-effective white tunable current-steering luminaire design with a single-channel constant current ballast. Direct PWM inputs can also interface to standard LED drivers or multi-channel ballasts for constant voltage LED lighting architectures.

A UART interface is provided for configuration, control and management of the CLE. This UART interface responds to simple Smart Lighting Set commands.

*Ordering Information and Content Guide appear at end of datasheet.*

## Key Benefits & Features

The benefits and features of this device are listed below:

**Figure 1:**  
Added Value of Using AS7221

Benefits	Features
<ul style="list-style-type: none"> <li>Accurate control of variable CCT and spectrally tunable lighting</li> </ul>	<ul style="list-style-type: none"> <li>Calibrated XYZ tri-stimulus color sensing for direct translation to CIE 1931/1976 standard observer color maps</li> </ul>
<ul style="list-style-type: none"> <li>Automatic spectral and lumen maintenance over temperature and time</li> </ul>	<ul style="list-style-type: none"> <li>Autonomous color point and lumen output adjustment resulting in automatic spectral and lumen maintenance</li> </ul>
<ul style="list-style-type: none"> <li>Direct serial interface for connection to standard networks</li> </ul>	<ul style="list-style-type: none"> <li>Simple UART interface for connection to network hardware clients for protocols such as Bluetooth, ZigBee and WiFi</li> </ul>
<ul style="list-style-type: none"> <li>Simple lamp or luminaire configuration and commissioning using defined command set</li> </ul>	<ul style="list-style-type: none"> <li>Smart Lighting Command Set (SLCS) uses simple text-based commands to control and configure a wide variety of functions</li> </ul>
<ul style="list-style-type: none"> <li>Compatible with standard dimmer controls and occupancy sensors</li> </ul>	<ul style="list-style-type: none"> <li>Directly interfaces to 0-10V dimmer controls and standard occupancy sensors</li> </ul>
<ul style="list-style-type: none"> <li>Directly interfaces to LED driver via PWM</li> </ul>	<ul style="list-style-type: none"> <li>Built-in PWM generator to dim LED lamps and luminaires</li> <li>12-bit resolution for precise dimming down to 1%</li> </ul>
<ul style="list-style-type: none"> <li>Directly interfaces to ballast via 0-10V</li> </ul>	<ul style="list-style-type: none"> <li>0-10V analog output for control of conventional dimming ballasts in a current steering design</li> </ul>
<ul style="list-style-type: none"> <li>Small package, wide operating range with critical optics built-in</li> </ul>	<ul style="list-style-type: none"> <li>20-pin LGA package 4.5mm x 4.7mm x 2.5mm with integrated aperture</li> <li>-40°C to 85°C</li> </ul>

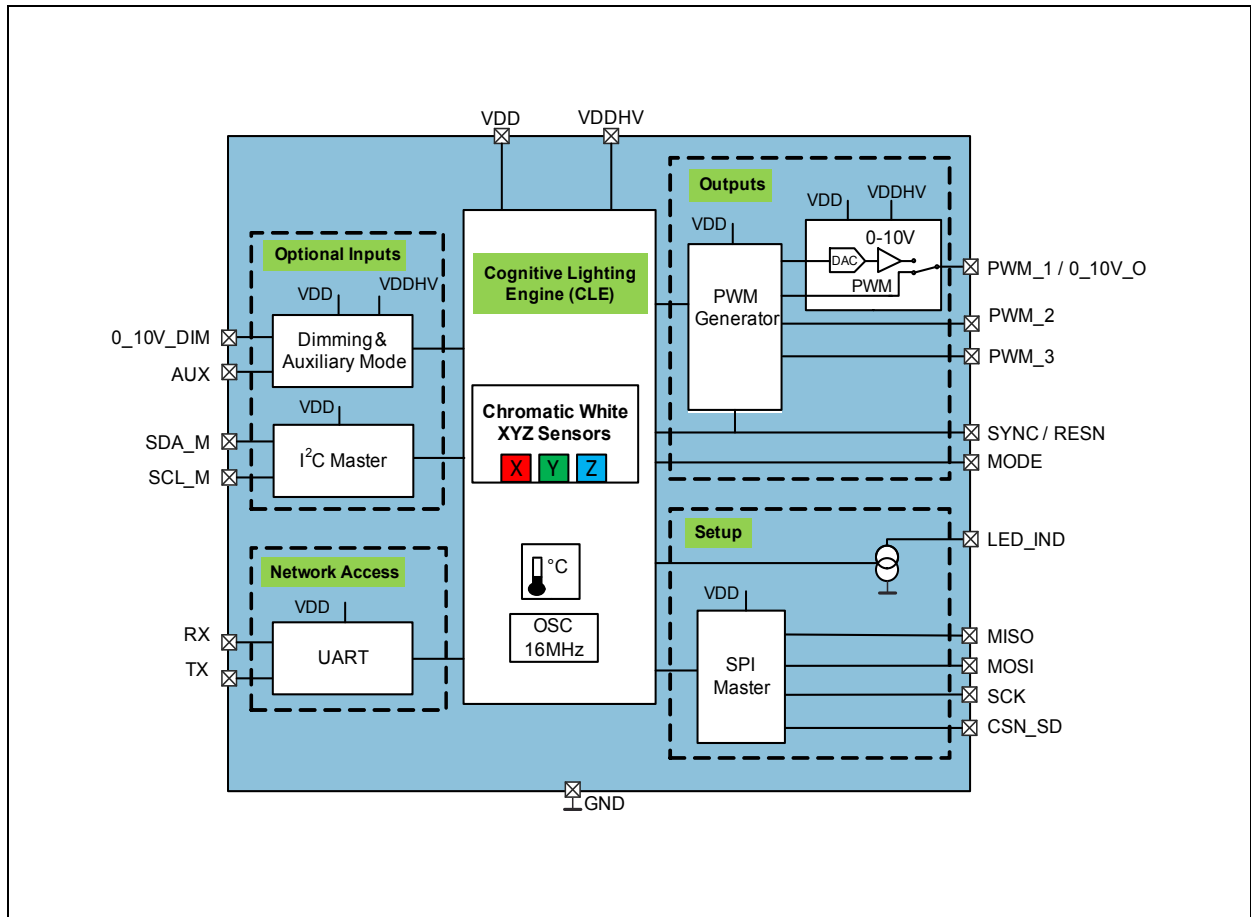
## Applications

Autonomous, networked solid-state lighting manager for variable CCT and daylight harvesting:

- Integrated smart lighting control of variable CCT white lighting solutions
- Luminaires intended to meet California Title 24 daylighting requirements
- Commercial, retail, and residential white/color changing LED lighting systems
- Networked lighting systems with IoT sensor expandability

## Block Diagram

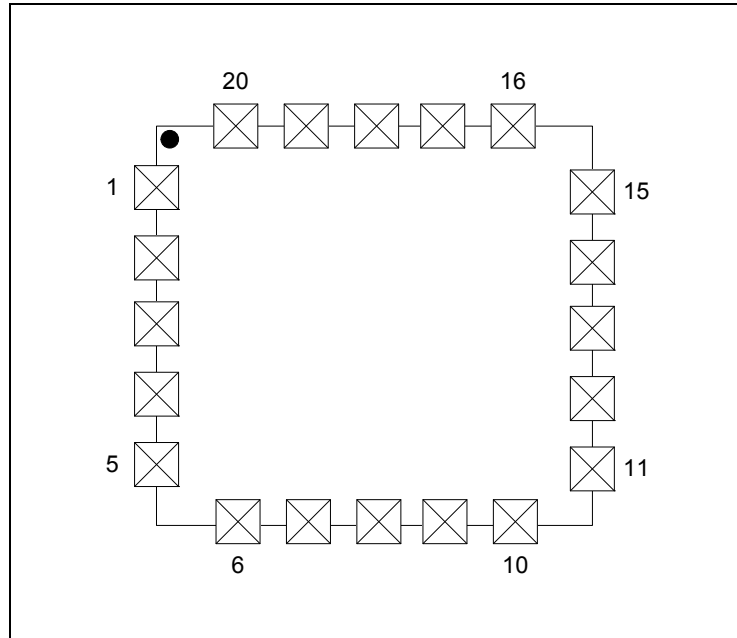
**Figure 2:**  
**Functional Blocks of AS7221**



**Functional Blocks of AS7221:** The AS7221 provides closed loop chromatic white sensing and PWM tuning while interfacing to local and network controls.

## Pin Assignments

**Figure 3:**  
Pin Diagram of AS7221 (Top View)



**Figure 4:**  
Pin Description of AS7221 (20 Pin LGA)

Pin Number	Pin Name	Description
1	PWM_3	Digital PWM 3
2	SYNC	SYNC input
	RESN	Reset pin, active low
3	SCK	SPI serial clock
4	MOSI	SPI MOSI
5	MISO	SPI MISO
6	CSN_EE	Chip select for the required external serial flash memory, active low
7	CSN_SD	Chip select for SD Card interface, active low
8	AUX	Auxiliary mode input pin
9	SCL_M	I <sup>2</sup> C master clock pin
10	SDA_M	I <sup>2</sup> C master data pin
11	RX	UART RX pin
12	TX	UART TX pin

Pin Number	Pin Name	Description
13	0_10V_DIM	0-10V input dimming pin
14	VDDHV	High Voltage Supply
15	MODE	Mode selection pin
16	GND	Ground
17	VDD	Low Voltage Supply
18	LED_IND	LED Driver output for Indicator LED, current sink
19	PWM_1	Digital PWM 1
	0_10V_O	0-10V output pin
20	PWM_2	Digital PWM 2

## Absolute Maximum Ratings

Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under [Electrical Characteristics](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. The device is not designed for high energy UV (ultraviolet) environments, including upward looking outdoor applications, which could affect long term optical performance.

