Datasheet

DS000479

AS7221

CCT Tuning Smart Lighting Manager

v4-00 • 2019-Jun-28

Content Guide

1 General Description

The AS7221 CCT Tuning Smart Lighting Manager device is part of the **ams** AS722x/1x Smart Lighting Manager/Director family of products that simplify tunable and environmentally responsive lighting designs, enable lights to be “aware” and adapt to their surroundings, and to autonomously serve human-centered lighting and energy conservation needs. The device is equipped with an advanced Cognitive Lighting Engine (CLE) to optimize, chromatic white tuning, daylight harvesting and lumen maintenance via a combination of PWM and/or 0-10 V controls with dimming ballasts. Direct connection to a local I/O network enables connectivity with standard occupancy sensors, dimmers or communications bridges.

The AS7221 is designed for use directly in tunable white luminaires, replacement lamps (bulbs) and light-engines/modules, or with a simple lightguide implementation, it can be incorporated directly into an LED driver to enable a highly cost-competitive, high-accuracy warm/cool CCT tuning solution.

AS7221 XYZ chromatic white 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 AS72211’s silicon via nano-optic deposited interference filters deliver high-stability over both time and temperature. The Manager’s integrated intelligence enables **ams** factory CCT calibration, which mitigates chip to chip variation. By combining this factory calibration with a supported luminaire design-level “application matrix”, an end luminaire design can often eliminate the need for light-by-light calibration while delivering lifetime color control. With such a system calibration, accuracies within 2-4 Macadam steps are possible. The LGA package includes a built in aperture to control light entering the sensor array. No additional optics are required.

The AS7221 connects to standard 0-10 V dimmers inputs and drives 0-10 V 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 PWM-dimmable LED drivers or multi-channel ballasts for constant voltage LED lighting architectures.

An UART interface is provided for configuration, control and management via a driverless, high-level text base Smart Lighting Command Set.

1.1 Key Benefits & Features

The benefits and features of AS7221, CCT Tuning Smart Lighting Manager, are listed below:

Figure 1:
Added Value of Using the AS7221

Benefits	Features
Lowers overall manufactured costs and adds precision to tunable white luminaires and lamps	Intelligent controller with integrated, calibrated XYZ Tristimulus Sensor (CIE 1931 Standard Observer Color Function)

Benefits	Features
Enables cost-optimized single channel drivers to deliver a precise tunable white result.	Selectable drive modes, including PWM-switched current steering, 0-10 V or PWM dimming or PWM-based duty cycle management
Supports legacy IO approaches, as well as digital deep dimming	Built-in 0-10 V analog or PWM digital dimming output generator for precise 1% dimming
Direct serial interface for connection to standard networks	UART interface for connection to network hardware clients for protocols such as Bluetooth, ZigBee and WiFi
Simple lamp or luminaire configuration and commissioning using defined command set	Smart Lighting Command Set (SLCS) uses simple text-based commands to control and configure a wide variety of functions
Compact lighting-capable package with no added optics required	20-pin LGA package 4.5mm x 4.7mm x 2.5mm with integrated aperture -40 °C to 85 °C

1.2 Applications

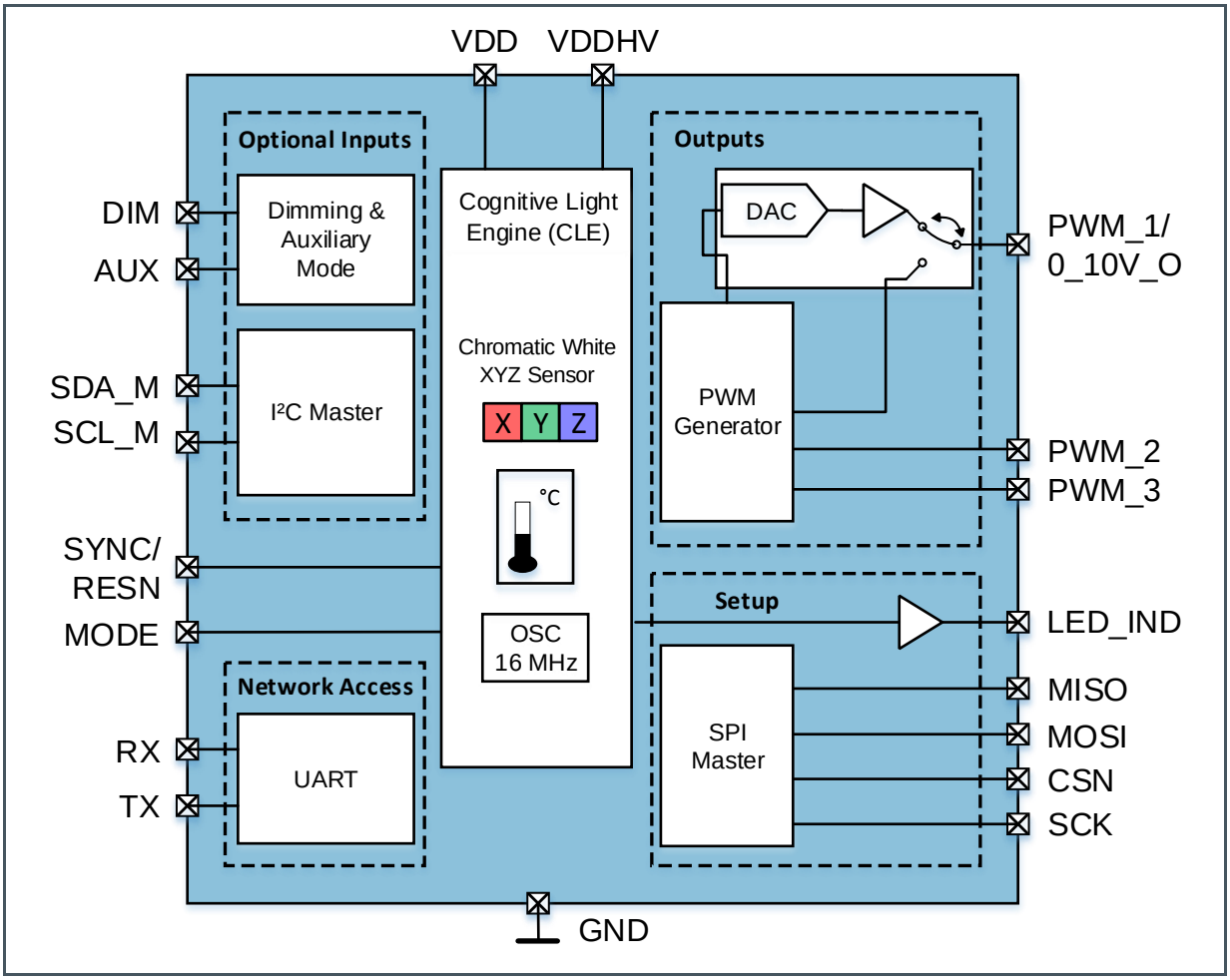
- Commercial, retail, and residential CCT tunable LED lighting systems
- Cost-optimized tunable white LED drivers
- Higher precision replacement lamps/bulbs
- Intelligent, networked solid-state lighting management for variable CCT and daylight harvesting
- Integrated smart lighting control of variable CCT white lighting solutions
- Luminaires intended to meet California Title 24 daylighting requirements
- Networked lighting systems with IoT sensor expandability

1.3 Block Diagram

The AS7221 provides closed loop chromatic white sensing and PWM tuning while interfacing to local and network controls.

The functional blocks of this device are shown below.

Figure 2 :
Functional Blocks of AS7221



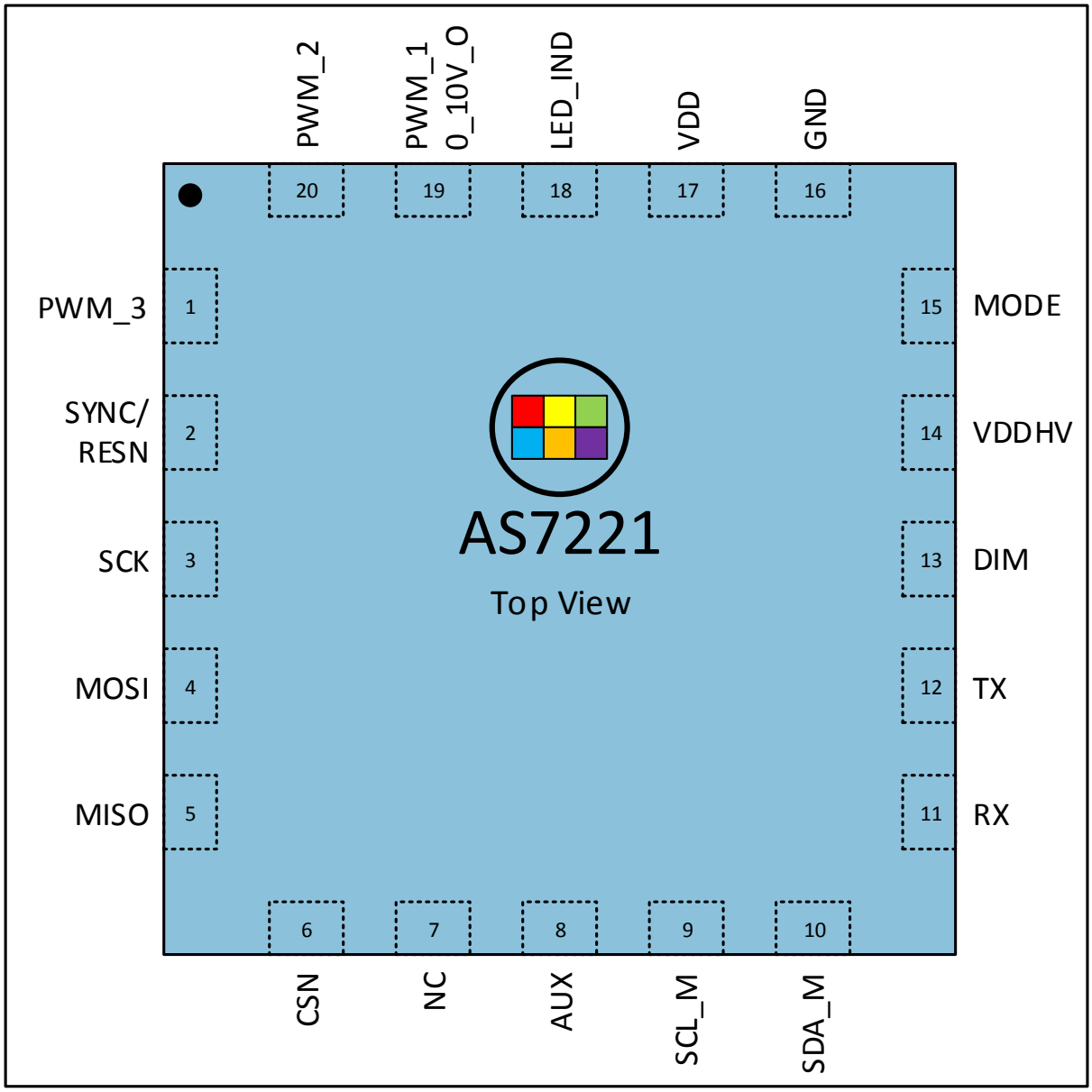
2 Ordering Information

Ordering Code	Description	Package	Marking	Delivery Form	Delivery Quantity
AS7221 – BLGT	CCT Tuning Smart Lighting Manager – Standard Reel	20-Pin LGA	AS7221	13-inch Tape & Reel	2000 pcs/reel
AS7221 – BLGM	CCT Tuning Smart Lighting Manager – Mini Reel	20-Pin LGA	AS7221	7-inch Mini Tape & Reel	500 pcs/reel

3 Pin Assignment

3.1 Pin Diagram

Figure 3:
Pin Diagram for AS7221 (Top View)



3.2 Pin Description

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

Pin Number	Pin Name	Pin Type(1)	Description
1	PWM_3	AO	Digital PWM 3
2	SYNC/RESN	DI	Active low (with internal pull-up to VDD)
3	SCK	DI	SPI serial clock
4	MOSI	DO	SPI MOSI
5	MISO	DI	SPI MISO
6	CSN	DO	Chip select for the required external serial flash memory, active low
7	NC	-	Not connected
8	AUX	AI	Auxiliary mode input pin
9	SCL_M	DI/O	I²C master clock pin
10	SDA_M	DI/O	I²C master data pin
11	RX	DI	UART RX pin
12	TX	DO	UART TX pin
13	DIM	AI	0-2 V or 0-10 V input dimming pin
14	VDDHV	P	High voltage supply
15	MODE	AI	Mode selection pin
16	GND	P	Ground
17	VDD	P	Low voltage supply
18	LED_IND	AO	LED Driver output for Indicator LED, current sink
19	PWM_1	AO	Digital PWM 1
	0_10V_O	AO	0-10 V output pin
20	PWM_2	AO	Digital PWM 2

(1) Explanation of abbreviations:

DI	Digital Input
DO	Digital Output
DI/O	Digital In Out
AO	Analog Out
AI	Analog In
P	Power Pin

4 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 “Operating Conditions” 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. All voltages with respect to GND. Device parameters are guaranteed at V_{DD} = 3.3 V and T_{AMB} = 25 °C unless otherwise noted.

Figure 5
Absolute Maximum Ratings of AS7221

Symbol	Parameter	Min	Typ	Max	Unit	Comments
Electrical Parameters						
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)		± 100		mA	JESD78D
Electrostatic Discharge						
ESD_{HBM}	Electrostatic Discharge HBM		±1000		V	JS-001-2014
ESD_{CDM}	Electrostatic Discharge CDM		±500		V	JEDEC JESD22-C101F Oct 2013
Temperature Ranges and Storage Conditions						
T_{STRG}	Storage Temperature	-40		85	°C	
T_{BODY}	Package Body Temperature			260	°C	IPC/JEDEC J-STD-020 (1)
RH_{NC}	Relative Humidity (non-condensing)	5		85	%	
MSL	Moisture Sensitivity Level		3			Represents a 168 hour max. floor lifetime
Bump Temperature (soldering)						
T_{PEAK} (1)	Peak Temperature	235		245	°C	Solder Profile

(1) The reflow peak soldering temperature (body temperature) is specified according to IPC/JEDEC J-STD-020 “Moisture/Reflow Sensitivity Classification for no hermetic Solid State Surface Mount Devices.” The lead finish for Pb-free leaded packages is “Matte Tin” (100 % Sn)

5 Electrical Characteristics

All limits are guaranteed with VDD = 3.3 V, VDDHV = 12 V, T_{AMB} = 25 °C. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods. If VDD and VDDHV are to be the same voltage, they must be sourced by the same 2.97 V to 3.6 V supply. All voltages with respect to GND.

