9 Programmable LED Driver

FEATURES

- 8-level LED Maximum Current for each LED, max 24.5mA
- Internal ASP with 256*16bit SRAM
- Programmable to Achieve Custom Light Effect
- 256-level Linear/Logarithmic PWM Dimming,9 bits PWM resolution
- Compatible I²C Interface, V_{IO}: 1.8V ~ 3.3V
- Single Power Supply, Voltage Range: 3.0V ~ 4.5V
- QFN 3mm×3mm×0.75mm- 20L Package

GENERAL DESCRIPTION

AW9109 integrates a SRAM program-controlled 9 LED driver. 9 LED driver uses common anode current source and PWM dimming. Each LED is 8-level driver current selectable with dimming independently controlled by external MCU or internal 256word*16bit SRAM program.

Compatible I²C interface of 400kHz fast mode is provided. It requires only 3.0V-4.5V single power supply.

APPLICATIONS

Mobile Phones, MID

Portable Media Player

Home Appliances

TYPICAL APPLICATION CIRCUIT

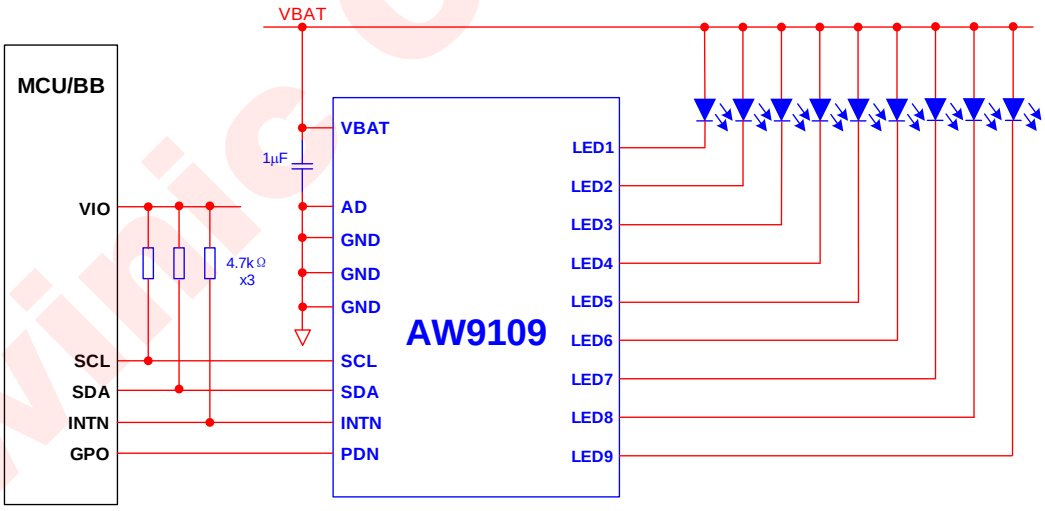

Figure 1 AW9109 Typical Application Circuit

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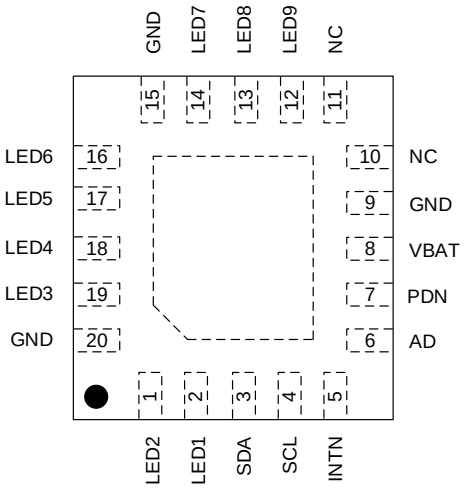
CONTENT

1 PIN CONFIGURATION AND TOP MARK

AW9109 Top View



AW9109 Marking

AW9109-AW9109QNR
XXXX-Production Tracing Code

2 PIN DEFINITION

No.	NAME	DESCRIPTION
1	LED2	LED2 cathode driver, anode connected to VBAT
2	LED1	LED1 cathode driver, anode connected to VBAT
3	SDA	Data I/O of I²C Interface
4	SCL	Clock input of I²C Interface
5	INTN	Open-drain Interrupt output, low active. Typically connected to VIO via a 4.7kΩ resistor. (floating if not unused)
6	AD	I²C address select pin
7	PDN	Power-down input , low active, internal 1MΩ pull-down resistor
8	VBAT	Power supply (3.0V to 4.5V)
9	GND	Ground
10	NC	NC
11	NC	NC
12	LED9	LED9 cathode driver, anode connected to VBAT
13	LED8	LED8 cathode driver, anode connected to VBAT
14	LED7	LED7 cathode driver, anode connected to VBAT
15	GND	Ground
16	LED6	LED6 cathode driver, anode connected to VBAT
17	LED5	LED5 cathode driver, anode connected to VBAT
18	LED4	LED4 cathode driver, anode connected to VBAT
19	LED3	LED3 cathode driver, anode connected to VBAT
20	GND	Ground

3 FUNCTIONAL BLOCK DIAGRAM

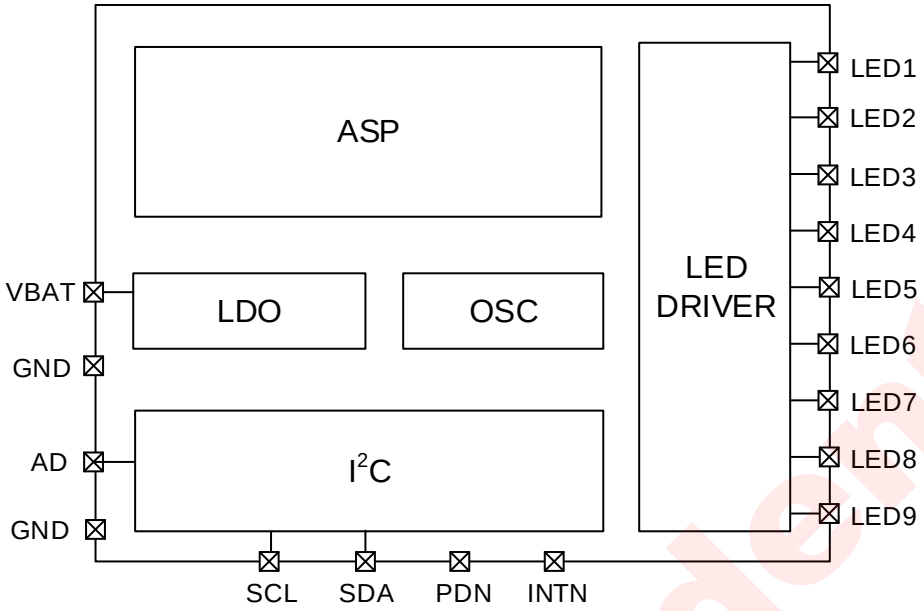


Figure 2 FUNCTIONAL BLOCK DIAGRAM

4 TYPICAL APPLICATION CIRCUITS

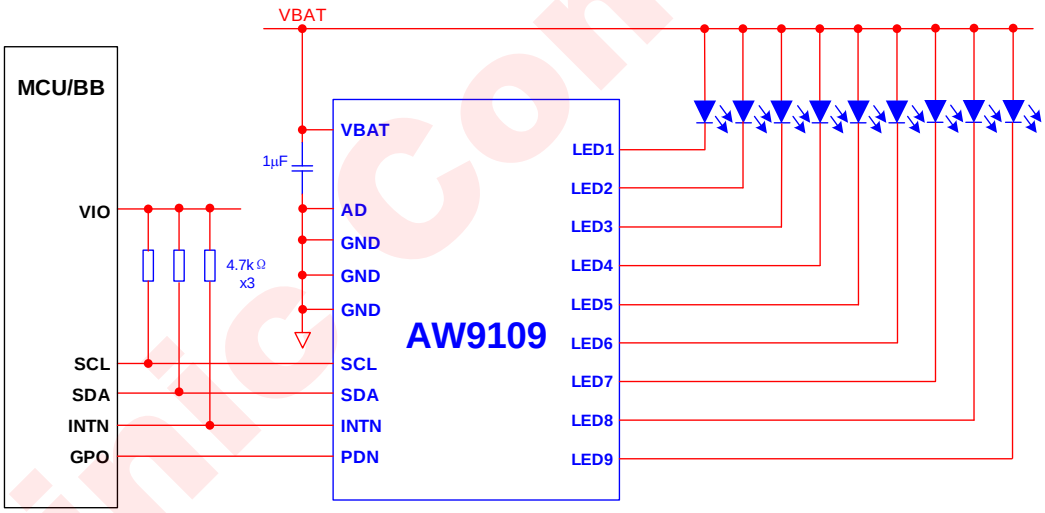
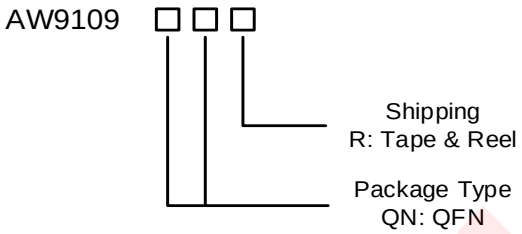


Figure 3 AW9109 Typical Application Circuit

5 ORDERING INFORMATION

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AW9109QNR	-40℃～85℃	3mm×3mm×0.75mm QFN-20L	AW9109	MSL3	ROHS+HF	6000 unit / Tape and Reel



6 ABSOLUTE MAXIMUM RATINGS(NOTE 3)

PARAMETERS		RANGE
Supply voltage range V_{BAT}		-0.3V to 5V
Input voltage range	SCL, SDA	-0.3V to 3.6V
	PDN, LED1~LED9	-0.3V to 4.5V
Output voltage range	SDA, INTN	-0.3V to 3.6V
Junction-to-ambient thermal resistance θ_{JA}		45℃/W
Operating free-air temperature range		-40℃ to 85℃
Maximum Junction temperature T_{JMAX}		150℃
Storage temperature T_{STG}		-65℃ to 150℃
Lead Temperature (Soldering 10 Seconds)		260℃
ESD(NOTE 4)		
HBM (human body model)		±4kV
Latch-up		
Test Condition: JEDEC STANDARD NO.78B DECEMBER 2008		+IT：450mA -IT：-450mA

NOTE3: Conditions out of those ranges listed in "absolute maximum ratings" may cause permanent damages to the device. In spite of the limits above, functional operation conditions of the device should within the ranges listed in "recommended operating conditions". Exposure to absolute-maximum-rated conditions for prolonged periods may affect device reliability.