**Figure 5:**  
Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Units	Comments
<b>Electrical Parameters</b>					
$V_{DD\_MAX}$	Supply Voltage VDD	-0.3	5	V	Pin VDD to GND, Low Voltage pin
$V_{DDHV\_MAX}$	Supply Voltage VDDHV	-0.3	20	V	Pin VDDHV to GND, High Voltage pin
$V_{DD\_IO}$	Input/Output Pin Voltage	-0.3	VDD + 0.3	V	Low Voltage pins to GND
$V_{DDHV\_IO}$	Input/Output Pin Voltage	-0.3	VDDHV + 0.3	V	High Voltage pins to GND
$I_{SCR}$	Input Current (latch-up immunity)	$\pm 100$		mA	JESD78D
<b>Electrostatic Discharge</b>					
$ESD_{HBM}$	Electrostatic Discharge HBM	$\pm 1000$		V	JS-001-2014
$ESD_{CDM}$	Electrostatic Discharge CDM	$\pm 500$		V	JSD22-C101F
<b>Temperature Ranges and Storage Conditions</b>					
$T_{strg}$	Storage Temperature	-40	85	°C	
$T_{body}$	Package Body Temperature		260	°C	IPC/JEDEC J-STD-020. The reflow peak soldering temperature (body temperature) is specified according IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non hermetic Solid State Surface Mount Devices"
$RH_{NC}$	Relative Humidity (non-condensing)	5	85	%	
MSL	Moisture Sensitivity Level	3			Represents a 168 hour max. floor lifetime

## Electrical Characteristics

All limits are guaranteed with  $V_{DD} = 3.3V$ ,  $V_{DDHV} = 12V$ ,  $T_{AMB} = 25^{\circ}C$ . The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods. If  $V_{DD}$  and  $V_{DDHV}$  are to be the same voltage, they must be sourced by the same 2.97-3.6V supply.

**Figure 6:**  
Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>General Operating Conditions</b>						
VDD	Low Voltage Operating Supply		2.97	3.3	3.6	V
VDDHV	High Voltage Operating Supply		VDD	12	15	V
$T_{AMB}$	Operating Temperature		-40	25	85	$^{\circ}C$
$I_{VDD}$	Operating Current				5	mA
<b>Internal RC Oscillator</b>						
$F_{OSC}$	Internal RC Oscillator Frequency		15.7	16	16.3	MHz
$t_{JITTER}^{(1)}$	Jitter	@25 $^{\circ}C$			1.2	ns
<b>0-10V Output (0_10V_O pin)</b>						
$R_{OUT\_10}$	Resistive Load		1			k $\Omega$
$I_{S\_10}$	Source Current		10			mA
$I_{SINK\_10}$	Sink Current		-10			mA
$I_{LEAK\_HV}$	HV Output Leakage Current	$V_{IN}=12V$ , DAC & PWM1 both disabled	0.73		1.6	mA
$C_{LOAD\_10}$	Capacitive Load				100	pF
$V_{OUT\_10}^{(2)}$	Output Swing		0		10	V
<b>0-10V Input</b>						
$R_{IN\_HV}$	Analog Input Resistance	$V_{DDHV} \geq 12V$	138	200	315	k $\Omega$
<b>Temperature Sensor</b>						
$D_{TEMP}$	Absolute Accuracy of the Temperature Measurement		-8.5		8.5	$^{\circ}C$

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Indicator LED</b>						
$I_{IND}$	LED Current	1, 2, 4 or 8	1		8	mA
$I_{ACC}$	Accuracy of Current		-30		30	%
$V_{LED}$	Voltage Range of Connected LED	Vds of current sink	0.3		VDD	V
<b>Digital Inputs and Outputs</b>						
$I_{IH}, I_{IL}$	Logic Input Current	$V_{in}=0V$ or VDD	-1		1	$\mu A$
$I_{IL}$ SYNC/RESN	Logic Input Current (SYNC/RESN pin)	$V_{in}=0V$	-1		-0.2	mA
$V_{IH}$	CMOS Logic High Input		$0.7 * VDD$		VDD	V
$V_{IL}$	CMOS Logic Low Input		0		$0.3 * VDD$	V
$V_{OH}$	CMOS Logic High Output	$I=1mA$			$VDD-0.4$	V
$V_{OL}$	CMOS Logic Low Output	$I=1mA$			0.4	V
$t_{RISE}^{(1)}$	Current Rise Time	$C(Pad)=30pF$			5	ns
$t_{FALL}^{(1)}$	Current Fall Time	$C(Pad)=30pF$			5	ns

**Note(s):**

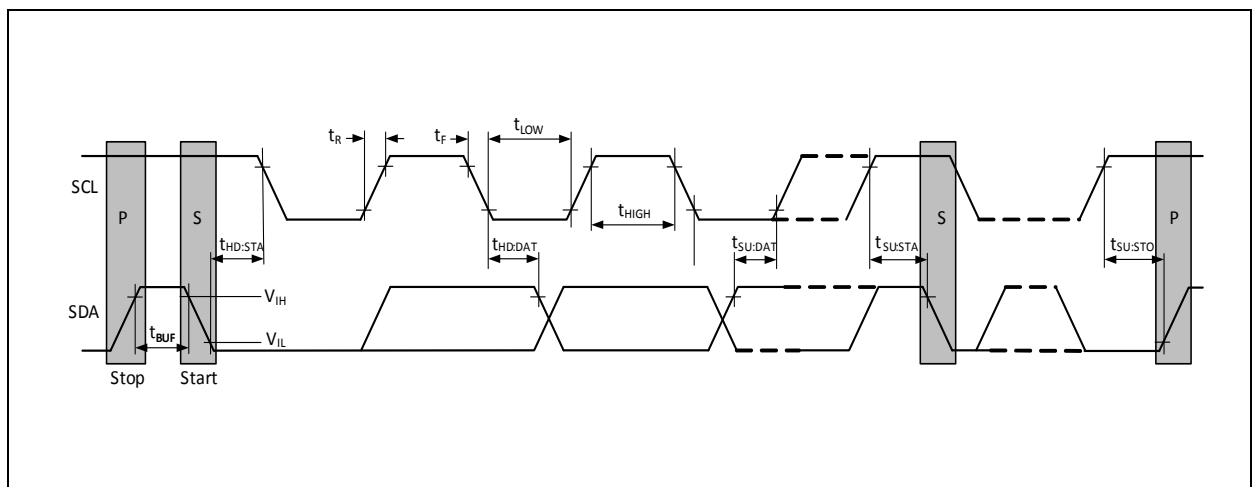
1. Guaranteed, not production tested
2. For  $VDDHV > 10.5$ , output max is 10V, else output max tracks VDDHV



**Figure 7:**  
AS7221 I<sup>2</sup>C Master Timing Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>I<sup>2</sup>C Interface</b>						
$f_{SCLK}$	SCL Clock Frequency			100	400	kHz
$t_{BUF}$	Bus Free Time Between a STOP and START		1.3			$\mu$ s
$t_{HD:STA}$	Hold Time (Repeated) START		0.6			$\mu$ s
$t_{LOW}$	LOW Period of SCL Clock		1.3			$\mu$ s
$t_{HIGH}$	HIGH Period of SCL Clock		0.6			$\mu$ s
$t_{SU:STA}$	Setup Time for a Repeated START		0.6			$\mu$ s
$t_{HD:DAT}$	Data Hold Time		0		0.9	$\mu$ s
$t_{SU:DAT}$	Data Setup Time		100			ns
$t_R$	Rise Time of Both SDA and SCL		20		300	ns
$t_F$	Fall Time of Both SDA and SCL		20		300	ns
$t_{SU:STO}$	Setup Time for STOP Condition		0.6			$\mu$ s
$C_B$	Capacitive Load for Each Bus Line	CB — total capacitance of one bus line in pF			400	pF
$C_{I/O}$	I/O Capacitance (SDA, SCL)				10	pF

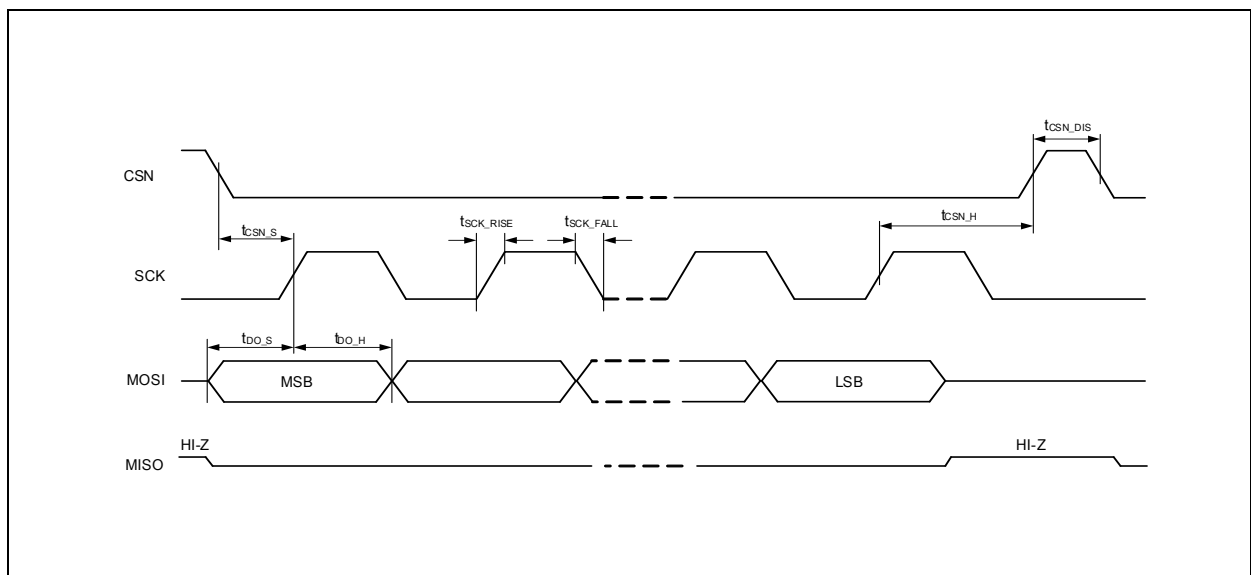
**Figure 8:**  
I<sup>2</sup>C Master Timing Diagram