Figure 6:
Electrical Characteristics of AS7221

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
General Operating Conditions						
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	°C
I_{VDD}	Operating Current	Excluding LED driver current			5	mA
Internal RC Oscillator						
F_{OSC}	Internal RC Oscillator Frequency		15.7	16	16.3	MHz
t_{JITTER} (1)	Jitter	@25 °C			1.2	ns
0-10 V Output (0_10V_O pin)						
R_{OUT_10}	Resistive Load		1			kΩ
I_{S_10}	Source Current		10			mA
I_{SINK_10}	Sink Current		-10			mA
I_{LEAK_HV}	HV Output Leakage Current	VIN=12 V, DAC & PWM1 both disabled	-1.6		-0.73	mA
C_{LOAD_10}	Capacitive Load				100	pF
V_{OUT_10} (2)	Output Swing		0		10	V
AUX Input						
AUX_{IN}	AUX Input Voltage	For 100% AUX A/D conversion		3.0		V
R_{IN_AUX}	Analog Input Resistance		168	240	312	kΩ
0-10 V Input						
R_{IN_HV}	Analog Input Resistance	VDDHV ≥ 12 V	138	200	315	kΩ

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Temperature Sensor						
D_{TEMP}	Absolute Accuracy of the Internal Temperature Measurement		-8.5		8.5	°C
Indicator LED						
I_{IND}	LED Current		1		8	mA
I_{ACC}	Accuracy of Current		-30		30	%
V_{LED}	Voltage Range of Connected LED	V_{DS} of current sink	0.3		VDD	V
Digital Inputs and Outputs						
I_{IH}, I_{IL}	Logic Input Current	Vin=0 V or VDD	-1		1	µA
$I_{IL\ SYNC/RESN}$	Logic Input Current (SYNC/RESN pin)	Vin=0 V	-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=1 mA			VDD - 0.4	V
V_{OL}	CMOS Logic Low Output	I=1 mA			0.4	V
t_{RISE}(1)	Current Rise Time	C(Pad)=30 pF			5	ns
t_{FALL}(1)	Current Fall Time	C(Pad)=30 pF			5	ns

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

6 Optical Characteristics

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 with 16-bit resolution ADC, which integrates current from photodiodes. Upon completion of the conversion cycle, the result is transferred to the corresponding data registers to drive internal tuning algorithms. Transfers are double-buffered to ensure integrity of the data is maintained.

Standard observer tri- stimulus (XYZ) interference filters are applied to the SLM's optical channels as part of the CMOS process. This unique process enables filter responses that mimic the human eye and is extremely stable over both operating temperature and time. This in turn allows lifetime correlated color temperature (CCT) calibration to be performed as part of the manufacturing process. Calibration is accomplished using standard white LEDs at a variety of CCTs to deliver high accuracy and typically eliminate the need for light-by-light calibration in most designs. Note that any change of the precalibrated measurement conditions have an impact on the accuracy of the measurement results. In such cases a design-level diffuser or color brightness calibration is recommended to achieve highest accuracies. The AS7221 provides 2 calibration matrices, a factory calibration and a second application specific matrix to optimize the measurement performance. The additional calibration values will be set using the Smart Lighting Command Set directives ATNORMGAIN and ATNORMINTT. These settings will be saved in the external flash and reloaded automatically by the sensor firmware. See Section 10 for description of the complete Smart Lighting Command Set.

The AS7221 LGA package contains an internal aperture that provides a package field of view (PFOV) of ± 20.5°. External optics can be used as needed to expand or reduce this built in PFOV.

Sensor data readout to the maximum count value range is limited by the ADC. The maximum count range value of 65535 is only reached with an integration time t_{INT} of approximately 177.92 ms. Below that value, the FSR will be less than the maximum 16-bit/65536 count maximum as described in the chart below.

Figure 7:
Overview Signal Resolution

Bit Resolution	t_{INT} in ms	Maximum Counts
10	2.78	1024
11	5.56	2048
12	11.12	4096
13	22.24	8192
14	44.48	16384
15	88.96	32768
16	177.92	65536

Figure 8:
AS7221 Optical Characteristics

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

(1) Typical values at Lux ≥50, Integration time=400.4 ms, Gain=1x, T_{AMB} = 25 ºC.
(2) Calibration and measurements were made at diffused light.

Figure 9:
Normalized Spectral Responsivity (all filters are normalized to 1)

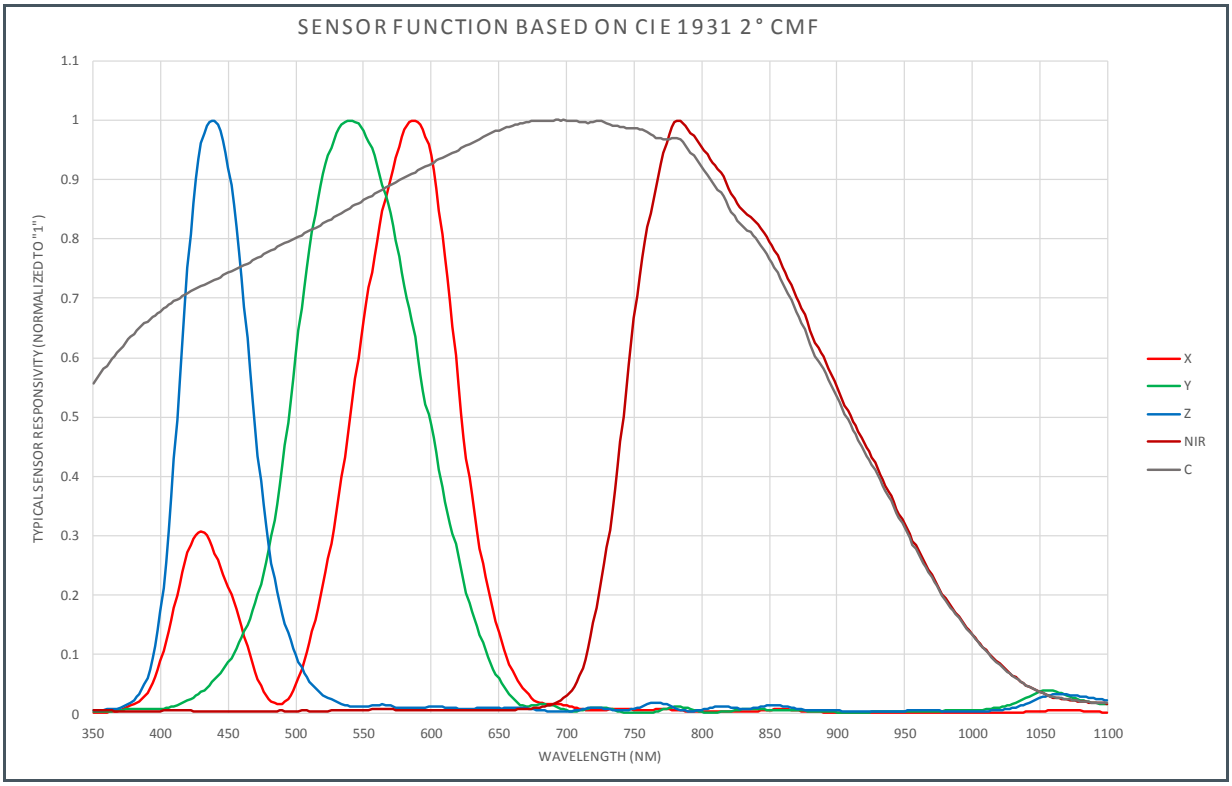
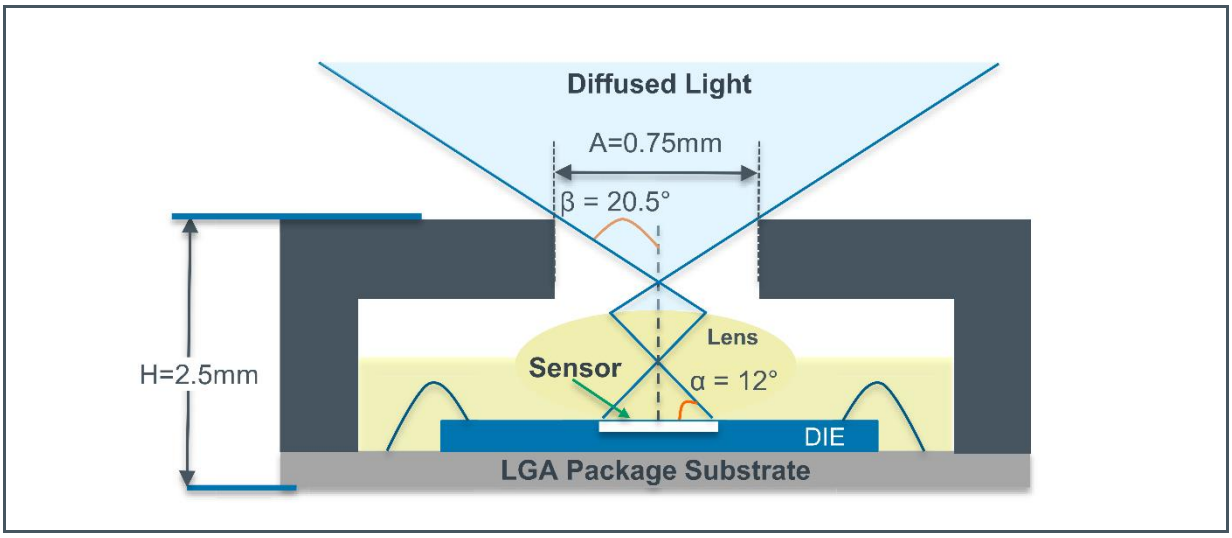


Figure 10:
AS7221 LGA Average Field of View



7 Functional Description

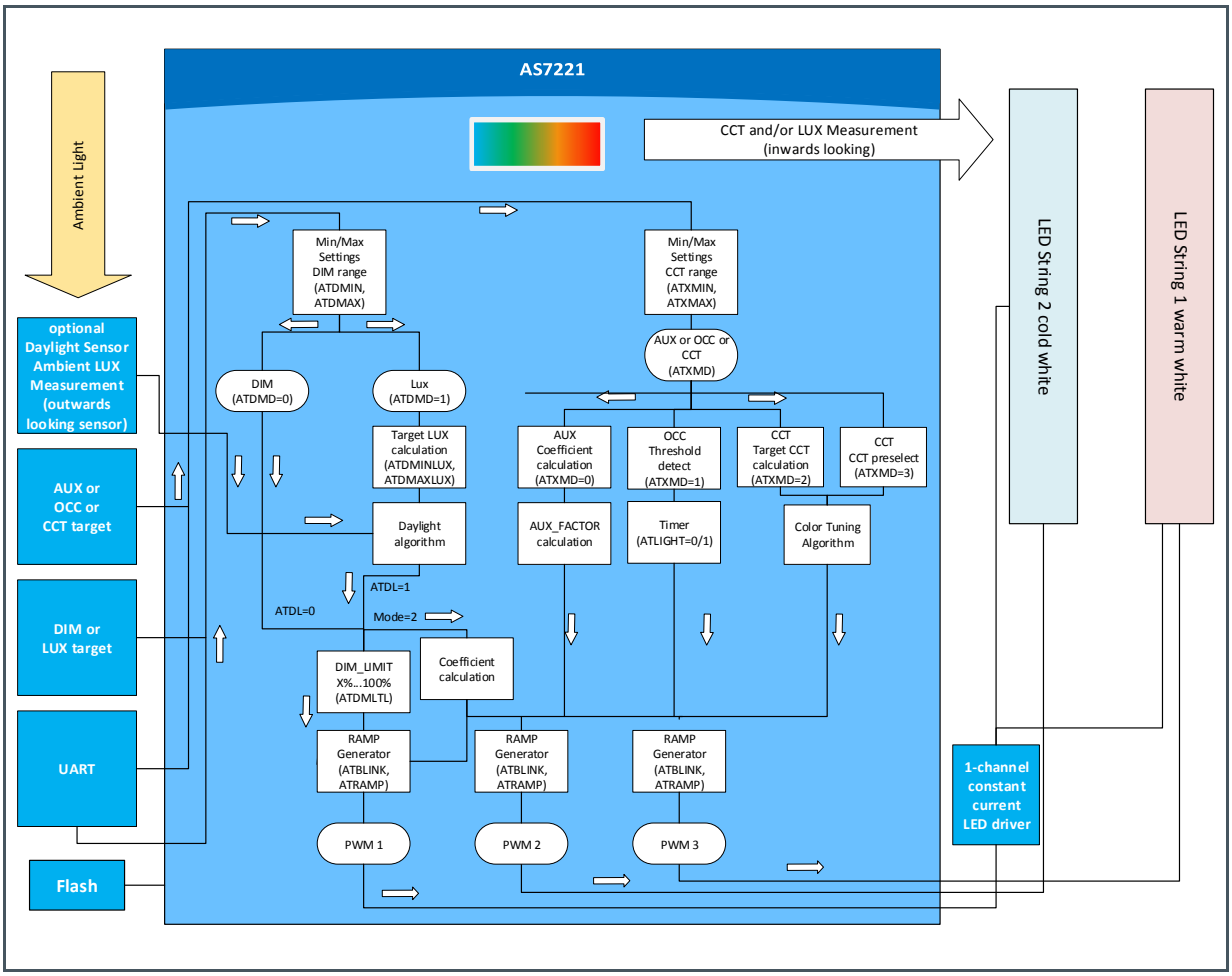
7.1 Smart Lighting Manager – Overview

The Cognitive Light Engine (CLE) is the “brains” of the Smart Lighting Manager (SLM). The CLE constantly processes information from the calibrated XYZ chromatic white/color sensor, Smart Lighting Command Interface and control inputs to adjust and control PWM and 0-10 V channel outputs to deliver the targeted light characteristics. AS7221 initial setup and ongoing parameter storage is automatically done by software within the required external serial Flash memory, via SPI bus. Only **ams**-verified models of Flash devices can be supported. A subset of supported devices is noted in the UART Command Interface section of this document, which also provides a reference to the current list of supported Flash memory devices. For the Flash memory overview please refer to Figure 30. A SPI Flash device is a required operating companion to the AS7221. Figure 30 includes a partial list of supported devices, which have been tested by **ams**. Using non-verified devices can cause communication issues and may not be compatible. Flash timing is provided in Figure 28 and Figure 29 for debug purposes.