NOTE4: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: MIL-STD-883G Method 3015.7

7 ELECTRICAL CHARACTERISTICS

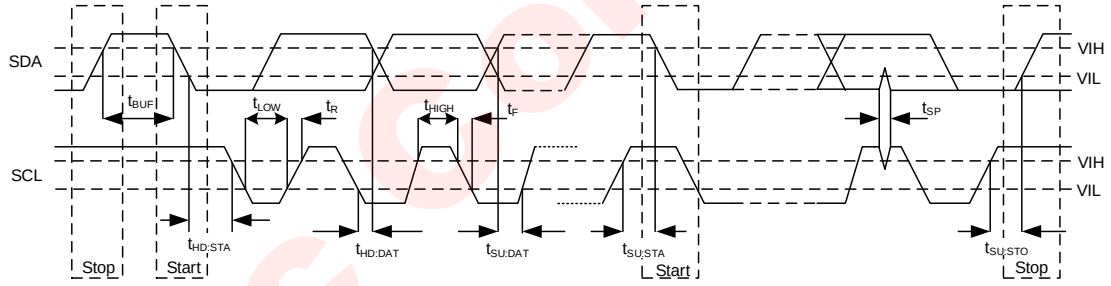
V_{BAT}=3.8V, T_A=25℃ for typical values (unless otherwise noted)

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
V_{BAT}	Power supply	-	3.0		4.5	V
$I_{SHUTDOWN}$	Current in Shutdown mode	PDN=GND		8	15	μA
$I_{STANDBY}$	Current in Standby mode	PDN=V_{IO}		130	160	μA
I_{ACTIVE}	Current in Active mode	PDN=V_{IO}, GCR=0x01		0.55	0.8	mA
F_{OSC}	Internal oscillator Frequency accuracy (16MHz)		14.8	16	17.2	MHz
Digital Logical Interface						
V_{IL}	Logic input low level	SDA,SCL,PDN	-0.3		0.45	V
V_{IH}	Logic input high level	SDA,SCL,PDN	0.9			V
I_{IL}	Low level input current	SDA,SCL,PDN		5		nA
I_{IH}	High level input current	SDA,SCL,PDN		5		nA
V_{OL}	Logic output low level	SDA, INTN I_{OUT}=3mA			0.4	V
I_{OL}	Maximum output current	SDA, INTN			10	mA
I_L	Output leakage current	SDA,INTN open drain			1	μA
I²C Interface						
F_{SCL}	I²C-BUS clock frequency				400	kHz
$T_{Deglitch}$	SCL deglitch time			200		ns
	SDA deglitch time			250		ns
LED Driver						
I_{MAX}	LED MAX Current	I_{LED}=24.5mA	18.5	24.5	30.5	mA
I_{MATCH}	Matching accuracy	I_{LED}=24.5mA			10	%
V_{DROP}	Drop-out voltage	I_{LED}=24.5mA			300	mV
F_{PWM}	PWM frequency	LCR.FREQ=1	110	122	135	Hz
		LCR.FREQ =0	220	244	270	Hz

NOTE5：the value is tested in default configuration.

8 I²C INTERFACE TIMING

Parameter Name			MIN	TYP	MAX	UNIT
F_{SCL}	Interface Clock frequency				400	kHz
$T_{DEGLITCH}$	Deglitch time	SCL		200		ns
		SDA		250		ns
$T_{HD:STA}$	(Repeat-start) Start condition hold time		0.6			μs
T_{LOW}	Low level width of SCL		1.3			μs
T_{HIGH}	High level width of SCL		0.6			μs
$T_{SU:STA}$	(Repeat-start) Start condition setup time		0.6			μs
$T_{HD:DAT}$	Data hold time		0			μs
$T_{SU:DAT}$	Data setup time		0.1			μs
T_R	Rising time of SDA and SCL				0.3	μs
T_F	Falling time of SDA and SCL				0.3	μs
$T_{SU:STO}$	Stop condition setup time		0.6			μs
T_{BUF}	Time between start and stop condition		1.3			μs



9 FUNCTIONAL DESCRIPTION

9.1 WORK MODE

9.1.1 Power On

After power-up, about 100μs delay is required before PDN set to high, otherwise, the device may work incorrectly. The minimal wait time for I²C communication is 5ms, during this period, some internal modules (such as LDO) start to work and reach a stable state.

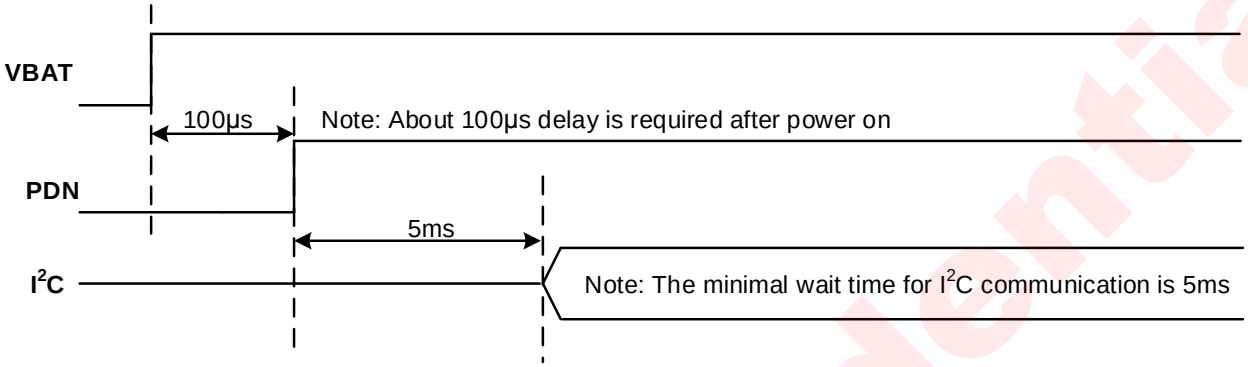


Figure 4 AW9109 Power On

9.1.2 Work Mode

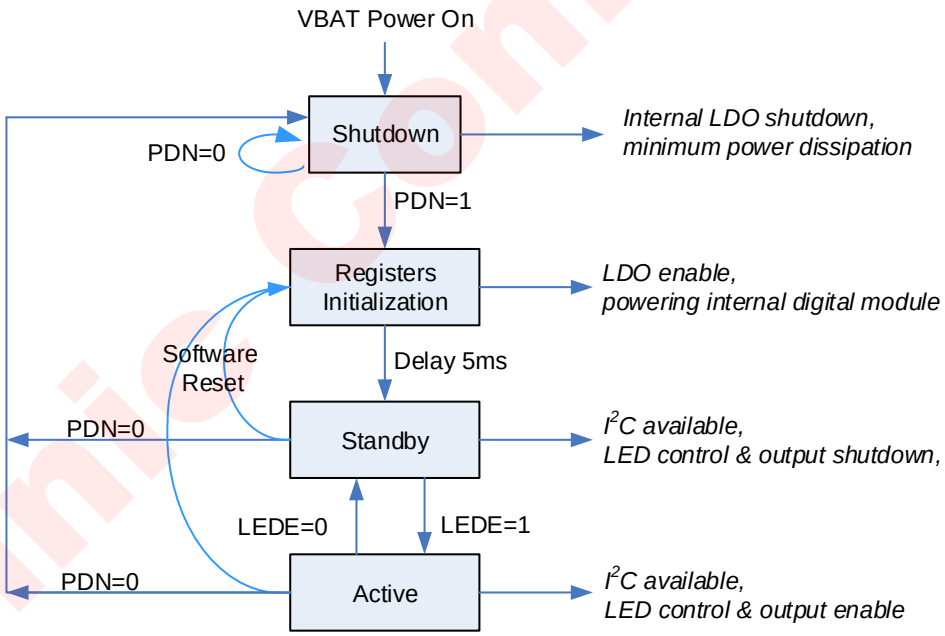


Figure 5 AW9109 Work Mode

After VBAT powered on, if PDN pin is low, the AW9109 is in shut-down mode, the current consumption is less than 15μA. When PDN pin becomes high, the internal LDO is activated, and a power-on reset (POR) signal is generated to initialize all internal registers, the device enters standby mode, this is a low power consumption mode, when all circuit functions are disabled. In standby mode, I²C interface is active, all internal configuration register can be written. If control bit GCR.LEDE is written high, the device enters the active mode.

9.2 RESET

9.2.1 Hardware Reset

When PDN pin changes from low to high, the power-up reset (POR) signal is generated, all internal registers are reset.

9.2.2 Software Reset

Writing 0x55AA to register RSTR via I²C interface will activate a software reset to reset all internal registers.