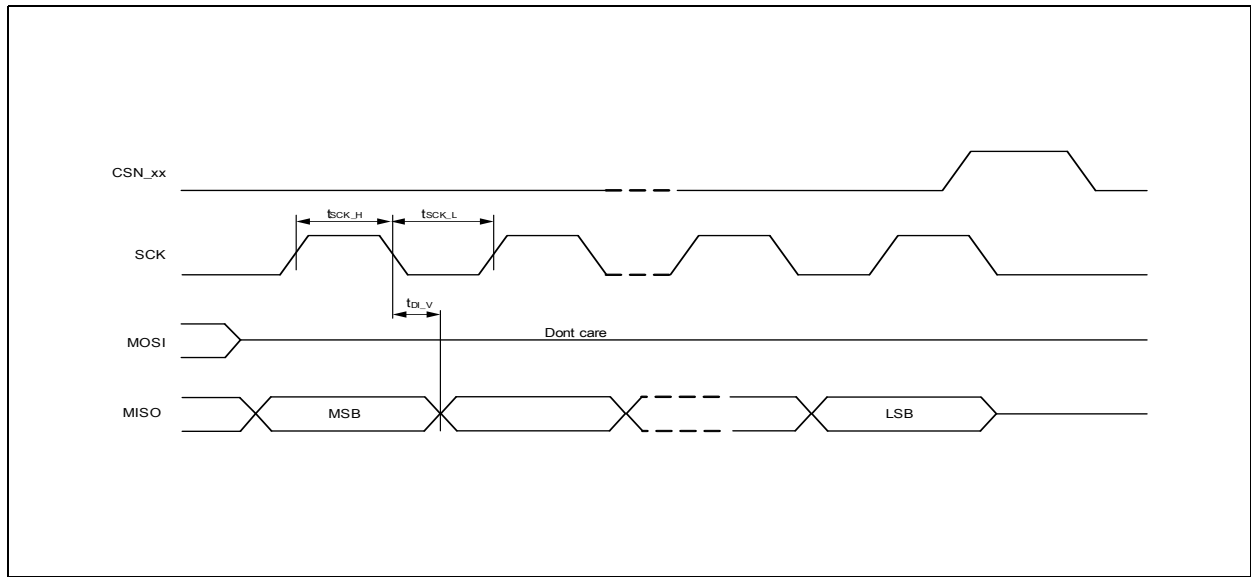
**Figure 9:**  
AS7221 SPI Timing Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>SPI Interface</b>						
$f_{SCK}$	Clock Frequency		0		16	MHz
$t_{SCK\_H}$	Clock High Time		40			ns
$t_{SCK\_L}$	Clock Low Time		40			ns
$t_{SCK\_RISE}$	SCK Rise Time		5			ns
$t_{SCK\_FALL}$	SCK Fall Time		5			ns
$t_{CSN\_S}$	CSN Setup Time	Time between CSN high-low transition to first SCK high transition	50			ns
$t_{CSN\_H}$	CSN Hold Time	Time between last SCK falling edge and CSN low-high transition	100			ns
$t_{CSN\_DIS}$	CSN Disable Time		100			ns
$t_{DO\_S}$	Data-Out Setup Time		5			ns
$t_{DO\_H}$	Data-Out Hold Time		5			ns
$t_{DI\_V}$	Data-In Valid		10			ns

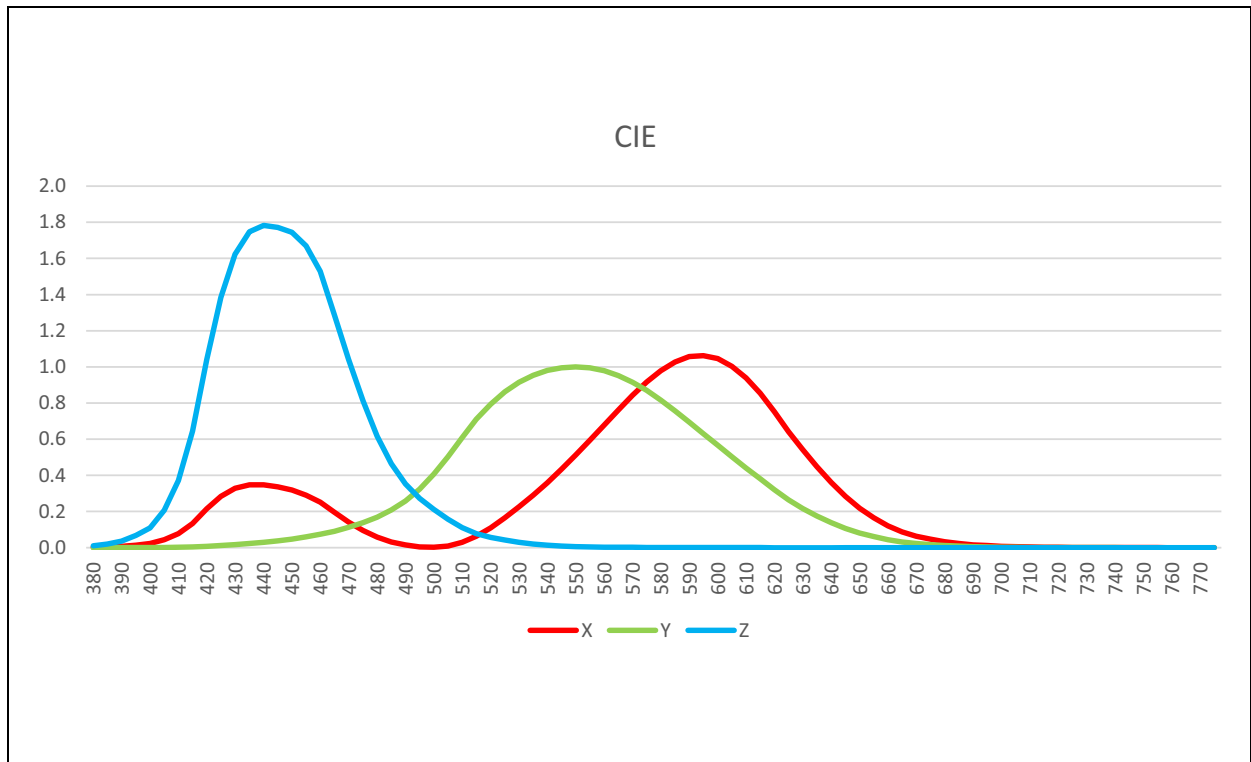
**Figure 10:**  
SPI Master Write Timing Diagram



**Figure 11:**  
**SPI Master Read Timing Diagram**



**Figure 12:**  
**Typical Spectral Responsivity**



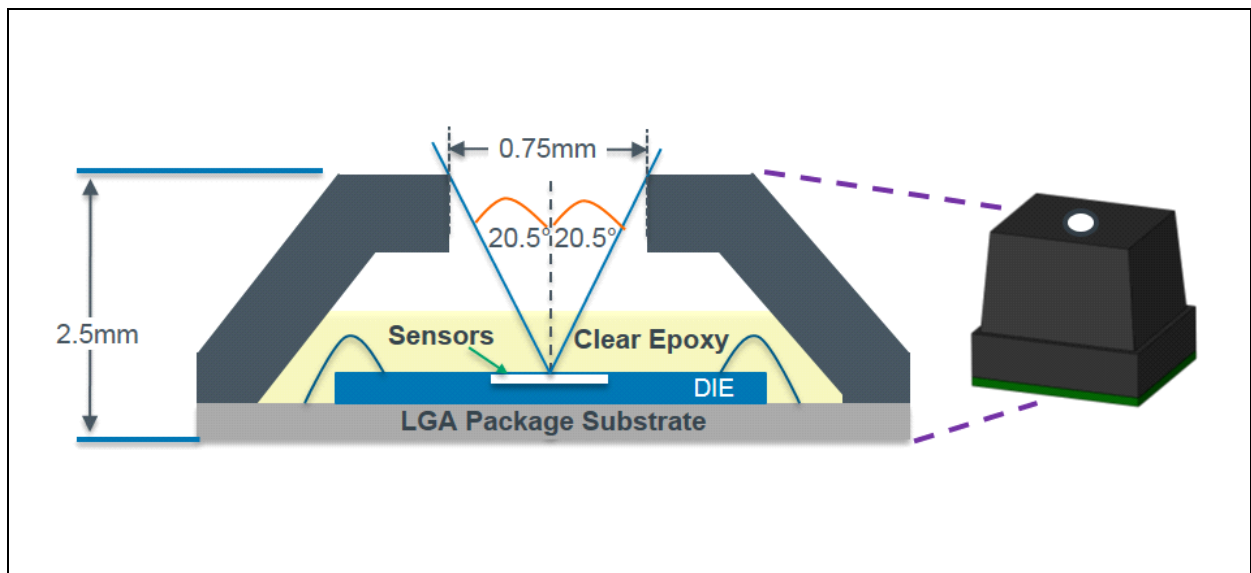
**Figure 13:**  
AS7221 Optical Characteristics

Symbol	Parameter	Conditions	Min	Typ <sup>(1)</sup>	Max	Unit
Color_m <sup>(2)</sup>	Color Measurement Accuracy	White Light CCT=2700K, 3500K, 4500K and 5700K		0.002		du'v'
Z_count	Z Channel Count Accuracy	White light CCT = 5700K	3.375	4.5	5.625	counts/ ( $\mu\text{W}/\text{cm}^2$ )

**Note(s):**

1. Typical values at Lux  $\geq 50$ , Integration time=400.4ms, Gain=1x,  $T_{\text{AMB}} = 25^\circ\text{C}$ .
2. Calibration and measurements are made using diffused light.

**Figure 14:**  
AS7221 LGA Package Field of View



## Detailed Description

### AS7221 Smart Lighting Manager - Overview

The Cognitive Light Engine (CLE) is the “brains” of the Smart Lighting Manager. The CLE constantly processes information from the calibrated XYZ chromatic white/color sensor, network access and inputs while controlling outputs. AS7221 initial setup and ongoing parameter storage is automatically done by software within the required external serial flash memory, via SPI bus.

A luminaire solution for chromatic white/color maintenance with lumen maintenance requires only the AS7221. A luminaire solution with chromatic white color/maintenance, lumen maintenance and daylighting requires just the addition of an **ams** TSL4531 single chip ambient light sensor, connected via I<sup>2</sup>C. Refer to the table in the Figure below.

Overall AS7221 timing generation uses an on chip 16MHz temperature compensated oscillator for master clock timing.

Refer to the separate AS7221 User Guide as well as the **ams** Smart Lighting Command Set document for additional usage and setup information.

**Figure 15:**  
AS7221 Solution Chart

Solution Required			Device Orientation (from luminaire light source)	
Chromatic Color Maintenance	Lumen Maintenance	Daylighting	AS7221	TSL4531 (optional)
✓	✓	✗	↑ (into luminaire)	✗ (not required)
✓	✓	✓	↑ (into luminaire)	↓ (into room)

### XYZ Chromatic White Color Sensor

The XYZ chromatic white/color sensor, part of the AS7221 Cognitive Light Engine (CLE), is a next-generation digital color sensor device. The sensor contains an integrating analog-to-digital converter (16-bit resolution ADC), which integrates current from photodiodes. Upon completion of the conversion cycle, the result is transferred to the corresponding data registers. Transfers are double-buffered to ensure integrity of the data is maintained.