By sensing a sample of the mixed warm and cool CCTs as either a reflection from the diffuser or other light-guide/optical light gathering technique, the AS7221 can support high precision multi-channel tuning results from a lower cost dual- or single channel LED driver architecture. Please note, that non-diffused applications require some form of reflective or other light gathering that delivers an adequate sample of mixed light to the sensor. Care should be taken to fulfill the angle of incidence requirements of the nano-optic filter set.

To support the growing need for more personalized or circadian-rhythm supportive lighting systems, up to 16 scenes can be preset into flash memory to support autonomous CCT and brightness adjustments, including programmable ramp/transition timing. Scene timing, targets and ramps are programmable via the high-level Smart Lighting Command Set described in Section 10.

Figure 11:
AS7221 Workflow Abstract



The AS7221 does not include embedded operating code. Initial programming of an installed, compatible Flash memory device must be accomplished external to the SLM at the time of end-product manufacturing to enable an initial functional state. Options include programming with a JTAG or serial programmer (e.g. FlashCat USB) or working with a components distributor or device programming service company for preprogramming devices. After initial programming, over-the-air/over-the-wire operating image updates are supported by commands in the Smart Lighting Command Set.

A binary image software configuration tool is available from **ams** to allow the luminaire, lamp or driver manufacturer to create their own “factory default” conditions that will be integrated with the **ams**–supplied initial binary image to create a ready-to-program default Flash image. The configuration tool is available from https://download.ams.com (see Smart Lighting Command Interface section).

XYZ color point response is accomplished via standard observer interference filters, which are extremely stable over time and temperature. To ensure accuracy, the AS7221 LGA package contains an internal aperture that limits the sensor package field of view (PFOV) of ± 20.5°, as shown in Figure 10. External optics can be used as needed to expand or reduce this built in PFOV.

For daylight operation, the AS7221 can be used two ways. As a standalone device pointing out of the luminaire, or if pointing inward for white color, it can support daylighting operation by using an I²C master connected to **ams** TSL25721 or TSL45315 for ambient light sensing.

Figure 12:
Solution Chart

Chromatic Color Maintenance			Lumen Maintenance	
Chromatic Color Maintenance	Lumen Maintenance	Daylighting	AS7221	TSL25721 or TSL45315 (optional)
✓	✓	×	↑ (into luminaire)	× (not required)
✓	×	✓	↑ (into luminaire)	↓ (into room)

TSL25721 device combines a channel 0 (CH0) which is responsive to both visible and infrared light, and channel 1 (CH1) which is responsive primarily to infrared light. Therefore, to get the LUX, a calibration is necessary. In this calibration, both channels has to be considered. First counts per lux (CPL) needs to be calculated in this calibration method.

Counts per LUX (CPL):

$$CPL = \frac{CH0 - (1.87 * CH1)}{LUX}$$

Calibration Scalar:

$$LUX = K0 * ADC0 - K1 * ADC1$$

Default setting K0 is 0.2178 (normal sunlight conditions in Europe in May, 1 m distance to a window). If K0=0, the result for K1 will be inverted to prevent negative LUX values. At different light conditions, this value has to adjust.

Example:

Spectrometer value = 9764 Lux,

CH0 = 22870,

CH1 = 2734

→ CPL = 1.8186

K0 = 1/CPL = 0.549855,

K1 = 1.87/CPL = 1.028228

To save the values, write in the console tab, ATLXSL0=0.549855 and ATLXSL1= 1.028228

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

7.2 XYZ Chromatic White Color Sensor

The XYZ chromatic 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 tri-stimulus (XYZ) interference filters are applied to the SLM's optical channels as part of the CMOS process. This unique process enables filter responses that mimic the human eye and are extremely stable over both operating temperature and time. This in turn allows lifetime correlated color temperature (CCT) calibration to be performed as part of the manufacturing process. Calibration is accomplished using standard white LEDs at a variety of CCTs to deliver high accuracy; eliminating the need for light-by-light calibration in most designs. The Smart Lighting Command Set (SLCS) also includes provisions for application level calibration to provide a mechanism for additional design-specific calibration and compensation. Note the AS7221 LGA package contains an internal aperture that provides a package field of view (PFOV) of ± 20.5°. External optics can be used as needed to expand or reduce this built in PFOV. Scalar commands supported in the SLCS enable a level of compensation for added optics.

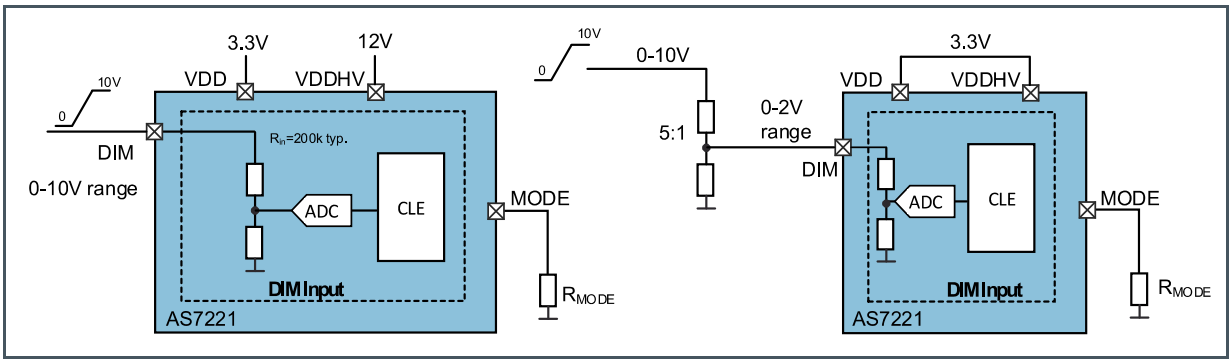
7.3 Inputs

Figure 13:
VDDHV Based Settings for Inputs

VDDHV	Dimming
10.5-15 V	Direct input for DIM, dimming input
2.97-10 V (1)	External 5:1 resistor divider for DIM, dimming input (2)

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

Figure 14:
0-10 V Dimming Pin Input



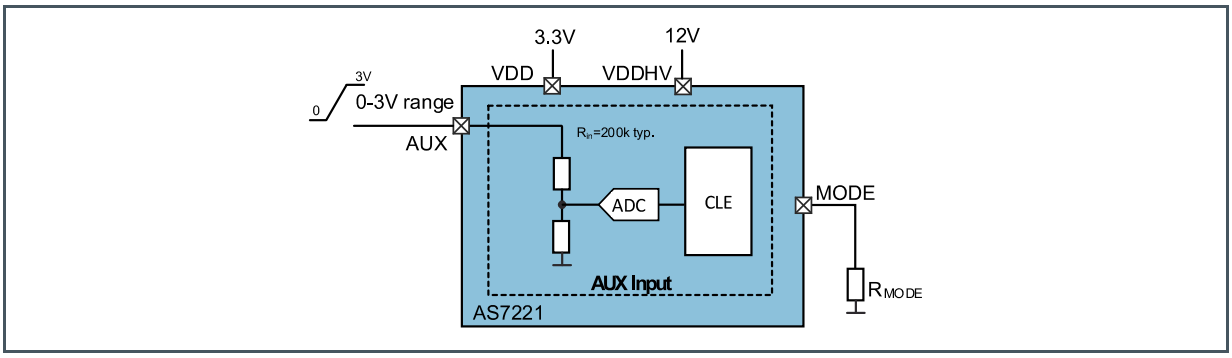
For the AS7221, dimming can be accomplished from either the input pin (DIM) or smart lighting command via the UART. For network commanded dimming, using the AS7221 Smart Lighting Command Set, the UART interface is used. To prevent flicker effects the low end of the dimming range can be adjusted via the ATDMLTL command to the provided range of the external dimming device.

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

If a second supply voltage 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 2 V. Hence, to accept a full range 10 V 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 Figure 14 and Figure 15.

If the DIM pin is not used, an external resister pull-up connecting it to VDDHV is recommended. For a complete description of the Smart Lighting Command Set refer to Section 10 Figure 32.

Figure 15:
AUX Pin Input



The AUX input is a multifunction pin that is configured via SLCS commands into one of several modes. It can be used as a secondary input to allow additional control, in addition to the 0-10 V slider dimming function of the DIM pin. In AUX mode, the sensed AUX voltage is scaled and used to multiply the dimming scale. The auxiliary sensor input (AUX) has a 0-3 V range for its default analog sensing mode. With this 0-3 V range, external ranges such as 0-10 V can be accommodated using external resister divider networks such as a 10:3 network for a 0-10 V occupancy sensor. The AUX pin can also be configured for digital sensing (0,1 where 1=VDD).

In the OCC mode an occupancy event from an external digital occupancy sensing device will trigger a timer restart, enabling the occupancy sensing function. An occupancy event enables the PWM output and resets the OCC timer. If the OCC signal falls below a detecting threshold (50%), the OCC timer restarts a countdown. The OCC timer counting time is set by the ATOCCT command. A value up to 10 minutes can be stored. After finishing the countdown without an occupancy event re-occurring, the PWM output is dimmed to 0 output (lights off).

In CCT_Tune mode, the analog pin input will be interpreted to linearly tune between min and max CCT values that are set via smart lighting commands. In this mode, all lights on a single CCT-tuning circuit will see the same CCT_Tune input value for light-to-light CCT consistency.

In CCT_SEL mode, a preselected CCT target value can be set via the provided voltage at the AUX pin. The selected CCT target values will be configured in 300 mV step width.

Figure 16:
CCT_SEL Targets

CCT (K)	V_{min} (mV)	V_{norm} (mV)	V_{max} (mV)
Default configured target value	0	150	300
2700	300	450	600
3000	600	750	900
3500	900	1050	1200
4000	1200	1350	1500
4100	1500	1650	1800
5000	1800	1950	2100
5700	2100	2250	2400
6500	2400	2550	2700
CT off	2700	2850	3000

If the AUX pin is not used, an external resistor pull-up connecting it to VDD is recommended.

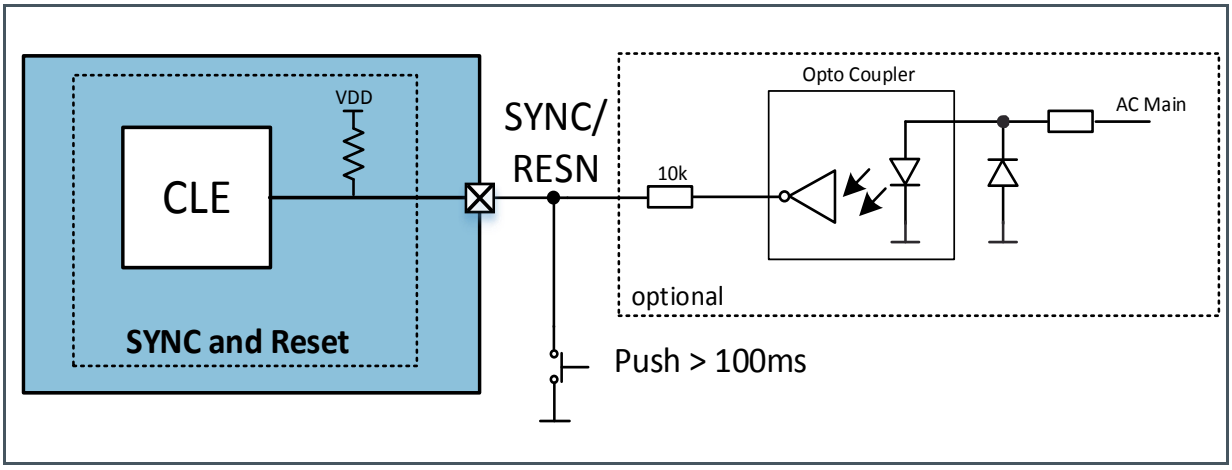
7.4 Synchronization and Reset

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 by the internal pull-up connected to the SYNC/RESN pin.

Refer to Figure 17 below. When pulled down for more than 100 ms 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.

Figure 17:
Synchronization and Reset



7.5 PWM 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 7-bit for direct configuration, 12-bit for automatic scaling (daylight and color tune algorithm) and factory set to 886 Hz. Refer to Figure 18. If necessary, an adjustment of the PWM output frequency from 100 Hz up to 4 kHz is possible.

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 0-100%. Digital Dimming range is 0-100%. PWM2 and PWM3 are used for cool white and warm white LED color controlling. The cool white LED string needs to be connected to PWM2 and the warm white LED string to PWM3 accordingly. Range is 0-100% for both PWM2 and PWM3. If the external dimming device does not support the full range 0-100% it is possible to adjust the low end of the dimming range via the ATDMLTL smart lighting command.

For test and scene configuration purposes 2 direct PWM AT-commands are available. ATXPWMx can be used for scene confiruations. It allows a direct PWM input at the scene ramp generator and override all PWM values calculated by the AS7221. ATPWMx can be used for hardware tests. It

allows a direct PWM input at the end of the sensor line and override all PWM values calculated by the AS7221 and all ATXPWMx values as well.

To set the desired device operation MODE use the appropriate RMODE resistor, also shown in Figure 18.