9.3 I²C INTERFACE

AW9109 supports the I²C serial bus and data transmission protocol in fast mode at 400kHz. It operates as a slave on the I²C bus. Connections to the bus are made via the open-drain I/O pins SCL and SDA. The pull-up resistor can be selected in the range of 1k~10kΩ and the typical value is 4.7kΩ. AW9109 can support different high level (1.8V~3.3V) of this I²C interface.

9.3.1 Device Address

The I²C device address (7-bit, followed by the R/W bit(Read=1/Write=0)) of AW9109 is 0x2C/0x2D.

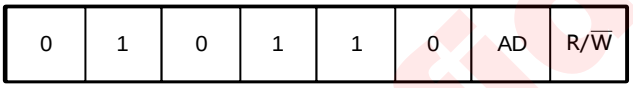


Figure 6 Device Address Configuration

9.3.2 Data Validation

When SCL is high level, SDA level must be constant. SDA can be changed only when SCL is low level.

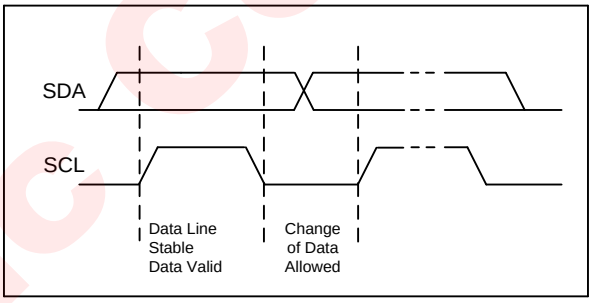


Figure 7 Data Validation Diagram

9.3.3 ACK(Acknowledgement)

ACK means the successful transfer of I2C bus data. After master sends 8bits data, SDA must be released; SDA is pulled to GND by slave device when slave acknowledges.

When master reads, AW9109 sends 8bit data, releases the SDA and waits for ACK from master. If ACK is send and I²C stop is not send by master, AW9109 sends the next data. If ACK is not send by master, AW9109 stops to send data and waits for I²C stop.

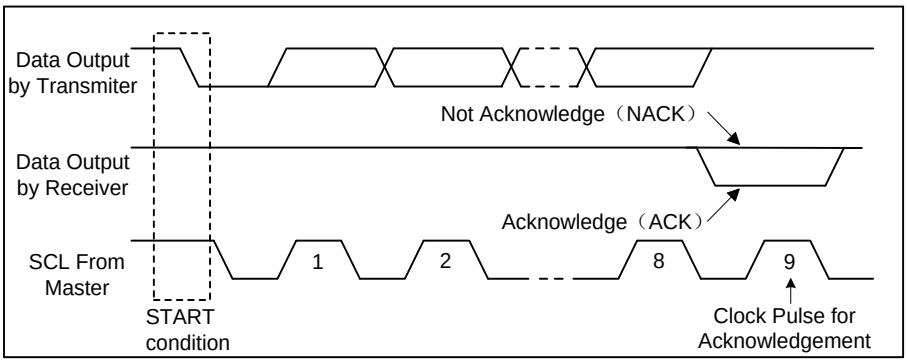


Figure 8 I²C ACK Timing

9.3.4 I²C Start/Stop

I2C start: SDA changes form high level to low level when SCL is high level.

I2C stop: SDA changes form low level to high level when SCL is high level.

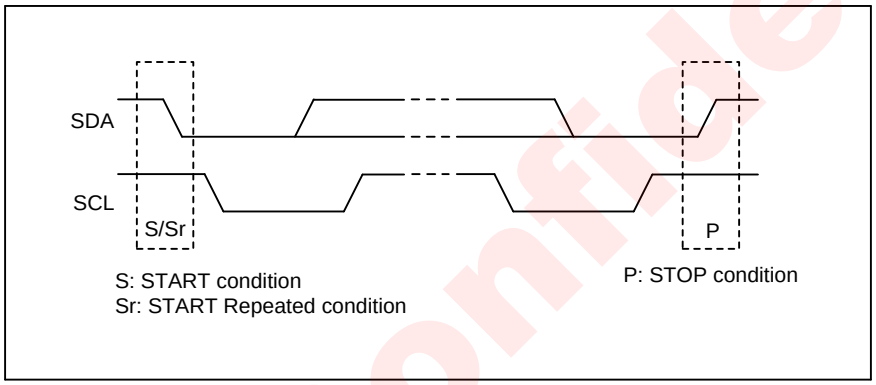


Figure 9 I²C Start/Stop Condition Timing

9.3.5 Write Cycle

One data bit is transferred during each clock pulse. Data is sampled during the high state of the serial clock (SCL). Consequently, throughout the clock's high period, the data should remain stable. Any changes on the SDA line during the high state of the SCL and in the middle of a transaction, aborts the current transaction. New data should be sent during the low SCL state. This protocol permits a single data line to transfer both command/control information and data using the synchronous serial clock.

Each data transaction is composed of a Start Condition, a number of byte transfers (set by the software) and a Stop Condition to terminate the transaction. Every byte written to the SDA bus must be 8 bits long and is transferred with the most significant bit first. After each byte, an Acknowledge signal must follow.

In a write process, the following steps should be followed:

a) Master device generates START condition. The "START" signal is generated by lowering the SDA signal while the SCL signal is high.

b) Master device sends slave address (7-bit) and the data direction bit (W = 0).

c) Slave device sends acknowledge signal if the slave address is correct.

d) Master sends control register address (8-bit)

e) Slave sends acknowledge signal

f) Master sends data high 8Bit to be written to the addressed register

g) Slave sends acknowledge signal

h) Master sends data low 8Bit to be written to the addressed register

I) Slave sends acknowledge signal

j) Master generates STOP condition to indicate write cycle end

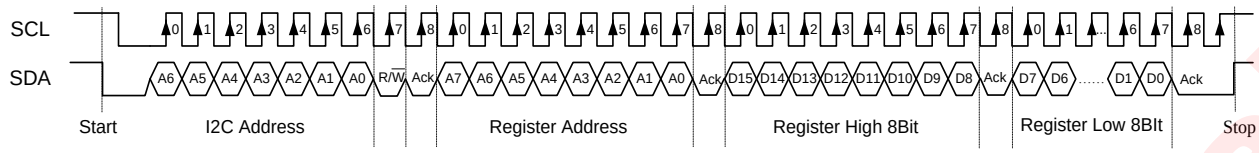


Figure 10 AW9109 I²C Write Timing

9.3.6 Read Cycle

In a read cycle, the following steps should be followed:

a) Master device generates START condition

b) Master device sends slave address (7-bit) and the data direction bit (W = 0).

c) Slave device sends acknowledge signal if the slave address is correct.

d) Master sends control register address (8-bit)

e) Slave sends acknowledge signal

f) Master generates STOP condition followed with START condition or REPEAT START condition

g) Master device sends slave address (7-bit) and the data direction bit (R = 1).

h) Slave device sends acknowledge signal if the slave address is correct.

i) Slave sends data high 8Bit from addressed register.

j) Master sends acknowledge signal

k) Slave sends data low 8Bit from addressed register.

l) If the master device sends acknowledge signal, the slave device will increase the control register address by one, then send the next data from the new addressed register. If master sends no acknowledge signal, the slave device stop to send data and wait for STOP condition.

m) If the master device generates STOP condition, the read cycle is ended.

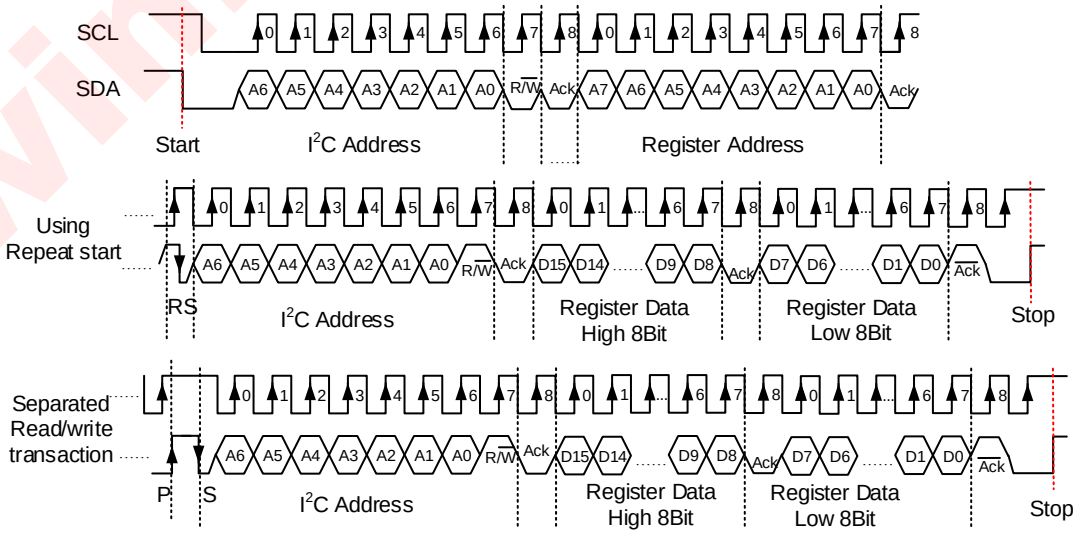


Figure 11 AW9109 I²C Read Timing

9.4 OSCILLATOR

An internal oscillator provides clock for LED controlling circuit. If register bit GCR.LEDE is high, the OSC starts to work, the start-up time is about 5 μs. When both the register bit GCR.LEDE are low, the internal OSC stops.

