THL3526

24-channel constant-current/open-drain output LED Driver

概要

THL3526 is a 24-channel LED driver IC with switchable constant-current output/open-drain output.
Different current values can be set for each of the three groups of constant-current outputs using external resistors.
The oscillator and PWM circuit are built-in, and LED brightness can be set individually for each channel in up to 256 steps.
The serial interface can be selected from 3-wire/2-wire serial bus or I2C bus with the setting pin. When multiple THL3526 units are used, cascade connection using the built-in serial interface buffer circuit enables stable serial communication.

Applications

Amusement machine
LED backlight
LED display
Digital signage system
LED illumination

Features

＜ LED driver output＞

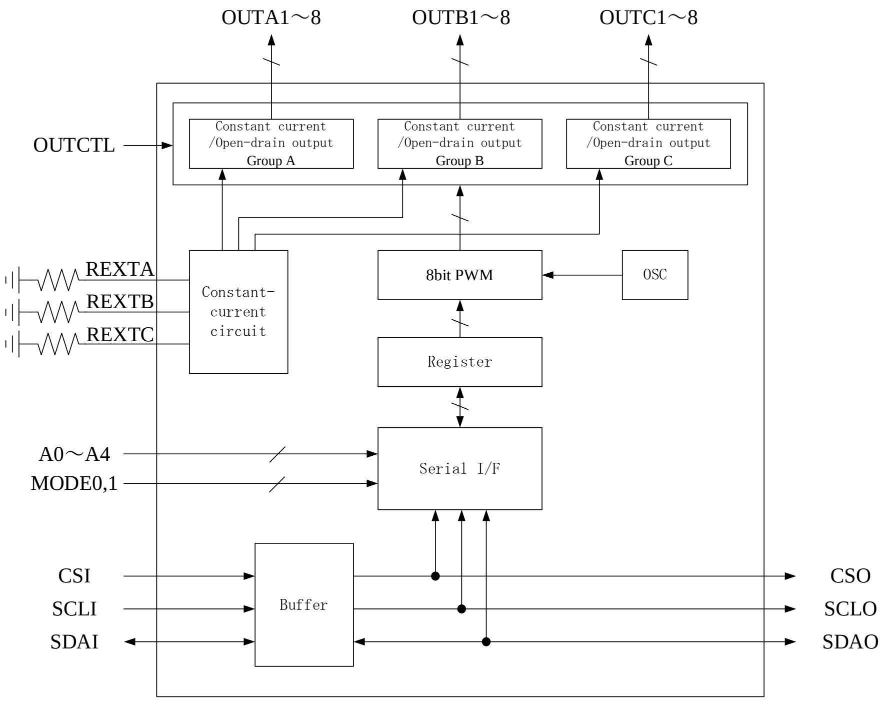
・24ch
・Constant current/open drain output switching setting
・Sink current max. 40mA/ch (constant current output)
・Sink current max. 80mA/ch (open drain output)
・Withstand voltage max. 40 V
・PWM phase control by channel/group

＜Serial interface＞

・3-wire/2-wire serial bus or I2C bus
・3-wire/2-wire serial bus repeater function
・Up to 30 device address
・Batch register write to all devices

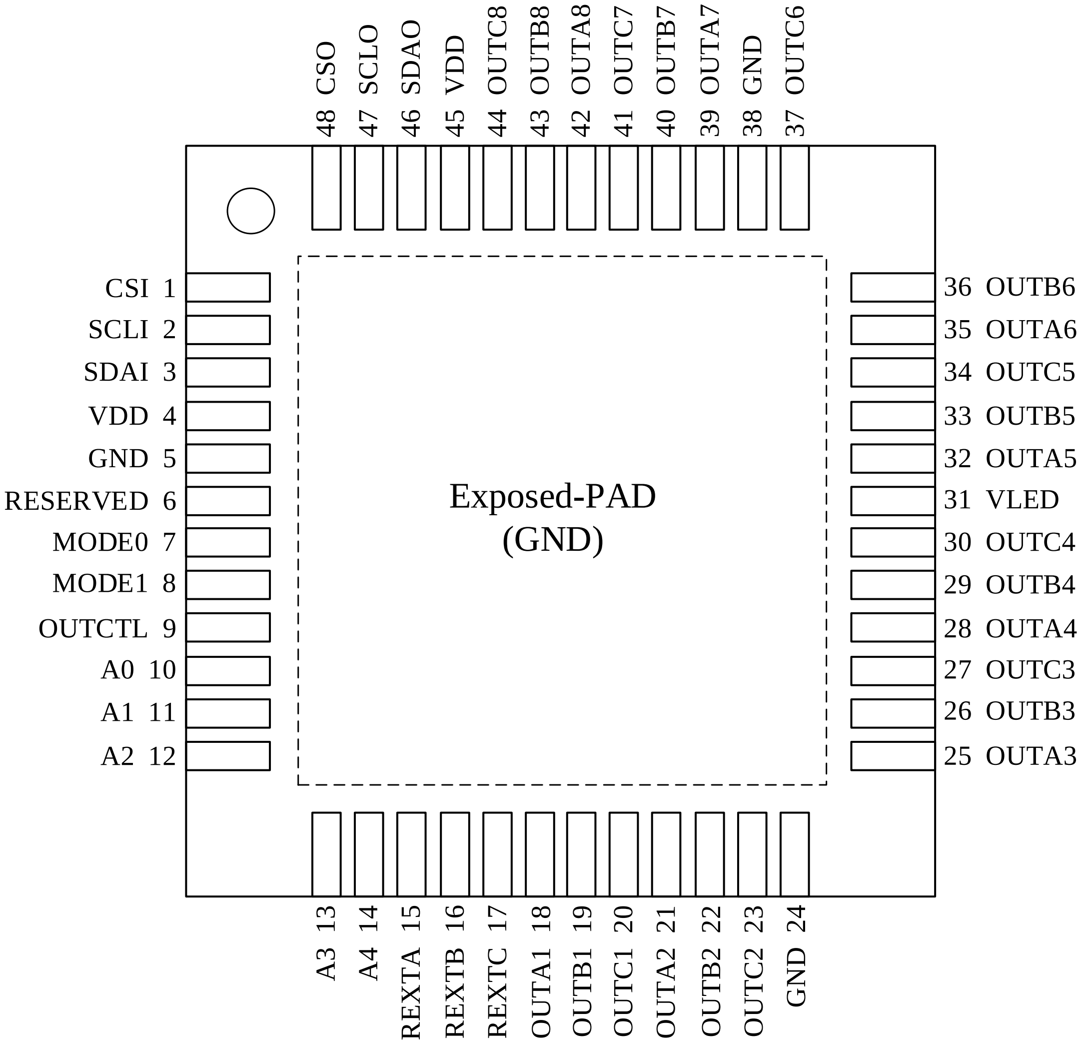
・UVLO
・Thermal shutdown
・Power supply voltage renge：4.5V ～ 5.5V
・Package：QFN48-pin Exposed Pad
・Compliant with RoHS and REACH
・HBM：ANSI/ESDA/JEDEC JS-001-2023 ±8KV
・CDM：ANSI/ESDA/JEDEC JS-002-2022 ±1000V

