带自动呼吸功能的18x11, 18x8阵列LED 驱动器

18x12, 18x8 Matrix LED Driver with Auto Breathing Function

■ FEATURES

- Supply voltage range: 2.7V to 5.5V
- 18 current sinks (CS), 11 or 8 current switches (SW)
- Programmable matrix size, up to 18×11 = 198 LED matrix
- Global 256 DC current steps
- Individual 256 PWM control steps for dimming
- Individual 256-level DC current for 16.8 million color calibration
- Auto breathing or group PWM control with 3 pattern controllers
- High-precision current sinks
  - -Device-to-device error: ±5%
  - -Channel-to-channel error: ±5%
- EMI and audible noise reduction
  - -Phase shift control
  - -Spread spectrum function
  - -Programmable slew rate
- Programmable H/L logic: 1.4V/0.4V or 2.4V/0.6V
- Clock synchronization between devices by SYNC pin
- UVLO and over-temperature protection
- Multiple PWM frequency selectable
- HTR7198, HTR7144: 1MHz I^2C-compatible interface, 16 I^2C device addresses
  HTR7198S, HTR7144S: 10MHz SPI interface
- Individual open and short error detect function
- De-Ghost
- QFN5×5-40L package

- 输入电压范围：2.7V-5.5V
- 18路电流源(CS)，11路或8路开关(SW)
- 可设置矩阵路数，最高支持18×11 = 198路
- 全局256个直流设置台阶
- 独立的256阶PWM调光
- 独立的256阶CS电流用于1680万细腻调色
- 3个模式控制器，用于自动呼吸或群组PWM控制
- 高精度电流控制：器件间误差±5%；通道间误差±5%
- EMI和可闻噪声的降低措施：
  - -相移设置
  - -扩频功能
  - -上升下降沿可设置
- 逻辑高/低电平可设置：1.4V/0.4V 或 2.4V/0.6V
- 支持通过SYNC脚进行多个芯片的时钟同步
- 欠压和过温保护功能
- 多种PWM频率可选
- HTR7198, HTR7144：支持1MHz的I^2C接口，16个I^2C器件地址
  HTR7198S, HTR7144S：支持10MHz SPI接口
- 独立的开路和短路错误检测功能
- De-Ghost
- QFN5×5-40L

■ APPLICATIONS

- Smart home appliances
- IOT device
- Consumer electronics
- Key Boards and Mouse

- 智能家居设备
- IOT设备
- 个人消费电子
- 键鼠

■ DESCRIPTION

HTR7198(S) is an 18x11, and HTR7144(S) is an 18x8 Matrix LED driver programmed via 1MHz I²C compatible interface (for HTR7198 and HTR7144) or 10MHz SPI interface (for HTR7198S and HTR7144S). Each LED can be programed individually with 8-bit PWM data (brightness dimming), and 8-bit DC scaling data (Color Calibration). There are also global current settings via register GCCR and external resistor R_{ISET}.

Three integrated pattern controllers provide auto breathing or group dimming control. Each pattern controller can work in auto breathing or manual control mode. All breathing parameters are configurable, including rising/falling slope, on/off time, repeat times, and minimum/maximum brightness, etc. Each LED's PWM parameter can be sourced from any one of the 3 pattern controllers optionally.

Additionally, each LED open and short state can be detected, HTR7198(S) or HTR7144(S) stores the open or short information in Open-Short Registers. The Open-Short Registers allowing MCU to read out via I²C compatible interface. Inform MCU whether there are LEDs open or short and the locations of open or short LEDs.

The HTR7198(S) or HTR7144(S) operates from 2.7V to 5.5V and features a very low shutdown and operational current. HTR7198(S) and HTR7144(S) are available in QFN5×5-40L package. It operates from 2.7V to 5.5V over the temperature range of -40°C to +125°C.

本系列产品是一款通过1MHz的I²C接口(HTR7198, HTR7144)或10MHz SPI接口(HTR7198S, HTR7144S)进行编程的支持18×11或18×8阵列的LED驱动芯片，每路SWx都支持8位PWM数据进行独立调光，并且每路CSx都有8位的直流扫描数据用来支持每个点的256阶的线性PWM调光，并且每个CSx都支持256阶的直流电流可调节等级。

HTR7198(S)或HTR7144(S)内置三个模式控制器，以提供不同的自动呼吸或群组调光控制。每个模式控制器可以工作在自动呼吸或手动控制模式。呼吸相关参数均可设置，如上升下降沿、开/关时间、重复次数、最高/最低亮度等。每个LED的PWM参数可从三个模式控制器中的任意一个得到。

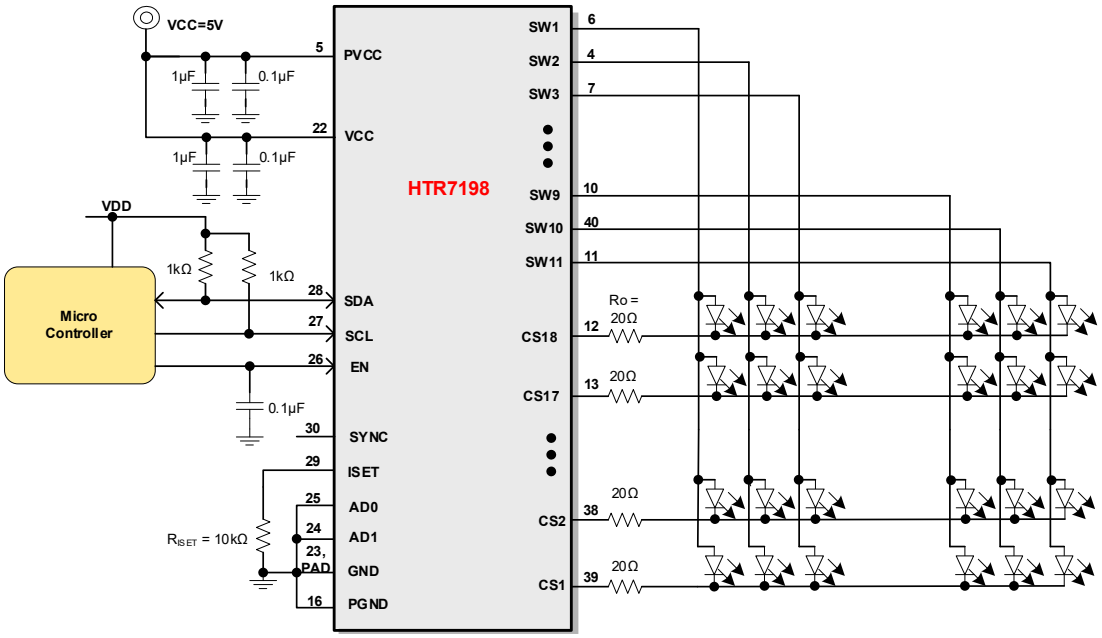
另外，每个LED的开路和短路状态都能被检测，HTR7198(S)或HTR7144(S)能够把开路和短路信息存储在Open-Short寄存器组中。

HTR7198(S)或HTR7144(S)的工作电压在2.7V到5.5V之间，并且关断电流和工作电流都非常小。HTR7198(S)或HTR7144(S)支持QFN5×5-40L封装，可在2.7V到5.5V和-40° C to +125° C下工作。

■ EXTENDED DEVICE INFORMATION

Part Number	Channel	Interface	Package
HTR7216SQER	18*12=216	I2C	QFN5*5-44L
HTR7216SSQER	18*12=216	SPI	QFN5*5-44L
HTR7198SQER	18*11=198	I2C	QFN5*5-40L
HTR7198SSQER	18*11=198	SPI	QFN5*5-40L
HTR7144SQER	18*8=144	I2C	QFN5*5-40L
HTR7144SSQER	18*8=144	SPI	QFN5*5-40L

■ TYPICAL APPLICATION



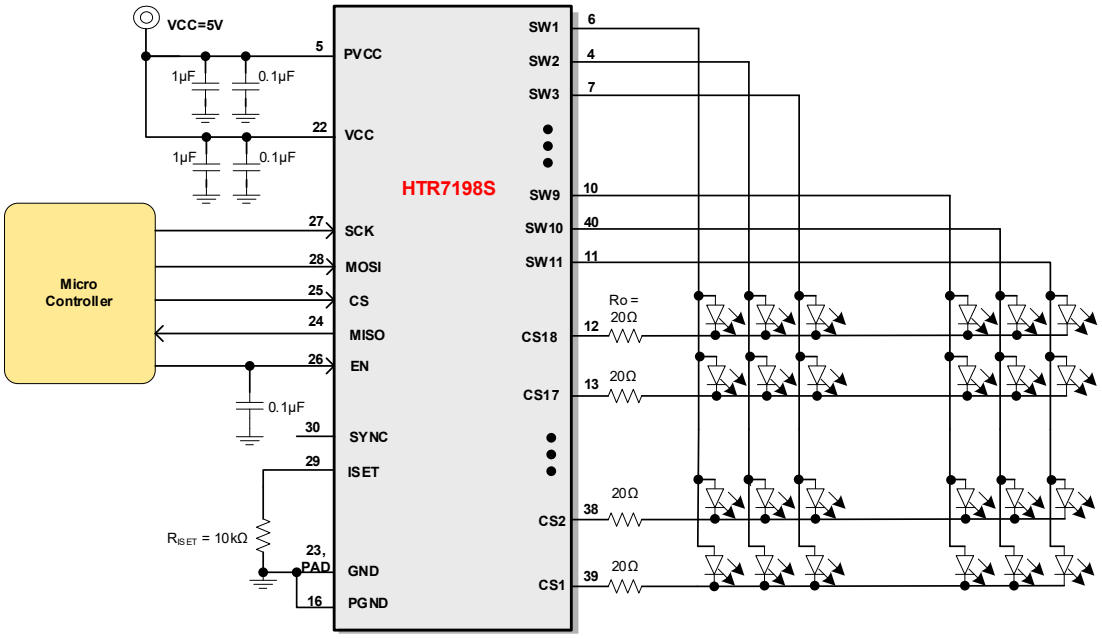
HTR7198 Driving 18×11 LEDs

The VDD should not larger than VCC.

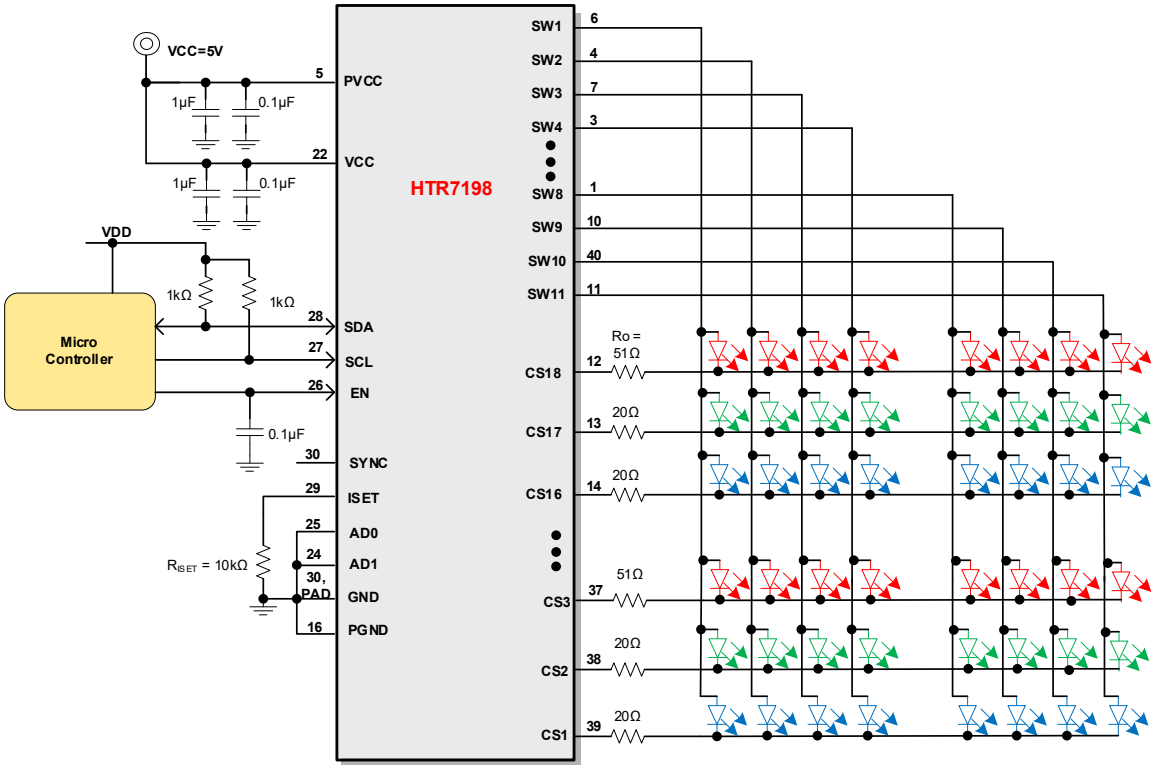
$$Ro = \frac{PVCC - VF_{LED} - VH_{CS} - VH_{SW}}{I_{max}}$$

VDD应小于等于VCC。

$$Ro = \frac{PVCC - VF_{LED} - VH_{CS} - VH_{SW}}{I_{max}}$$



HTR7198S Driving 18×11 LEDs

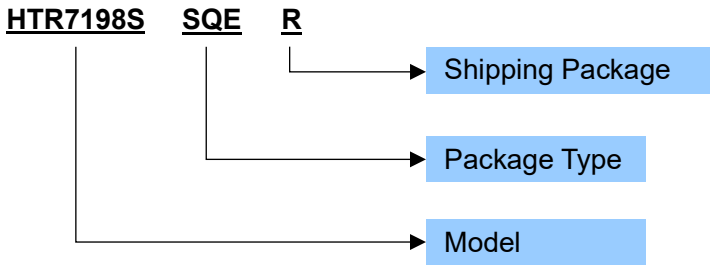


Driving 6×11 RGBs

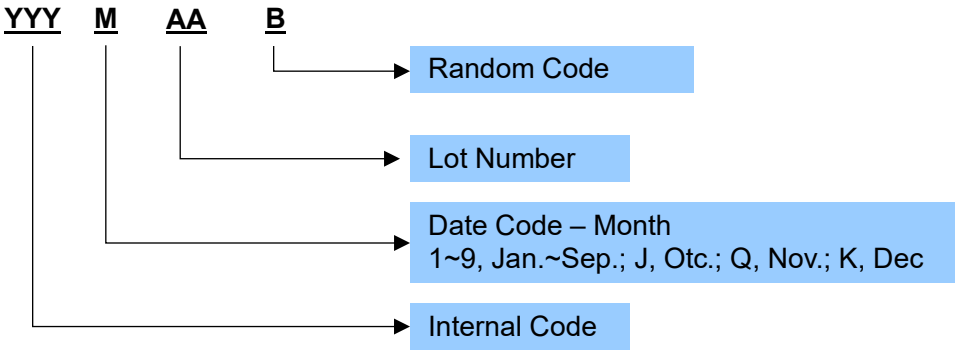
■ ORDERING INFORMATION

Part Number	Package Type	Package Abbr.	Eco Plan	MSL Level	Marking	Shipping Package / MOQ
HTR7198SSQER	QFN5×5-40L (SQE)	SQE	RoHS	MSL3	HTR7198S YYYMAAB[1]	Tape and Reel (R) / 5000pcs
HTR7198SQER	QFN5×5-40L (SQE)	SQE	RoHS	MSL3	HTR7198 YYYMAAB	Tape and Reel (R) / 5000pcs