9.5 LED DRIVER

LED driver provide 9 current sources to drive LEDs, a dedicated Application-Specific-Processor（ASP）is designed to produce versatile lighting effect for mobile devices.

If the control bit GCR.LEDE is 0 , LED driver circuit is in reset state, all 9 LED outputs are disabled. If control bit GCR.LEDE is 1, the LED driver circuit is enabled, the control bit LER.LENx (x=1 to 9) configure the corresponding LED channel is active or not.

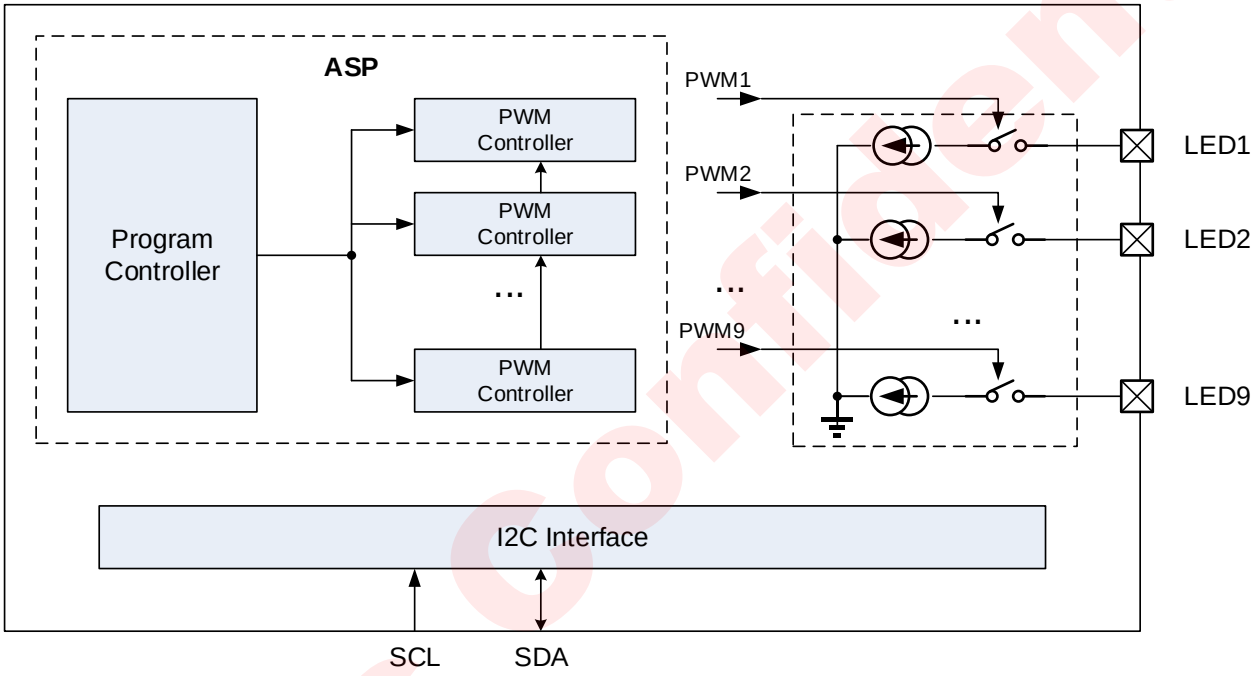


Figure 12 AW9109 LED Dimming Control Module Diagram

9.5.1 LED brightness controller

Pulse Width Modulation (PWM) is used to adjust the brightness of LED, 256 level brightness with 9bit resolution is adapted. The PWM frequency can be configured between 125Hz or 250Hz by control bit LCR.FREQ.

The ASP generates the PWM signal with dedicated and highly efficient dimming control instruction for all 9 independent LED constant current source. By programming, user-defined complicated lighting effect could be produced.

The LED control instruction executed by ASP could come from LED SRAM or external I²C register. The register CTRS can choose every LED channel to be controlled by SRAM program or by I²C register.

- CTRS[n] = 0, LED n controller is controlled by the internal SRAM instruction;
- CTRS[n] = 1, LED n controller is controlled by the external I²C register.

9.5.2 LED Constant current driver

For each LED, the maximum output constant current is 24.5mA, with 8 level adjustable by register IMAXn (n=1~9).

9.5.3 ASP

ASP module is consist of one program controller and 9 PWM controllers.

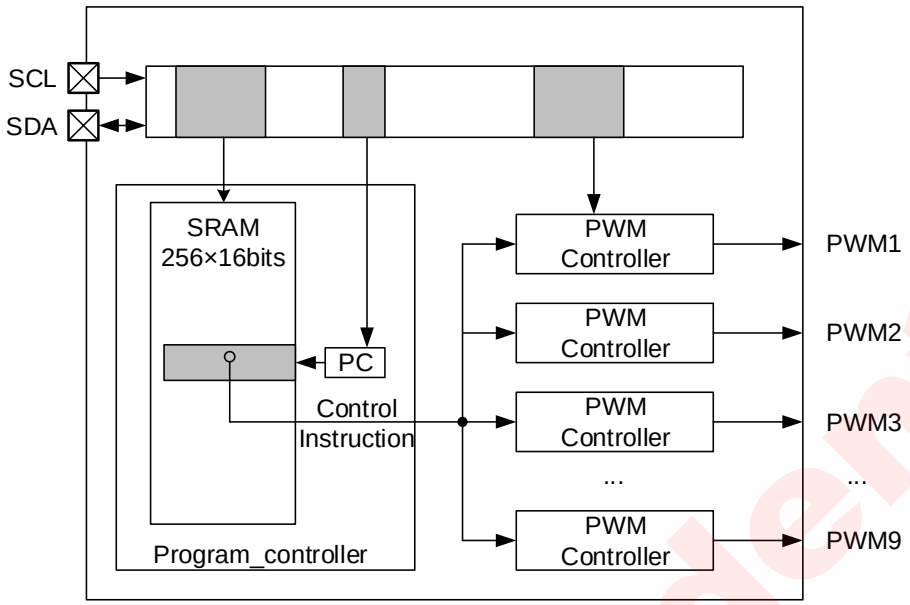


Figure 13 ASP Structure Diagram

9.5.3.1 Program Controller

The program controller is clocked by 32kHz internal clock, each instruction is executed in one clock cycle. The program controller is consist of a program SRAM, an algorithmic logic unit (ALU) and other internal registers. The 256x16bit internal SRAM is used to store LED lighting effect program loaded through I²C interface, the I²C interface also can start or stop the program execution. There are 4 internal registers RA/RB/RC/RD participating ALU operation so as to generate complicated program control such as repeating and looping. Except for that, there are 8 8bit temporary data registers(R1~R8) and 5 special function registers. Their internal address and function description is shown in the table below.

Table 1 Address allocation of internal data register in ASP

Register	Address(HEX)	Description
R1	00	R1 data temporary register，8bit，I²C readable
R2	01	R2 data temporary register，8bit，I²C readable
R3	02	R3 data temporary register，8bit，I²C readable
R4	03	R4 data temporary register，8bit，I²C readable
R5	04	R5 data temporary register，8bit，I²C readable
R6	05	R6 data temporary register，8bit，I²C readable
R7	06	R7 data temporary register，8bit，I²C readable
R8	07	R8 data temporary register，8bit，I²C reading
GMSK1	0d	Global control mask register(M6~M1)
GMSK2	0e	Global control mask register(M9~M7)

Table 2 Special function registers definition

Register	B7	B6	B5	B4	B3	B2	B1	B0	Description
GMSK1	M6	M5	M4	M3	M2	M1	-	-	Mask control for global control instruction. When Mn=1, LEDn will not be affected by global
GMSK2						M9	M8	M7	

									control instruction.

9.5.3.2 PWM Controller

The PWM controller is execution unit of LED control instruction. There are 9 PWM controllers receiving the LED effect instruction from SRAM, and generate 8bit PWM code, which will be convert to 9bit duty cycle control code by logarithmic l transformation. If LCR.LOGLN=00, the transformation is natural logarithm($\log_e$). If LCR.LOGLN=01, the transformation is logarithm of 10 ($\log_{10}$), otherwise the 8b-to-9b transformation of PWM code is linear.