Standard observer interference filters realize the XYZ response, which enables both a no life-time drift and very high temperature stability. Note the AS7221 LGA package contains an internal aperture that provides a package field of view (PFOV) of  $\pm 20.5^\circ$ . External optics can be used as needed to expand or reduce this built in PFOV.

### AS7221 Inputs

**Figure 16:**  
VDDHV Based Settings for Inputs

VDDHV	Dimming
10.5-15V	Direct input for 0_10V_DIM, dimming input
2.97-10V <sup>(1)</sup>	External 5:1 resistor divider for 0-10V_DIM, dimming input <sup>(2)</sup>

**Note(s):**

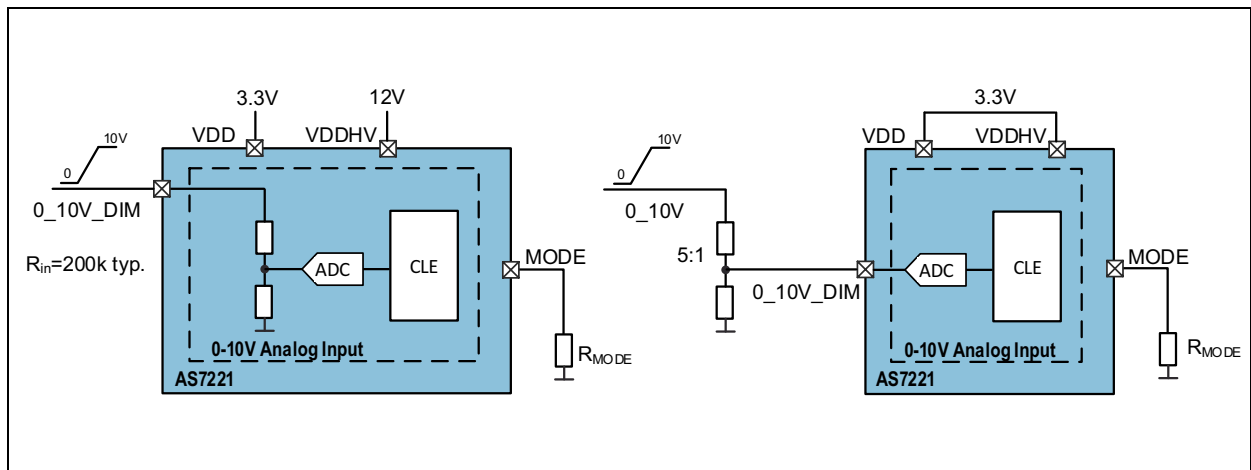
1. For VDDHV  $\leq$  3.6V, VDDHV and VDD should be tied together.
2. With external dividers connected to 0-10V inputs, the max voltage to the device input is 2V.

For the AS7221, dimming can be accomplished from either the input pin (0\_10V\_DIM) or network command via the UART. For network commanded dimming, using the AS7221 Smart Lighting Command set, the UART interface is used.

Local hardware inputs can be provided by, for example, a slide control dimmer. The 0-10V DIM analog input signal is downscaled by the AS7221 with an internal voltage divider and converted to a 10 bit digital value, 0V=full dimming, 10V=no dimming. When using the internal voltage divider the voltage at the VDDHV pin has to be higher than 10V.

If a second supply is not available, VDDHV and VDD are tied together and the downscale has to be done by an external resistor divider. The maximum range in the downscaled input is limited to 2V. Hence to accept a full range 10V signal the input resistor divider has to be 5:1 ratio. Dependent on the level at pin VDDHV the Smart Lighting Manager automatically selects either the internal or the external voltage divider. Refer to the Figures above and below. If the 0\_10V\_DIM pin is not used, an external resistor pull-up connecting it to VDDHV is recommended.

**Figure 17:**  
0-10V Dimming Pin Input

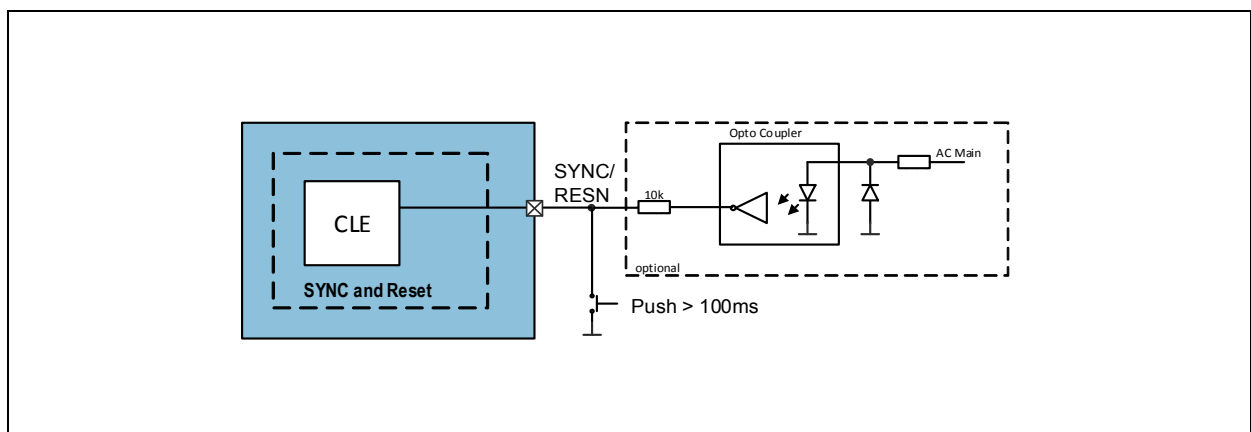


The auxiliary sensor input (AUX) can be configured for 0-10V analog sensing using a 5:1 resistor divider. Or, AUX can be configured for digital sensing. Both types are common for external occupancy sensors. If the AUX pin is not used, an external resistor pull-up connecting it to VDD is recommended.

External sensors with native support by the AS7221, include **ams** temperature/humidity sensing (ENS-210), and **ams** ambient light sensing (TSL4531) can be added via the I<sup>2</sup>C master interface. The TSL4531 is used to add daylighting to the AS7221.

**Synchronization and Reset**

**Figure 18:**  
Synchronization and Reset Circuit



**Synchronization and Reset Circuit:** This figure shows the basic diagram when using reset and synchronization function together.

AS7221 provides optional synchronization of the PWMs. This sync signal can be derived from the AC mains to enable all luminaires in a room to be synchronized to prevent beat frequency flicker. If the SYNC pin is left open, synchronization is automatically disabled.

Refer to the Figure above. When pulled down for more than 100ms the SYNC/RESN pin will reset the AS7221 Smart Lighting Manager. In this case the push-button “overrides” the output of the opto-coupler. Therefore a resistor should be placed in series with the opto-coupler.

### AS7221 Outputs

The AS7221 outputs, used to control dimming and LED warm/cool strings, can be configured as either three PWM outputs, two PWMs and one analog output, or two PWMs. The PWMs are 12 bit and factory set to 888 Hz. Refer to the Figure below.

The three PWM outputs, PWM\_1, PWM\_2 and PWM\_3 all switch with the same frequency, but are not simultaneous for better EMI performance.

The PWM\_1 output can be set to either analog (0-VDDHV) or digital (0-VDDHV) dimming. Analog dimming range is 10-100%. Digital Dimming range is 1-100%. PWM2 and PWM3 are used for cool white and warm white LED color controlling. Either string can be warm or cool as the AS7221 automatically configures string color type. Range is 0-100% for both PWM2 and PWM3.

To set the desired device operation MODE use the appropriate  $R_{MODE}$  resistor, also shown in the Figure below.

**Figure 19:**  
Outputs

MODE	$R_{MODE}$	Setting	Outputs	
			PWM_1/0_10V_O	PWM_2 and PWM_3
0	100 $\Omega$	0-10V analog	Analog 0-VDDHV <sup>(1)</sup>	Digital PWMs (0-VDD)
1	470 $\Omega$	0-10V digital	Digital PWM (0-VDDHV) <sup>(1)</sup>	Digital PWMs (0-VDD)
2	1000 $\Omega$	Digital 2-CH color tuning	n.a.	Digital PWMs (0-VDD), w/Dimming

**Note(s):**

1. For VDDHV>10.5, output max is 10V, else output max tracks VDDHV.

### Indicator LED

An LED, connected to pin LED\_IND, is used to indicate programming progress of the device. During programming of the AS7221 via an external SD card the indicator LED starts. When programming is finished the indicator LED is off. The LED\_IND pin is set for 1mA operation by the AS7221 factory firmware, and is not under user control.

Refer to the separate **ams** document for a complete description of AS7221 Firmware Update Methodology.



## UART and Smart Lighting Command Interface

The UART block implements the TX and RX signals as defined in the RS-232 / V.24 standard communication protocol.

### UART Feature List

- Full Duplex Operation (Independent Serial Receive and Transmit Registers) with FIFO buffer of 8 bytes for each.
- Factory set to 115.2k Baud
- Supports Serial Frames with 8 Data Bits, no Parity and 1 Stop Bit.