Figure 18:
Outputs

MODE	R_{MODE}	Setting	Outputs	
			PWM_1/0_10V_O	PWM_2 and PWM_3
0	100 Ω	0-10 V analog	Analog 0-VDDHV (1)	Digital PWMs (0-VDD)
1	470 Ω	0-10 V digital	Digital PWM (VDDHV)(2)	Digital PWMs (0-VDD)
2	1000 Ω	Digital 2-CH color tuning	Analog 0-VDDHV, not used for dimming	Digital PWMs (0-VDD), w/Dimming

(1) For VDDHV>10.5 V, output max is 10 V, else output max tracks VDDHV.
(2) Digital PWM output is following VDDHV and it not limited to 10 V in digital PWM mode.

7.6 Indicator LED

An LED, connected to pin LED_IND, is used to indicate boot and programming progress of the device. If an error occurs with the memory access the indicator LED starts blinking operation. When programming is finished and programming tool disconnected the indicator LED turns on (default setting).

The LED_IND pin is set for 1 mA operation by the AS7221 factory firmware. This is not under user control. The indicator LED can be enabled or disabled by using the ATLED0 command. Consideration should be taken with respect to any final product design to avoid light intrusion from the indicator LED into the direct or reflected field of view of the sensor.

8 I²C Master Interface

External sensors with native support by the AS7221 can be added via the I²C master interface. For example the **ams** current TSL25721 or legacy TSL45315 can be used to add daylighting operation to the AS7221. Once the supported ambient light sensor is detected by the AS7221, and the daylighting is activated by using the ATDL=1 command, daylighting operation begins. Native support is provided for selected **ams** environmental sensors including temperature, humidity and air quality/VOC.

The I²C Master interface uses I²C serial protocol for communication with 7+1-bit chip addressing mode and full-speed clock frequency. Read and Write transactions comply with the standard set by Philips (now NXP).The I²C master interface can be used as a UART to I²C Bridge to connect to other I²C external sensors that do not have native support in the smart lighting firmware. Supporting smart lighting commands enable pass-through communications with non-natively supported devices.

8.1 I²C Protocol

Figure 19:
I²C 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 I²C symbol definition table describes the symbols used in the following Read and Write descriptions.

8.2 I²C Write Access

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

Figure 20:
I²C Byte Write

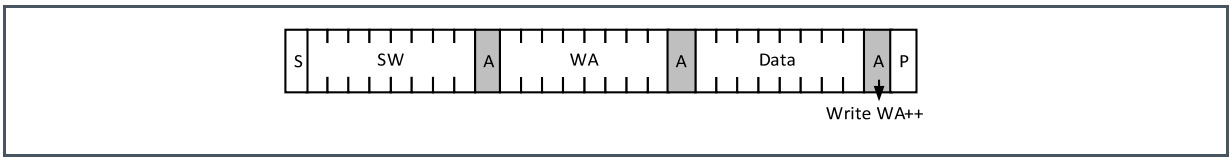
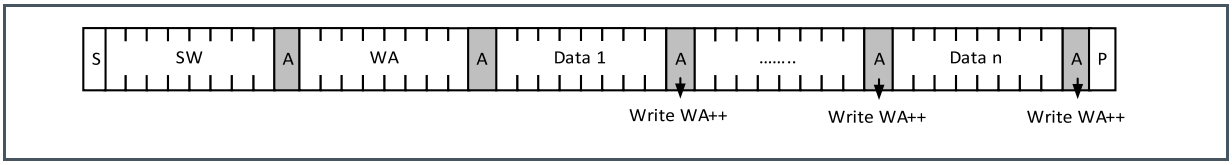


Figure 21:
I²C Page Write



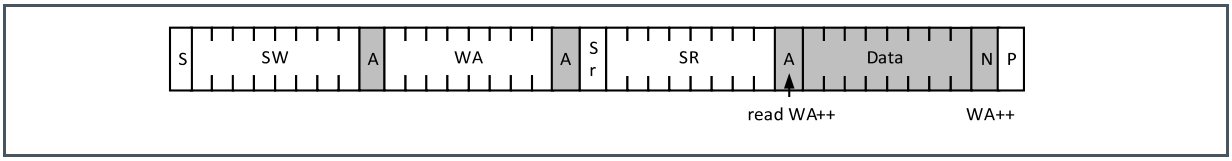
The transmission begins with the START condition, which is generated by the master when the bus is in IDLE state (the bus is free). The device-write address is followed by the word address. After the word address any number of data bytes can be sent to the slave. The word address is incremented internally,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

8.3 I²C Read Access

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

Figure 22:
I²C Random Read

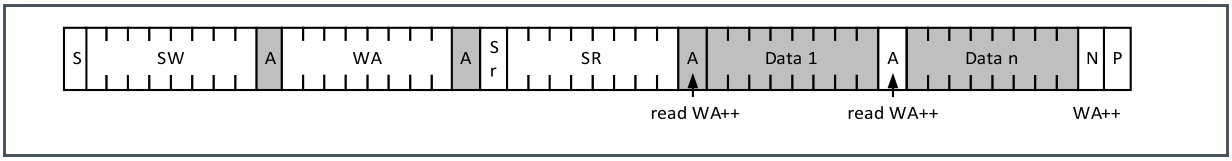


Random Read and Sequential Read are combined formats. The repeated START condition is used to change the direction after the data transfer from the master.

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 23:
I²C Sequential Read(1)



(1) Shows the format of an I²C 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.
http://www.nxp.com/documents/user_manual/UM10204.pdf Version 4.0 Feb 2012 for standard mode and fast mode

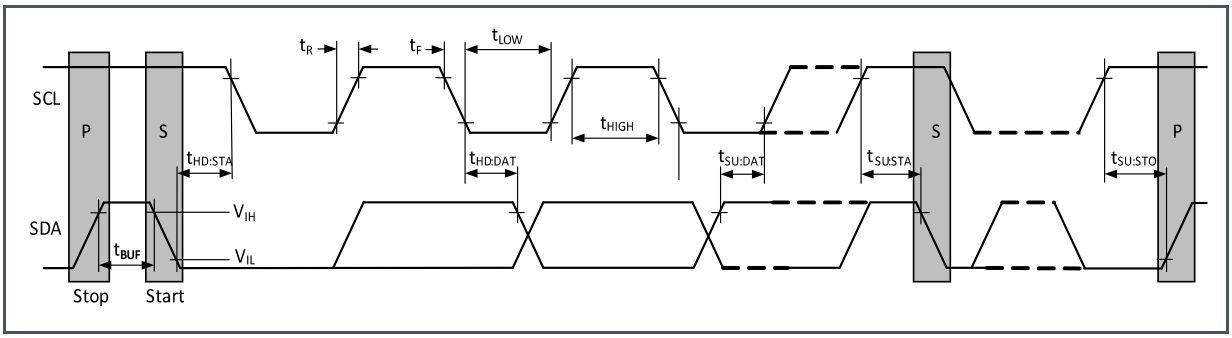
8.4 Timing Characteristics

Figure 24 :
AS7221 I²C Master Timing Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCL}	SCL Clock Frequency			400	400	kHz
t_{BUF}	Bus Free Time Between a STOP and START		1.3			µs
$t_{HD:STA}$	Hold Time (Repeated) START		0.6			µs
t_{LOW}	LOW Period of SCL Clock		1.3			µs
t_{HIGH}	HIGH Period of SCL Clock		0.6			µs
$t_{SU:STA}$	Setup Time for a Repeated START		0.6			µs
$t_{HD:DAT}$	Data Hold Time		0		0.9	µs
$t_{SU:DAT}$	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			µs
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

8.5 Timing Diagrams

Figure 25:
I²C Master Timing Diagram



9 UART Command Interface

The UART block implements the TX and RX signals as defined in the RS-232 / V.24 standard communication protocol. A SPI Flash is a required operating companion device for the AS7221 to function or to communicate via the UART interface. Using non-verified flash devices can cause communication issues and may not be compatible. See Figure 30 for a subset of supported devices, which are tested by **ams**. The “xx” in the serial flash name stands for alternative packages and a reference is provided to the current list of verified flash devices. Flash timing is provided in Figure 25 for debug purposes.

9.1.1 UART Feature List

- Full Duplex Operation (Independent Serial Receive and Transmit Registers)
- Factory set to 115.2 kBaud
- Supports Serial Frames with 8 Data Bits, no Parity and 1 Stop Bit.

9.1.2 Operation

Transmission

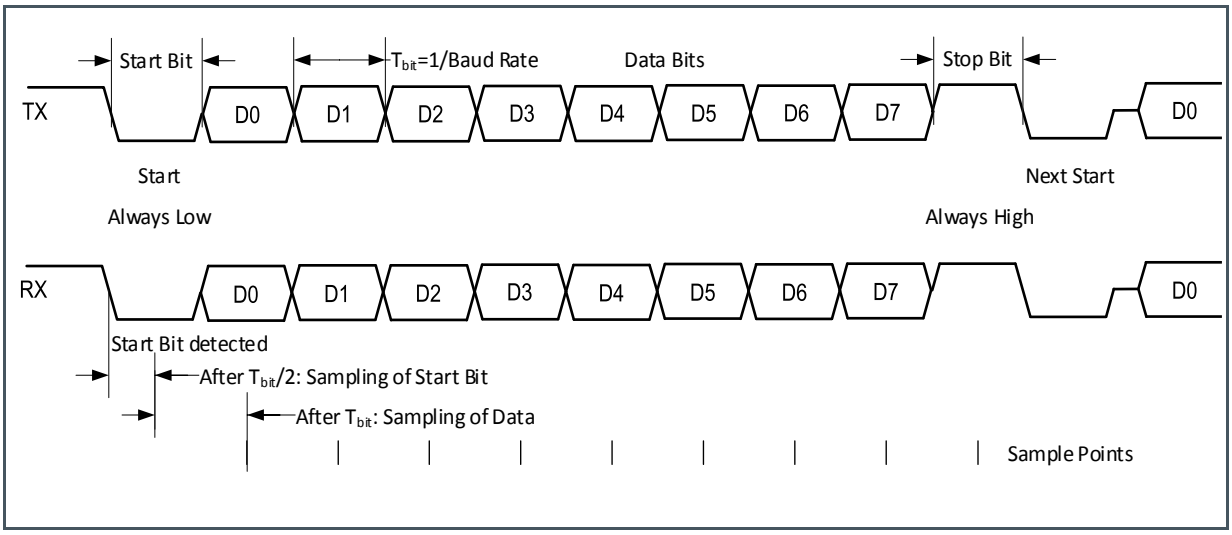
If data is available, it will be moved into the output shift register and the data will be transmitted at the Baud Rate, starting with a Start Bit (logic zero) and followed by a Stop Bit (logic one).

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. The following Stop Bit will be checked to be logic one.

9.2 UART Protocol

Figure 26:
UART Protocol



9.3 SPI Timing Characteristics

The AS7221 contains a serial UART interface to connect to a Flash memory. An Overview can be found in Figure 30. The required timing characteristics for a serial interface is shown in Figure 28 and in Figure 29 accordingly. If a Flash memory is used for debug purposes which is not listed in Figure 30 it should be ensured that the SPI timing is achieved. Contact **ams** for requests to support/verify additional Flash devices beyond those listed in the most current device verification listing.

Figure 27:
AS7221 SPI Timing Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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	5			ns
t_{CSN_H}	CSN Hold Time	Time between last SCK falling edge and CSN low-high transition	5			ns
t_{CSN_DIS}	CSN Disable Time		10			ns
t_{DO_S}	Data-Out Setup Time		5			ns

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_{DO_H}	Data-Out Hold Time		5			ns
t_{DI_V}	Data-In Valid		10			ns

9.4 SPI Timing Diagrams

Figure 28:
SPI Master Write Timing Diagram

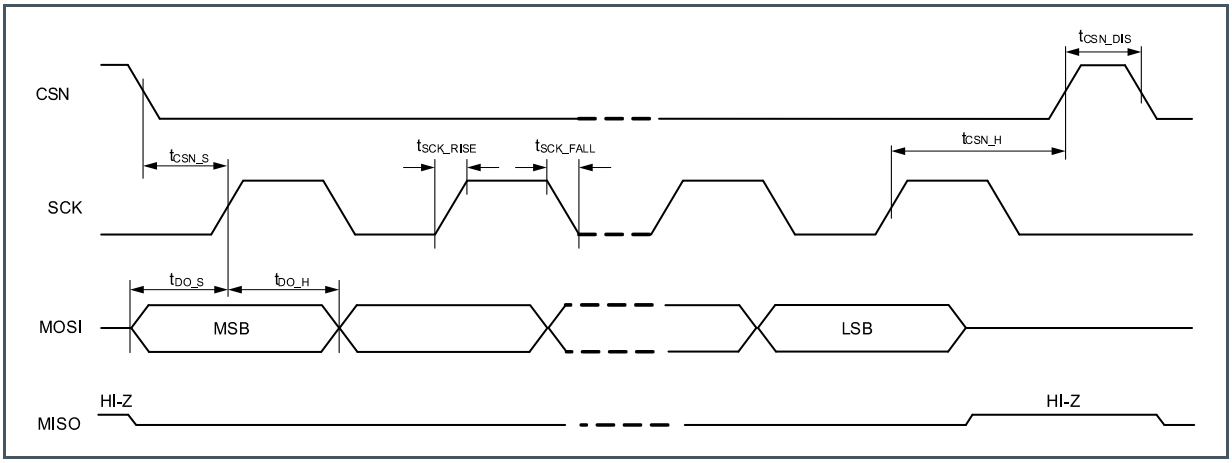
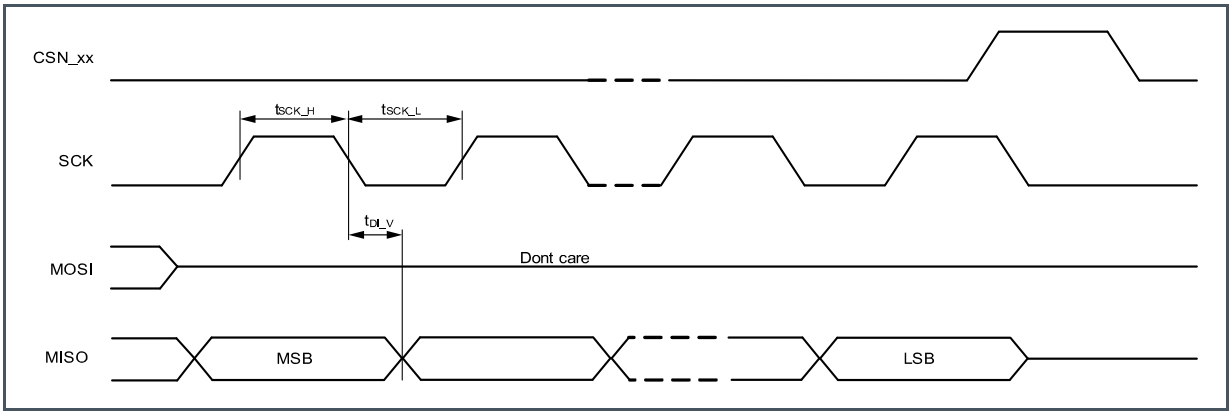


Figure 29:
SPI Master Read Timing Diagram



9.5 Serial Flash

A SPI Flash device is a required operating companion to the AS7221. See Figure 30 for supported devices, which are tested by **ams**. Using other devices can cause communication issues and may not be compatible Flash timing is provided in Figure 25 for debug purposes.