Part Number

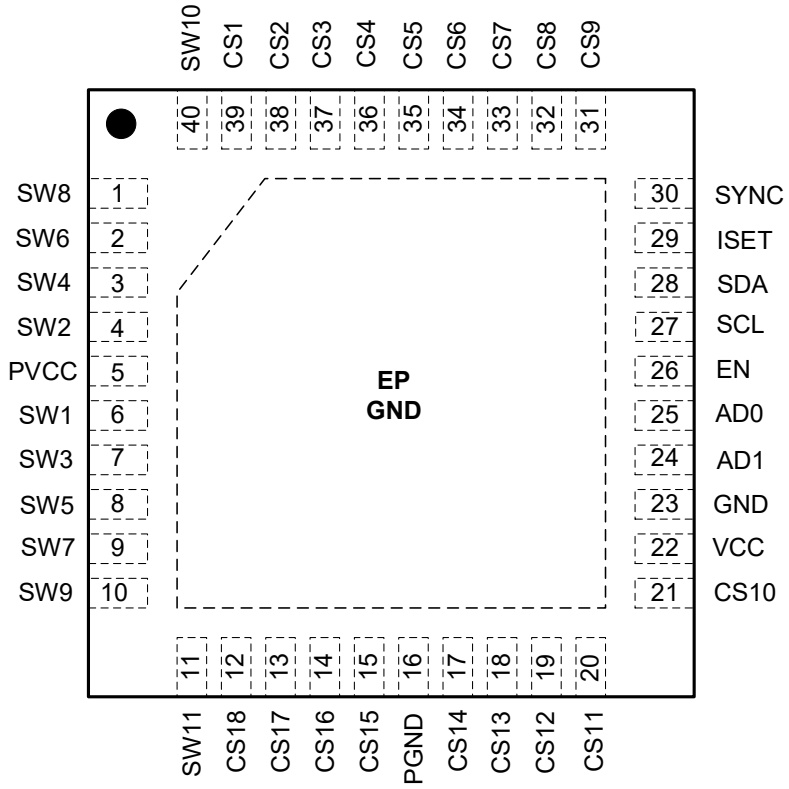


Production Tracking Code

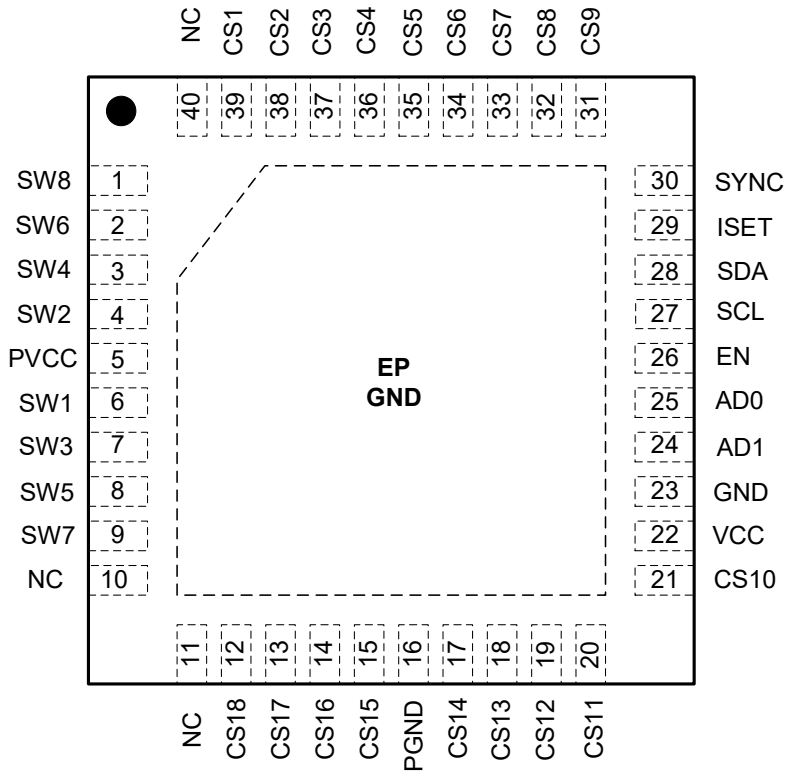


[1] YYYMAAB is production tracking code

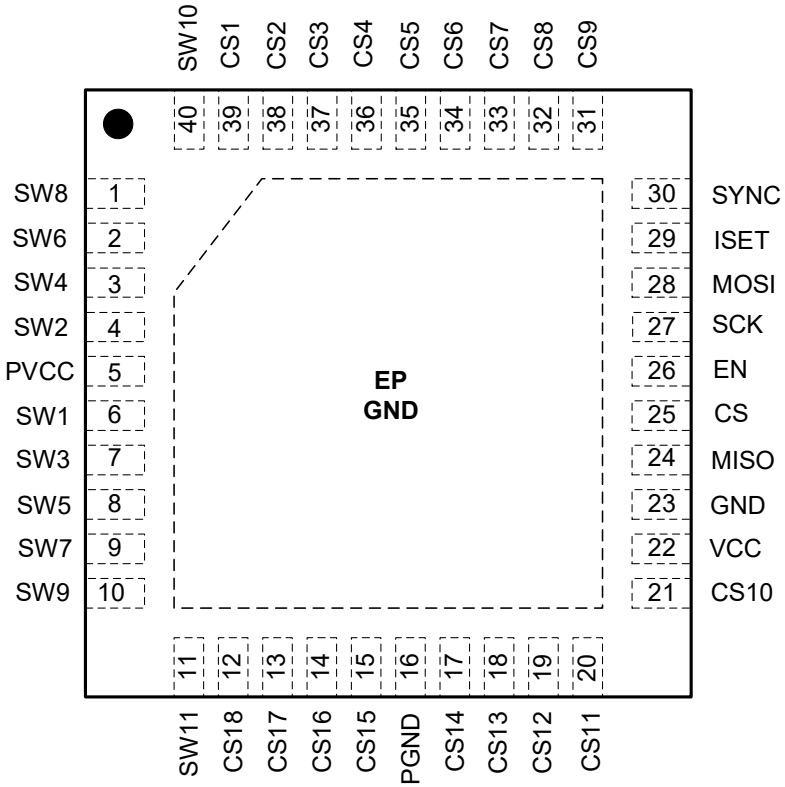
■ TERMINAL CONFIGURATION



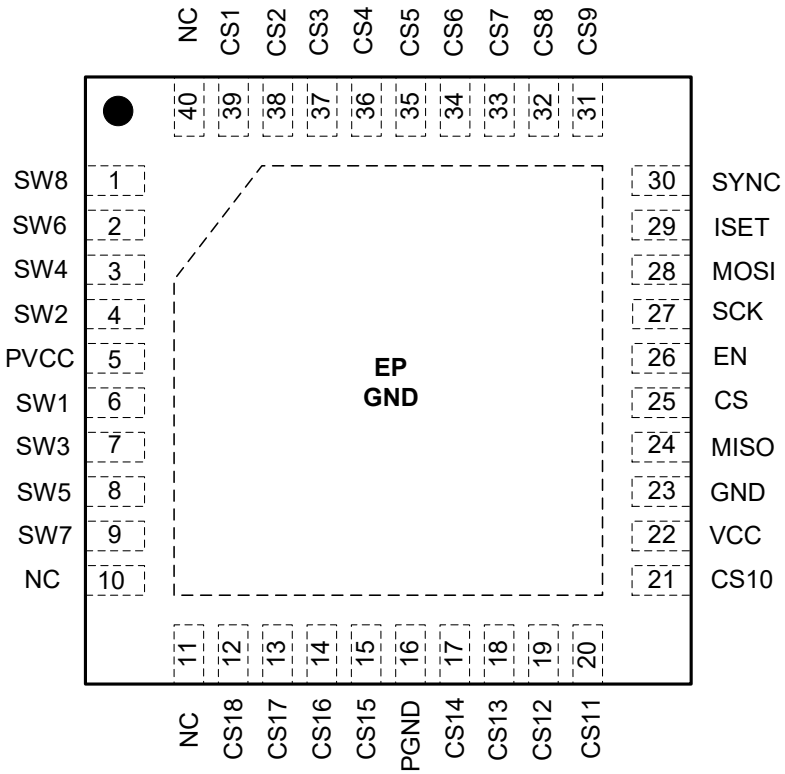
HTR7198 Top View



HTR7144 Top View



HTR7198S Top View



HTR7144S Top View

■ TERMINAL FUNCTION

Terminal No.		Name	Description
HTR7198	HTR7198S		
31~39, 17~21, 12~15		CS1~CS18	Current sinks output.电流源输出
6~11, 1~4, 40		SW1~SW11	Switch power source 开关电源
5		PVCC	Power supply for LED current. 电源输入端
22		VCC	Power supply for internal circuit. 电源输入端
(10,11,40 for HTR7144 or HTR7144S)		NC	No connection. 内部无连接
24, 25	--	AD1, AD0	I^2C Address setting. I^2C的地址设置端
27	--	SCL	I^2C serial clock. I^2C数据
28	--	SDA	I^2C serial data. I^2C时钟
--	24	MISO	Serial output data for SPI. SPI数据输出端
--	25	CS	Chip select for SPI. SPI片选端
--	27	SCK	Serial clock for SPI. SPI时钟端
--	28	MOSI	Serial input data for SPI. SPI数据输入端
26		EN	Shutdown the chip when pull to low. 当拉低时关闭芯片
29		ISET	Current setting pin. 电流设置引脚
30		SYNC	Clock synchronization pin in multiple devices application. 多芯片应用时，时钟同步端
16		PGND	Power ground. 地
23		GND	Ground. 地
EP		GND	Connect to GND. 接地散热。

■ SPECIFICATIONS[1]

● Absolute Maximum Ratings [2]

PARAMETER	Symbol	MIN	TYP	MAX	UNIT
Power supply voltage for VCC and PVCC	VCC	-0.3		6	V
Voltage at SCL, SDA, AD0, AD1, EN, SCK, MOSI, CS, MISO	V_I	-0.3		VCC	V
Voltage at SWx, CSx	V_I	-0.3		PVCC	V
Voltage at ISET	V_{ISET}	-0.3		2	V
Moisture Sensitivity Level (MSL)			MSL3		
Ambient Operating Temperature	T_A	-40		125	℃
Junction Temperature	T_J	-40		150	℃
Storage Temperature	T_{STG}	-65		150	℃
Package thermal resistance, junction to ambient (4 layer standard test PCB based on JEDEC standard)	θ_{JA}		30		°C/W
ESD (HBM)			±2		kV
ESD (CDM)			±1		kV

● Main Electrical Characteristics

Condition: T_A = 25°C, VCC = 3.6V, R_{ISET}=10kΩ, unless otherwise specified

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Power supply voltage for VCC and PVCC	VCC		2.7		5.5	V
Quiescent power supply current	I_{CC}	V_{EN}= Vcc, CHIPEN = 1, all LEDs off		1.8		mA
Shutdown current	I_{SD}	V_{EN}= 0V		3		uA
		V_{EN}= Vcc，CHIPEN = 0		3		uA
Maximum constant current of CSX	I_{OUTmax}	R_{ISET} = 10kΩ, V_{LED} = 0.5V GCC= 0xFF, SL=0xFF		40		mA
Current switch headroom voltage SWx	V_{HR}	I_{SWITCH}=720mA, R_{ISET}=10kΩ, GCC= 0xFF, SL=0xFF		750		mV
Current sink headroom voltage CSx		I_{SINK}=40mA, R_{ISET}=10kΩ, GCC= 0xFF, SL=0xFF		300		mV
Internal sink current limit	I_{LIM}	R_{ILIM}=0, UVCR.OCPTh=0		75		mA
		R_{ILIM}=0, UVCR.OCPTh=1		120		mA
Device to device current error	I_{MATCH}	All Channels' current set to 40mA	-5		+5	%
Channel to channel current error	$\triangle I_{LED}$	All Channels' current set to 40mA	-5		+5	%
OSC clock frequency	F_{OSC}			16		MHz
Period of scanning	t_{SCAN}			216		us
Non-overlap blanking time between SW	t_{NO}			1		us
Delay time between the falling edge of CS18 and SWx	t_{DT1}			125		ns
Delay time between the rising edge of SWx and CS1	t_{DT2}			250		ns
Delay time of each CS group, there are 6 groups of CS	t_{DT3}			125		ns
Thermal shutdown	T_{SD}			165		℃
Thermal shutdown hysteresis	T_{SD_HYS}			25		℃
Output voltage of ISET pin	VISET			0.8		V

[1] Depending on parts and PCB layout, characteristics may be changed.
[2] Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.

- **Logic Electrical Characteristics (SDA, SCL, AD0, AD1, EN, SCK, MOSI, CS, MISO)**

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Logic “0” input voltage	V_{IL}	V_{CC}= 2.7V~5.5V，LGC= “0”	GND		0.4	V
Logic “1” input voltage	V_{IH}	V_{CC}= 2.7V~5.5V，LGC= “0”	1.4		Vcc	V
Logic “0” input voltage	V_{IL}	V_{CC}= 2.7V~5.5V，LGC= “1”	GND		0.6	V
Logic “1” input voltage	V_{IH}	V_{CC}= 2.7V~5.5V，LGC= “1”	2.4		Vcc	V

- **I²C Control Port (HTR7198, HTR7144)**

PARAMETER	Symbol	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
Serial-Clock frequency	f_{SCL}			400			1000	kHz
Bus free time between a STOP and a START condition	t_{BUF}	1.3			0.5			us
Hold time (repeated) START condition. After this period, the first clock pulse is generated.	$t_{h(STA)}$	0.6			0.26			us
Setup time for a repeated START condition	$t_{su(STA)}$	0.6			0.26			us
Setup Time for SCL to STOP condition	$t_{su(STO)}$	0.6			0.26			us
Data hold time	$t_{h(DAT)}$	0			0			us
Setup Time, SDA to SCL	$t_{su(DAT)}$	100			50			ns
Required Pulse Duration, SCL HIGH	t_{HIGH}	0.7			0.26			us
Required Pulse Duration, SCL LOW	t_{LOW}	1.3			0.5			us
Rise Time, SCL and SDA	T_r			300			120	ns
Fall Time, SCL and SDA	T_f			300			120	ns

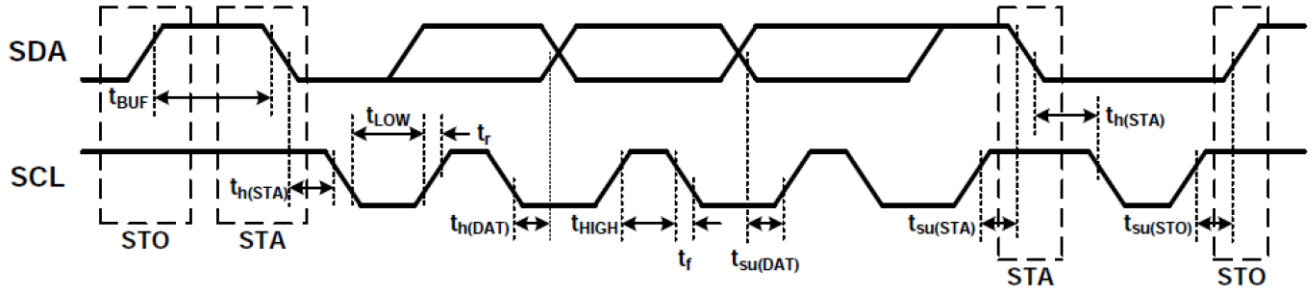


Figure 1 I²C Timing

- **SPI Control Port (HTR7198S, HTR7144S)**

PARAMETER	Symbol	MIN	TYP	MAX	UNIT
Clock frequency	f_C			10	MHz
CS active setup time	t_{CSAS}	30			ns
CS active hold time	t_{CSAH}	15			ns
CS not active setup time	t_{CSNS}	15			ns
CS not active hold time	t_{CSNH}	15			ns
SCK high time	t_{CH}	20			ns
SCK low time	t_{CL}	35			ns
Data in set up time	t_{DS}	10			ns
Data in hold time	t_{LOW}	15			ns
SCK falling edge to MISO data update time	T_f		12	42	ns