### Operation

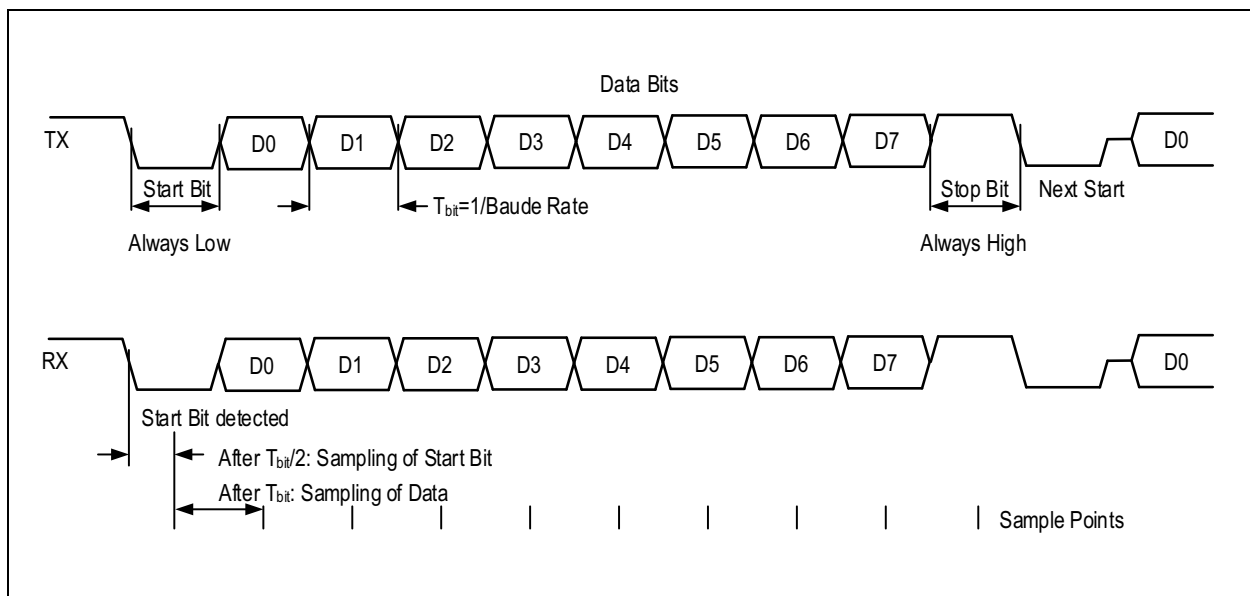
#### Transmission

If data is available in the transmit FIFO, it will be moved into the output shift register and the data will be transmitted at the configured Baud Rate, starting with a Start Bit (logic zero) and followed by a Stop Bit (logic one).

#### Reception

At any time, with the receiver being idle, if a falling edge of a start bit is detected on the input, a byte will be received and stored in the receive FIFO. The following Stop Bit will be checked to be logic one.

**Figure 20:**  
UART Protocol



### Smart Lighting Command Interface

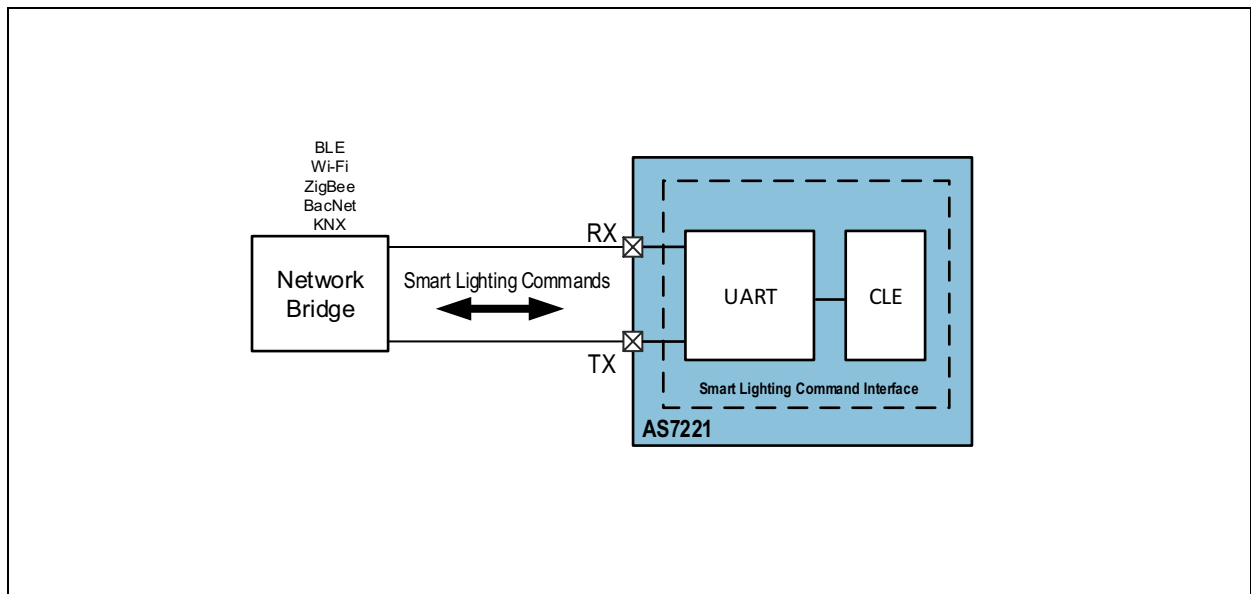
The network interface on the Smart Lighting Manager supporting the Smart Lighting Commands is the UART interface. The Smart Lighting Manager adapts the concept of a simple command set for lighting control and configuration. The Smart Lighting Manager uses a text-based serial command interface as popularized by the “AT Command” model used in early Hayes modems.

For example:

- Set the desired daylight LUX level target:  
ATLUXT = 500 >> OK

The “Smart Lighting Command Interface”, shown below between the network interface and the core of the system, provides access to the Smart Lighting Manager’s lighting control and configuration functions

**Figure 21:**  
Smart Lighting Command Interface



Refer to the separate **ams** AS7221 Smart Lighting Command Set document for the complete command set and usage.

### I<sup>2</sup>C Master Interface (Local Sensor Interface)

The I<sup>2</sup>C Master interface can be used to connect external sensors (such as daylight, occupancy, CO sensors, etc.). Refer to the separate **ams** Application Note for external sensor usage with the AS7221.

#### I<sup>2</sup>C Feature List

Clock is set to 100kHz

7+1-bit addressing mode.

**Write formats:** Single-Byte-Write, Page-Write

**Read formats:** Random-Read, Sequential-Read

SDA input delay and SCL spike filtering by integrated RC-components.

#### I<sup>2</sup>C Protocol

**Figure 22:**  
I<sup>2</sup>C Symbol Definition

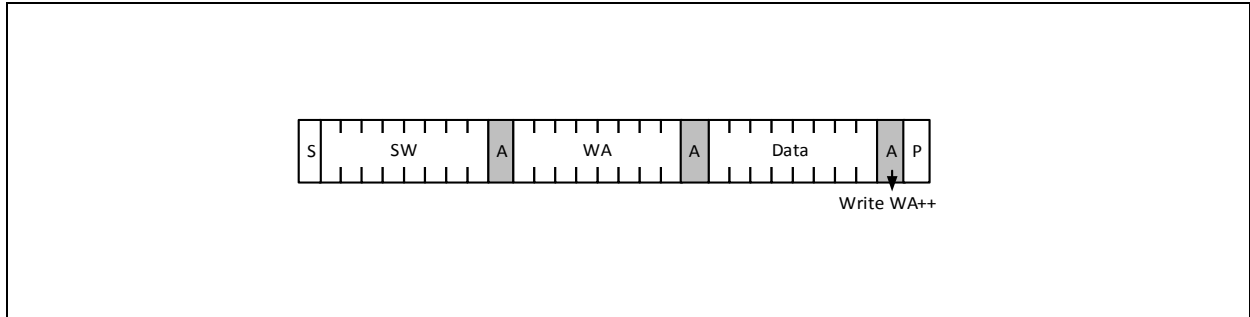
Symbol	Definition	RW	Note
S	Start condition after stop	R	1 bit
Sr	Repeated start	R	1 bit
SW	Slave address for write	R	Slave address
SR	Slave address for read	R	Slave address
WA	Word address	R	8 bit
A	Acknowledge	W	1 bit
N	No acknowledge	R	1 bit
Data	Data/write	R	8 bit
Data (n)	Data/read	W	8 bit
P	Stop condition	R	1 bit
WA++	Slave increment word address	R	During acknowledge

The above I<sup>2</sup>C symbol definition table describes the symbols used in the following mode descriptions.

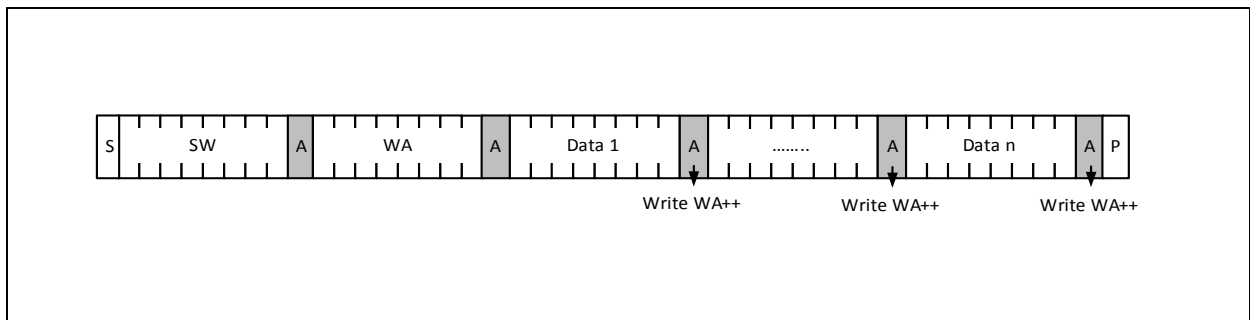
**I<sup>2</sup>C Write Access**

Byte Write and Page Write formats are used to write data to the slave.

**Figure 23:**  
I<sup>2</sup>C Byte Write



**Figure 24:**  
I<sup>2</sup>C Page Write



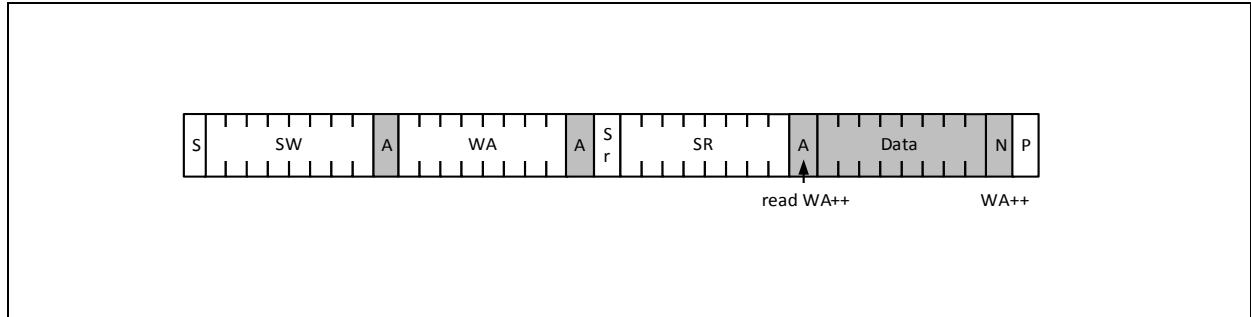
The transmission begins with the START condition, which is generated by the master when the bus is in IDLE state (the bus is free). The device-write address is followed by the word address. After the word address any number of data bytes can be sent to the slave. The word address is incremented internally, in order to write subsequent data bytes on subsequent address locations.