Figure 30:
Flash Memory Overview

Serial Flash	Manufacturer
AT25SF041xx	Adesto Technologies
AT25DF041xx	Adesto Technologies
MX25L4006ExxI-12G	Macronix
SST25PF040C	Microchip Technology
W25X40CLSNIG	Winbond Electronics
LE25U40CMD	ON Semiconductor
GD25Q40C	GigaDevice
FS25Q004F1	Foresee

Additional devices may have been added to this list after publication of this datasheet. See “AS72xx External Flash program and update” application note available on the **ams** AS7221 product document section of the **ams** website.

10 Smart Lighting Command Interface

The Smart Lighting Manager supports a high-level, driverless text control interface using its Smart Lighting Command Set (SLCS) communicated through the UART interface. The SLCS provides a rich configuration and control interface to speed the time-to-design and time-to-market for luminaire, replacement lamp and driver manufacturers. The Smart Lighting Manager uses a variation of an “AT command model” as popularized by early Hayes modems. The SLCS is integrated into the required binary operating image that is included on the USB memory stick provided with an AS722x/1x Smart Lighting Demo Kit. Updates or the latest version of the SLCS can be downloaded via https://download.ams.com. Login is required and a login can be obtained through the email address provided on the download site.

A configuration tool is available from **ams** to allow the luminaire, lamp or driver manufacturer to create their own “factory default” conditions that will be integrated with the **ams** -supplied initial binary image to create a ready-to-program default Flash image. The configuration tool is also available from https://download.ams.com.

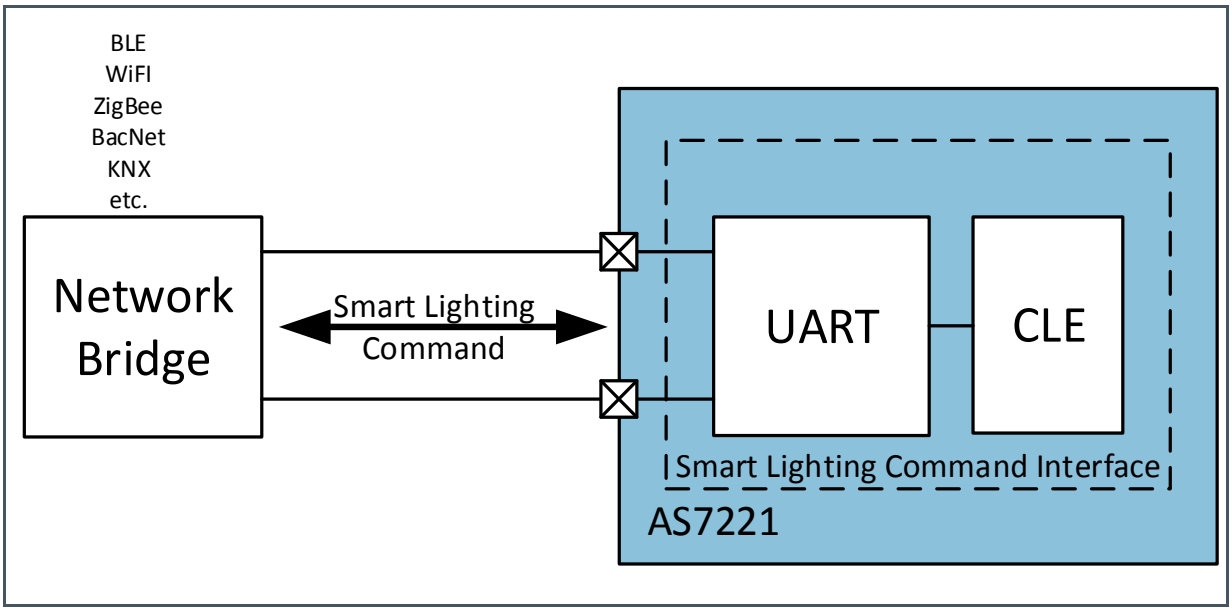
Write commands are constructed in the format “ATcmd=xxx” with the SLM returning the requested data value followed by the “OK” text reply. Commands that are unsuccessfully interpreted or are otherwise invalid will return an “ERROR” text reply.

For example:

- Set the desired daylight LUX level target: ATLUXT=500 <OK>
- Read current lux target set point: ATLUXT <500 OK>
- Read current calibrated lux level as observed by the sensor: ATLUXC <497 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 31:
Smart Lighting Command Interface



10.1 AT Commands

The command interface to control the AS7221 is via the UART, using AT commands across the UART interface. The AT command interface block diagram, shown in Figure 31 between the network interface and the core of the system, provides access to the AS7221's Cognitive Light Engine's control and configuration functions (see also chapter UART).

In the command description below, numeric values may be specified with no leading prefix, in which case they will be interpreted as decimals, with leading "0x" to indicate that they are hexadecimal numbers, or with a leading "b" to indicate, that they are binary numbers. The commands are grouped into functional areas Texts appearing between angle brackets ('<' and '>') are commands or response argument. A carriage return character, a linefeed character, or both may terminate commands to the SLM. The SLM command output is a response followed by a linefeed character. Note that any command that cannot interpreted or which encounters an error will generate "ERROR" response.

Figure 32:
AT Commands

Command	Direction	Description	Format	Value Range	Default
Status and Basic Initialization					
AT	R	NOP	-	-	-
ATLIGHT	R/W	Enables/disables the light (PWM output)	DEZ	1:ON, 0:OFF	1

Command	Direction	Description	Format	Value Range	Default
ATINTTIME	R/W	Set sensor integration time. Integration time = <value> x ~2.8 ms	DEZ	1 – 255	20
ATGAIN	R/W	Set sensor gain: 0=1x gain, 1=3.7x, 2=16x, 3=64x	DEZ	0 – 3	1
ATLED0	R/W	Enables or disables the indication led	DEZ	0: LED off / 1: LED on	1
ATLAI	R/W	Read lower light address identifier	DEZ	0 – 65535	65535
ATLAIE	R/W	Read higher light address identifier	DEZ	0 – 65535	65535
ATTEMP	R	Read the current device temperature in degrees Celsius	DEZ	-	-
ATEVENT	R	Read the 16-bit EVENT register, clearing the entire register after the read	HEX	Bit0: OCC An occupancy (OCC) event has occurred since the last register read Bit1: DIM An adjustment to the dimming level (DIM) has occurred since the last register read. Bit2: LED23M An adjustment to the color tune level (LED23M) has occurred since the last register read. Bit3: Not used Bit4: SCENE A scene has triggered since the last register read Bit5: DL_LIMIT The lumen controller has reached a limit, target value cannot reached Bit6: CT_LIMIT The color temperature controller has reached a limit, target value cannot reached	0x0000
ATPERSMEM	R/W	Enable/Disable writing to persistent memory	DEZ	0: Disabled, 1: Enabled	0
ATSRST	W	Software Reset	-	-	-
ATFRST	W	Factory Reset. Stored values are reset to ‘Factory’ defaults. Afterwards a software reset is started.	-	-	-
Basic CCT Tuning Control and Color Data					
ATCT	R/W	Enables/disables color tuning	DEZ	1: ON, 0: OFF	0
ATCCTT	R/W	Set the color control target value in integer (in K)	DEZ	400 – 15000	2700
ATCCTC	R	Return the calibrated CCT value	DEZ	400 – 15000	-
ATDUVC	R	Read delta uv values	DEZ	XXXX.XXXX	-

Command	Direction	Description	Format	Value Range	Default
ATXYZC	R	Read calibrated X, Y, and Z data	DEZ	<XXX.X, YYY.Y, ZZZ.Z>	-
ATSMALLXYC	R	Read calibrated x and y for CIE 1931 color gamut	DEZ	<xxxxx.xxxx, yyyyy.yyyy>	-
ATUVPRIMEC	R	Read calibrated u', v' and u, v for CIE 1976 color gamut	DEZ	<u'u'u'u'u'.u'u'u'u',v'v'v'v'v'.v'v'v'v', uuuuu.uuuu,vvvvv.vvvv>	-
Daylight Harvesting / Illumination Control					
ATDL	R/W	Enables/disables daylight harvesting	DEZ	1: ON, 0: OFF	0
ATLUXT	R/W	Set illumination target LUX value	DEZ	0 – 64000	400
ATLUXS	R/W	Switch between lux values from internal sensor and external ambient light sensor	DEZ	0: Auto detect (higher priority is external sensor) 1: Internal sensor 2: External ambient light sensor	0
ATLUXC	R	Read the illumination of the internal sensor in lux	DEZ	0 – 64000 65535 – LUX value is in saturation	-
ATDMLTL	R/W	Configures the low-end DIM output to support also dimmers without full range dimming (e.g. 10%-100%)	DEZ	0 – 50	0
DIM Input Pin and Mapping					
ATDE	R/W	Enable/disable DIM pin	DEZ	1: ON, 0: OFF	0
ATDMD	R/W	Set DIM pin mode. Only used if ATDE enabled!	DEZ	0: DIM mode Range from 0% to 100%, direct regulation of the brightness of the PWM outputs 1: LUX mode Range from 0% to 100%, direct regulation of the illumination [LUX]. Ranges can be set via ATDMINLUX and ATDMAXLUX. Overwrites the ATLUXT command	0
ATDMIN	R/W	ATDMIN sets low end of DIM pin, using an integer percentage of 10V. For example ATDMIN=20 sets the lower DIM pin range to 2.0 V (10V x 20%) for 0% brightness.	DEZ	0: ATDMAX	0
ATDMAX	R/W	ATDMAX sets high end of DIM pin, using an integer percentage of 10 V. For example ATDMAX=80 sets the higher DIM pin range to 8.0 V (10V x 80%) for 100% brightness.	DEZ	ATDMIN – 100	100
ATDMINLUX	R/W	Set the current min LUX target value for the DIM pin range.	DEZ	0: ATDMAXLUX	0

Command	Direction	Description	Format	Value Range	Default
ATDMAXLUX	R/W	Set the current max LUX target value for the DIM pin range.	DEZ	ATDMINLUX – 64000	64000
ATPCTLUX	R/W	Set the lux target value in percentage between ATDMINLUX and ATDMAXLUX	DEZ	0 – 100, can read back also 101, which means that the internal set target value is out of range	0
ATDVAL	R	Reads the current analog value of the DIM pin in digits	DEZ	0 – 1023	-
AUX Input Pin and Mapping					
ATXE	R/W	Set AUX input function enable. When set to 0, all ATXMD operations are held in default mode.	DEZ	1: ON, 0: OFF	0
ATXMD	R/W	Set AUX pin mode. When ATXE=0, all ATXMD operations are disabled.	DEZ	0: AUX mode This is for AUX pin usage as a 0 – 3 V input that can scale the DIM pin input. 1: OCC mode This is for the AUX pin to act as a digital occupancy input (50% threshold) for the OCC timer. 1 = Occupancy, 0 = No occupancy. See also ATOCCT 2: CT_TUNE mode This is for AUX pin usage as CCT target. Overwrites the ATCCTT command 3: CT_SEL mode Selected CCT target values, configured in 300 mV step width	0
ATXMIN	R/W	Sets lower end of 0-3 V AUX pin, using an integer percentage of 3 V. For example if ATXMIN=25 sets an AUX pin range from 0.75 V (25% x 3v) to 3 V for 0-100% scaling.	DEZ	0: ATXMAX	0
ATXMAX	R/W	Sets higher end of 0-3 V AUX pin, using an integer percentage of 3 V. For example if ATXMAX=75 sets an AUX pin range to 2.25 V (25% x 3v) to 3 V for 0-100% scaling.	DEZ	ATXMIN – 100	100
ATXMINCCT	R/W	Sets min CCT for minimum AUX value in K in AUX CCT_TUNE mode	DEZ	400 – ATXMAXCCT	400
ATXMAXCCT	R/W	Sets max CCTT for AUX pin=3 V in K in AUX CCT_TUNE mode	DEZ	ATXMINCCT – 15000	15000
ATXVAL	R	Reads the current analog value of the AUX pin in digits	DEZ	0 – 1023	-
ATOCCT	R/W	Set Occupancy timeout value for ATXMD = 1	DEZ	1 – 10 [minutes]	10