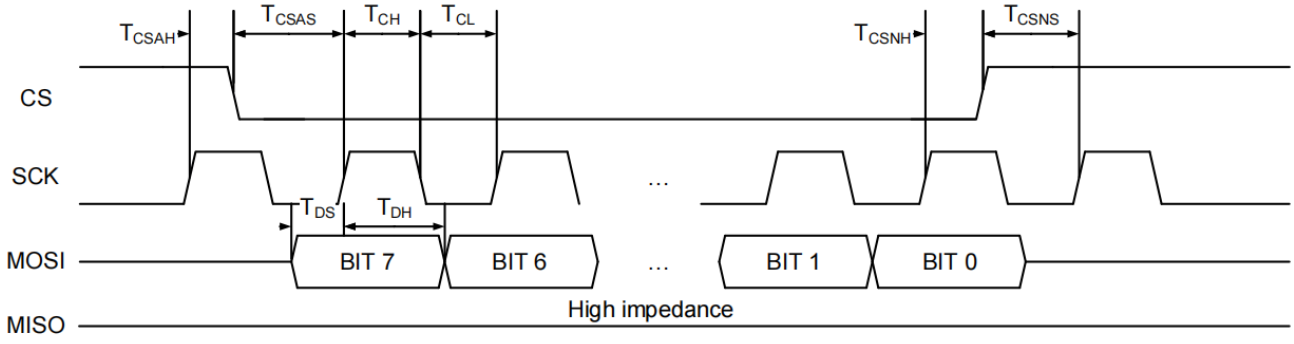


Figure 2 SPI Input Timing

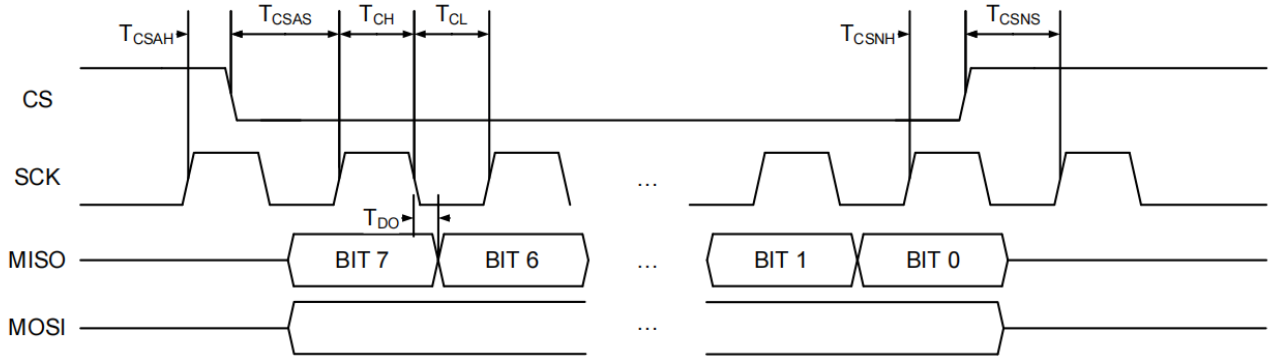


Figure 3 SPI Output Timing

■ APPLICATION INFORMATION

1 Power On Timing and Reset

The recommended power on timing shows as the follows. 推荐的上电时序如下图。

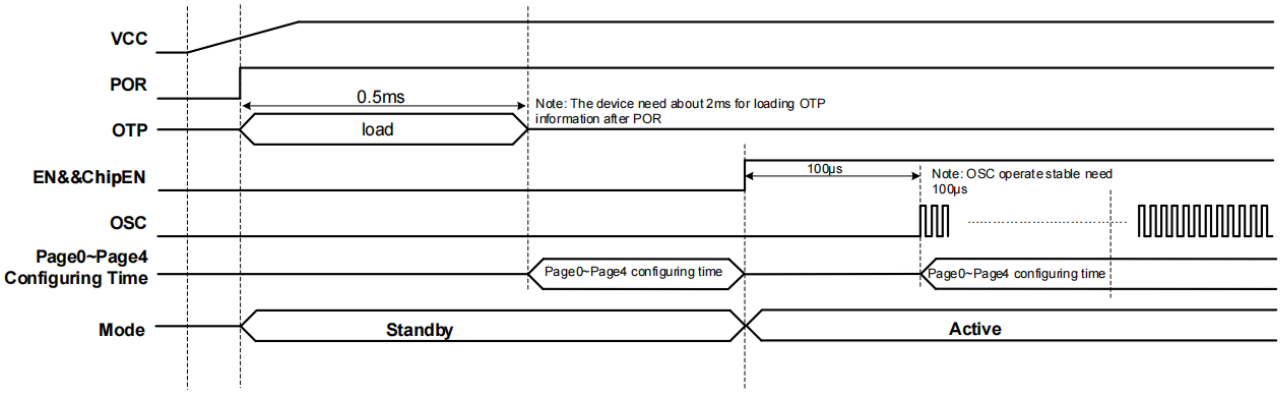


Figure 4 Power on Timing

Once the device is powered on, the device is reset, all the registers are reset to default value.

Once the power supply VCC voltage drops below POR threshold (2.5V typ), the device is reset. PRStatus of register UVCR (page 0, address = 0x2A) shows if a POR reset is occurred.

当芯片上电时，芯片复位，所有寄存器恢复到默认值。

当 VCC 降低到 POR 阈值(2.5V 典型值)，芯片复位。寄存器 UVCR (page 0, address = 0x2A) 中的 PRStatus 可以显示是否发生了 POR 复位。

Software Reset

Once the register RSTN (page 0, address = 0x2F) is written into 0xAE, device is reset, all the registers are reset to default value and the device goes into shutdown mode.

Any other I2C or SPI communication can be done only 0.5ms after the software reset or power on reset.

软件复位

当寄存器 RSTN (page 0, address = 0x2F)写 0xAE，芯片复位，所有寄存器回复到默认值，芯片进入关断模式。

软件复位或上电复位后，需经过 0.5ms，才能进行有效的 I2C 或 SPI 通讯。

2 Operation Mode

2.1 Active Mode

Once EN = H, and bit ChipEN of register GCR (Page 0, address = 0x00) is set to “1”, the device goes into active mode.

当 EN = H，寄存器 GCR(Page 0, address = 0x00)中的 ChipEN 设为“1”，芯片进入工作模式。

2.2 Shutdown Mode

Once EN = L, or bit ChipEN of register GCR (Page 0, address = 0x00) is set to “0”, or UVLO is triggered (UVFlag = 1), or over temperature protection is trggered, the device goes into shutdown mode, where all analog module is shutdown to save the power consumption, all the registers remain the values and still can be read or written via I2C or SPI. When POR (Power On Reset) is triggered, the devices goes into shutdown mode and all registers will be reset to default value.

当 EN = L，或者寄存器 GCR(Page 0, address = 0x00)中的 ChipEN 设为“0”，或者 UVLO 欠压保护启动((UVFlag = 1))，或者过温保护启动，芯片进入关断模式，此时所有模拟模块关断以节省功耗，所有寄存器保留值并可通过 I2C 或 SPI 读写。当 POR 启动，芯片进入关断模式，所有寄存器被复位为初始值。

2.3 Low Power Mode

Once bit LPEN of register MIXCR (Page 0, address = 0x46) is set to "1", or all PWM regesters [7:0] (page 1) are 0x00 in active mode, the device goes into low power mode. If any bit of PWM[7:0] is not 0, the device exits low power mode immediately.

当 MIXCR 寄存器(Page 0, address = 0x46)中的 LPEN 写"1"，或在工作模式下所有 PWM[7:0]为 0x00，芯片进入低功耗模式。一旦 PWM[7:0]中的任意一位为非"0"，芯片退出低功耗模式。

3 I2C Operation (HTR7198, HTR7144)

The HTR7198 or HTR7144 uses a serial bus, which conforms to the I²C protocol, to control the chip's functions with two wires: SCL and SDA. The chip supports 1MHz write and read operations.

HTR7198 或 HTR7144 使用两条符合 I²C 通信协议的串行传输线 SDA 和 SCL 来控制芯片的工作方式。其支持 1MHz 的读写操作。

The chip has a 7-bit slave device address (A7:A1), followed by the R/W bit, A0. The slave device addresses can be determined by AD0 and AD1, see as the following table. The device also supports using a slave broadcast address of 0x5A.

HTR7198 或 HTR7144 使用 7 位的从器件地址（A7:A1），最后一位为读写位。器件地址由 AD1 和 AD1 决定，如下表。其还支持广播地址 0x5A，所有 HTR7198 或 HTR7144 均可使用其作为器件地址。

Table1 Slave Device Address

A7:A5	A4:A3	A2:A1	A0 (wire/read)	AD0	AD1	Device Address [A7:A1]	Device Address [A7:A0], A0=0
010	00	00	0/1	GND	GND	0x20	0x40
	00	01		GND	VCC	0x21	0x42
	00	10		GND	SCL	0x22	0x44
	00	11		GND	SDA	0x23	0x46
	01	00		VCC	GND	0x24	0x48
	01	01		VCC	VCC	0x25	0x4A
	01	10		VCC	SCL	0x26	0x4C
	01	11		VCC	SDA	0x27	0x4E
	10	00		SCL	GND	0x28	0x50
	10	01		SCL	VCC	0x29	0x52
	10	10		SCL	SCL	0x2A	0x54
	10	11		SCL	SDA	0x2B	0x56
	11	00		SDA	GND	0x2C	0x58
	11	01		SDA	VCC	0x2D	0x5A
	11	10		SDA	SCL	0x2E	0x5C
	11	11		SDA	SDA	0x2F	0x5E

The SCL line is uni-directional. The SDA line is bi-directional (open-collector) with a pull-up resistor (typically 400K IIC with 4.7kΩ ,1MHz IIC with 1kΩ). The maximum clock frequency specified by the I²C standard is 1MHz. In this discussion, the master is the microcontroller and the slave is the HTR7198 or HTR7144.

The SDA is latched in on the stable high level of the SCL. When there is no interface activity, the SDA line should be held high.

The "START" signal is generated by lowering the SDA signal while the SCL signal is high. The start signal will alert all devices attached to the I²C bus to check the incoming address against their own chip address.

The 8-bit chip address is sent next, most significant bit first. Each address bit must be stable while the SCL level is high.

After the last bit of the chip address is sent, the master checks for the HTR7198 or HTR7144's acknowledge. The master releases the SDA line high (through a pull-up resistor). Then the master sends an SCL pulse. If the HTR7198 or HTR7144 has received the address correctly, then it holds the SDA line low during the SCL pulse. If the SDA line is not low, then the master should send a "STOP" signal (discussed later) and abort the transfer.

Following acknowledge of HTR7198 or HTR7144, the register address byte is sent, most significant bit first. HTR7198 or HTR7144 must generate another acknowledge indicating that the register address has been received.

Then 8-bit of data byte are sent next, most significant bit first. Each data bit should be valid while the SCL level is stable high. After the data byte is sent, the HTR7198 or HTR7144 must generate another acknowledge to indicate that the data was received.

The "STOP" signal ends the transfer. To signal "STOP", the SDA signal goes high while the SCL signal is high..

I²C 总线支持数据双向传输。SCL 为单向端口；SDA 为双向端口，开漏输出驱动，需外接上拉电阻（典型值为 400k 下为 4.7k，1M 下为 1k）。最大时钟频率为 1MHz。在这种情况下，主控器件为单片机等控制器，从器件为 HTR7198 或 HTR7144。

在 SCL 为稳定的高电平时，SDA 为闭锁状态，并且在不使用的时候应保持高电平。

"开始"信号由 SCL 为高电平时将 SDA 拉低产生。"开始"信号会提醒所有的设备接收 I²C 总线上即将到来的地址与自己的地址进行比较。

接着发送的是 8bit 芯片地址，高位优先。在 SCL 为高电平的时候每个地址位必须保持稳定。

在最后一位传送出去后，主控器件应检测 HTR7198 或 HTR7144 的应答信号。主控器件通过上拉电阻释放 SDA 为高电平，然后使 SCL 发送一个脉冲。如果 HTR7198 或 HTR7144 正确的接收到 8 位数据，在 SCL 的脉冲期间它将使 SDA 拉低；如果 SDA 线不为低，则表示数据没有正确接收，主控器件将会发送一个"停止"信号并且中断数据传递。

在 HTR7198 或 HTR7144 的应答信号发送之后，寄存器的地址将被发送，高位优先。寄存器地址发出后，HTR7198 或 HTR7144 必须再产生一个应答位来表示寄存器地址已被正确接收。

接下来传送的是 8 位的寄存器数据。在 SCL 保持稳定的高电平时每位数据都是有效的。8 位数据传送完后，HTR7198 或 HTR7144 同样需要产生一个应答位来表示数据的正确接收。

传送结束后需要发送"停止"信号。结束信号由 SCL 为高时将 SDA 拉高。

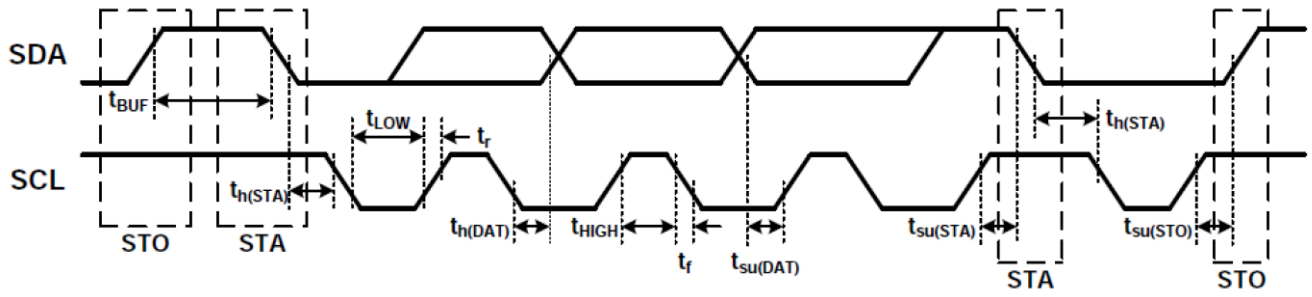


Figure 5 I²C Interface Timing

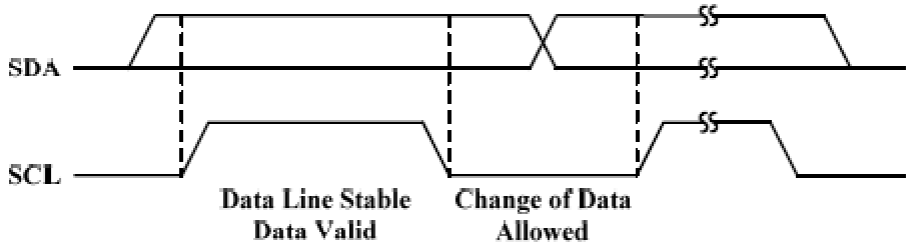


Figure 6 Bit Transfer

Address Auto Increasement

To write multiple bytes of data into HTR7198 or HTR7144, load the address of the data register that the first data byte is intended for. During the HTR7198 or HTR7144 acknowledge of receiving the data byte, the internal address pointer will increment by one. The next data byte sent to HTR7198 or HTR7144 will be placed in the new address, and so on. The auto increment of the address will continue as long as data continues to be written to HTR7198 or HTR7144 (Figure 5).

如果有多个数据要传送给 HTR7198 或 HTR7144，只需发送第一个数据写入的寄存器地址。在HTR7198或HTR7144接收数据器件，寄存器地址会自动加 1，下一个传送的数据将写入新的寄存器地址中，如此继续，直到 I²C 写入“停止”信号。如下图 5。

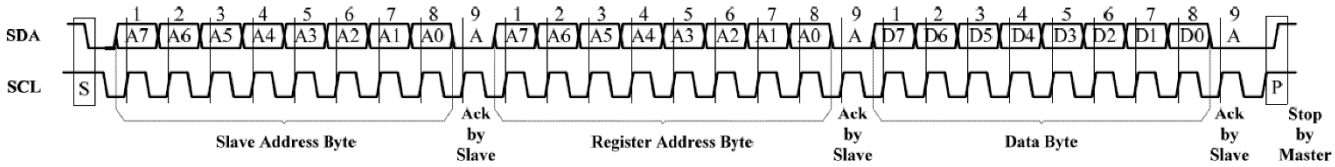


Figure 7 Typical I²C Writing

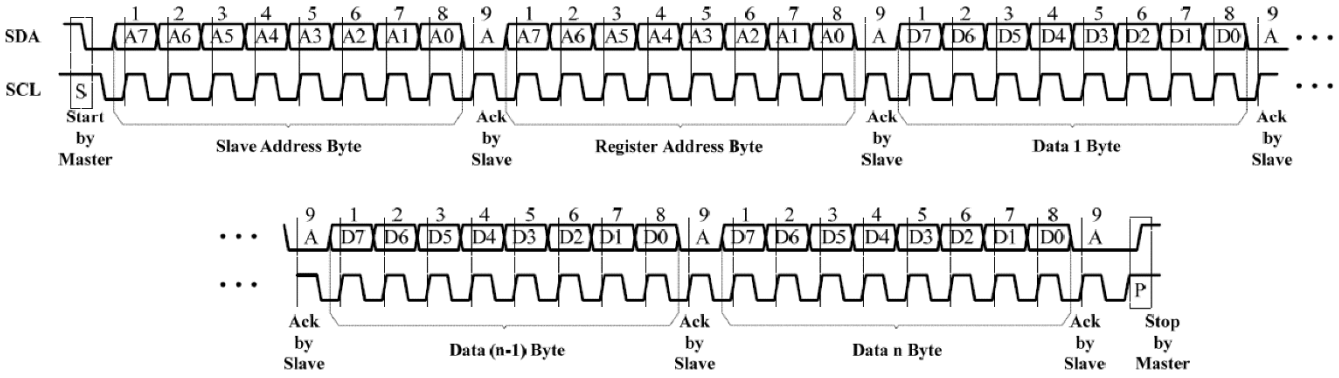


Figure 8 I²C Writing with Automatic Address Increment

Read Operation

Most of the registers can be read.