For reading data from the slave device, the master has to change the transfer direction. This can be done either with a repeated START condition followed by the device-read address, or simply with a new transmission START followed by the device-read address, when the bus is in IDLE state. The device-read address is always followed by the 1st register byte transmitted from the slave. In Read Mode any number of subsequent register bytes can be read from the slave. The word address is incremented internally.

**I<sup>2</sup>C Read Access**

Random, Sequential and Current Address Read are used to read data from the slave.

**Figure 25:  
I<sup>2</sup>C Random Read**

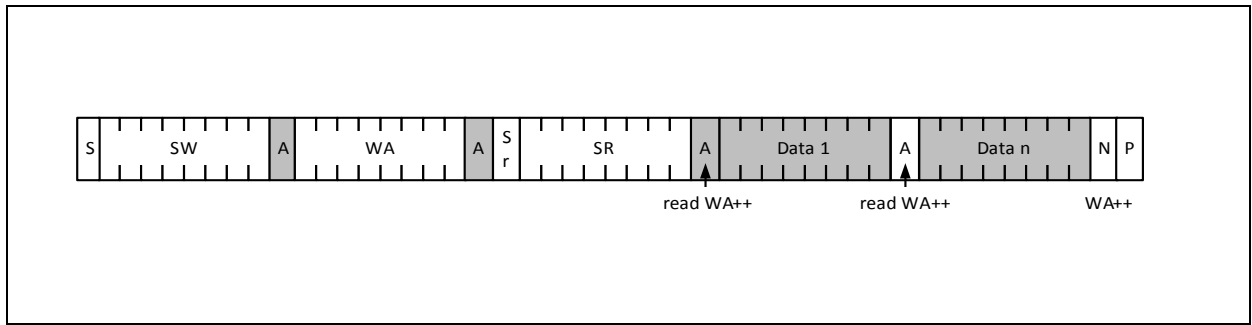


Random Read and Sequential Read are combined formats. The repeated START condition is used to change the direction after the data transfer from the master.

The word address transfer is initiated with a START condition issued by the master while the bus is idle. The START condition is followed by the device-write address and the word address.

In order to change the data direction a repeated START condition is issued on the 1st SCL pulse after the acknowledge bit of the word address transfer. After the reception of the device-read address, the slave becomes the transmitter. In this state the slave transmits register data located by the previous received word address vector. The master responds to the data byte with a not-acknowledge, and issues a STOP condition on the bus.

**Figure 26:**  
**I<sup>2</sup>C Sequential Read**



**I<sup>2</sup>C Sequential Read:** Shows the format of an I<sup>2</sup>C sequential read access.

Sequential Read is the extended form of Random Read, as more than one register-data bytes are transferred subsequently. In difference to the Random Read, for a sequential read the transferred register-data bytes are responded by an acknowledgement from the master. The number of data bytes transferred in one sequence is unlimited (consider the behavior of the word-address counter). To terminate the transmission the master has to send a not-acknowledge following the last data byte and generate the STOP condition subsequently.

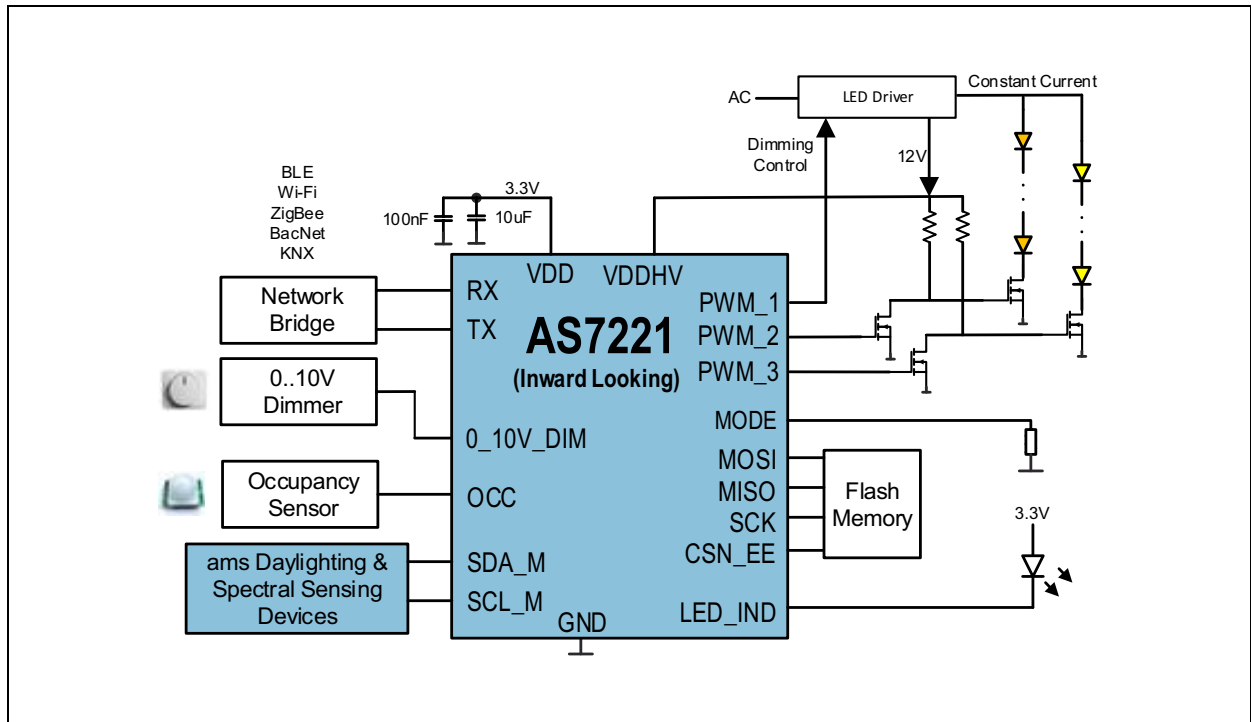
The AS7221 is compatible to the NXP two wire specifications. [www.nxp.com/documents/user\\_manual/UM10204.pdf](http://www.nxp.com/documents/user_manual/UM10204.pdf)

Version 4.0 Feb 2012 for standard mode and fast mode.