Command	Direction	Description	Format	Value Range	Default
PWM Configuration and Overrides					
ATDIM	R/W	Set dim level in percent (0% off, 100% full brightness)	DEZ	0 – 100	0
ATBLINK	R/W	Starts the light on a low-high-low output blink to allow identification during a commissioning or maintenance process	DEZ	1: ON, 0: OFF	0
ATLOG	R/W	Set alternate dimming curve (DALI approximation)	DEZ	1: Logarithmic 0: Linear	0
ATRAMP	R/W	Set ramp time for lighting adjustments in percent. Time configuration is used for ATXPWM, ATDIM, ATLED23M, occupancy and Light on/off	DEZ	0: No ramp used 1 – 100: Ramp time in percent (1s - 10s) Example: DIM 50% – 0% with ATRAMP=50 takes 2.5 s	50
ATPWMFREQ	R/W	Set/Get the PWM frequency in Hertz, SYNC-Input is only at 886 Hz enabled	DEZ	100 – 4000 Hz	886
ATPWMx	R/W	Set PWMx Duty Cycle target as an integer percentage value between 0 and 100, removing it from any control loop. Returns always the current configured PWM value in percent (x = 1 … 3)	DEZ	0 – 100 102 - Release PWM back into loop control	PWM1: 0 PWM2: 50 PWM3: 50
ATXPWMx	R/W	Set PWMx Duty Cycle target as an integer percentage value between 0 and 100, removing it from any control loop. Returns always the current configured PWM value in percent. Note: A PWM in an XPWM override mode will be affected by the DIM pin value when AUX is in DIM mode. In AUX mode it is also affected by the AUX pin value. (x = 1 .. 3)	DEZ	0 – 100 102 - Release PWM back into loop control	PWM1: 0 PWM2: 50 PWM3: 50
ATPWMOVR	R	Read the single 16-bit sum of PWMs to identify which have been over-ridden and removed from any closed-loop control loop	HEX	Bit0: ATXPWM1 active Bit1: ATXPWM2 active Bit2: ATXPWM3 active Bit4: ATPWM1 active Bit5: ATPWM2 active Bit6: ATPWM3 active	0x00

Command	Direction	Description	Format	Value Range	Default
ATLED23M	R/W	Set the value for PWM2 as a percentage to drive manual LED string mixing. PWM3 = 100 - PWM2. The sum is 100	DEZ	PWM2: 0 – 100	50
Scene Configuration and Management					
ATTIMENOW	R/W	Set the current time with 1 minute resolution (update every 30min recommended for best scene synchronization)	DEZ	0 – 1439, 65535 - Disabled	65535
ATDOW	R/W	Set day of week	DEZ	0 (Monday) – 6 (Sunday) 255 - Disabled	255
ATCCLR	W	Restores scene command defaults in the specified scene.	HEX	One bit for each scene. 1 = Reset	-
ATSnDAY	R/W	Set scene n day(s) of week for scene operation, as a decimal sum	HEX	A 1 in a bit location activates that day. lsb=1=Monday operation, etc. (e.g. 07 hex=Wed,Tue, Mon) 0x00 - Days not configured	0x00
ATSnTIME	R/W	Set scene n start time	DEZ	0 – 1439: 1 minute steps from Midnight 65535 - Scene time not configured	0xFFFF
ATSnCCT	R/W	Calls the ATCCTT command at scene trigger time	DEZ	See command ATCCT, 65535 – Value not used	65535
ATSnLUX	R/W	Calls the ATLUXT command at scene trigger time	DEZ	See command ATLUXT, 65535 – Value not used	65535
ATSnDIM	R/W	Calls the ATDIM command at scene trigger time	DEZ	0 – 100, 255 – Value not used	255
ATSnLED23M	R/W	Calls the ATLED23M command at scene trigger time	DEZ	0 – 100, 255 – Value not used	255
ATSnPWMx	R/W	Calls the ATXPWMx command at scene trigger time	DEZ	0 - 100, 255 – Value not used	255
ATSnRAMP	R/W	Sets ramp duration time in minutes for the command: - ATSnPWMx, ATSnDIM, ATLED23 – ramp will be handled by RAMP-generator - ATSnLUX, ATSnCCT – ramp is handled by scene loop (every second) and can be stopped by configuration of new target values This command acts only for the scene trigger time and not global like the ATRAMP command	DEZ	0 – 240 255 – Value not used	255

Command	Direction	Description	Format	Value Range	Default
ATSnFLAGS	R/W	This command is used to enable/disable configuration flags like daylight control, color tuning, dimming, auxiliary and calls directly the related commands: ATDL, ATCT, ATDE, ATXE	HEX	0x0001 – Enable DL 0x0002 – Enable CT 0x0004 – Enable DIM pin 0x0008 – Enable AUX pin functions 0xFFFF - Value not used	0xFFFF
ATSnON	W	Set scene n to be on/off.	DEZ	1: ON, 0: OFF	0
ATTSON	R	Read scenes on/off status.	HEX	Each bit for one scene	0x0000
I²C Configurations and UART-I²C Data Bridge					
ATESP	R	Read the single 16-bit sum to determine availability of natively supported I²C devices	HEX	Bit0: **ams** TSL4531 or TSL2572 Bit1: **ams** ENS210 Bit2: HTU20D (ESP1 only- obsolete) Bit3: **ams** CCS811	-
ATTEMPX	R	Read the external temperature in degrees Celsius	DEZ	-40 – 125°C (format: XXX.XX)	-
ATRHX	R	Read the external humidity in percent	DEZ	0 – 100% (format: XXX.XX)	-
ATECO2	R	Reads the eCO2 [in ppm] value from the external gas sensor, if available	DEZ	400 ppm – 64000 ppm 0 - Means that values will be measured, but internal calibration is not finished (wait 1min)	-
ATTVOC	R	Reads the TVOC [in ppb] value from the external gas sensor, if available	DEZ	0ppb – 64000ppb	-
ATI2C	W	Perform a single write to the I2C bus at the specified 7-bit device using the 8 bits of specified data. Supports also a single register set (without value)	-	ATI2C=<7-bit_address>, <8-bit_reg>, [<8-bit_data>] - [<8-bit_data>] is optional Examples: - ATI2C=50,0x12, 0xFF: Writes value 0xFF to register 0x12 on device address 50 - ATI2C=50,0x12,: Set register 0x12 on device address 50	-
ATI2C	R	Perform a single read from the I2C bus at the specified 7-bit device address and 8-bit register, returning 8 bits of data or ERROR	HEX	ATI2C=<7-bit_address>, <8-bit_reg>	-

Command	Direction	Description	Format	Value Range	Default
ATI2CB	W	Starts a burst transfer up to 10 bytes for writing and reading. At first the data will be written and after then read sequence will be started	HEX	ATI2CB=<7-bit_address>,<read_length>[,<write_data>] - first two parameter can be hex or dez, - <write_data> must be hex without leading 0x, but is optional examples: ATI2CB=<7-bit_address>,<read_length>[,<write_data>] - first two parameter can be hex or dez, - <write_data> must be hex without leading 0x, but is optional examples: ATI2CB=0x49,2: reads two byte from addr 0x49 ATI2CB=50,4,5BF3: writes 0x5B and 0xF3 to address 50 and read 4 bytes after this	-
Calibration Management					
ATDATA	R	Read all six raw values: X, Y, Z, IR, dark, clear	DEZ	<X, Y, Z, ir, d, c>	-
ATAMxy	R/W	Write 3x3 application matrix to flash, x,y = [0..2]	DEZ	-	1,0,0 0,1,0 0,0,1
ATNORMGAIN	R/W	Set/Get the gain which the calibration values were measured	DEZ	0 – 3	1
ATNORMINTT	R/W	Set/Get the integration time which the calibration values were measured	DEZ	1 – 255	59
ATIRXS	R/W	Write IR scalar for value X	DEZ	-	p2ram value 0.0
ATIRYS	R/W	Write IR scalar for value Y	DEZ	-	p2ram value 0.0
ATIRZS	R/W	Write IR scalar for value Z	DEZ	-	p2ram value 0.0
ATPMxy	R/W	Write 3x3 color matrix to flash, x,y = [0..2]	DEZ	-	p2ram value 1,0,0 0,1,0 0,0,1
ATLXSL0	R/W	Reads and writes the calibration scalar K0 for external ambient light sensor (TSL2572 only); Formula: LUX=K0*ADC0-K1*ADC1	DEZ	≥0	0.2178

Command	Direction	Description	Format	Value Range	Default
ATLXSL1	R/W	Reads and writes the calibration scalar K1 for external ambient light sensor (TSL2572 only); Formula K0>0: LUX=K0*ADC0-K1*ADC1 K0=0: LUX=K1*ADC1	DEZ	≥0	0
Firmware and Firmware Update					
ATVERSW	R	Return the current software version number	DEZ	<MAJOR.MINOR.PATCH>	-
ATVERHW	R	Returns the system hardware as a HEX value of the form PRDTx where P=PartID and R=ChipRevision and DT= DeviceType	HEX	<0xPRDT> PR: 40 DT: 15 (AS7221)	0x4015
ATFWU	W	Starts firmware update process and transfer the bin file checksum	-	-	-
ATFW	W	Download new firmware Up to 10 bytes of FW image at a time (20 hex bytes with no leading or trailing 0x) Repeat command till all 56Kbytes of firmware are downloaded	-	HEX STRING (without 0x)	-
ATFWS	W	Tests the checksum on the non-active FW partition and, if correct, switches active partition. This is a toggle and can be used to toggle between the 2 FW partitions. Note: the first 5 bytes in page 0 are not touched. It is only a temporary switch and must be used to check the new firmware whether the communication works!	-	-	-
ATFWL	W	This command locks the current firmware to starts on power cycles. It rewrites the first five bytes in page0!	-	-	-

Command	Direction	Description	Format	Value Range	Default
ATFWC	R	This command gives information about the current firmware state	-	Bit0: Checksum of non-active firmware OK Bit1: Error occurred Bit2: Is bank 1 active Bit3: Not used Bit4: Current firmware is locked Bit5: 56 kBytes transferred Bit6: Not used Bit7: Firmware update active	-
ATFWA	W	Only for backward compatibility to support old firmware update mechanism. Always returns with OK. Because of flash devices it is not possible to increment the address separately (Page erase necessary!)	-	-	-

11 Application Information

Figure 33, Figure 34 and Figure 35 showing typical application schematics for the AS7221. Figure 37 illustrates a routing example for the device and Figure 38 gives the recommended pad layout for the LGA package.

11.1 Schematic

Figure 33:
Chromatic Color Tuning with Networking and Spectral Sensing (page 1)

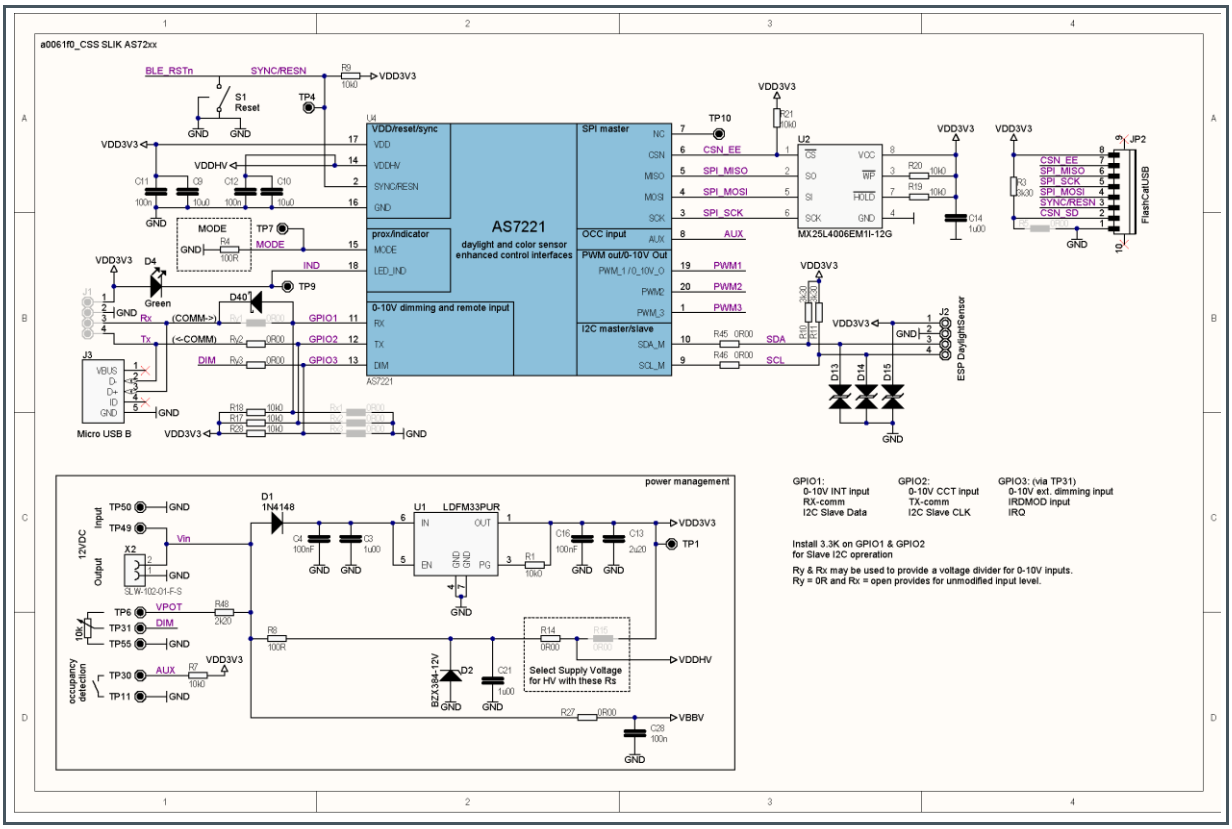


Figure 34:
Chromatic Color Tuning with Networking and Spectral Sensing (page2)