To read the register, after I²C start condition, the bus master must send the HTR7198 or HTR7144 device address with the R/W bit set to "0", followed by the register address which determines which register is accessed. Then restart I²C, the bus master should send the HTR7198 or HTR7144 device address with the R/W bit set to "1". Data from the register defined by the command byte is then sent from the HTR7198 or HTR7144 to the master. (Figure 5)

大部分的寄存器都是可读的。

要读取寄存器的话，在 I²C 启动信号以后，主机在发送 HTR7198 或 HTR7144 的器件地址时 R/W 位给 0，然后发送寄存器地址决定哪个寄存器被选中，然后发送 I²C 重启信号，之后主机在发送 HTR7198 或 HTR7144 的器件地址时 R/W 位给 1，之后倍选中的寄存器中的数据就会由 HTR7198 或 HTR7144 发送到主机(如图 5）。

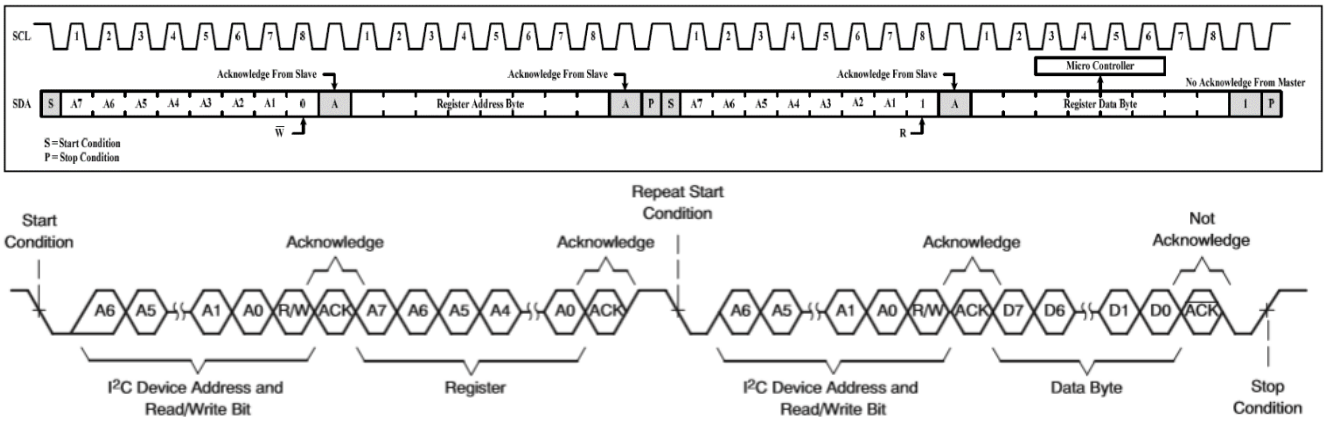


Figure 9 I²C Reading

4 SPI Operation (HTR7198S or HTR7144S)

The HTR7198S OR HTR7144S uses a serial bus, which conforms to the SPI protocol, to control the chip's functions. The HTR7198S OR HTR7144S supports 10MHz write and read operations.

The SPI data is 8-bit long for a byte. The first comand byte is composed by 4-bit chip ID, 3-bit page ID and W/R bit. Then is followed by register address and register data.

The chip ID of HTR7198S OR HTR7144S is "1010', and the command byte is shown in the following table.

HTR7198S 或 HTR7144S 使用符合 SPI 通信协议的串行传输线来控制芯片的工作方式。HTR7198S 或 HTR7144S 支持最高 10MHz 的读写操作。

SPI 数据为 8-bit 一个 byte。读写时，第一个 byte 为 command byte，包含 4-bit 的器件 ID，3-bit 的 page ID 和 1bit 的读写位。随后是寄存器地址位和寄存器值位。

HTR7198S 或 HTR7144S 的器件 ID 是"1010"，command byte 如下表。

Table2 Command Byte

Bits	A7:A4 Chip ID	D3:D1 Page ID	A0 (write/read)
Value	1010	000: page 0 001: page 1 010: page 2 011: page 3 100: page 4	0/1

SPI Writing

Typical SPI writing:

Step1, the master pulls CS low;

Step2, the master sends the command byte through MOSI;

Step3, the master sends the register address through MOSI;

Step4, the master sends the register data through MOSI;

Step5, the master pulls CS high, the writing process ends.

Address Auto Increasement Writing

To write multiple bytes of data into HTR7198S OR HTR7144S, the master only needs to send the register address of the first data byte. During the first rising edge of finishing sending the first data byte, the internal address pointer will increment by one automatically. The next data byte sent to HTR7198S OR HTR7144S will be placed in the new address, and so on. The auto increment of the address will continue as long as data continues to be written to HTR7198S OR HTR7144S (Figure 8).

SPI 写

典型 SPI 写：

第一步，主机将 CS 拉低；

第二步，主机通过 MOSI 发送 command byte；

第三步：主机通过 MOSI 发送寄存器地址；

第四步：主机通过 MOSI 发送寄存器数据；

第五步：主机将 CS 拉高，SPI 写结束。

地址自动增加的写

如果有多个数据要传送给 HTR7198S 或 HTR7144S，只需发送第一个数据写入的寄存器地址。第一个数据结束后的第一个上升沿，寄存器地址会自动加 1，下一个传送的数据将写入新的寄存器地址中，如此继续，直到 CS 拉高。如下图 8。

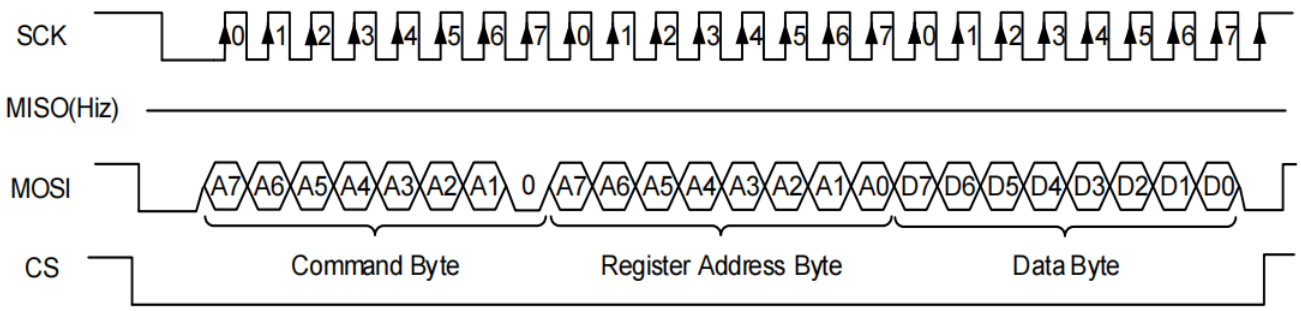


Figure 10 Typical SPI Writing Timing

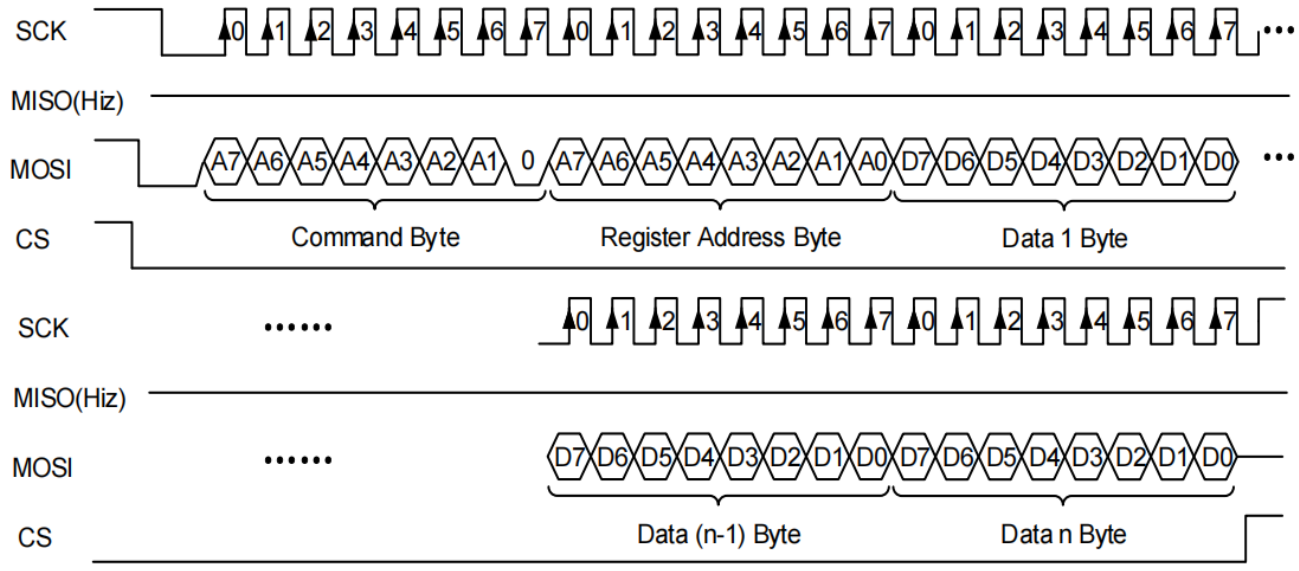


Figure 11 Address Auto Increment Writing Timing

SPI Reading

Typical SPI reading:

Step1, the master pulls CS low;

Step2, the master sends the command byte through MOSI;

Step3, the master sends the register address through MOSI;

Step4, the device sends the register data through MISO to the master;

Step5, the master pulls CS high, the writing process ends.

Address Auto Increasement Reading

To read multiple bytes of data from HTR7198S OR HTR7144S, the master only needs to send the register address of the first data byte. During the first rising edge of finishing reading the first data byte, the internal address pointer will increment by one automatically. The next data byte sent from HTR7198S OR HTR7144S will be placed in the new address, and so on. The auto increment of the address will continue as long as data continues to be read from HTR7198S OR HTR7144S (Figure 10).

SPI 读

典型 SPI 读：

第一步，主机将 CS 拉低；

第二步，主机通过 MOSI 发送 command byte；

第三步：主机通过 MOSI 发送寄存器地址；

第四步：芯片通过 MISO 向主机发送寄存器数据；

第五步：主机将 CS 拉高，SPI 写结束。

地址自动增加的读

如果有多个数据要从 HTR7198S 或 HTR7144S 读取，只需发送需要读取的第一个数据的寄存器地址。第一个数据读取结束后的第一个上升沿，寄存器地址会自动加 1，新的寄存器地址中数据将被传送，如此继续，直到 CS 拉高。如下图 10。

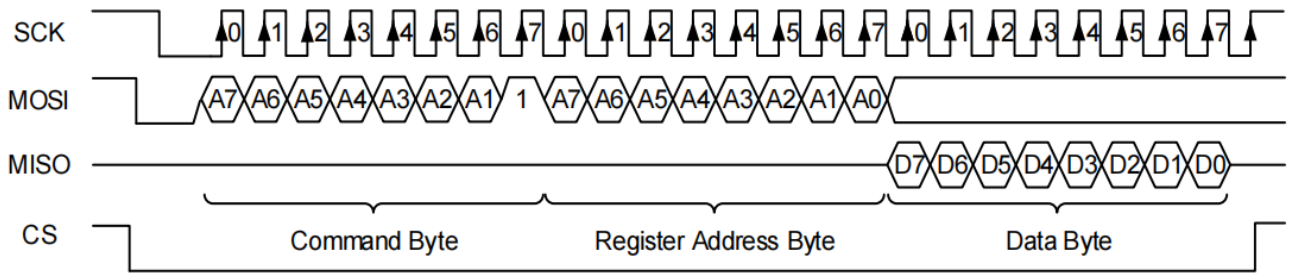


Figure 12 Typical SPI Reading Timing

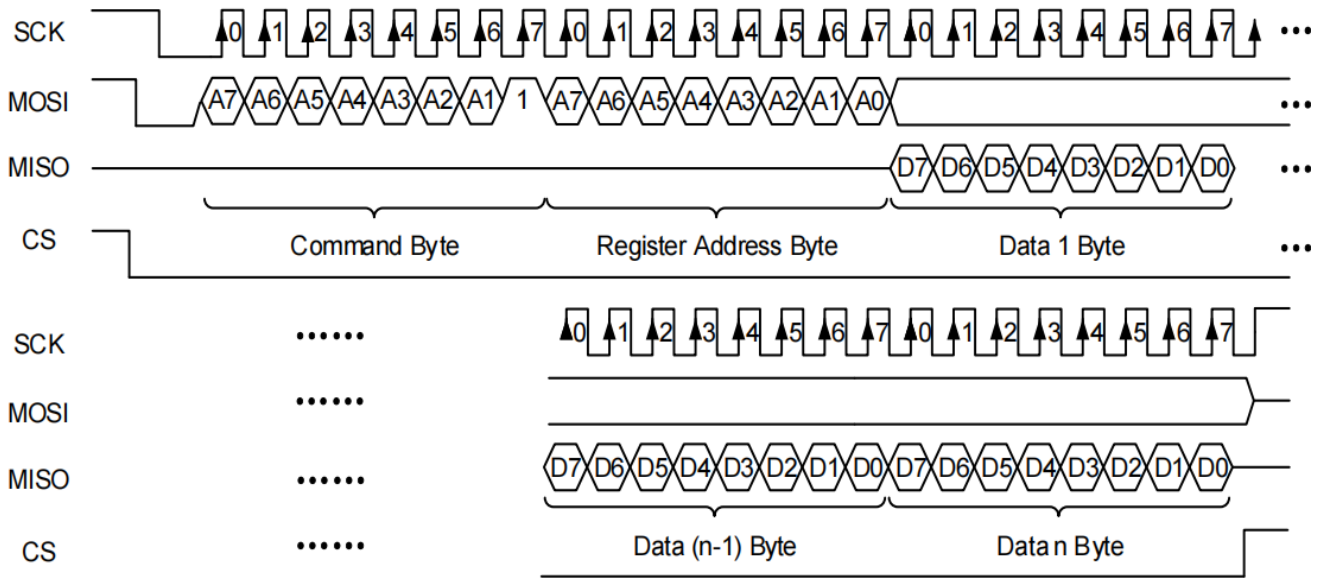


Figure 13 Address Auto Increment Reading Timing

Under Voltage Lockout (UVLO)

Once the bit UVDetect is of the register UVCR (page 0, address = 0x2A) is set to “0”, the devices monitors the VCC voltage. Once the VCC voltage falls below UVLO threshold (2.5V typ.), UVFlag of the register UVCR (page 0, address = 0x2A) is changed to “1”. After read-out, UVFlag will be clear.

If both the bit UVDetect and the bit UVProtect of the register UVCR (page 0, address = 0x2A) are set to “0”, UVLO protection is enabled, so that once VCC voltage falls below threshold (2.5V typ.), the bit ChipEN of the register GCR (page0, address=0x00) will be cleared to “0”, and then the device will enter into shutdown mode. If the VCC voltage rises above the UVLO threshold, first read UVCR (0x2A) and then write “1” to bit ChipEN, the device will enter into active mode again.