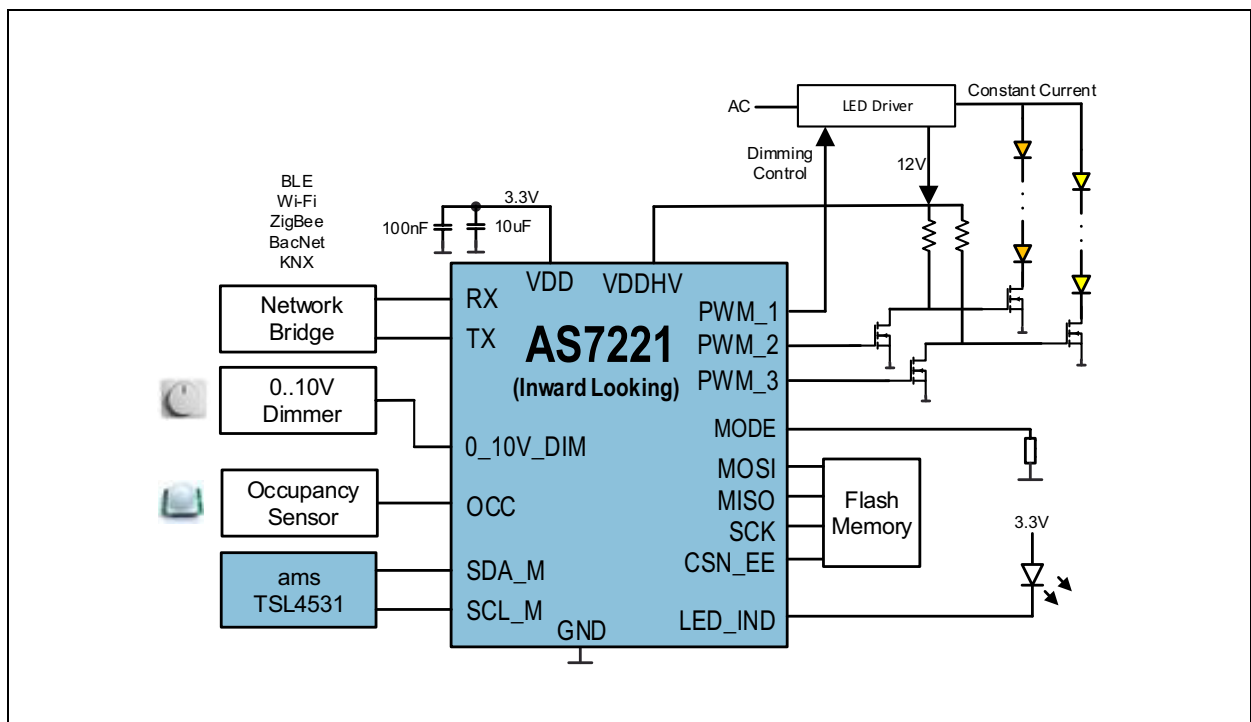
## Application Information

### Schematics

**Figure 27:**  
Chromatic Color Tuning with Networking and Spectral Sensing

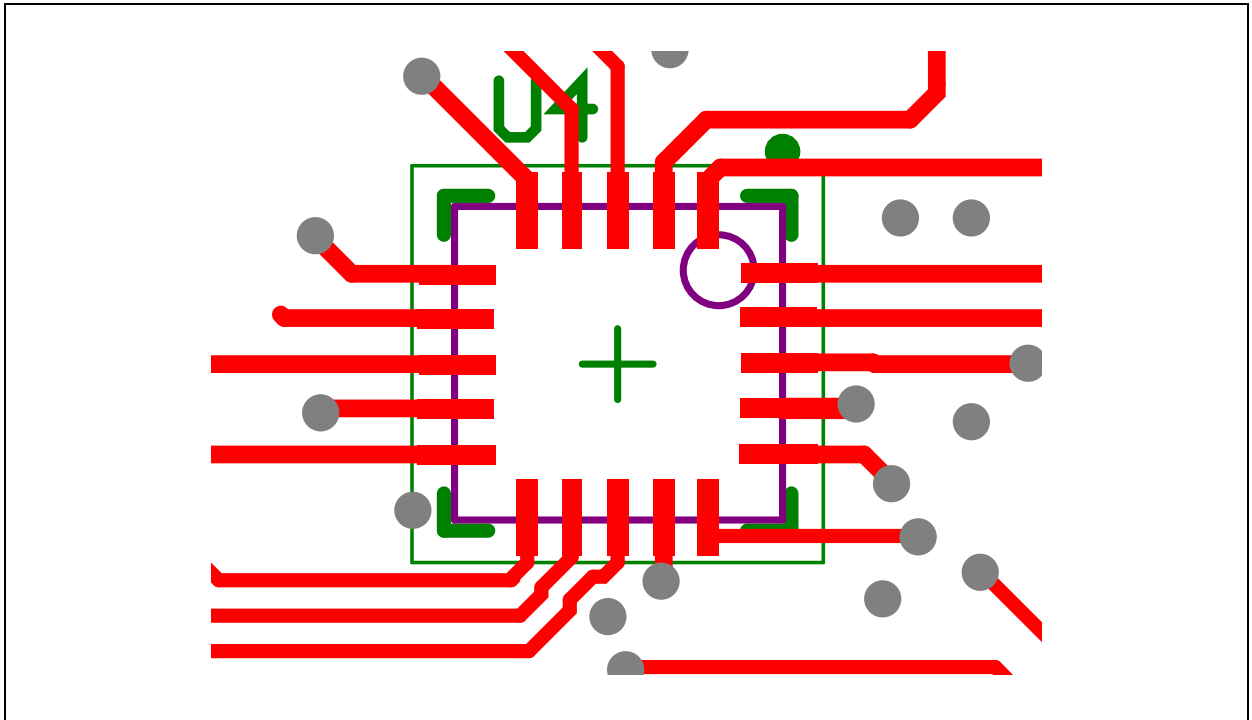


**Figure 28:**  
LED Chromatic Color Tuning with Daylighting



## PCB Layout

Figure 29:  
Typical Layout Routing



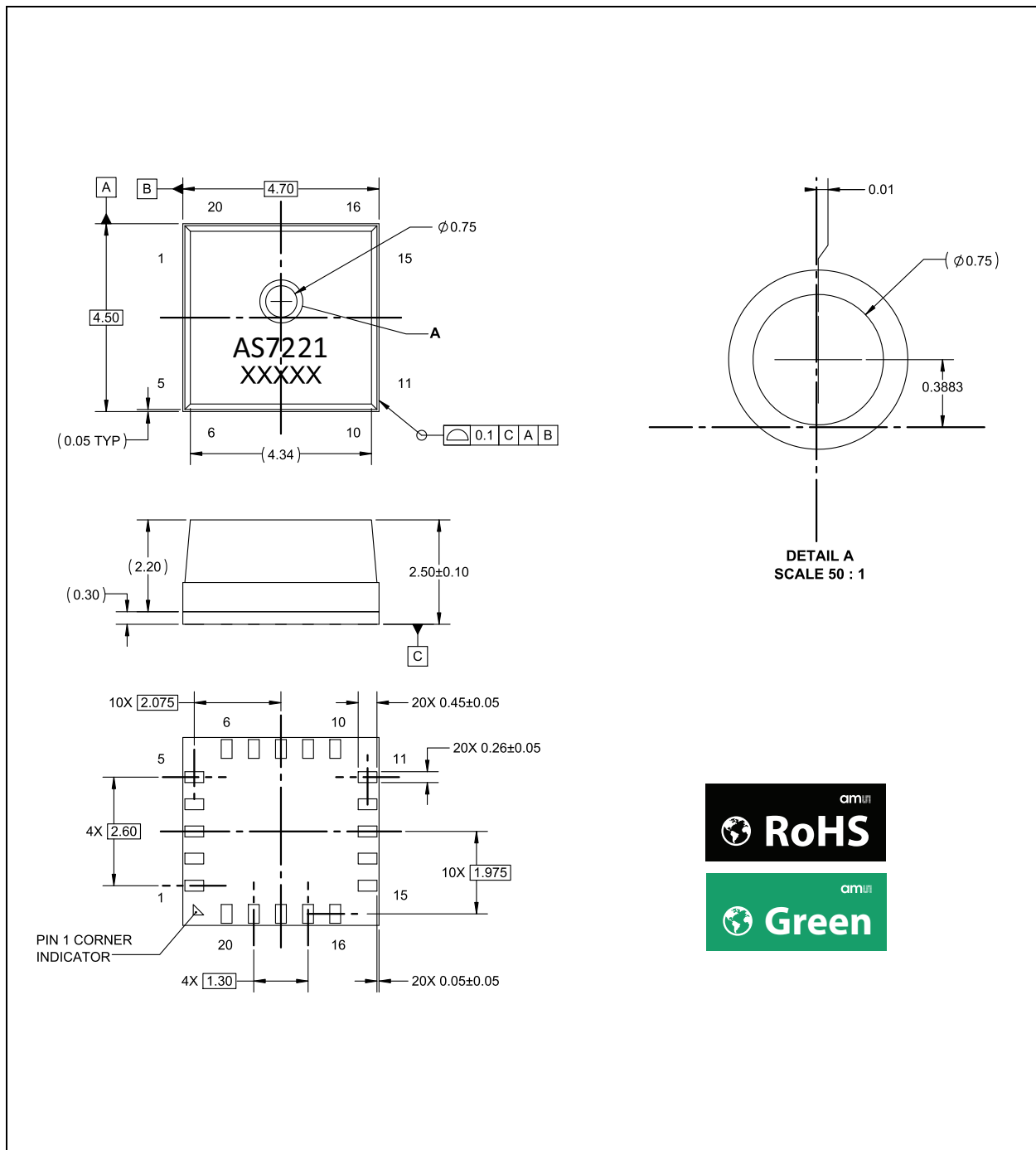
As shown, trace routing feedthroughs with exposure directly under the AS7221 should be avoided.

The AS7221 Smart Lighting Integration Kit (SLIK) demo board with schematic and PCB layout documentation is available from **ams** for additional design information.



## Package Drawings & Markings

Figure 30:  
Package Drawing



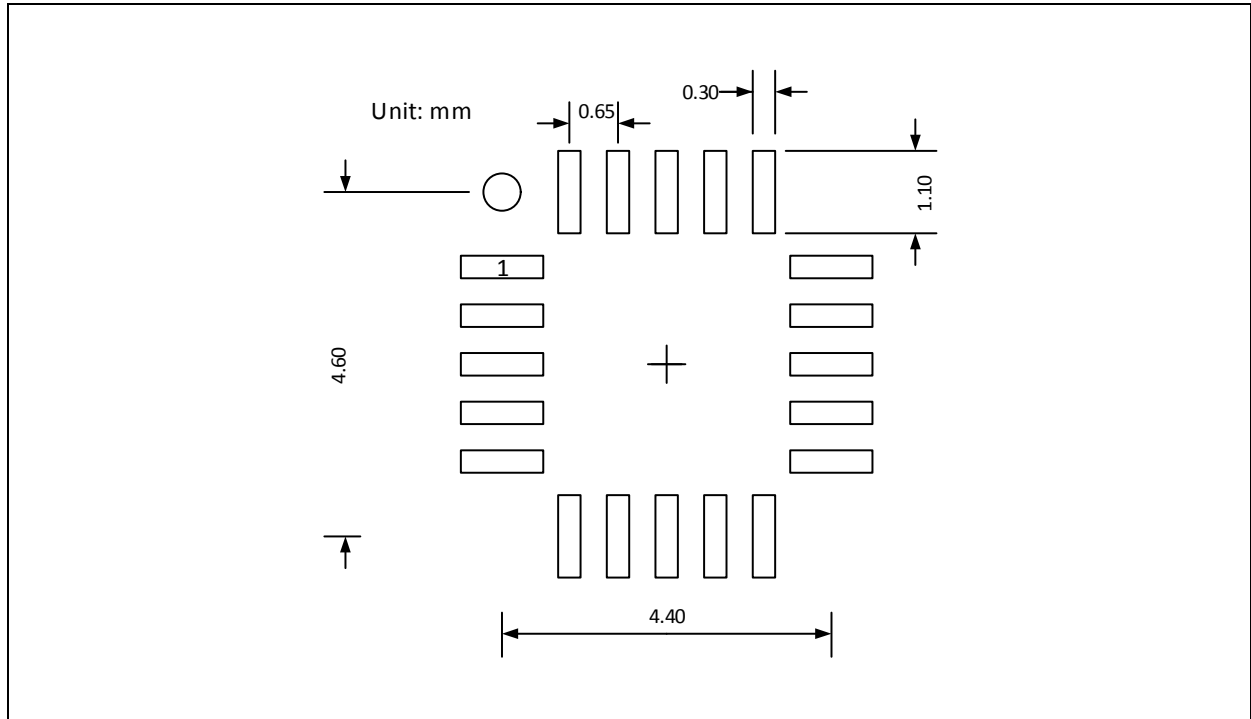
**Note(s):**

1. XXXXX = tracecode
2. Unless otherwise specified, all dimensions are in millimeters.
3. Tolerances: Angular ( $\pm 0.5^\circ$ ), Two Place Decimal ( $\pm 0.015$ ), Three Place Decimal ( $\pm 0.010$ )
4. Contact finish is Au.
5. This package contains no lead (Pb).
6. This drawing is subject to change without notice.

**PCB Pad Layout**

Suggested PCB pad layout guidelines for the LGA package are shown. Flash Gold is recommended as a surface finish for the landing pads.