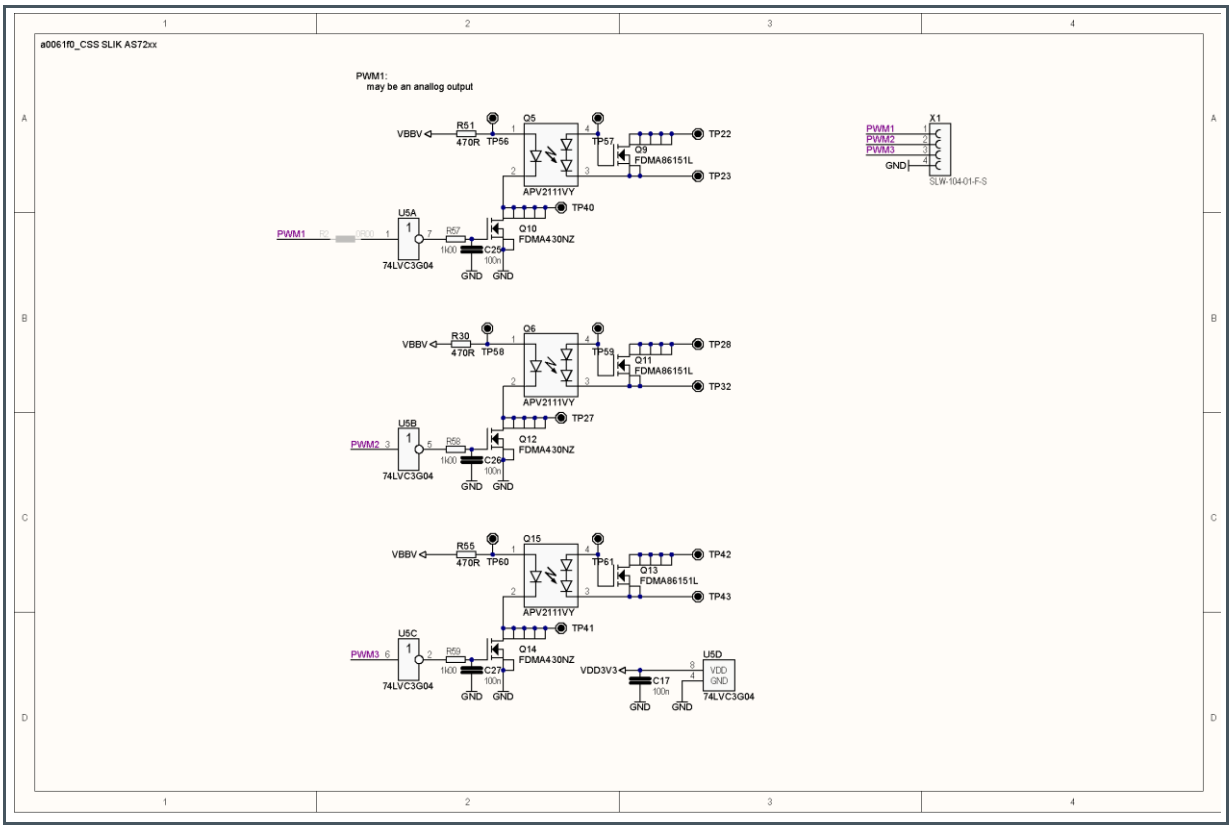
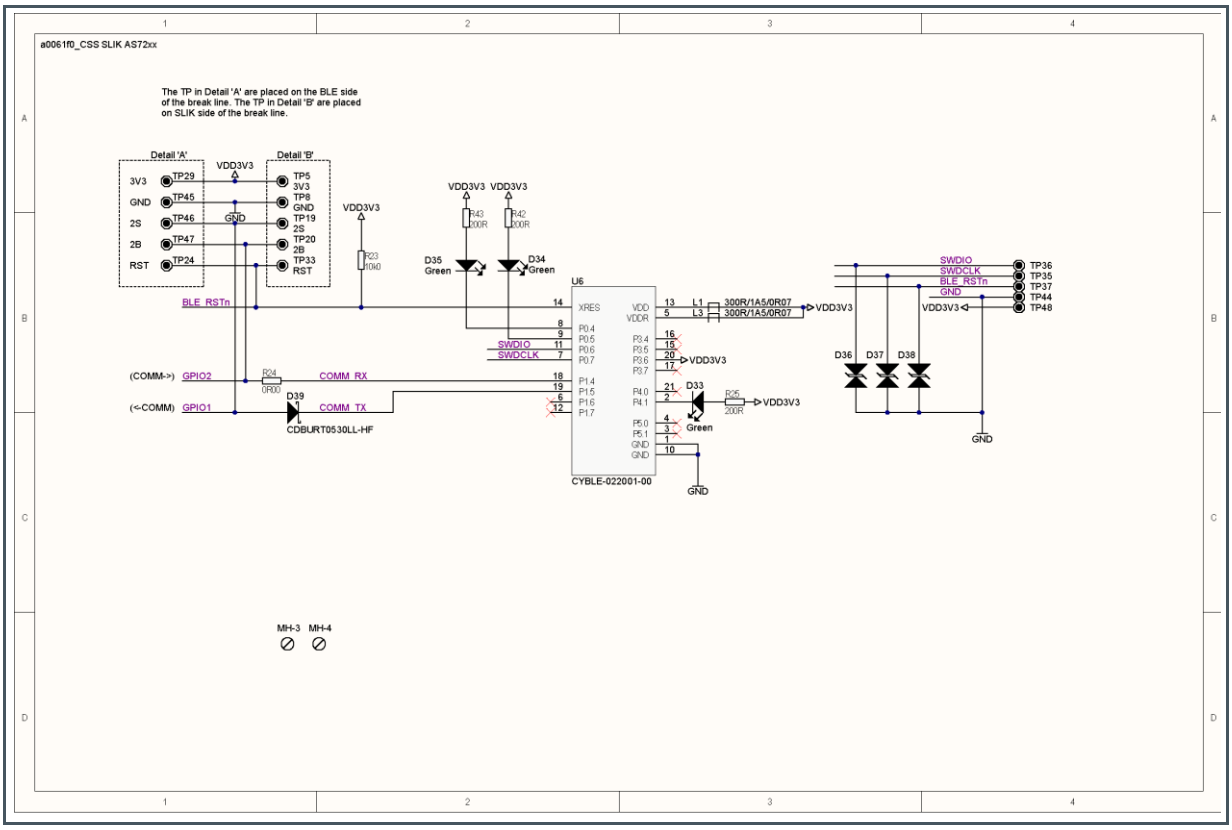
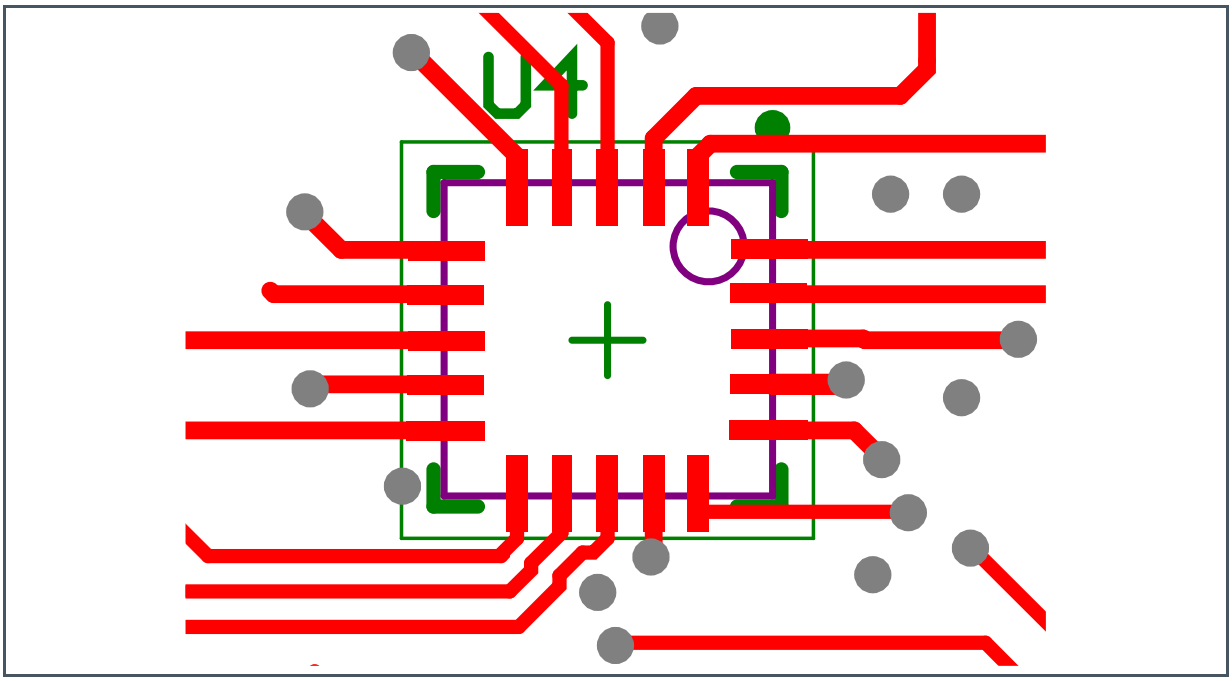


Figure 35:
Chromatic Color Tuning with Networking and Spectral Sensing (page3)



11.2 PCB Layout

Figure 36:
Typical Layout Reading



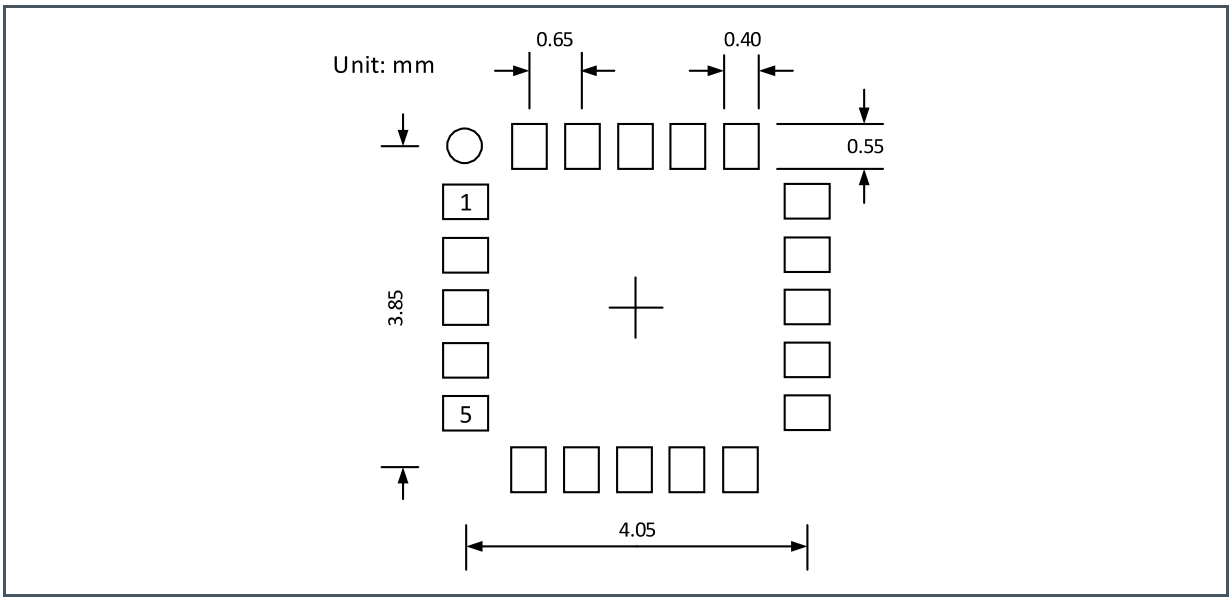
In order to prevent interference, avoid trace routing feedthroughs with exposure directly under the AS7221. An example routing is illustrated in the diagram.

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

11.3 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.

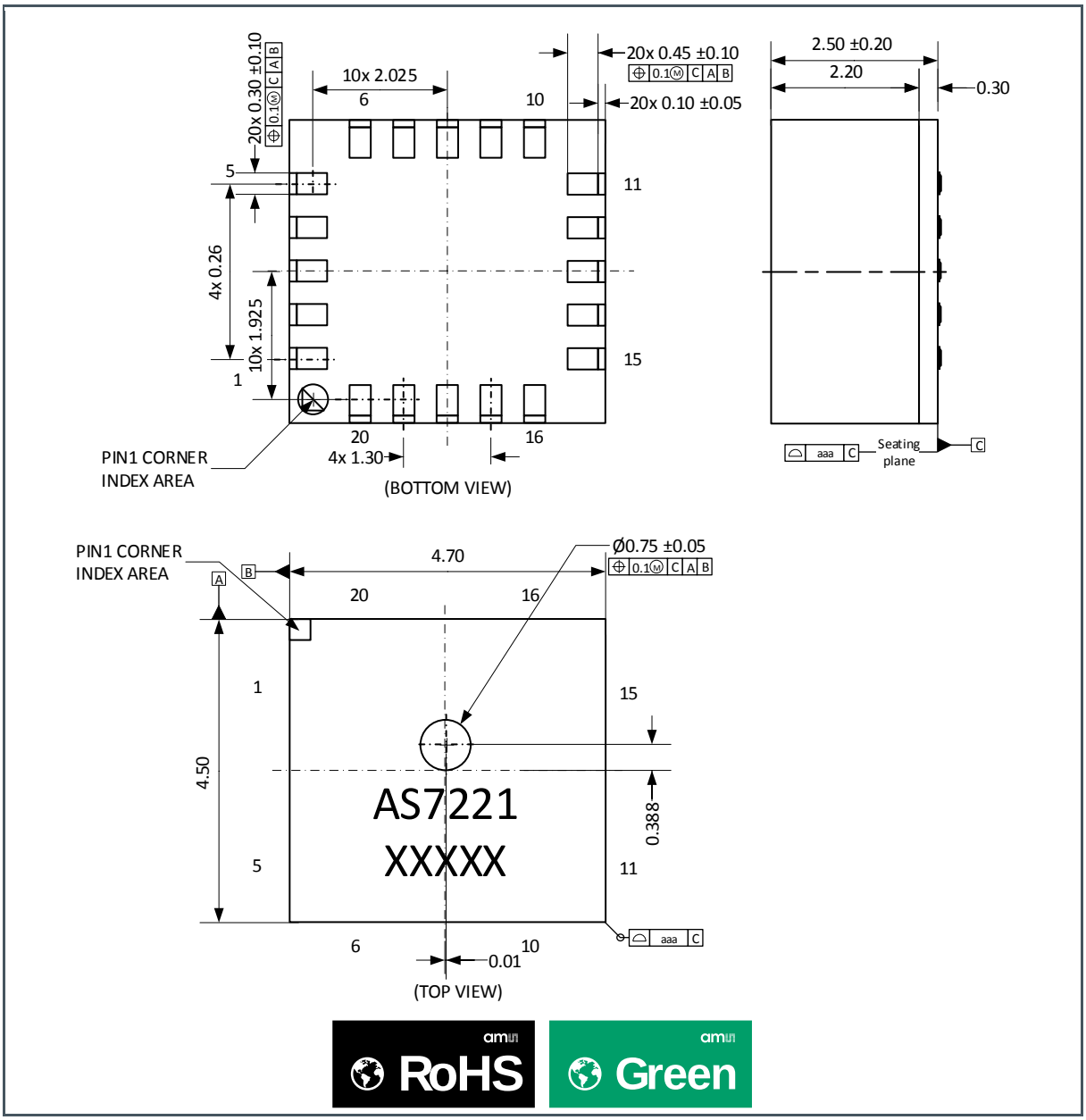
Figure 37:
Recommended PCB Pad Layout (Top View)



(1) Unless otherwise specified, all dimensions are in millimeters.
(2) Add 0.05mm all around the nominal lead width and length for the PCB pad land pattern.
(3) This drawing is subject to change without notice.