寄存器 UVCR (page 0, address = 0x2A) 中的 UVDetect 位为“0”，芯片会监测 VCC 电压。一旦 VCC 电压低于 UVLO 阈值（2.5V 典型值），寄存器 UVCR (page 0, address = 0x2A) 中的 UVFlag 变为“1”，其被读取后，又会清零。

如果寄存器 UVCR (page 0, address = 0x2A) 中的 UVDetect 位和 UVProtect 位均为“0”，则欠压保护功能开启，一旦 VCC 电压低于 UVLO 阈值（2.5V 典型值），GCR 寄存器中的 ChipEN 会置“0”，芯片进入关断模式。如果 VCC 电压回升到 UVLO 阈值后，需先读 UVCR(0x2A)，并将 ChipEN 写“1”，芯片重新进入工作模式。

5 Over Temperature Protection

Thermal Foldback

Once the iunction temperature of the device exceeds the value of bit TFTh of register OTCR (page 0, address = 0x27), the flag bit TFFlag of register OTCR is set to “1”, and I_{OUT} will be decreased by the value of bit TFOf of register OTCR.

Over Temperature Shutdown

Once the bit OTDetect of the register OTCR (page 0, address = 0x27) is set to “0”, the over temperature detection is enabled, and the bit OTFlag of the register OTCR will be set to “1” after the junction temperature of the device exceeds 165℃ (typ.). After read-out, OTFlag will be clear.

If both bit OTDetect and bit OTProtect of the register OTCR (page0, address=0x27) are set to “0”, the Over Temperature Protection (OTP) function is enabled. Once the temperature exceeds 165°C (typ.), the bit ChipEN of the register GCR (page0, address=0x00) will be cleared to “0”, and then the device will enter into shutdown mode.

When the temperature falls below 140°C (typ.), first read OTCR and then write “1” to bit ChipEN, the device will enter into active mode again.

温度折返

当芯片结温超过 OTCR 寄存器(page 0, address=0x27)中 TFTh 位的值，TFFlag 会置“1”I_{OUT} 会减小一个百分比（即 OTCR 寄存器中 TFOf 的值)。

过温关断

如果寄存器 OTCR (page0, address=0x27) 中的 OTDetect 设“0”，过温监测开启，芯片结温超过 165℃后，OTCR 寄存器中的 OTFlag 置“1”。读取后，OTFlag 自动清零。

如果寄存器 OTCR (page0, address=0x27) 中的 OTDetect 和 OTProtect 位均为“0”，则过温关断保护功能开启，一旦芯片结温高于 OTP 阈值（165°C 典型值），GCR 寄存器中的 ChipEN 会置“0”，芯片进入关断模式。

如果芯片结温降低到 OTP 阈值（140°C 典型值）后，需先读 OTCR，并将 ChipEN 写“1”，芯片重新进入工作模式。

6 LED Display and Control

HTR7198(S) or HTR7144(S) are able to drive up to 18x11=198 or 18x8=144 Matrix LEDs, shown as the following picture.

HTR7198(S)或 HTR7144(S)支持驱动最多 18x11=198 或 18x8=144 矩阵 LED，如下图。

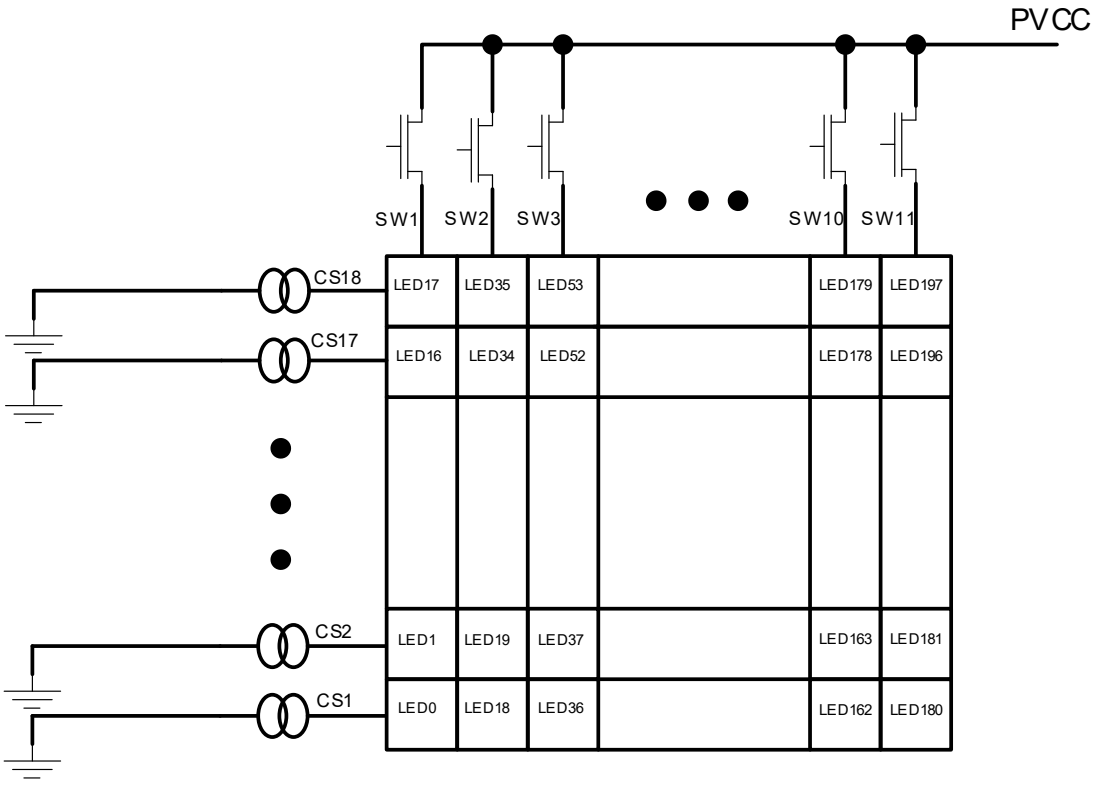


Figure 14 LED Display Map

Each LED is controlled by 4 parameters:

(1) Global current control, set by register GCCR (page0, address = 0x01); it can adjust the global current for all LEDs.

(2) PWM control, set by register PWMx (page1, address 0x00~0xC5); it can be used for brightness dimming for each LED.

(3) SL control, set by register SLx (page2, address 0x00~0xC5); it can control the constant current and can be used for colour calibration.

(4) Pattern controller choice, set by register PCx (page3, address 0x0~0x41). It can be used for dimming synchronously or outputing a same breathing effect.

每个 LED 由 4 个参数控制：

（1） 全局电流控制，由 GCCR 寄存器(page0, address = 0x01)设置，其可控制全局电流；

（2） PWM 控制，由 PWMx 寄存器(page1, address 0x00~0xC5) 设置，其可用于每个 LED 的各自调光；

（3） SL 控制，由 SLx 寄存器(page2, address 0x00~0xC5) 设置，其可用于对应 LED 的调色；

（4） 模式控制器选择，由 PCx 寄存器(page3, address 0x0~0x41)设置，其可用于群组调光或群组呼吸。

7 Scanning Timing

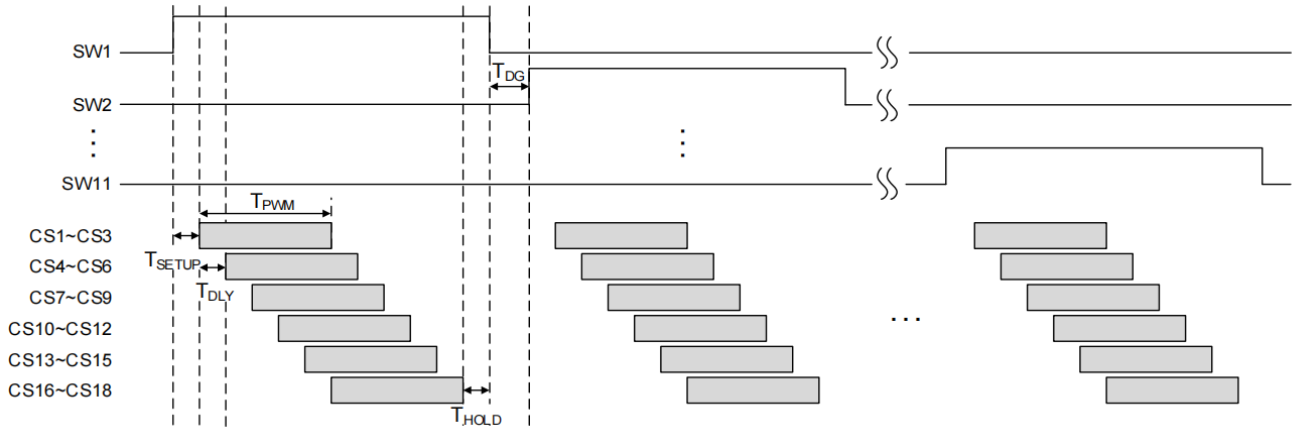


Figure 15 Scanning Timing

As shown in Figure above, the SW1~SW11 is turned on by serial, LED is driven by CS1~CS18 within the SWx (x=1~11) on time (SWx, x=1~11 is source and it is high when LED on).

SW scanning number N (N=1~11) can be controlled by bits SWSEL[3:0] in register GCR. When PCCR.Freq[2:0] = 000 (page0, address=0x29), the DUTY is:

$$Duty = \frac{15.9375us}{0.25us + 5 \times 0.125us + 16us + 0.125us + 1us} \times \frac{1}{N}$$

Where T_{PWM} = 15.9375us, T_{SETUP} = 0.25us, T_{DLY} = 0.125us, T_{HOLD} = 0.125us, and T_{DG} = 1us.

如上图所示，SW1~SW11 次打开，LED 随着 SWx 依次打开（SW 是电源，当它为高时 LED 打开）。

SW 扫描数 N（N=1~11）由寄存器 GCR 中的 SWSEL[3:0]决定。当 PCCR.Freq[2:0] =000 (page0, address=0x29)，

$$Duty = \frac{15.9375us}{0.25us + 5 \times 0.125us + 16us + 0.125us + 1us} \times \frac{1}{N}$$

其中 T_{PWM} = 15.9375us, T_{SETUP} = 0.25us, T_{DLY} = 0.125us, T_{HOLD} = 0.125us, T_{DG} = 1us。

8 R_{ISET} and LED Current

The resistor R_{ISET} determines the maximum LED current Imax:

$$I_{max}(mA) = \frac{400}{R_{ISET\ (kohm)}}$$

LED average current (I_{LED})) can be described in following Formula.

$$I_{LED} = \frac{400}{R_{ISET}} \times \frac{GCC}{255} \times \frac{SL}{255} \times \frac{PWM}{256} \times Duty$$

电阻 R_{ISET} 可以设置最大的 LED 电流：

$$I_{max}(mA) = \frac{400}{R_{ISET\ (kohm)}}$$

LED 平均电流 I_{LED} 可计算如下：

$$I_{LED} = \frac{400}{R_{ISET}} \times \frac{GCC}{255} \times \frac{SL}{255} \times \frac{PWM}{256} \times Duty$$

9 PWM CONTROL

9.1 PWM Frequency Control

The PWM frequency can be set through bits Freq[2:0] of register PCCR (page0, address = 0x29).

PWM 频率由 PCCR 寄存器（page0, address = 0x29）的 Freq 设置。

9.2 PWM Phase Control

HTR7198(S), HTR7144(S) support 3 different PWM phase mode to reducing peak load current and audible ringing.

HTR7198(S), HTR7144(S)支持 3 中不同的 PWM 相位模式，以降低尖峰电流和可能的可闻噪声。

10 EMI Reduction

10.1 Slew Rate

The slew rate of the LED current sink (CS1 ~ CS18) on or off can be set through bits SRR and SRF of register SRCR (page0, address = 0x2B).

LED 开关的上升下降沿，可通过 SRCR 寄存器(page0, address = 0x2B)的 SRR 和 SRF 设置。

10.2 Spread Spectrum

Spread specturm function can be enabled by setting bit SSEN in register SSCR (page0, address = 0x28) as “1”. Four spread spectrum ranges (5%, 15%, 25%, 35%) can be chosen through bit SSR in register SSCR.

扩频功能可通过寄存器 SSCR (page0, address = 0x28)中的 SSEN 设“1”来开启。4 种扩频范围可选，分别是 5%, 15%, 25%, 35%，在 SSCR 寄存器种的 SSR 选择。

11 Open/Short Detection Function

HTR7198(S), HTR7144(S) have open and short detect bit for each LED.

Before using the open/short detect function, the following settings should be followed:

(1) ChipEN is “1”;

(2) Phase[1:0] = 00 (page0, PCCR[1:0]);

(3) 0x05≤GCC≤0x80 (page0, GCCR);

(4) SL = 0xFF (Page2, SLx);

(5) 0x20≤PWM≤0xFF (page1, PWMx);

By setting the OSDetect bits of the register GCR (page0, address = 0x00) from “0x” to “10” or “11”, the register OSRxx will start to store the open/short information and the MCU can get the open/short information by reading the register OSRxx if ChipEN is “1”.

The detect action is one-off event and each time before reading out the open/short information, the OSDetect bit of the Configuration Register (A0h) need to be set from “0x” to “10” or “11” (clear before set operation).

HTR7198(S), HTR7144(S)每个LED都有一个开路和短路检测位。

在使用开短路检测功能前需要设置：

(1) ChipEN = “1”;

(2) Phase[1:0] = 00 (page0, PCCR[1:0]);

(3) 0x05≤GCC≤0x80 (page0, GCCR);

(4) SL = 0xFF (Page2, SLx);

(5) 0x20≤PWM≤0xFF (page1, PWMx);

随后通过设置 GCR 寄存器(page0, address = 0x00)的 OSDetect 位从“0x”到“10”或“11”，LED 开路/短路寄存器会开始存储开路/短路信息， MCU 就可以从 OSRxx 寄存器中读取到开路/短路信息。

检测行为是一种一次性的行为，每次在读取开路/短路信息之前，配置寄存器的 OSDetect 位需要从 0x 变为 10 或 11。

12 De-ghost Function

The “ghost” term is used to describe the behavior of an LED that should be OFF but instead glows dimly when another LED is turned ON. A ghosting effect typically can occur when multiplexing LEDs. In matrix architecture any parasitic capacitance found in the constant-current outputs or the PCB traces to the LEDs may provide sufficient current to dimly light an LED to create a ghosting effect.

To prevent this LED ghost effect, the HTR7198(S), HTR7144(S) have integrated Pull down resistors for each SWx and Pull up resistors for each CSx. Select the right SWx Pull down resistor (Register DGCR, Page0, 0x02) and CSx Pull up resistor (Register DGCR, Page0, 0x02) which eliminates the ghost LED for a particular matrix layout configuration.

“ghost” 这个词是用来描述某个 LED 灯处于 OFF 态，但在别的 LED 灯打开时，却有比较淡的发光。鬼影现象通常发生在 LED 多路复用的时候。在阵列结构中，任何在恒流输出端或者 PCB 到 LED 灯的寄生电容都可能提供足够的电流去点亮某个 LED 灯，从而导致鬼影现象。

为了防止这种鬼影，在 HTR7198(S), HTR7144(S)中，对于每个 SWx 有多组下拉电阻，对于每个 CSx 有多组上拉电阻，选择合适的下拉和上拉电阻(Register DGCR, Page0, 0x02)可以有效限制鬼影现象。

13 Pattern Controllers

3 pattern controllers (PC0~PC2) is integrated in the device. Each LED can be selected in different pattern controllers by Page3, eg. LEDG0_PC set the LED0, LED1 and LED2 in which pattern controller.

PC0Set~PC2Set(page0, address=0x42~0x44) are PC0~PC2 parameters setting registers. When bit PCEN in register PCxSet (x=0~2) is set to "1", pattern controller is enabled. Pattern controller can be configured as autonomous breathing mode or manual-controlled mode by PCMode.

芯片具有 3 个模式控制器。每个 LED 可以通过 Page3 选择一个模式控制器，如 LEDG0_PC 可以设置 LED0, LED1, LED2 选择不同的模式控制器。

PC0Set~PC2Set (page0, address=0x42~0x44)是 PC0~PC2 的参数设置寄存器。当 PCEN 为"1"，该模式控制器使能。模式控制器可以通过 PCMode 设置为自动呼吸模式，或手动控制模式。

Autonomous Breathing Mode

By setting PCMode bit of the register PCxSet (x=0~2) to "1", the pattern controller will operate in autonomous breathing mode.