**Figure 31:**  
Recommended PCB Pad Layout

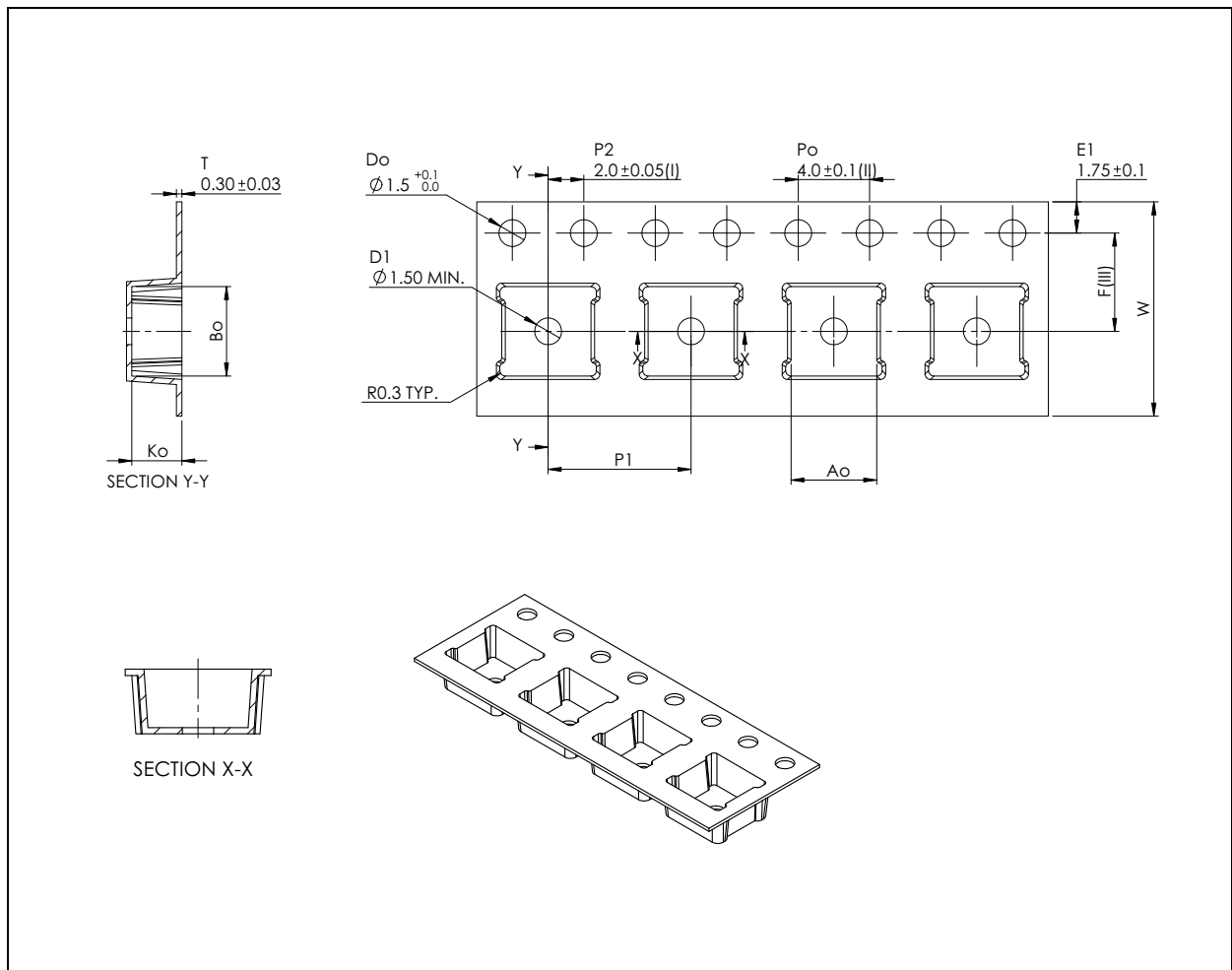


**Note(s):**

1. Unless otherwise specified, all dimensions are in millimeters.
2. Dimensional tolerances are  $\pm 0.05\text{mm}$  unless otherwise noted.
3. This drawing is subject to change without notice.

## Tape & Reel Information

Figure 32:  
Tape & Reel Information



## Soldering & Storage Information

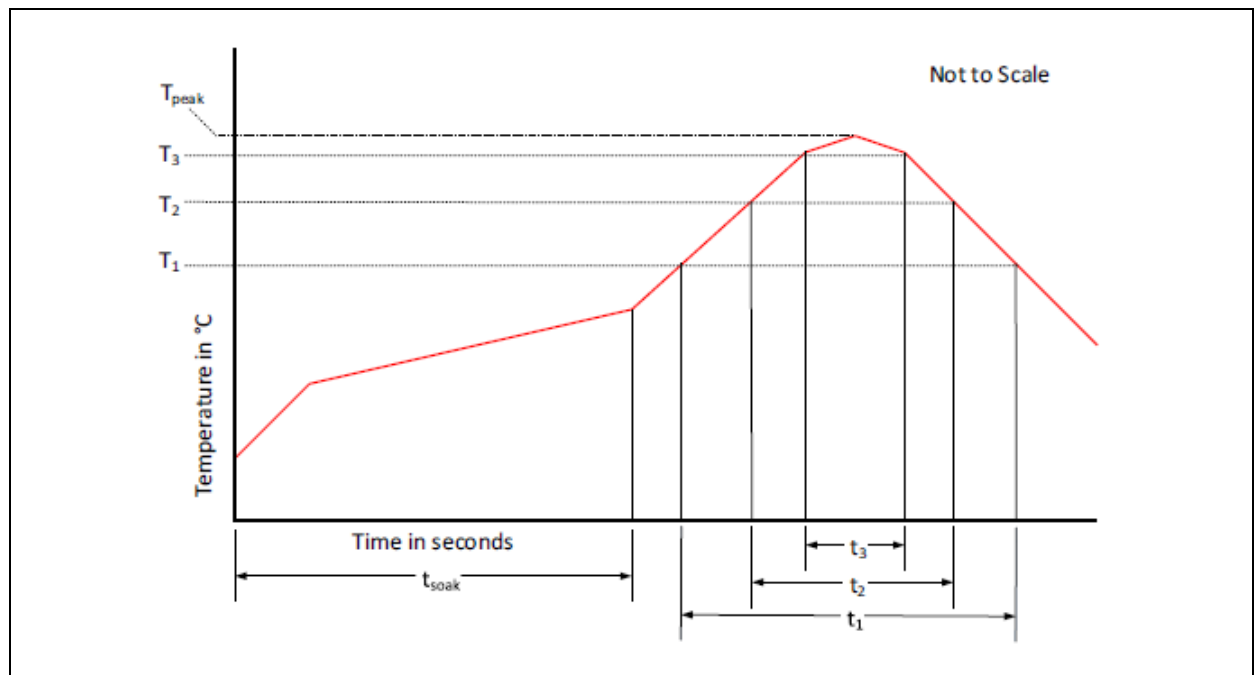
### Solder Reflow Profile

The module has been tested and has demonstrated an ability to be reflow soldered to a PCB substrate. The solder reflow profile describes the expected maximum heat exposure of components during the solder reflow process of product on a PCB. Temperature is measured on top of component. The components should be limited to a maximum of three passes through this solder reflow profile.

**Figure 33:**  
Recommended Reflow Soldering Profile

Profile Feature	Reference	Device
Average temperature gradient in preheating		2.5°C/s
Soak Time	$t_{SOAK}$	2 to 3 minutes
Time above 217°C (T1)	$t_1$	Max 60s
Time above 230°C (T2)	$t_2$	Max 50s
Time above $T_{peak} - 10^\circ\text{C}$ (T3)	$t_3$	Max 10s
Peak temperature in reflow	$T_{peak}$	260°C
Temperature gradient in cooling		Max - 5°C/s

**Figure 34:**  
Soldering Profile Graph



## **Manufacturing Process Considerations**

The AS7221 package is compatible with standard reflow no-clean and cleaning processes including aqueous, solvent or ultrasonic techniques. However, as an open-aperture device, precautions must be taken to avoid particulate or solvent contamination as a result of any manufacturing processes, including pick and place, reflow, cleaning, integration assembly and/or testing. Temporary covering of the aperture is allowed. To avoid degradation of accuracy or performance in the end product, care should be taken that any temporary covering and associated sealants/debris are thoroughly removed prior to any optical testing or final packaging.

## **Storage Information**

Moisture sensitivity optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package. To ensure the package contains the smallest amount of absorbed moisture possible, each device is baked prior to being dry packed for shipping. Devices are dry packed in a sealed aluminized envelope called a moisture-barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

### ***Shelf Life***

The calculated shelf life of the device in an unopened moisture barrier bag is 12 months from the date code on the bag when stored under the following conditions:

- Shelf Life: 12 months
- Ambient Temperature: <40°C
- Relative Humidity: <90%

Rebaking of the devices will be required if the devices exceed the 12 month shelf life or the Humidity Indicator Card shows that the devices were exposed to conditions beyond the allowable moisture region.

### ***Floor Life***

The module has been assigned a moisture sensitivity level of MSL 3. As a result, the floor life of devices removed from the moisture barrier bag is 168 hours from the time the bag was opened, provided that the devices are stored under the following conditions:

- Floor Life: 168 hours
- Ambient Temperature: <30°C
- Relative Humidity: <60%

If the floor life or the temperature/humidity conditions have been exceeded, the devices must be rebaked prior to solder reflow or dry packing.

### **Rebaking Instructions**

When the shelf life or floor life limits have been exceeded, rebake at 50°C for 12 hours.

## Ordering & Contact Information

**Figure 35:**  
Ordering Information

Ordering Code	Description	Package	Marking	Delivery Form	Delivery Quantity
AS7221- BLGT	Calibrated XYZ Chromatic Manager for Network Enabled Smart Lighting	20-pin LGA	AS7221	Tape & Reel	2000 pcs/reel

**Note(s):**

1. Required companion serial flash memory (must be **ams** verified) is ordered from the flash memory supplier (e.g. AT25SF041-SSHD-B from Adesto Technologies).
2. AS7221 flash memory software is available from **ams**.

Online product information is available at:

[www.ams.com/AS7221](http://www.ams.com/AS7221)

Buy our products or get free samples online at:

[www.ams.com/ICdirect](http://www.ams.com/ICdirect)

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## Document Status

Document Status	Product Status	Definition
Product Preview	Pre-Development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice
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## Revision Information

Changes from 0-92 (2016-Sep-27) to current revision 1-01 (2016-Dec-08)	Page
<b>0-92 (2016-Sep-27) to 1-00 (2016-Dec-02)</b>	
Initial production version for release	
Completely revised version	
<b>1-00 (2016-Dec-02) to 1-01 (2016-Dec-08)</b>	
Updated General Description	1
Updated Figure 6 and notes below	7
Updated Figure 17	15
Updated Figure 27 and Figure 28	23

**Note(s):**

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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