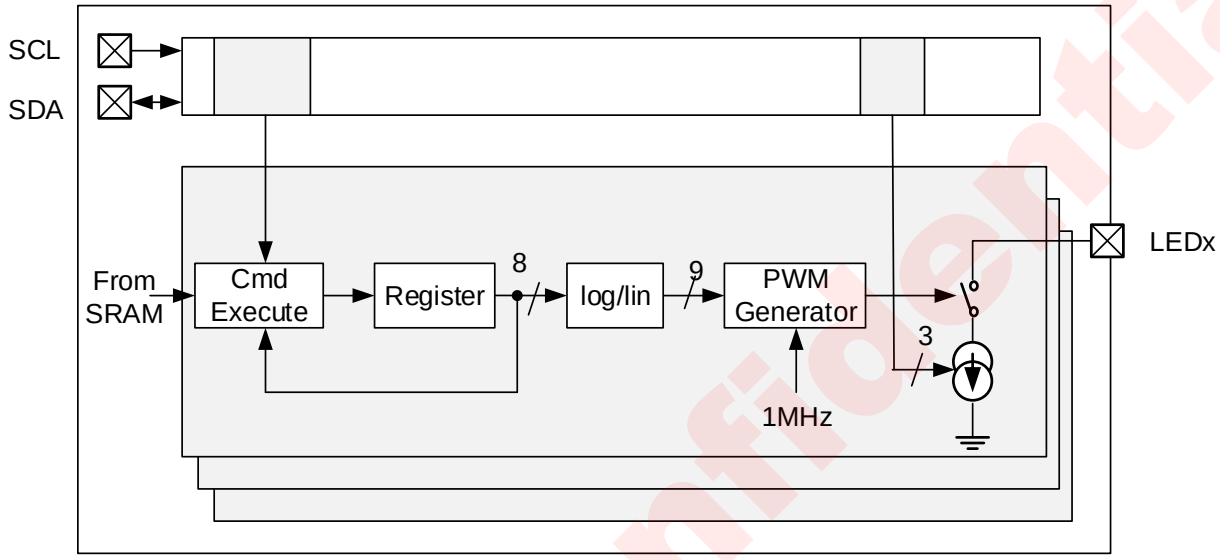


Figure 14 PWM Controller Schematic Diagram

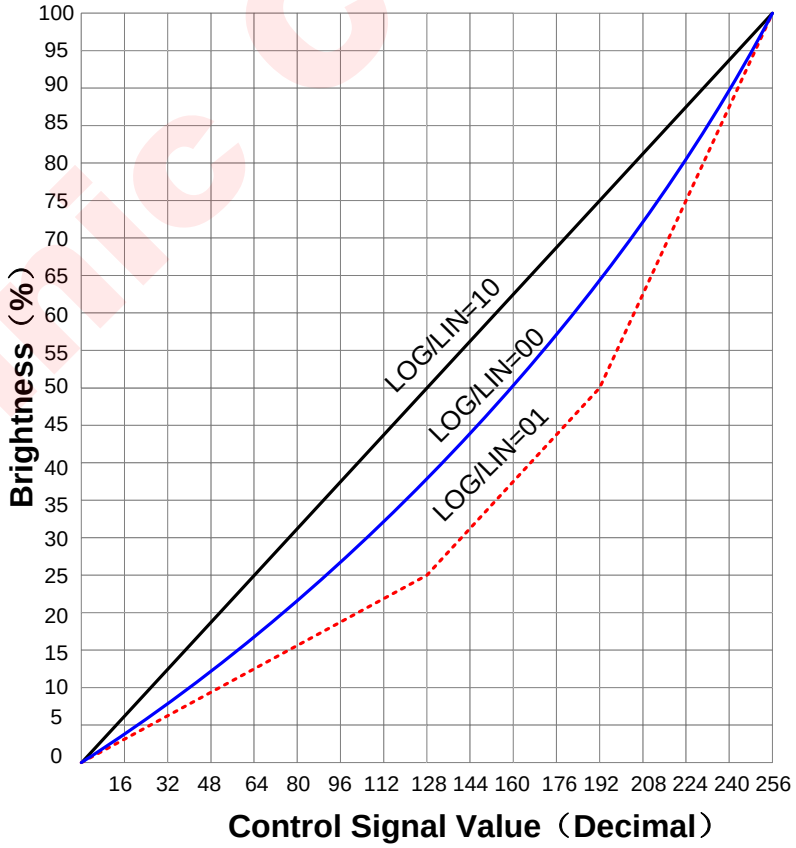


Figure 15 8bit-to-9bit PWM code transformation curve

9.5.3.3 Program Loading and execution

a) Program loading

It is recommended to load SRAM program only when control bit PMD.PROGMD is 00. In this state, the internal program can be read/write through I²C interface. When loading program, please write the SRAM loading address in register WADDR(0x7E) at first, and then write the 16bit LED effect instruction to register WDATA(0x7F). Continuously loading program is supported, after a 16b instruction is written through register WDATA, the value of WADDR will automatically plus by 1.

b) Program execution

Register bit PMD.PROGMD[1:0] controls the loading and execution mode of SRAM program.

When register bit IPMD.PROGMD[1:0]=00, program execution is shut down, SRAM program and program pointer(PC) are permitted to be loaded.

When IPMD.PROGMD[1:0] is written to be 01 from another value, current program will stop , and PC will be reload by register SADDR, and then executes the SRAM program starting from the address of PC

When Register bit PMD.PROGMD[1:0] =10, the SRAM program will be executed by the mode defined by register bit RMD.RUNMD[1:0]

Table 3 Program running mode control register

RMD.RUNMD	Function Description
0 0	Hold mode. program stop and PC hold after one instruction is finished.
0 1	Single step mode, only used for debugging. Once writing 01 to RUNMD, only one instruction will be executed with PC+1, and then RMD.RUMND is cleared (return to hold mode)
1 0	Continuously running mode, program starts from the address of PC.
1 1	Repeating mode, only used for debugging. Once writing 11 to RUNMD, current instruction will be executed without PC+1, and then RMD.RUMND is cleared (return to hold mode)

9.5.3.4 SRAM program Instruction

There are 27 commands in ASP instruction set, including LED control command, data operation and transfer command, wait and branch control command. The Rx,Ry and Rz in instruction list means the internal register RA, RB, RC and RD, each of them can participate the ALU operation as source or destination register.

Table 4 LED Effect Instruction

Command	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
JP	0	0	0	0	0	0	0	0	ADDR[7:0]							
NOP	0	0	0	0	0	0	0	1	-	-	-	-	-	-	-	-
-----	0	0	0	0	0	0	1	X								
JPZ Addr	0	0	0	0	0	1	0	0	ADDR[7:0]							
JPNZ Addr	0	0	0	0	0	1	0	1	ADDR[7:0]							
JPS Addr	0	0	0	0	0	1	1	0	ADDR[7:0]							
JPNS Addr	0	0	0	0	0	1	1	1	ADDR[7:0]							

LD Rz Im	0	0	0	0	1	0	Rz		Im[7:0]									
CMPI Rz Im	0	0	0	0	1	1	Rz		Im[7:0]									
ANDR Rz Im	0	0	0	1	0	0	Rz		Im[7:0]									
ORR Rz Im	0	0	0	1	0	1	Rz		Im[7:0]									
RDR Rz Addr	0	0	0	1	1	0	Rz		ADDR[7:0]									
WDR Rz Addr	0	0	0	1	1	1	Rz		ADDR[7:0]									
ADDI Rz Im	0	0	1	0	0	0	Rz		Im[7:0]									
AUBI Rz Im	0	0	1	0	0	1	Rz		Im[7:0]									
ADDR Rx Ry	0	0	1	0	1	0	Rz		-	-	-	-	Rx		Ry			
SUBR Rx Ry	0	0	1	0	1	1	Rz		-	-	-	-	Rx		Ry			
CMPR Rx Ry	0	0	1	1	0	0	0	0	-	-	-	-	Rx		Ry			
----	0	0	1	1	0	0	X	X										
END Int Rst	0	0	1	1	0	1	0	0	-	-	-	-	-	-	Int		Rst	
INTN_MASKOFF	0	0	1	1	0	1	1	0	-	-	-	-	-	-	-		-	
INTN_MASKON	0	0	1	1	0	1	1	1	-	-	-	-	-	-	-		-	
WAITI Pre Time	0	0	1	1	1	Pre	T[9:0]											
SETPWMR Rx Ry	0	1	0	0	0	0	0	-	-	0	0	0	Rx		Ry			
RAMPR Dir Rx Ry	0	1	0	0	0	0	1	Dir	-	0	0	0	Rx		Ry			
SETSTEPTMRR Pre Rx Ry	0	1	0	0	0	1	0	-	Pre	0	0	0	Rx		Ry			
SETSTEPTMRI Pre Ch Im	1	0	0	Ch[4:0]					Pre	-	Im[5:0]							
SETPWMI Ch Im	1	0	1	Ch[4:0]					Im[7:0]									
RAMPI Dir Ch Im	1	1	Dir	Ch[4:0]					Im[7:0]									

a) Special LED Control Command

There are 3 types of LED control command.

- **SETPWM:** set the brightness level (0~255)for specified LED channel;
- **RAMP:** set the specified LED channel fade in or fade out for expected step(0~255)
- **SETSTEP:** set the fading slope for specified LED channel;

All control parameter in above commands can either come from specified register (RA~RD), or from immediate data contained in command..

All LED control command supports broadcast mode, one instruction may send to multiple or all LEDs

When SRAM program running, if Ch field or value of Rx in LED control command is '11111', the current command is active for all LED with setting of CTRSR.bitn=0. If Ch field or value of Rx in LED control command is '11110', the current command is only active for those channel with setting of GMSKx=0.

When LED instruction is come from I²C interface directly, it is recommended to use only the command with immediate data. If the Ch field in command is "11111", the current command is only active for those LED with STRSR.bitn=1..