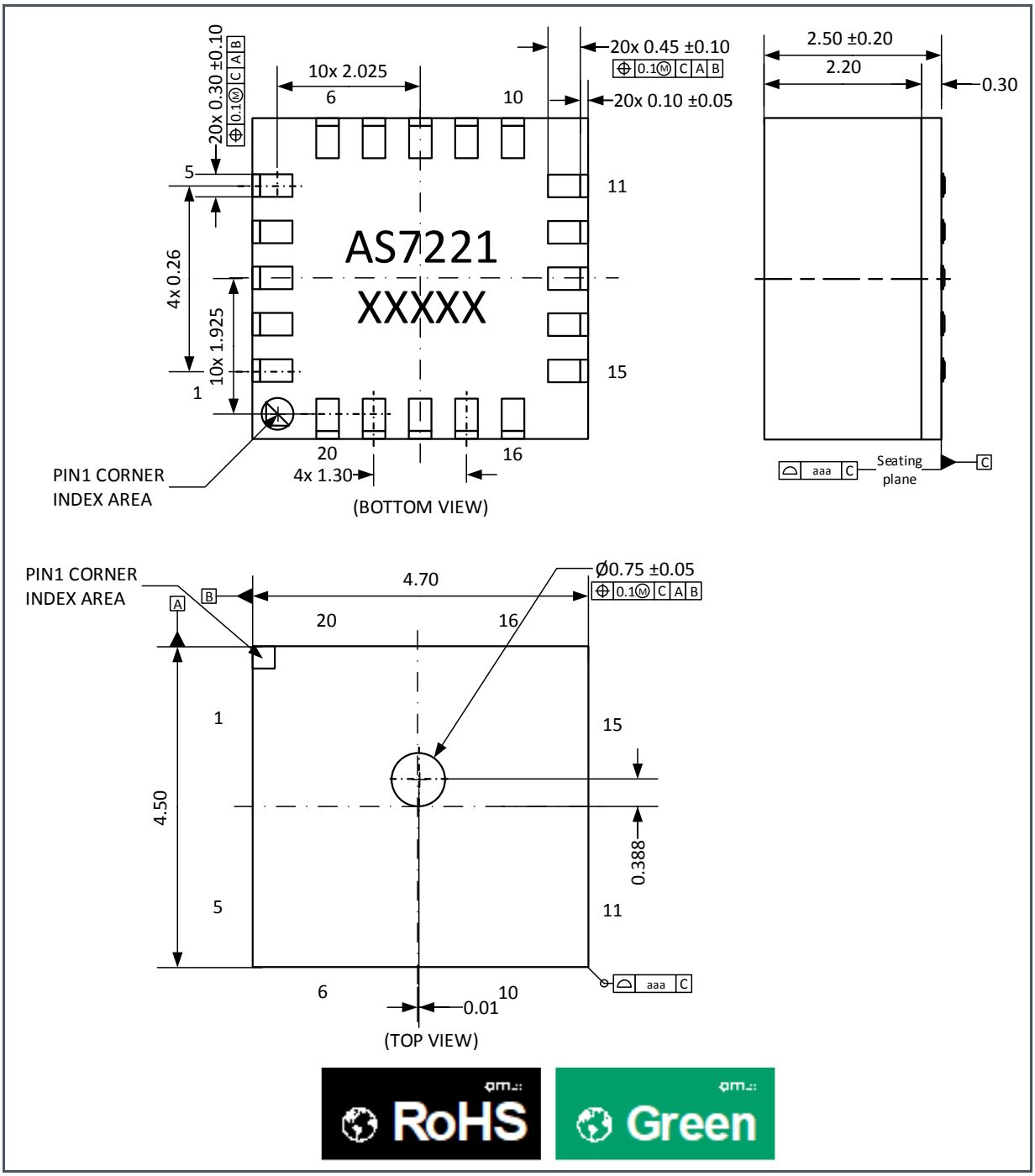
12 Package Drawings & Markings

Figure 38:
20-Pin LGA Package Outline Drawing (Front Side Marking)



(1) All dimensions are in millimeters. Angles in degrees.
(2) Dimensioning and tolerancing conform to ASME Y14.5M-1994.
(3) XXXXX = tracecode
(4) This package contains no lead (Pb).
(5) This drawing is subject to change without notice.

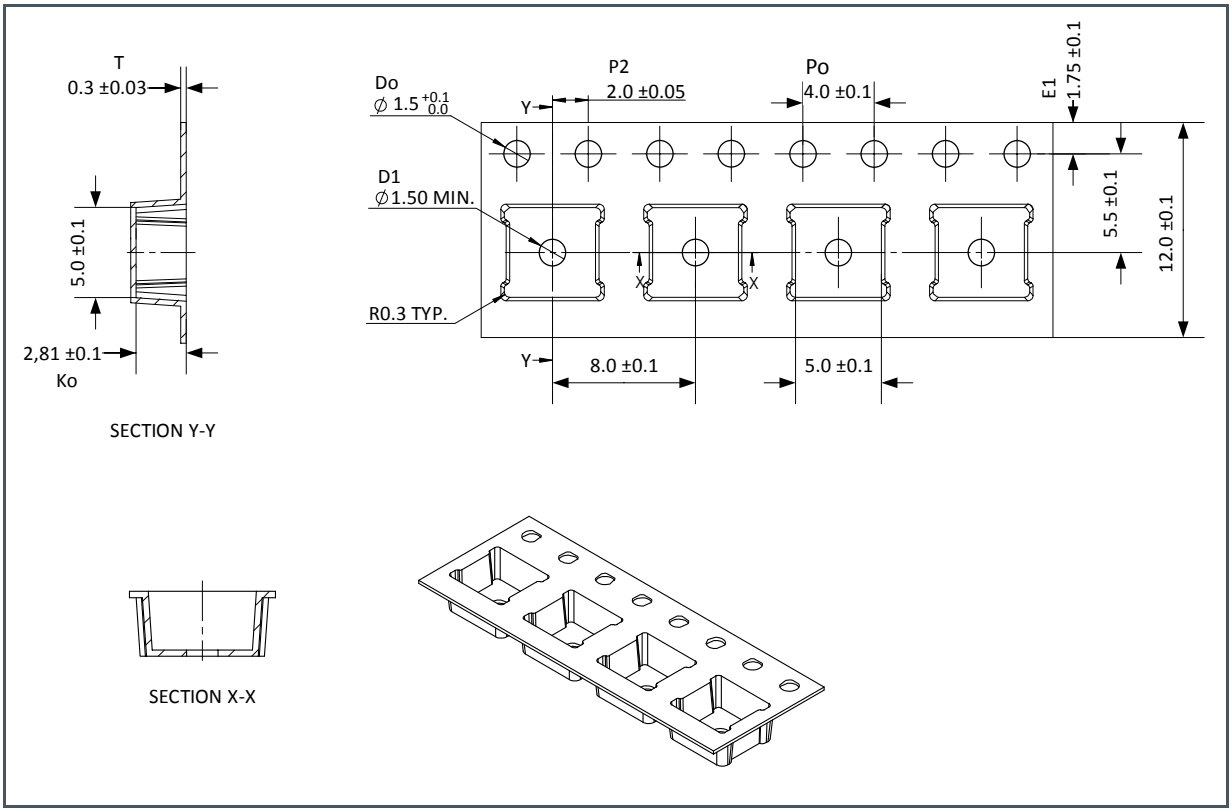
Figure 39:
20-PIN LGA Package Outline Drawing (Back Side Marking)



(1) All dimensions are in millimeters. Angles in degrees.
(2) Dimensioning and tolerancing conform to ASME Y14.5M-1994.
(3) XXXXX = tracecode
(4) This package contains no lead (Pb).
(5) This drawing is subject to change without notice.

13 Tape & Reel Information

Figure 40:
Tape Dimensions



(1) All dimensions are in millimeters. Angles in degrees.
(2) Geometric dimensioning and tolerancing conform to ASME Y14.5M-1994.
(3) This drawing is subject to change without notice.

14 Soldering & Storage Information

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 the component. The components should be limited to a maximum of three passes through this solder reflow profile.

Figure 41:
Solder Reflow Profile Graph

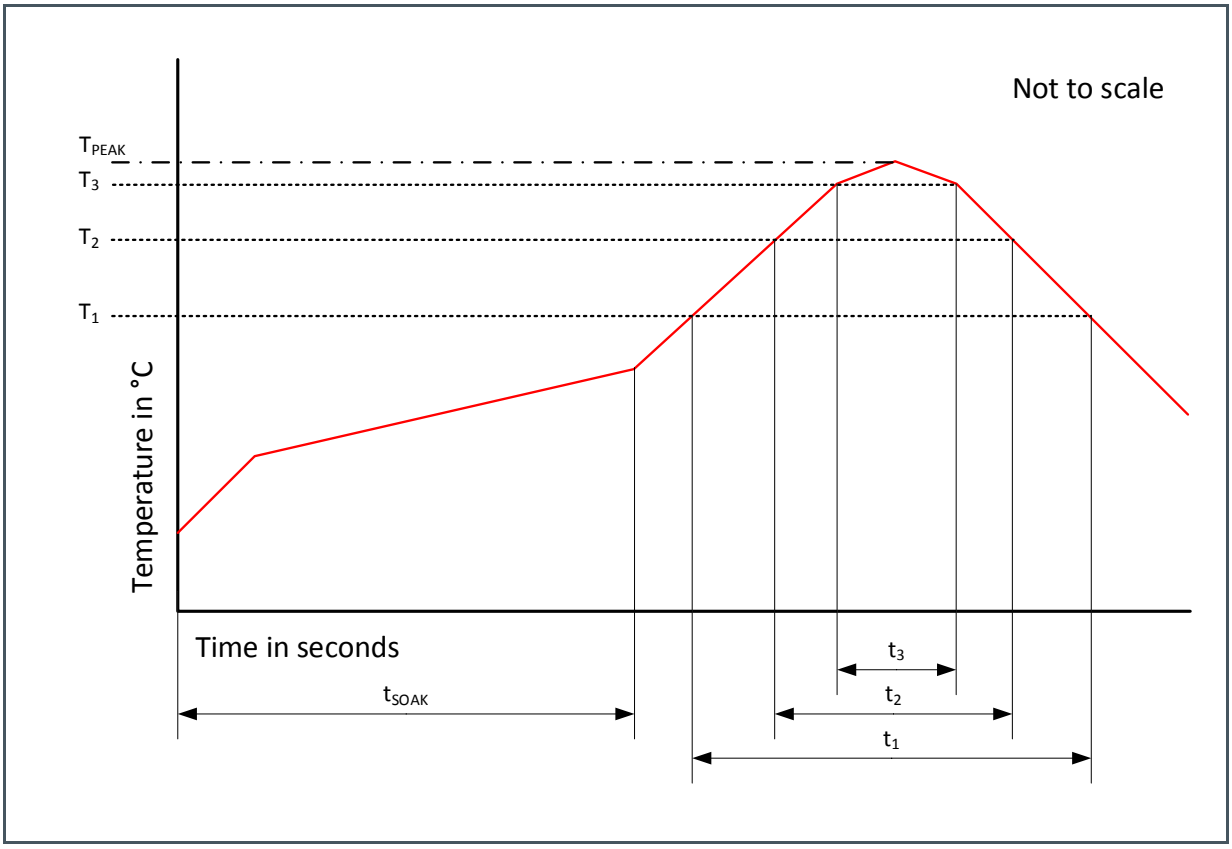


Figure 42:
Solder Reflow Profile

Parameter	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

Parameter	Reference	Device
Time above T_{peak} – 10 °C (T3)	t_3	Max 10s
Peak temperature in reflow	T_{peak}	260°C
Temperature gradient in cooling		Max - 5°C/s

14.1 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.

14.2 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.

14.2.1 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.

14.2.2 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.

14.3 Rebaking Instructions

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

15 Revision Information

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
Preliminary Datasheet	Pre-Production	Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice
Datasheet	Production	Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade
Datasheet (discontinued)	Discontinued	Information in this datasheet is based on products which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs

Changes from previous version to current revision v4-00	Page
Update Figure 2 Block Diagram	5
Update Figure 5, format	9
Update Optical Characteristic	12
Added diffusor functionality	15
Added scene ramps	15
Added Figure xx AS7221 workflow abstract	16
Update ALS, replacement TSL25911 due to TSL2572	16, 17, 23, 39
Added calibration TSL2572	17
Update dimming input	19
Added CCT_SEL mode	20
Update PWM output frequency	21
Update indicator LED behavior	22
Added f_{SCL} max in Figure 22	24
Update intro UART command interface	28
Update Figure 27 SPI Timing Characteristic	29, 30
Update Figure 30 Serial Flash Overview	31
Update Figure 32 AT Command List	33-42
Added Figure 39 Backside Marking	49

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