When in autonomous breathing mode, the pattern controller will generate a breathing lighting effect with user-defined timing parameters. The user-difined timing parameters are including:

(1) The maximum and minimum brightness of the breathing (Register PWMxH (x=0~2, page0, address=0x30~0x32) and PWMxL (x=0~2, page0, address=0x33~0x35));

(2) Rise and fall in logarithmic mode or in linear mode (bit LogEN in register PCxSet (x=0~2));

(3) T0, T1, T2 and T3 (register PCxT0T1, PCxT2T3);

The real time of T0 or T2 is as the following equation, and the real value of T1 or T3 is the exact value shown in the register table;

$$T0\ or\ T2_{real} = \frac{PWMxH - PWMxL}{256} \times T0\ or\ T2$$

(4) Start point and end point of a auto-breath loop (bit SP and EP in register PCxContr1);

(5) Auto-breath loop times (LT[11:8] in register PCxContr1 and LT[7:0] in register PCxContr2); Notice that when LT[11:0] is set to "0", the auto breathing will run unlimited times.

通过对 PCxSet (x=0~2)寄存器中的 PCMode 位置"1"，模式控制器工作在自动呼吸模式。

在自动呼吸模式下，模式控制器会按照用户自定义的参数进行 LED 呼吸。用户自定义参数包括：

（1） 最大和最小亮度（寄存器 PWMxH (x=0~2, page0, address=0x30~0x32) and PWMxL (x=0~2, page0, address=0x33~0x35)）；

（2） 变亮和变暗的过程采用 log 方式或线性方式（PCxSet (x=0~2)寄存器中的 LogEN 位）；

（3） T0, T1, T2 和 T3（寄存器 PCxT0T1, PCxT2T3）；

T0 或 T2 的真实时间如下公式，而 T1 或 T3 的真实时间则同寄存器中的说明；

$$T0\ or\ T2_{real} = \frac{PWMxH - PWMxL}{256} \times T0\ or\ T2$$

（4） 自动呼吸循环的开始点和结束点（PCxContr1 寄存器中的 SP 和 EP 位）；

（5） 自动呼吸循环次数（PCxContr1 寄存器中的 LT[11:8]和 PCxContr2 寄存器中的 LT[7:0]）；需要注意的是，LT[11:0]全为 0 时，自动呼吸将一直循环。

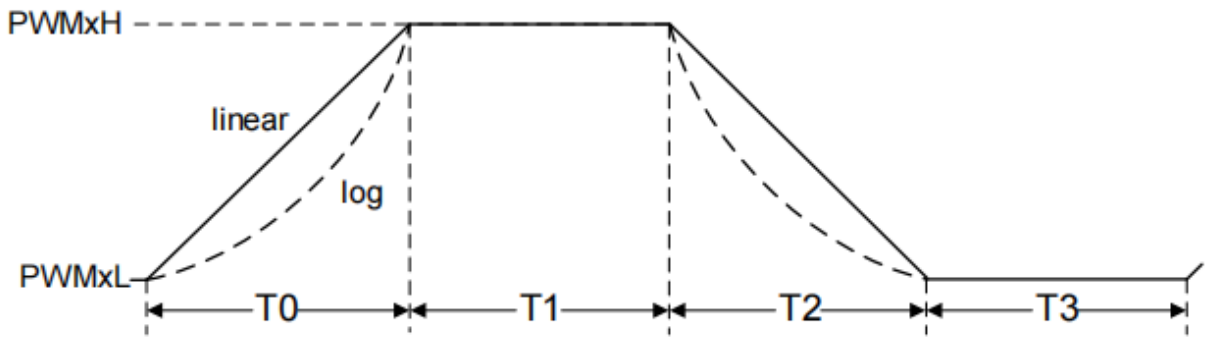


Figure 16 Autonomous Breathing Parameters

After the auto breathing is over, the status bit PCFlag in register PCxSet (x=0~2) will be set to "1", and PCFlag will be cleared to "0" after reading out through I2C or SPI bus. Once auto breathing starts again or pattern controller switches to manual-controlled mode, the PATFLG will also be cleared.

When bit RUNx in register PCGO (x=0~2, page0, address=0x45) is set to "1", auto breathing of pattern controller x is started.

The full process of the autonomous breathing is as follows:

(1) Set GCC, SL and PWMxH/L;

(2) Set Page 3 to select pattern controller of each LED;

(3) Set Register PCxT0T1, PCxT2T3, PCxContr1, PCxControl2;

(4) Set PCEN = 1 to enable the pattern controller;

(5) Set PCMode = 1 and RampEN = 1 to select auto breathing mode and enable breathing ramp;

(6) Set LogEN to select breathing in log mode or linear mode;

(7) Set RUNx = 1 to start the auto breathing.

Manual-Controlled Mode

If bit PCMode is set to "0", manual control mode is selected. In manual control mode, user could set parameters as follows:

(1) The maximum and minimum brightness. The bit Switch of register PCxSET (x=0~2) to control the output of pattern controller. When Switch is "1", the output of pattern controller is decided by register PWMxH (x=0~2). When bit Switch is set to "0", the output is the decided by register PWMxL (x=0~2).

(2) Rise and fall in logarithmic mode or in linear mode (bit LogEN in register PCxSet (x=0~2)), smoothly or directly (bit RampEN in register PCxSET(x=0~2)).

自动呼吸结束时，PCxSet (x=0~2)寄存器中的 PCFlag 位置"1"， 其通过 I2C 或 SPI 读取后清"0"。当自动呼吸再次开始或模式控制器切换至人工模式时，PCFlag 同样清零。

当 PCGO (x=0~2, page0, address=0x45) 寄存器中的 RUNx 位写"1"，模式控制器 x 的自动呼吸开始启动。

自动呼吸完成步骤如下：

（1） 设置 GCC, SL and PWMxH/L；

（2） 设置 Page3，选择每个灯的模式控制器；

（3） 设置寄存器 PCxT0T1, PCxT2T3, PCxContr1, PCxContr2；

（4） 设置 PCEN = 1，使能模式控制器；

（5） 设置 PCMode = 1 和 RampEN = 1，选择自动呼吸模式，使能呼吸渐变；

（6） 设置 LogEN，设置变量变暗采用 log 模式或线性模式；

（7） 设置 RUNx = 1，开启自动呼吸。

当 PCMode 位写"0"，模式控制器工作在手动控制模式。用户可设置如下参数：

（1） 最高和最低亮度。寄存器 PCxSET (x=0~2)的 Switch 位为"1"时，模式控制器输出由 PWMxH (x=0~2) 寄存器决定；当寄存器 PCxSET (x=0~2)的 Switch 位为"0"时，模式控制器输出由 PWMxL (x=0~2) 寄存器决定。

（2） 变亮和变暗的过程采用 log 方式或线性方式（PCxSet (x=0~2)寄存器中的 LogEN 位），渐变还是瞬变（PCxSET(x=0~2) 寄存器中的 RampEN 位）。

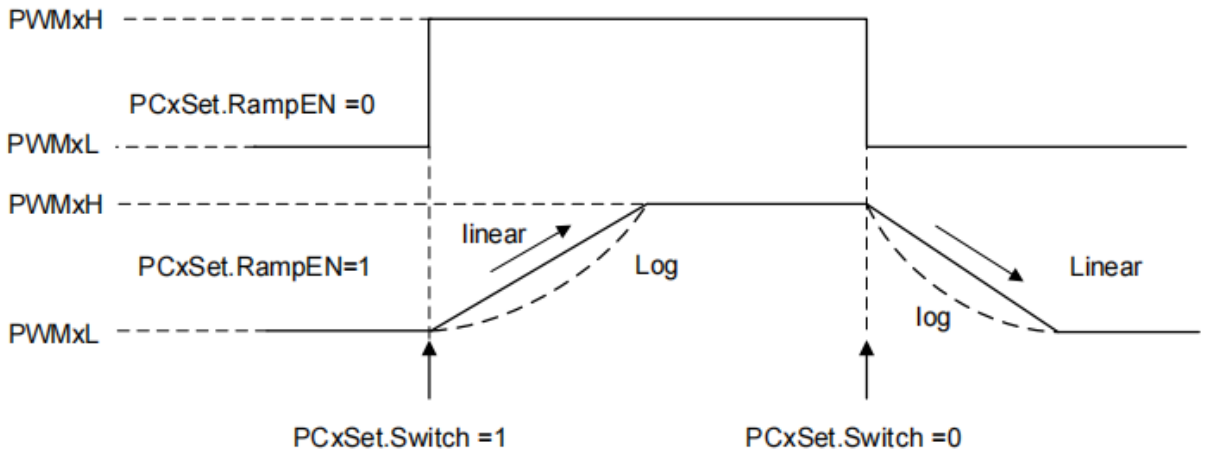


Figure 17 Manual Control Parameters

14 Multiple Devices Synchronization

HTR7198(S) or HTR7144(S) can drive more than 198 or 144 LEDs by synchronizing multiple devices, where all other devices share a common clock that is output from one master HTR7198(S) and HTR7144(S)'s SYNC pin. Bit CLKOE and CLKSEL in Register SSCR (page0, address=0x28) select the clock input or output on pin SYNC.

HTR7198(S) 或 HTR7144(S)可以驱动比 198 或 144 个更多的 LED 灯，通过同步更多的芯片。此时，其他芯片同时使用由一个主机 HTR7198(S)或 HTR7144(S)的 SYNC 脚输出的时钟。寄存器 SSCR (page0, address=0x28)中的 CLKOE 和 CLKSEL 位可以选择主/从和 SYNC 脚的输入/输出

Table3 Clock Input or Output Setting

CLKOE	CLKSEL	Device Clock Selection
0	0	Internal clock, SYNC pin is High-Z
1	0	Master, internal clock, and also output clock on SYNC pin
0	1	Slave, external clock from SYNC pin
1	1	Reserved, do not set in this mode

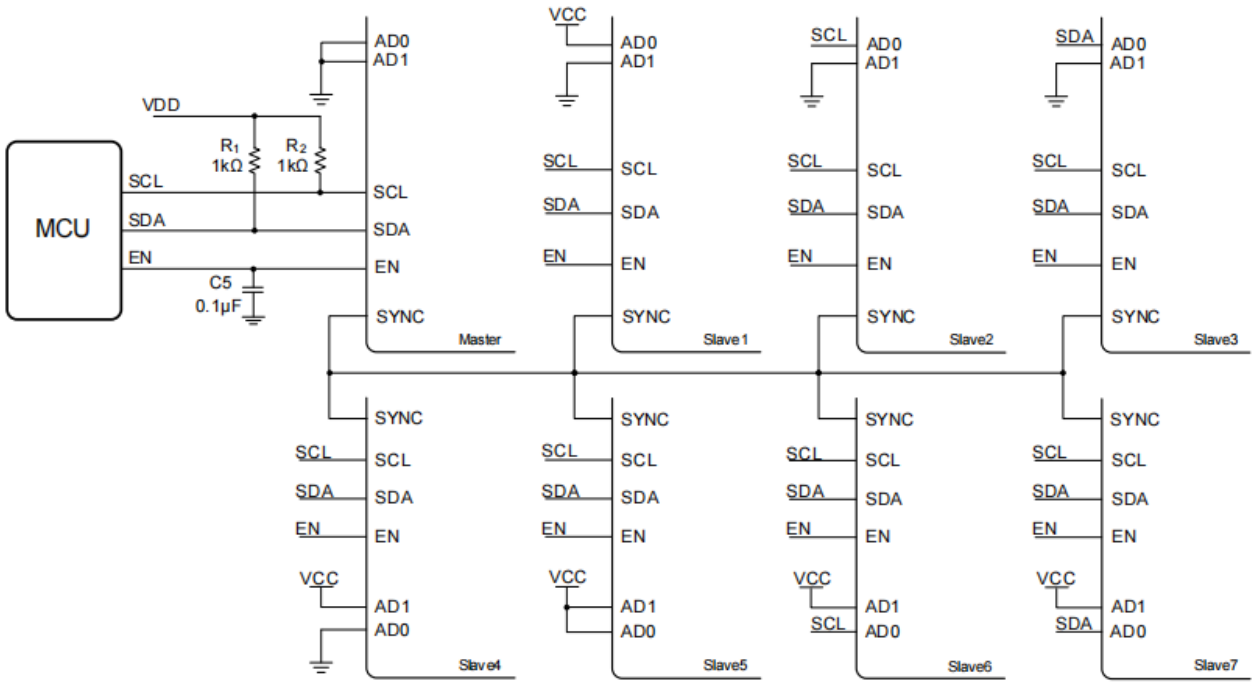


Figure 18 Multiple Devices Synchronization for HTR7198 or HTR7144 (8 devices e.g.)

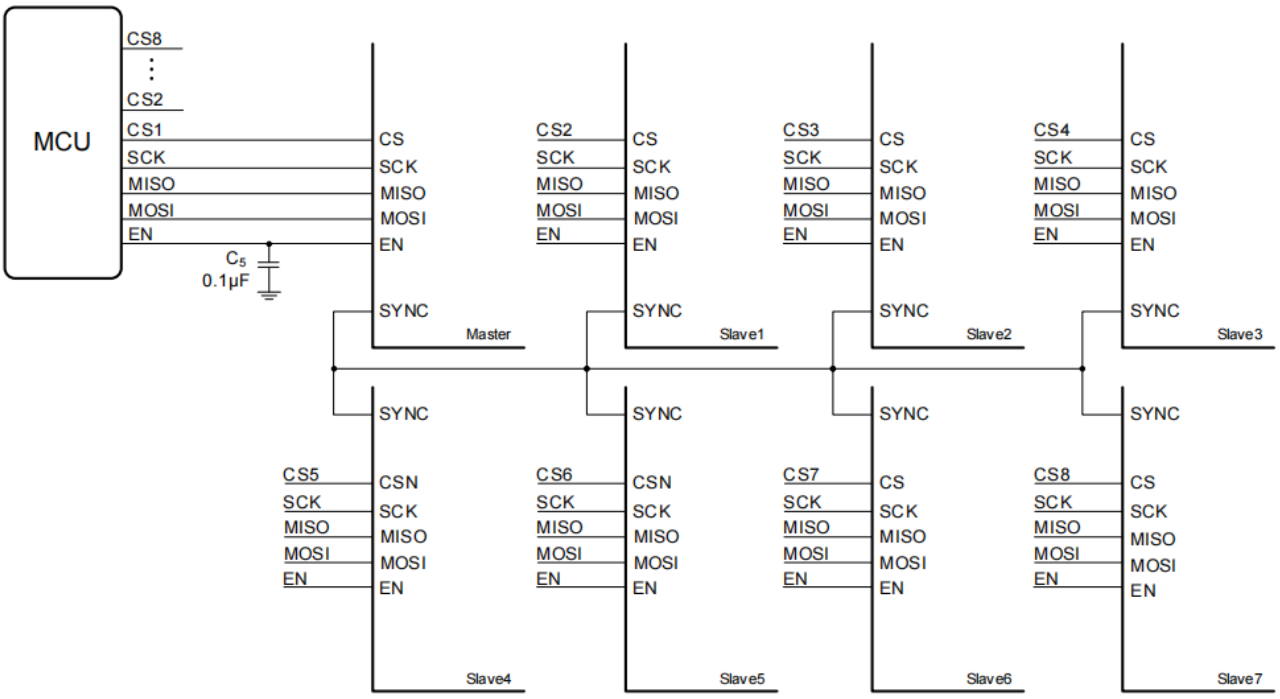


Figure 19 Multiple Devices Synchronization for HTR7198S or HTR7144S (8 devices e.g.)