Table 5 LED Control Instruction explanation

Instruction	Description

Register Parameter	
SETPWMR Rx Ry	**Set the PWM brightness level with parameter in register** Rx: LED channel number, 2~10 for LED 1~ LED 9 respectively Ry: Brightness level, 0~255
RAMPR Dir Rx Ry	**Set the Fade-in/Fade-out for specified step with parameter in register** Dir: 1: Fade-in; 0: Fade-out Rx: LED channel number, 2~10 for LED 1~ LED 9 respectively Ry: the step number of Fade-in/Fade-out
SETSTEPTMRR Pre Rx Ry	**Set the RAMP slope with parameter in register** Pre: basic time unit, 0: 0.5ms; 1: 16ms Rx: LED channel number, 2~10 for LED 1~ LED 9 respectively Ry: RAMP step time = (Ry+1)*Pre
Immediate Data	
SETPWMI Ch Im	**Set the PWM brightness level with immediate parameter** Ch: LED channel number, 2~10 for LED 1~ LED 9 respectively Im: Brightness level, 0~255
RAMPI Dir Ch Im	**Set the Fade-in/Fade-out for specified steps with immediate parameter** Dir: 1: Fade-in; 0: Fade-out Ch: LED channel number, 2~10 for LED 1~ LED 9 respectively Im: the steps of Fade-in/Fade-out
SETSTEPTMRI Pre Ch Im	**Set the RAMP step time with immediate parameter** Pre: basic unit of time, 0: 0.5ms; 1: 16ms Ch: LED channel number, 2~10 for LED 1~ LED 9 respectively Im: RAMP step time = (Im +1)*Pre, 0~63

Table 6 Program Control and operation Instruction

Instruction	Encoding	Description
branch Instruction		
JP Addr	0x00xx	Immediate Jump, jump to PC = Addr
JPZ Addr	0x04xx	Conditional Jump, If Rz is 0, jump to PC = Addr
JPNZ Addr	0x05xx	Conditional Jump, If Rz is not 0, jump to PC = Addr
JPS Addr	0x06xx	Conditional Jump, If Rz < 0, jump to PC = Addr
JPNS Addr	0x07xx	Conditional Jump, If Rz >= 0, jump to PC = Addr
Data Transfer Instruction		
LD Rz Im	0x08xx - 0x0bxx	Rz = Im
RDR Rz Addr	0x18xx - 0x1bxx	Rz = *Addr
WDR Rz Addr	0x1cxx - 0x1fxx	*Addr = Rz
Computation Instruction		
CMPI Rz Im	0x0cxx - 0x0fxx	Rz – Im, only change S/Z flag
CMPR Rx Ry	0x30xx	Rx – Ry, only change S/Z flag
ANDR Rz Im	0x10xx - 0x13xx	Rz = Rz & Im, affect S/Z flag
ORR Rz Im	0x14xx - 0x17xx	Rz = Rz | Im, affect S/Z flag
ADDI Rz Im	0x20xx - 0x23xx	Rz = Rz + Im, affect S/Z flag
SUBI Rz Im	0x24xx - 0x27xx	Rz = Rz - Im, affect S/Z flag
ADDR Rz Rx Ry	0x28xx - 0x2bxx	Rz = Rz + Ry, affect S/Z flag
SUBR Rz Rx Ry	0x28xx - 0x2bxx	Rz = Rz - Ry, affect S/Z flag
Control Instruction		
END Int Rst	0x34xx	Program end with optionally reset register RMD and generate interrupt

		Int= 0: no interrupt after instruction executed; Int= 1: generate interrupt after instruction executed Rst=0: PC add 1 after instruction executed; Rst=1: Reload PC with SADDR after instruction executed
INTN_MASKOFF	0x36xx	Unmask internal interrupt
INTN_MASKON	0x37xx	Mask internal interrupt
WAITI Pre Time	0x38xx - 0x3fxx	Wait for specified time Pre: time of basic waiting cycle, 0: 0.5ms; 1: 16ms Time: number of waiting cycle, max value is 1023, wait time=Pre*Time

9.6.3.5 Example

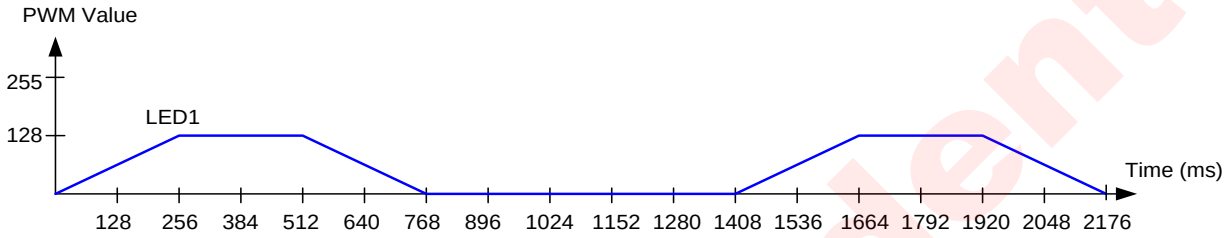


Figure 16 LED Effect Programming Diagram

Table 7 Reference Instruction of LED Effect Programming

PC	Assemble Instruction	Machine Code	explanation
0	SETSTEPTMRI 0x00 0x1F 0x03	0x9F03	RAMPI step time: 2ms
1	SETPWMI 0x1F 0x00	0xBF00	ALL LED turn off
	START:		Address Label “START” (01H)
2	RAMPI 0x01 0x02 0x80	0xE280	LED1 fade in, 128 steps breath
3	WAITI 0x01 0x20	0x3C20	Wait 512ms
4	RAMPI 0x00 0x02 0x80	0xC280	LED1 fade out, 128 steps breath
5	WAITI 0x01 0x38	0x3C38	Wait 896ms
6	JP START	0x0002	Jump to START, PC=2

Step1: Power On, configure register

- VBAT power on, 4.2V
- Pull PDN to 3V
- Wait 5ms
- GCR = 0x0001 // enable LED module
- LER = 0x0004 // enable LED1
- IMAX1 = 0x0100 // IMAX1 = 3.5mA
- PMD.PROGRMD = 00 //hold mode
- RMD.RUNMD = 00 //hold mode

Step2: Load Instruction to SRAM

- WADDR = 0x0000 // load program starting at address =0x0000
- WDATA = 0x9F03
- WDATA = 0xBF00
- WDATA = 0xE280
- WDATA = 0x3C20
- WDATA = 0xC280

- WDATA = 0x3C38
- WDATA = 0x0002

Step3: Run

- SADDR = 0x0000
- RMD.RUNMD = 10 // execution mode change to run mode,
- PMD.PROGMD = 01 // start program from 0x0000

10 REGISTER DESCRIPTION

10.1 REGISTER CONFIGURATION

Address	Register	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	IDRST	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0x01	GCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LEDE
0x50	LER	0	0	0	0	0	LED9	LED8	LED7	LE6	LE5	LE4	LE3	LE2	LE1	0	0
0x51	-	RESERVED															
0x52	LCR	0	0	0	0	0	0	0	SRMINI	LIRMD		TIMD		LIE	FREQ	LOG/LIN	
0x53	PROGMD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PROGMD	
0x54	RUNMD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RUNMOD	
0x55	CTRS						CS9	CS8	CS7	CS6	CS5	CS4	CS3	CS2	CS1	0	0
0x56	-	RESERVED															
0x57	IMAX1	0	IMAX2			0	IMAX1			0				0			
0x58	IMAX2	0	IMAX6			0	IMAX5			0	IMAX4			0	IMAX3		
0x59	IMAX3	0	0	0	0	0	IMAX9			0	IMAX8			0	IMAX7		
0x5a 0x5B	-	RESERVED															
0x5C	TIER	0	0	0	0	0	TIE	0	0	0	0	0	0	0	0	0	KIE
0x5D	TIVEC	0	0	0	0	0	0	0	0	TIVEC							
0x5E	ISR2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LIS
0x5F	SADDR	0	0	0	0	0	0	0	0	SADDR							
0x60	PCR	0	0	0	0	0	0	0	0	PC							
0x61	CMDR	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0x62	RA	0	0	0	0	0	0	0	0	RA							
0x63	RB	0	0	0	0	0	0	0	0	RB							
0x64	RC	0	0	0	0	0	0	0	0	RC							
0x65	RD	0	0	0	0	0	0	0	0	RD							
0x66 ~ 0x6D	R1 ~ R8	0								R1 ~ R8							
6E	GRPR	0	0	0	0	0	GS9	GS8	GS7	GS6	GS5	GS4	GS3	GS2`	GS1	D1	D0
7D	WP	WPW								0	0	0	0	0	0	0	0
7E	WADDR	0	0	0	0	0	0	0	0	ADDR							
7F	WDATA	CODE															

10.2 GLOBAL REGISTER DESCRIPTION

10.2.1 IDRST, Chip ID and Software Reset

Address: 0x00, R/W															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Bit	Symbol		Description												
15:0	IDRST		Chip ID: 0xB223 Software Reset: write 0x55AA to IDRST, reset the whole device.												

10.2.2 GCR, Global Control Register

Address: 0x01, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LEDE
Bit	Symbol		Description												
0	LEDE		LED driver function 0: disable LED driver (default) 1: enable LED driver												

10.3 LED Effect Control Register

10.3.1 LER1, LED Driver Enable Register

Address: 0x50, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	LE9	LE8	LE7	LE6	LE5	LE4	LE3	LE2	LE1	0	0
Bit	Symbol		Description												
1:0	-		Reserved, must be 0												
10:2	LEx		LED output enable 0: disable 1: enable												
15:11	-		Reserved, must be 0												

10.3.2 LCR, LED Effect Configuration Register

Address: 0x52, R/W, default: 0x0080															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	SRMINI	LIRMD		0		LIE	FREQ	LOGLIN	
Bit	Symbol		Description												
1:0	Log/Lin		Log/Linear dimming mode selection 00: log dimming 1, log(e) （default） 01: log dimming 2, log10 1x: linear dimming												
2	FREQ		PWM frequency selection 0: 250Hz （default） 1: 125Hz												
3	LIE		LED program end interrupt enable 0: disable interrupt（default） 1: enable interrupt												
5:4	-		Reserved												
7:6	LIRMD		LED effect code run mode after responding to interrupt request 00: hold mode, PC point can be changed, program hold and wait for RMD.RUNMD 01: step mode 10: run mode (default)												
8	SRMINI		SRAM reset bit, write 1, reset SRAM; read SRAM status, default is 0.												

10.3.3 PMD, Program Mode Register

Address: 0x53, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PROGMD
Bit	Symbol		Description												
1:0	PROGMD		Program control mode 00: load program via I²C interface (default) 01: re-load program and execute. When write 01 to PROGMD[1:0], set PC pointer will be updated with SADDR, then start to run program, and finally PROGMD[1:0] is changed to 10 automatically 10: run program. Under this mode, the control bit RUNMD in register RMD can configure different program running mode for normal operation or debug. 11: undefined												

10.3.4 RMD, Program Run Mode Register

Address: 0x54, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	RUNMD	
Bit	Symbol		Description												
1:0	RUNMD		SRAM program run mode, only active for these LED set with CTRSR.CSx=0 00: hold mode, program stop and hold PC pointer (default) 01: step mode, RUNMD reset, PC+1 after the current program executed 10: run mode, normal program run 11: repeat mode, RUNMD reset, PC hold after the current program executed												

10.3.5 CTRSR, LED Control Source Selection Register

Address: 0x55, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0		CS9	CS8	CS7	CS6	CS5	CS4	CS3	CS2	CS1	0	0
Bit	Symbol		Description												
7:2	CSx		LED control source 0: LEDx controlled by SRAM program 1: LEDx controlled by external MCU via I²C interface												

10.3.6 IMAX1～IMAX6, LEDx Maximum Output Current Register

Address: 0x57~0x59, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	IMAX2			0	IMAX1			0							
0	IMAX6			0	IMAX5			0	IMAX4			0	IMAX3		
0	0	0	0		IMAX9				IMAX8				IMAX7		
Bit	Symbol		Description												
10:8	IMAX1		LEDx maximum output current selection 000: 0mA (default) 001: 3.5mA 010: 7.0mA 011: 10.5mA 100: 14.0mA 101: 17.5mA 110: 21.0mA 111: 24.5mA												
14:12	IMAX2														
2:0	IMAX3														
6:4	IMAX4														
10:8	IMAX5														
14:12	IMAX6														
2:0	IMAX7														
6:4	IMAX8														
10:8	IMAX9														

10.3.7 LISR, LED Interrupt Status Register

Address: 0x5E, R(clear by reading), default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LIS
Bit	Symbol		Description												
1	LIS		LED program end interrupt status, set by END instruction with parameter int=1, used for inform external MCU that program has finished. LCR.LIE is the enable bit for LIS. 0: no interrupt 1: interrupt request												

10.3.8 SADDR, Program Start Address Register

Address: 0x5F, R/W, default: 0x0000																
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	SADDR							
Bit	Symbol		Description												
7:0	SADDR		SRAM program starting address. For reload and run mode, if setting PMD.PROGMD=10, program will jump to PC=SADDR and run again.												

10.3.9 PCR, LED Program Control Pointer Register

Address: 0x60, R/W, default: 0x0000																
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	PC							
Bit	Symbol		Description												
7:0	PC		SRAM program pointer(PC), can be written by I²C interface. For normal program execution, set the PC pointer at PMD.PROGMD= 00 mode at first, and then write PMD.PROGMD with 10.												

10.3.10 CMDR, LED Command Register

Address: 0x61, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CMD															
Bit	Symbol	Description													
15:0	CMD	External controlled Command. used to send external LED command which is only active for those LED configured with control bit CTRSR.CSx=1. The external controlled command adapted the same instruction with internal ASP.													

10.3.11 RA/RB/RC/RD,LED Internal Program Register

Address: 0x62~0x65, R, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	RA							
0	0	0	0	0	0	0	0	RB							
0	0	0	0	0	0	0	0	RC							
0	0	0	0	0	0	0	0	RD							
Bit	Symbol		Description												
7:0	RA/RB/RC/RD		LED internal program register, read only, for debug usage.												

10.3.12 R1~R8, LED Internal Data Register

Address: 0x66~0x6D, R, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	R1							
0	0	0	0	0	0	0	0	R2							
0	0	0	0	0	0	0	0	R3							
0	0	0	0	0	0	0	0	R4							
0	0	0	0	0	0	0	0	R5							
0	0	0	0	0	0	0	0	R6							
0	0	0	0	0	0	0	0	R7							
0	0	0	0	0	0	0	0	R8							
Bit	Symbol		Description												
7:0	R1～R8		LED internal data register, for debug usage.												

10.3.13 GRP, LED Group Operation Register

Address: 0x6E, R, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	GS9	GS8	GS7	GS6	GS5	GS4	GS3	GS2	GS1		
Bit	Symbol		Description												

10:2	GS[8:0]	LED channel selection for external group control command. GS[n]=0, LED_n is not included in external LED command with chan=0x1E; GS[n]=1, LED_n is included in external LED command with chan=0x1E;

10.3.14 WADDR, LED Program Loading Address Register

Address: 0x7E, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	ADDR							
Bit	Symbol		Description												
7:0	ADDR		SRAM address for program access via I^2C interface												

10.3.15 WDATA, LED Program Loading Data Register

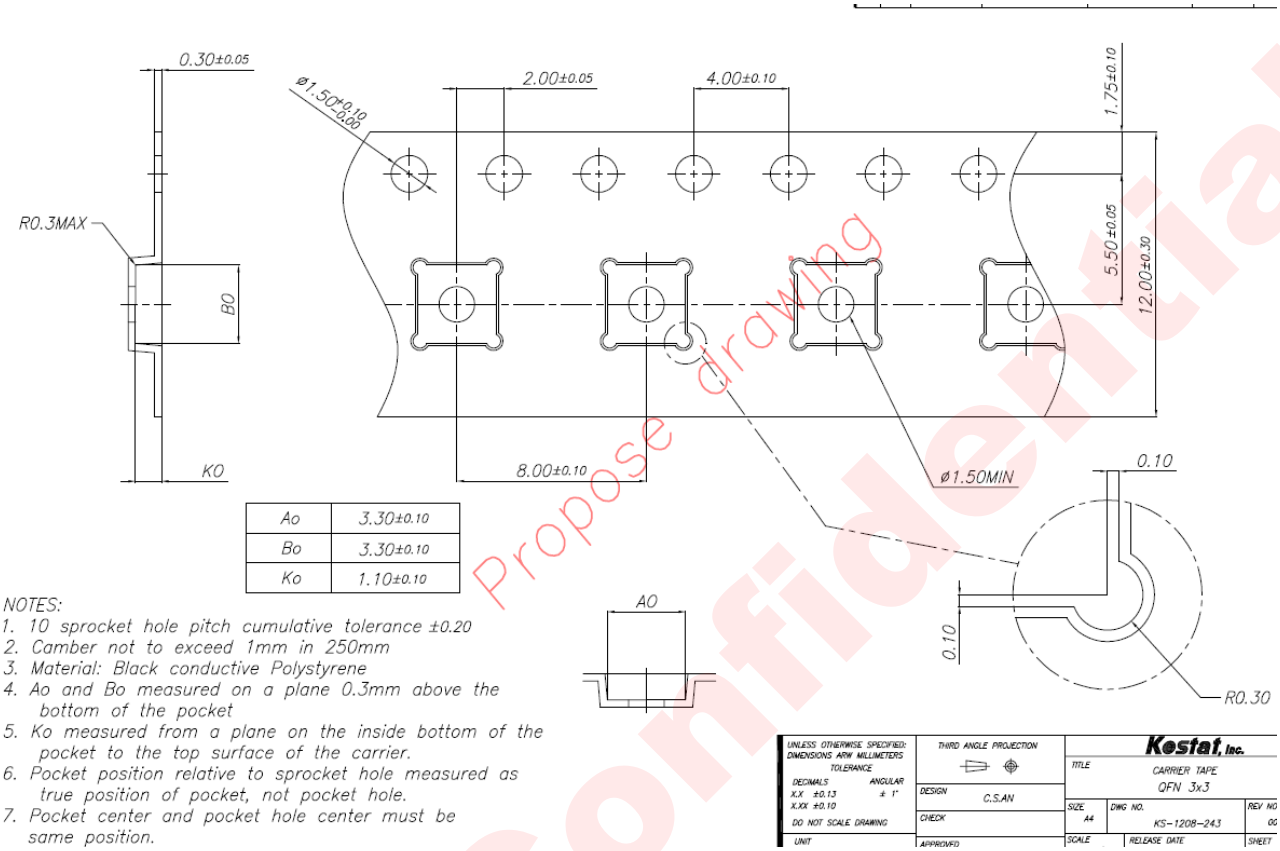
Address: 0x7F, R/W, default: 0x0000															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CODE															
Bit	Symbol		Description												
15:0	CODE		SARM data for program access via I^2C interface												

10.3.16 WPR, Writing Protection Register

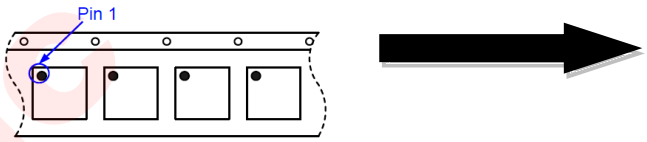
Address: 0x7D, R/W, default: 0x5500															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WPW								0	0	0	0	0	0	0	0
Bit	Symbol		Description												
15:8	WPW		writing protection control, If WPW=0x55, all register is writable, otherwise all register except for WPR is not allowed to be written.												