15 Register Map

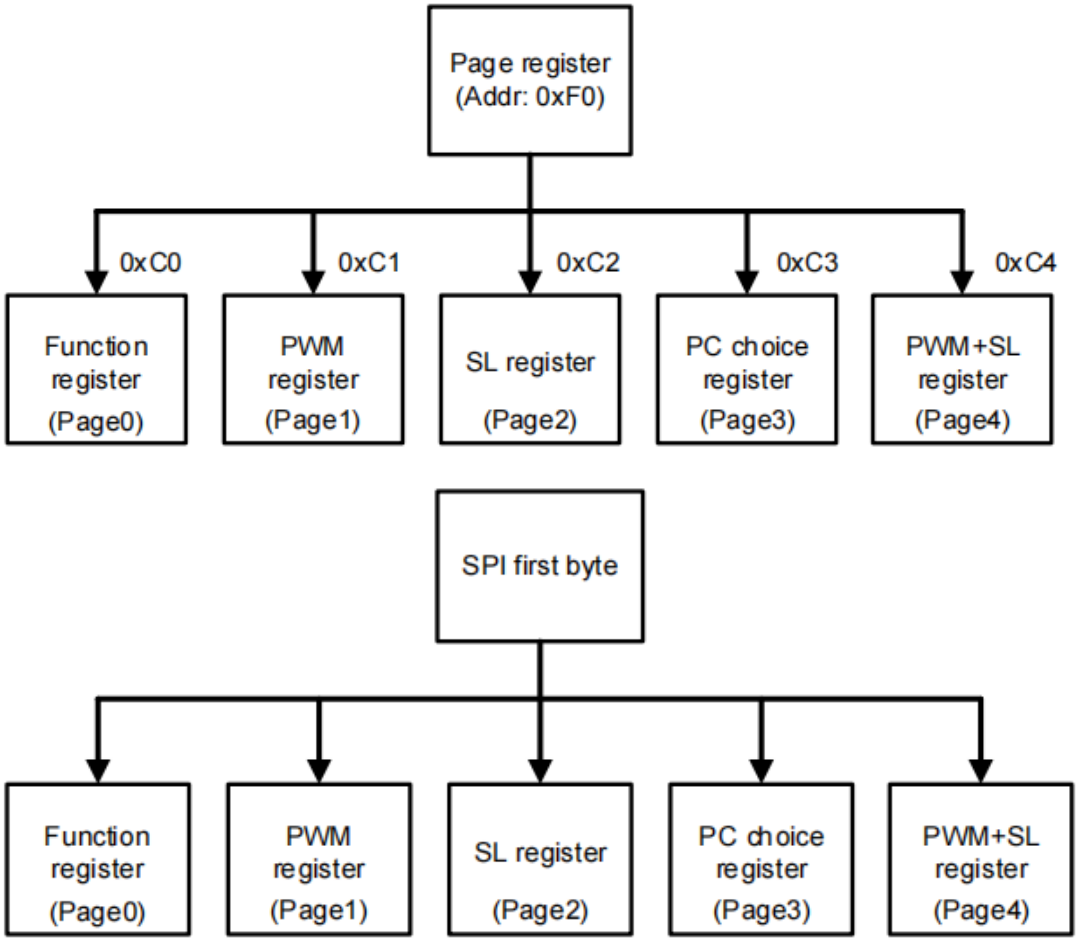


Figure 20 Register Structure

Which page (page0 ~ page4) can be selected by writing 0xC0 ~ 0xC4 in page register (address = 0xF0) in any page for HTR7198 or HTR7144, and by changing the command byte of SPI for HTR7198S or HTR7144S. Page0 is activated by default. Page 4 is a virtual page that can set PWM and SL in the same time, and the address auto-increases by one after the PWM and SL data are written. The page 4 only supports writing, and is available when bit Page4EN in register MIXCR (page0, address = 0x46) is set to "1".

通过对 page 寄存器（address = 0xF0）写 0xC0 ~ 0xC4(HTR7198 或 HTR7144), 或写相应的 SPI Command byte (HTR7198S 或 HTR7144S), 可以在任何 page 下选择到对应的 page。在默认状态下处于 Page 0。Page 4 是一个虚拟 page，其可同时设置 PWM 和 SL，写完一个 PWM 和 SL 后，其地址会自动增加。Page 4 只支持写，并需要在寄存器 MIXCR. (page0, address = 0x46) 中的 Page4EN 位写 "1" 时使能。

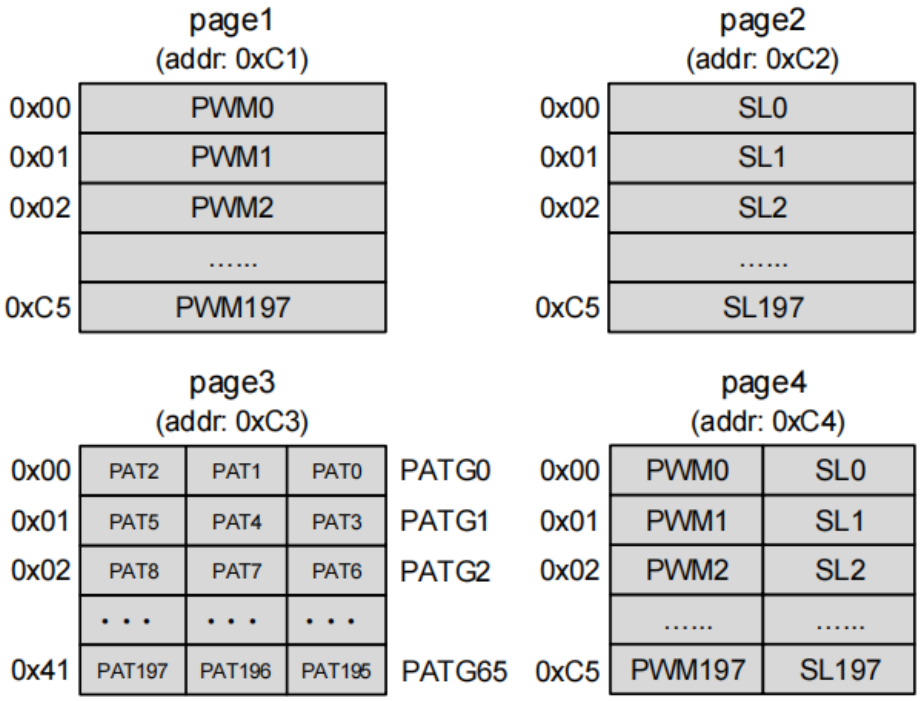


Figure 21 Register Distribution

Table4 Register Map

Register Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default Value
Page 0, Function Registers										
0x00	GCR	SWSEL				LGC	OSDetect		ChipEN	0xB0
0x01	GCCR	GCC								0x00
0x02	DGCR	PUMode	CSPUR			PDMode	SWPDR			0x44
0x03~ 0x23	OSR0~ OSR32	Reserved		LED0 ~ LED197 open/short status						0x00
0x27	OTCR	OTFlag	OTprotect	OTDetect	TFFlag	TFTh		TFOf		0x00
0x28	SSCR	CLKOE	CLKSEL	reserved	SSEN	SSRR		CLT		0x00
0x29	PCCR	Freq			Reserved			Phase		0x00
0x2A	UVCR	RISET_Status		OCPTh	OCProtect	PRStatus	UVFlag	UVProtect	UVDetct	0x00
0x2B	SRCR	Reserved		OTh	STh	Reserved	SRR	SRF		0x02
0x2F	RSTN	RSTN/ID								0x70
0x30	PWMH0	PWMH0								0x00
0x31	PWMH1	PWMH1								0x00
0x32	PWMH2	PWMH2								0x00
0x33	PWML0	PWML0								0x00
0x34	PWML1	PWML1								0x00
0x35	PWML2	PWML2								0x00
0x36	PC0T0T1	T0				T1				0x00
0x37	PC0T2T3	T2				T3				0x00
0x38	PC0Contr1	EP		SP		LT[11:8]				0x00
0x39	PC0Contr2	LT[7:0]								0x00
0x3A	PC1T0T1	T0				T1				0x00
0x3B	PC1T2T3	T2				T3				0x00

0x3C	PC1Contr1	EP		SP		LT[11:8]			0x00
0x3D	PC1Contr2	LT[7:0]							0x00
0x3E	PC2T0T1	T0				T1			0x00
0x3F	PC2T2T3	T2				T3			0x00
0x40	PC2Contr1	EP		SP		LT[11:8]			0x00
0x41	PC2Contr2	LT[7:0]							0x00
0x42	PC0Set	Reserved		PCFlag	LogEN	Switch	PampEN	PCMode	PCEN	0x00
0x43	PC1Set	Reserved		PCFlag	LogEN	Switch	PampEN	PCMode	PCEN	0x00
0x44	PC2Set	Reserved		PCFlag	LogEN	Switch	PampEN	PCMode	PCEN	0x00
0x45	PCGO	Reserved	PC2Stat	PC1Stat	PC0Stat	Reserved	Run2	Run1	Run0	0x00
0x46	MIXCR	Reserved					Page4EN	LPEN	BCDIS	0x02
0x4D	SWI	Reserved					SWI			0x00
0xF0	Page	Reserved					Page			0x00
Register Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default Value
Page 1, PWM Registers										
0x00	PWM0	PWM0								0x00
0x01	PWM1	PWM1								0x00
…	…	…								0x00
0xC5	PWM197	PWM197								0x00
0xF0	Page	Reserved					Page			0x00
Register Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default Value
Page 2, SL Registers										
0x00	SL0	SL0								0x00
0x01	SL1	SL1								0x00
…	…	…								0x00
0xC5	SL197	SL197								0x00
0xF0	Page	Reserved					Page			0x00
Register Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Default Value
Page 3, Pattern Controller Choice Register										
0x00	LEDG0PC	Reserved		LED2PC		LED1PC		LED0PC		0x00
0x01	LEDG1PC	Reserved		LED5PC		LED4PC		LED3PC		0x00
…	…	Reserved		…		…		…		0x00
0x41	LEDG65PC	Reserved		LED197PC		LED196PC		LED195PC		0x00
0xF0	Page	Reserved					Page			0x00
Register Address	Register Name	Bit15	Bit14	…	Bit8	Bit7	Bit6	…	Bit0	Default Value
Page 4, PWMx+SLx Register										
0x00	PWM0+SL0	PWM0				SL0				0x00
0x01	PWM1+SL1	PWM1				SL1				0x00
…	…	…				…				0x00
0xC5	PWM197+SL197	PWM197				SL197				0x00
0xF0	Page	Reserved						Page		0x00

Page 0, Register Address: 0x00, GCR (Global Control Register)

Bit	Label	R/W	Default	Description
D7:D4	SWSEL	R/W	1011	Select the active sw. 选择工作的 SW. 0000; SW1 active, SW2~SW12 not active; 0001: SW1~SW2 active, SW3~SW12 not active; 1010: SW1~SW11 active, SW12 not active; 1011~1111: SW1~SW12 active.
D3	Reserved	R	0	Reserved
D2:D1	OSDetect	R/W	00	Open/short detect enable: 开短路监测开启： 0x: open/short detect is disabled; 开/短路监测关闭 10: short detect is enabled; 短路监测开启 11: open detect is enabled. 开路监测开启
D0	ChipEN	R/W	0	Chip enable: 0: the chip is Disabled; 芯片关闭 1: the chip is enabled. 芯片使能

Page 0, Register Address: 0x01, GCCR (Global Current Control Register)

Bit	Label	R/W	Default	Description
D7:D0	GCC	R/W	00000000	Global current control. 全局电流控制。

Page 0, Register Address: 0x02, DGCR (De-ghost Control Register)

Bit	Label	R/W	Default	Description
D7	PUMode	R/W	0	Select pull up resistor mode of CSx: 0: only in CSx off time; 1: all the time
D6:D4	CSPUR	R/W	100	CSx Pull up Resistor Selection CSx 上拉电阻选择寄存器 000: No pull up resistor 001: 8kΩ 010: 8kΩ 011: 8kΩ 100: 1kΩ 101: 2kΩ 110: 2kΩ 111: 2kΩ
D3	PDMode	R/W	0	Select pull down resistor mode of SWx: 0: only in SWx off time; 1: all the time
D2:D0	SWPDR	R/W	100	SWx Pull down Resistor Selection，SWx 下拉电阻选择寄存器 000: No pull-down resistor 001: 1kΩ 010: 1kΩ 011: 1kΩ 100: 2kΩ 101: 4kΩ 110: 4kΩ 111: 4kΩ

Page 0, Register Address: 0x03~0x23, Open/Short Status Register

Bit	Label	R/W	Default	Description
D7:D6	Reserved	R	00	Reserved
D5:D0	OSR	R	000000	Open/short status of LED0~LED215 0: open/short not occur; 1: open/short occurred

Bit	CSx\SWx	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11
D7	0	0x05	0x08	0x0B	0x0E	0x11	0x14	0x17	0x1A	0x1D	0x20	0x23
D6	0											
D5	CS18											
D4	CS17											
D3	CS16											
D2	CS15											
D1	CS14											
D0	CS13											
D7	0	0x04	0x07	0x0A	0x0D	0x10	0x13	0x16	0x19	0x1C	0x1F	0x22
D6	0											
D5	CS12											
D4	CS11											
D3	CS10											
D2	CS9											
D1	CS8											
D0	CS7											
D7	0	0x03	0x06	0x09	0x0C	0x0F	0x12	0x15	0x18	0x1B	0x1E	0x21
D6	0											
D5	CS6											
D4	CS5											
D3	CS4											
D2	CS3											
D1	CS2											
D0	CS1											

Page 0, Register Address: 0x27, OTCR (Over Temperature Control Register)

Bit	Label	R/W	Default	Description
D7	OTFlag	R	0	Over temperature flag 0: over temperature not occur; 1: over temperature occurred.
D6	OTProtect	R/W	0	Over temperature protect (OTP) enable: 0: over temperature protect enabled, when OTP occurred, the device will clear ChipEN to “0” 1: OTP disabled.
D5	OTDetect	R/W	0	Over temperature detect enable: 0: over temperature detect enabled, when OTP occurred, OTFlag set “1”; 1: over temperature detect disabled
D4	TFFlag	R	0	Thermal Foldback flag: 0: Thermal Foldback not occurred; 1: Thermal Foldback occurred
D3:D2	TFTh	R/W	00	Thermal Foldback threshold: 00: 140℃; 01: 120℃ 10: 100℃ 11: 90℃

D1:D0	TFOf	R/W	00	Percentage of I_{OUT} in Thermal Foldback: 00: 100% 01: 75% 10: 55% 11: 30%

Page 0, Register Address: 0x28, Spread Spectrum Control Register

Bit	Label	R/W	Default	Description
D7	CLKOE	R/W	0	Clock output enable: 0: disabled 1: enabled
D6	CLKSEL	R/W	0	Clock selection: 0: Use internal 16MHz clock 1: use clock input from SYNC pin
D5	Reserved	R	0	Reserved
D4	SSEN	R/W	0	Spread spectrum enable: 0: disabled; 1: enabled
D3:D2	SSR	R/W	00	Spread spectrum range: 00: ±5%; 01: ±15%; 10: ±25%; 11: ±35%
D1	CLT	R/W	00	Spread spectrum cycle time: 00: 1980us; 01: 1200us; 10: 820us; 11: 660us

Page 0, Register Address: 0x29, PWM Clock Control Register

Bit	Label	R/W	Default	Description
D7:D5	Freq	R/W	000	PWM frequency selection: 000: 62.5kHz; 001: 32.5kHz; 010: 15.6kHz; 011: 7.8kHz; 100: 3.9kHz; 101: 1.95kHz; 110: 977Hz; 111: 488Hz
D4:D2	Reserved	R	000	Reserved
D1:D0	Phase	R/W	00	PWM phase shift control: 00: phase delay mode (6 groups); 01: phase inverting mode (9 groups); 1x: 3 phase mode (6 groups)

Page 0, Register Address: 0x2A, UVLO Control Register

Bit	Label	R/W	Default	Description
D7:D6	R_{ISET}_Status	R	00	R_{ISET} pin status: 00: Normal; 01: RISET is open; 10: RISET is short or OCP; 11: reserved

D5	OCPTh	R/W	0	OCP threshold 0: 75mA; 1: 120mA
D4	OCProtect	R/W	0	Over Current Protection (OCP) enable: 0: OCP enabled; 1: OCP disabled.
D3	PRStatus	R	0	Power on reset status: 0: power on reset not occurred; 1: power on reset occurred
D2	UVFlag	R	0	UVLO Flag: 0: under voltage not occurred; 1: under voltage occurred
D1	UVProtect	R/W	0	UVLO protect enable: 0: UVLO protect enabled, when under voltage occurs, the device will clear ChipEN to “0”; 1: UVLO protect disabled.
D0	UVDetect	R/W	0	UVLO detect enable: 0: UVLO detect enabled, when under voltage occurs, UVFlag will set “1”’ 1: UVLO detect disabled

Page 0, Register Address: 0x2B, Open/short Control Register

Bit	Label	R/W	Default	Description
D7:D6	Reserved	R	00	Reserved
D5:	OTh	R/W	0	Open threshold 0: 0.1V 1: 0.2V
D4	STh	R/W	0	Short threshold 0: PVCC-1.5V 1: PVDD-0.8V
D3	Reserved	R	0	Reserved
D2	SRR	R/W	0	Rising time of LED output 0: 1ns; 1: 6ns
D1:D0	SRF	R/W	00	Falling time of LED output 00: 1ns; 01: 3ns; 10: 6ns; 11: 10ns

Page 0, Register Address: 0x2F, Reset Register

Bit	Label	R/W	Default	Description
D7:D0	RSTN	R/W	0x70	Write 0xAE to this register will reset all the registers to their default value. The chip ID will be read out from the register.