11 TAPE AND REEL INFORMATION

11.1 Carrier Tape（All Dimensions are in Millimeters）

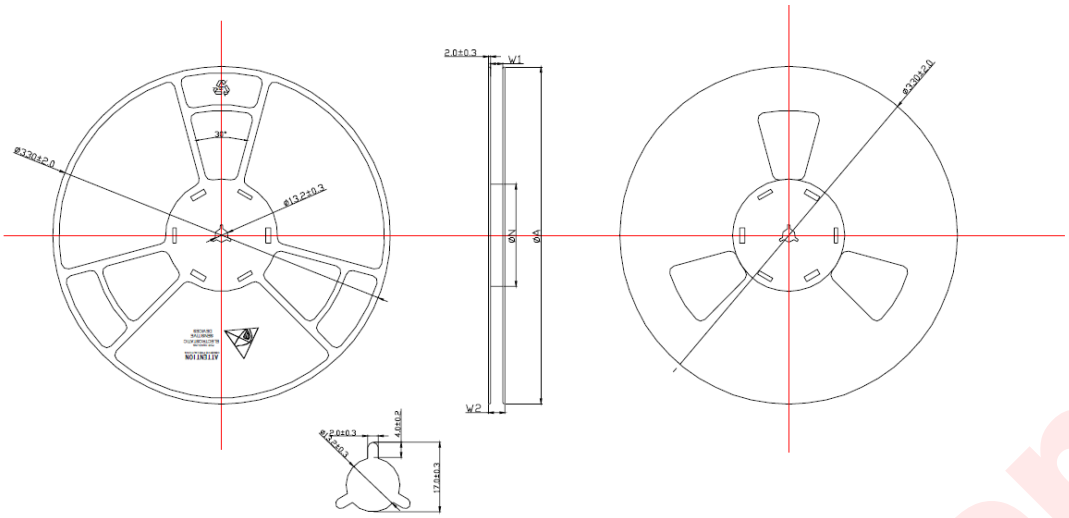


11.2 PIN1 Direction



User Direction of Feed

11.3 Reel

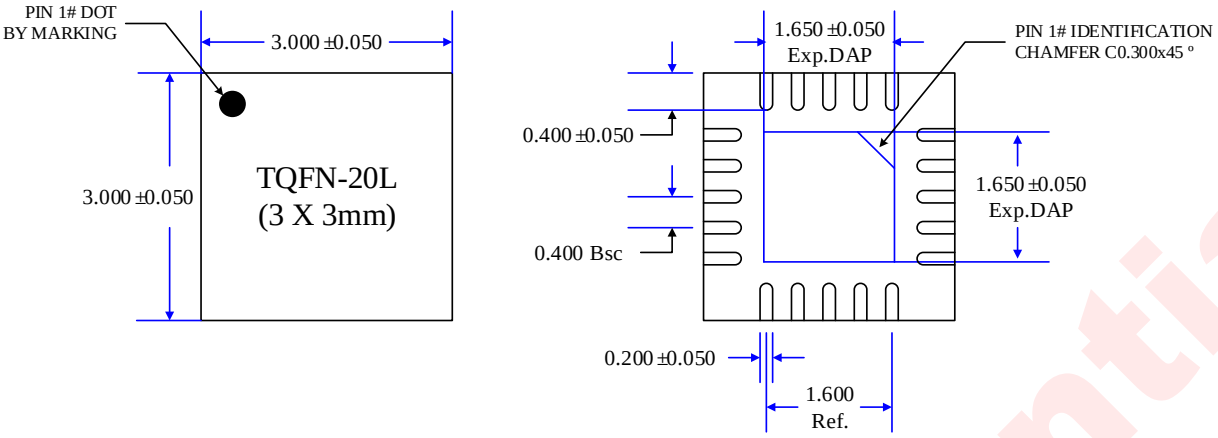


PRODUCT SPECIFICATIONS							
TYPE WIDTH	∅A	∅N	W1 (Min)	W2 (Max)	DRN. : ZHD	2005. 06. 25	TITLE:Platic Reel
12MM	330±2.0	100±1.0	12.4	19.4			

Notes:

i. Material: polystyrene
ii. Flatness: maximum permissible 3mm
iii. All dimensions are in millimeters
iv. Surface resistivity: 10^5 to 10^{11} ohms/sq or less
v. All unmarked tolerance: ±0.5

12 PACKAGE DESCRIPTION

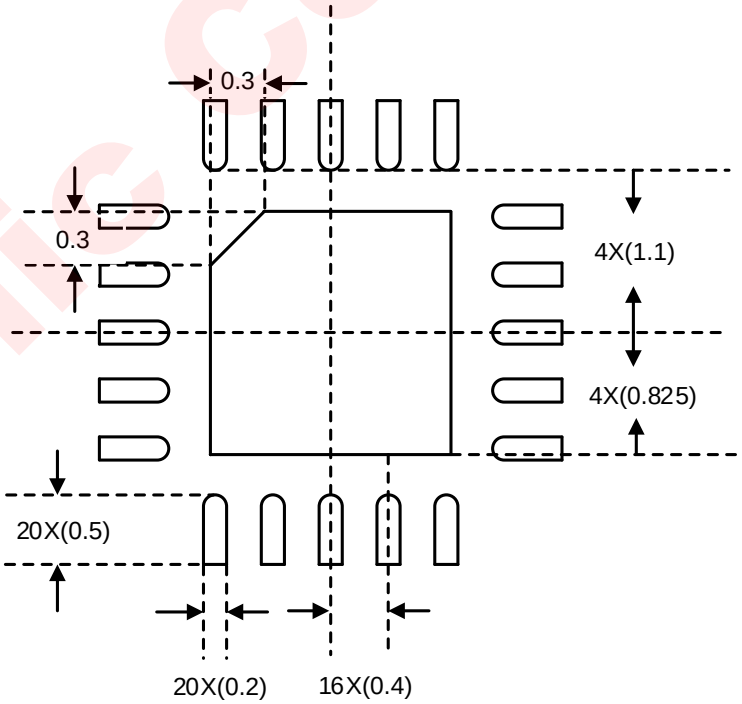


TOP VIEW BOTTOM VIEW

Note: All Dimensions are in Millimeters

SIDE VIEW

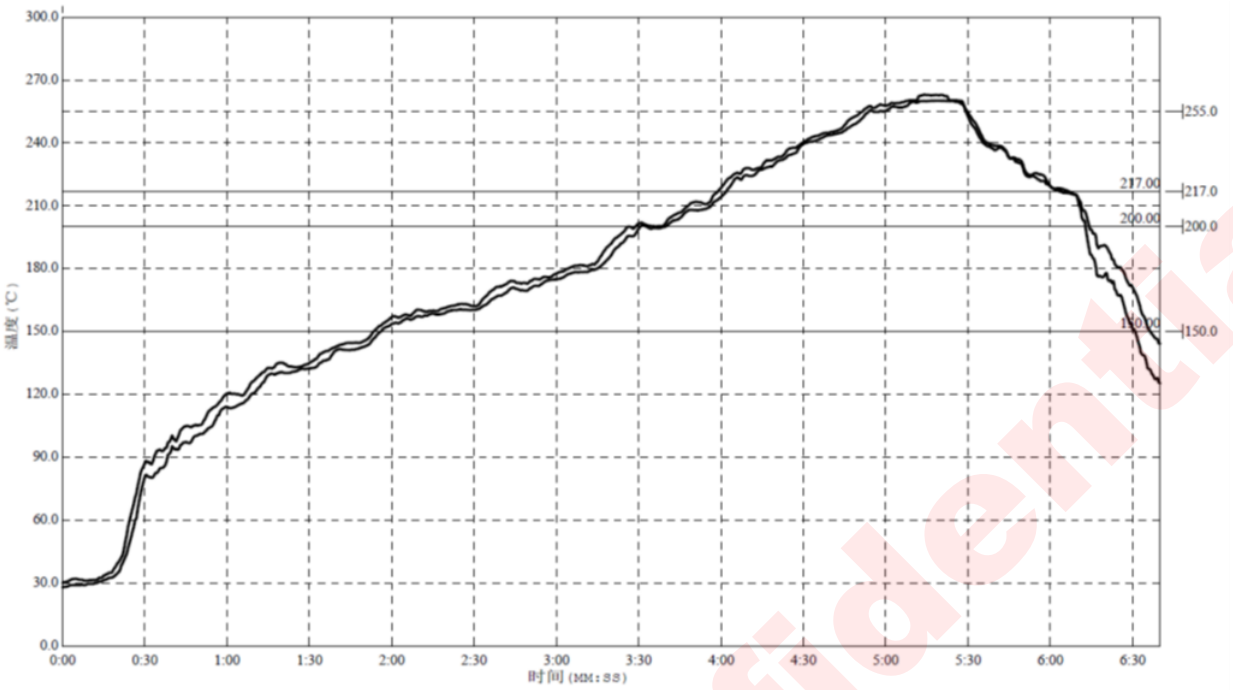
13 RECOMMENDED LAND PATTERN



TOP VIEW

Note：All Dimensions are in Millimeters

14 REFLOW



Reflow Note	Spec
Average ramp-up rate (217°C to peak)	Max. 3°C /sec
Time of Preheat temp. (from 150°C to 200°C)	60-120sec
Time to be maintained above 217°C	60-150sec
Peak Temperature	>260°C
Time within 5°C of actual peak temp	20-40sec
Ramp-down rate	Max. 6°C /sec
Time from 25°C to peak temp	Max. 8min

Package Reflow Standard Profile

NOTE 1: All data are compared with the package-top temperature, measured on the package surface;

NOTE 2: AW9109 adopted the Pb-Free assembly.

15 REVISION HISTORY

Vision	Date	Change Record
V1.0	Sept. 2017	Officially Released
V1.1	June. 2018	Update the ordering information Add the recommended land pattern Update the electrical characteristics Update the reflow information
V1.2	Sep. 2018	Update the storage temperature
V1.3	Nov. 2018	Update document description of AW9109
V1.4	Feb. 2019	Add power on procedure

16 DISCLAIMER

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