Page 0, Register Address: 0x30~0x32, Max Brightness for Auto Breathing

Bit	Label	R/W	Default	Description
D7:D0	PWMH	R/W	00000000	Set the maximum brightness for auto breathing.

Page 0, Register Address: 0x33~0x35, Min Brightness for Auto Breathing

Bit	Label	R/W	Default	Description
D7:D0	SL	R/W	00000000	Set the minimum brightness for auto breathing.

Page 0, Register Address: 0x36, 0x3A, 0x3E, PC0T0T1~PC2T0T1 (Pattern Controller T0 and T1)

Bit	Label	R/W	Default	Description	
D7:D4	T0	R/W	0000	Set the T0 time	
				0000: 0s	1000: 2.1s
				0001: 0.13s	1001: 2.6s
				0010: 0.26s	1010: 3.1s
				0011: 0.38s	1011: 4.2s
				0100: 0.51s	1100: 5.2s
				0101: 0.77s	1101: 6.2s
				0110: 1.04s	1110: 7.3s
				0111: 1.6s	1111: 8.3s
D3:D0	T1	R/W	0000	Set the T1 time	
				0000: 0.04s	1000: 2.1s
				0001: 0.13s	1001: 2.6s
				0010: 0.26s	1010: 3.1s
				0011: 0.38s	1011: 4.2s
				0100: 0.51s	1100: 5.2s
				0101: 0.77s	1101: 6.2s
				0110: 1.04s	1110: 7.3s
				0111: 1.6s	1111: 8.3s

Page 0, Register Address: 0x37, 0x3B, 0x3F, PC0T2T3~PC2T2T3 (Pattern Controller T2 and T3)

Bit	Label	R/W	Default	Description	
D7:D4	T2	R/W	0000	Set the T2 time	
				0000: 0s	1000: 2.1s
				0001: 0.13s	1001: 2.6s
				0010: 0.26s	1010: 3.1s
				0011: 0.38s	1011: 4.2s
				0100: 0.51s	1100: 5.2s
				0101: 0.77s	1101: 6.2s
				0110: 1.04s	1110: 7.3s
				0111: 1.6s	1111: 8.3s
D3:D0	T3	R/W	0000	Set the T3 time	
				0000: 0.04s	1000: 2.1s
				0001: 0.13s	1001: 2.6s
				0010: 0.26s	1010: 3.1s
				0011: 0.38s	1011: 4.2s
				0100: 0.51s	1100: 5.2s
				0101: 0.77s	1101: 6.2s
				0110: 1.04s	1110: 7.3s
				0111: 1.6s	1111: 8.3s

Page 0, Register Address: 0x38, 0x3C, 0x40, PC0Contr1~PC2Contr1 (Pattern Controller Register)

Bit	Label	R/W	Default	Description
D7:D6	EP	R/W	00	End point of the auto-breathing loop: 00: off state; Others: On state
D5:D4	SP	R/W	00	Start point of the auto-breathing loop: 00: Rise state; 01: On state; 10: fall state; 11: Off state
D3:D0	LT[11:8]	R/W	0000	4 MSB of auto breathing loop times

Page 0, Register Address: 0x39, 0x3D, 0x41, PC0Contr2~PC2Contr2 (Pattern Controller Register)

Bit	Label	R/W	Default	Description
D7:D0	LT[7:0]	R/W	00000000	8 LSB of auto breathing loop times

Page 0, Register Address: 0x42~0x44, PC0Set~PC2Set (Pattern Controller Setting)

Bit	Label	R/W	Default	Description
D7:D6	Reserved	R	00	Reserved
D5	PCFlag	R/W	0	Auto breathing loop end flag: 0: loop not ended; 1: loop ended
D4	LogEN	R/W	0	Log curve output enable: 0: disabled; 1: enabled
D3	Switch	R/W	0	Switch on or off at manual mode: 0: LED off; 1: LED on
D2	RampEN	R/W	0	Ramp enable: 0: disabled; 1: enabled
D1	PCMode	R/W	0	PC mode selection: 0: manual mode; 1: Auto breathing mode
D0	PCEN	R/W	0	Auto breathing enable: 0: disabled; 1: enabled

Page 0, Register Address: 0x45, PCGO (Pattern Controller Start Control Register)

Bit	Label	R/W	Default	Description
D7	Reserved	R	0	Reserved
D6	PC2Stat	R	0	Auto breathing status of PC2: 1: stopped; 2: running
D5	PC1Stat	R	0	Auto breathing status of PC1: 1: stopped; 2: running
D4	PC0Stat	R	0	Auto breathing status of PC0: 1: stopped; 2: running
D3	Reserved	R	0	Reserved
D2	Run2	R/W	0	1: Run the auto breathing of PC2; to restart a new auto breathing, it should be firstly written to “0” and then “1”
D1	Run1	R/W	0	1: Run the auto breathing of PC1; to restart a new auto breathing, it should be firstly written to “0” and then “1”
D0	Run0	R/W	0	1: Run the auto breathing of PC0; to restart a new auto breathing, it should be firstly written to “0” and then “1”

Page 0, Register Address: 0x46, MXCR (Mix Function Register)

Bit	Label	R/W	Default	Description
D7:D3	Reserved	R	00000	Reserved
D2	Page4EN	R/W	0	Rage 4 enable: 0: Disabled 1: Enabled
D1	LPEN	R/W	0	Low power mode enable:

				0: Disabled 1: Enabled
D0	BCDIS	R/W	0	Broadcast enable: 0: Enabled; 1: Disabled

Page 0, Register Address: 0x4D, SWI (SW Drive Current Capability Register)

Bit	Label	R/W	Default	Description	
D7:D3	Reserved	R	00000	Reserved	
D2:D0	SWI	R/W	000	Select the SW drive current capability	
				000: 0.99A	100: 1.61A
				001: 1.08A	101: 1.72A
				010: 1.19A	110: 1.85A
				011: 1.32A	111: 2.00A

Page 1, Register Address: 0x00~0xC5, PWM0~PWM197 (PWM Register)

Bit	Label	R/W	Default	Description
D7:D0	PWMx	R/W	00000000	PWM setting

Page 2, Register Address: 0x00~0xC5, SL0~SL197(SL Register)

Bit	Label	R/W	Default	Description
D7:D0	SLx	R/W	00000000	SL current setting

Page 3, Register Address: 0x00~0x41, LEDG0PC~LEDG65PC (Pattern Controller Choice Register)

Bit	Label	R/W	Default	Description
D7:D6	Reserved	R	00	Reserved
D5:D4	LED3x+2PC	R/W	00	Choose the pattern controller for LED3x+2: 00: pattern controller not chose, PWM parameter comes from PWM register; 01: choose pattern controller 0; 10: choose pattern controller 1; 11: choose pattern controller 2;
D3:D2	LED3x+1PC	R/W	00	Choose the pattern controller for LED3x+1: 00: pattern controller not chose, PWM parameter comes from PWM register; 01: choose pattern controller 0; 10: choose pattern controller 1; 11: choose pattern controller 2;
D1:D0	LED3xPC	R/W	00	Choose the pattern controller for LED3x: 00: pattern controller not chose, PWM parameter comes from PWM register; 01: choose pattern controller 0; 10: choose pattern controller 1; 11: choose pattern controller 2;

Page 4, Register Address: 0x00~0xC5, PWM0+SL0 ~ PWM197+SL197 (PWM and SL Setting Register)

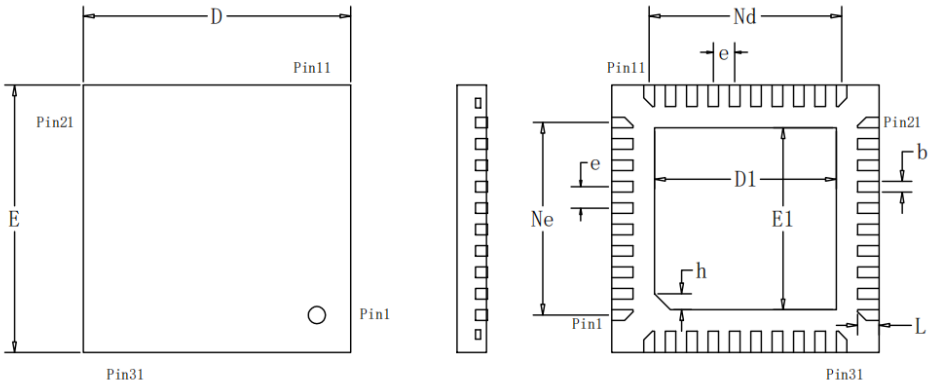
Bit	Label	R/W	Default	Description
D15:D8	PWMx	R/W	00000000	PWM Setting
D7:D0	SLx	R/W	00000000	SL current setting

■ Revision History

Date	Version	Revision Content
2025-9-28	V0.5	Preliminary Version.
2025-12-15	V1.0	Formal version. No change.

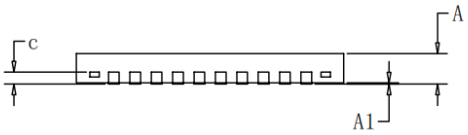
■ PACKAGE OUTLINE

SQE (QFN5×5-40L)



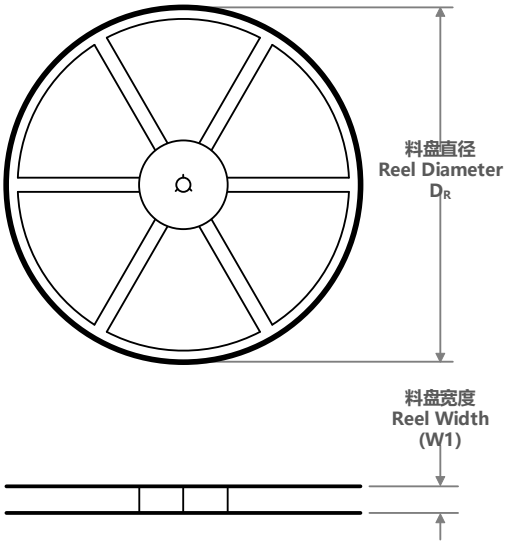
Top View Side View Bottom View

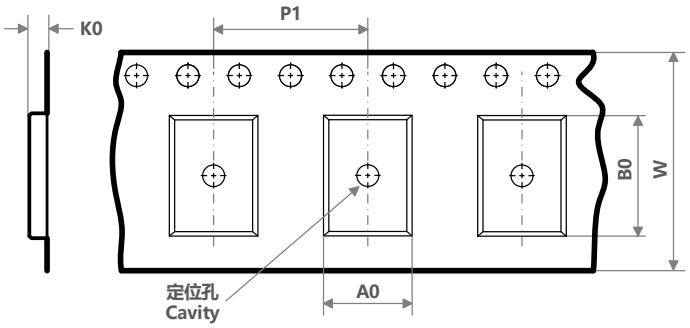
SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.50	0.55	0.60
A1	—	0.02	0.05
b	0.15	0.20	0.25
c		0.203 REF	
D	4.90	5.00	5.10
D1	3.30	3.40	3.50
Nd		3.60 BSC	
e		0.40 BSC	
E	4.90	5.00	5.10
E1	3.30	3.40	3.50
Ne		3.60 BSC	
h	0.25	0.30	0.35
L	0.35	0.40	0.45



Side View

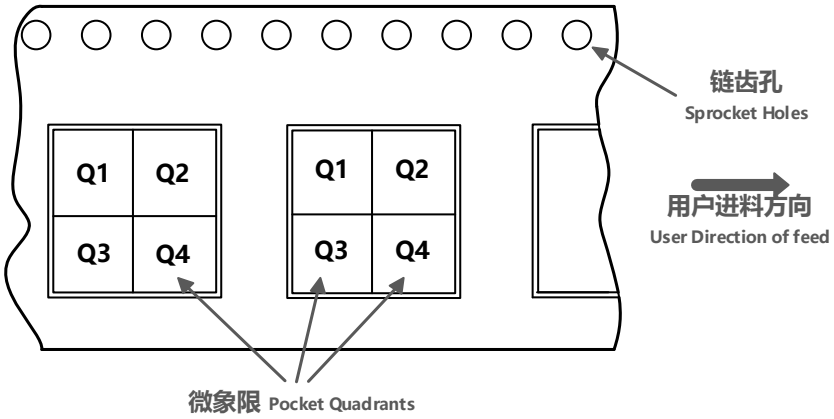
■ TAPE AND REEL INFORMATION





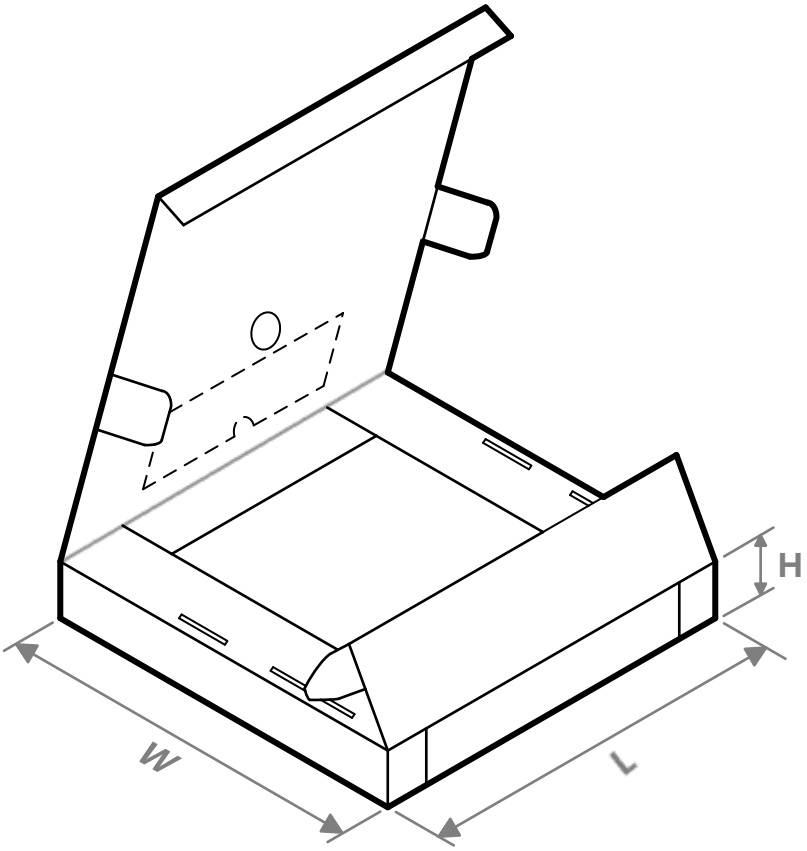
A0	Dimension designed to accommodate the component width; 料槽宽度
B0	Dimension designed to accommodate the component length; 料槽长度
K0	Dimension designed to accommodate the component thickness; 料槽厚度
W	Overall width of the carrier tape; 载带整体宽度
P1	Pitch between successive cavity centers; 相邻槽中心间距

编带 PIN1 方位象限分配
Quadrant Assignments for Pin1 Orientation in Tape



器件料号 Part No.	封装类型 Package Type	封装标识 Package Code	引脚数 Pins	SPQ	料盘直径 D_R(mm)	料盘宽度 W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 象限 Quadrant
HTR7198SQER	QFN5×5	SQE	40	5000	330	12	5.4	5.4	1.25	8	12	Q1
HTR7198SSQER	QFN5×5	SQE	40	5000	330	12	5.4	5.4	1.25	8	12	Q1

■ TAPE AND REEL BOX INFORMATION



器件料号 Part No.	封装类型 Package Type	封装标识 Package Code	引脚数 Pins	SPQ	长度 Length (mm)	宽度 Width (mm)	高度 Height (mm)
HTR7198SQER	QFN4×4	SQE	40	10000	360	345	65
HTR7198SSQER	QFN4×4	SQE	40	10000	360	345	65

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