Block diagram



Contents

1. Pin diagram（TOP VIEW）



2. Pin description

<table>
<tr><th>Pin name</th><th>Type</th><th>Description</th></tr>
<tr><td>MODE0
MODE1</td><td>Digital input</td><td>Serial interface select
<table>
<tr><th>MODE0</th><th>MODE1</th><th>Serial interface</th></tr>
<tr><td>Low</td><td>Low</td><td>2wire-serial</td></tr>
<tr><td>High</td><td>Low</td><td>3wire-serial</td></tr>
<tr><td>Low</td><td>High</td><td>I2C</td></tr>
<tr><td>High</td><td>High</td><td>Prohibition</td></tr>
</table></td></tr>
<tr><td>CSI</td><td>Digital input</td><td>Depending on the selected interface
3-wire serial : Chip select input
2-wire serial / I2C : Fix to GND</td></tr>
<tr><td>SCLI</td><td>Digital input</td><td>Serial clock input</td></tr>
<tr><td>SDAI</td><td>Digital input</td><td>Serial data input</td></tr>
<tr><td>CSO</td><td>Digital output</td><td>Depending on the selected interface
3-wire/2-wire serial : Chip select output
I2C : Invalid (Hi-Z)</td></tr>
<tr><td>SCLO</td><td>Digital output</td><td>Depending on the selected interface
3-wire/2-wire serial : Serial clock output
I2C : Invalid (Hi-Z)</td></tr>
<tr><td>SDAO</td><td>Digital output</td><td>Depending on the selected interface
3-wire/2-wire serial : Serial data output
I2C : Invalid (Hi-Z)</td></tr>
<tr><td>OUTCTL</td><td>Digital input</td><td>LED driver output select
High ： Constant-current
Low ： Open-drain</td></tr>
<tr><td>OUTA1～8</td><td>LED driver output</td><td>“Group A” LED driver output</td></tr>
<tr><td>OUTB1～8</td><td>LED driver output</td><td>“Group B” LED driver output</td></tr>
<tr><td>OUTC1～8</td><td>LED driver output</td><td>“Group C” LED driver output</td></tr>
<tr><td>REXTA</td><td>Analog output</td><td>“Group A” Resistor connection for constant current value setting</td></tr>
<tr><td>REXTB</td><td>Analog output</td><td>“Group B” Resistor connection for constant current value setting</td></tr>
<tr><td>REXTC</td><td>Analog output</td><td>“Group C” Resistor connection for constant current value setting</td></tr>
<tr><td>A0～A4</td><td>Digital input</td><td>Device address settings</td></tr>
<tr><td>RESERVED</td><td>-</td><td>Fix to GND</td></tr>
<tr><td>VLED</td><td>-</td><td>LED power line connection terminal</td></tr>
<tr><td>VDD</td><td>-</td><td>Circuit power supply</td></tr>
<tr><td>GND</td><td>-</td><td>Ground</td></tr>
<tr><td>Exposed-PAD(GND)</td><td>-</td><td>Ground、 for heat dissipation</td></tr>
</table>

3. Absolute maximum ratings

Parameter	Condition	Min	Typ	Max	Unit
Power supply voltage (VDD)		-0.4	-	6.0	V
Digital input voltage		-0.5	-	6.0	V
LED driver output voltage		-	-	40	V
Ambient storage temperature		-55	-	150	℃
Junction temperature (Tj)		-	-	150	℃

The Absolute maximum ratings is an indication of the allowable value that must not be exceeded, even for a moment. Stresses in excess of the absolute maximum ratings can damage the device. Exceeding these ratings may impair device functionality, cause damage, and affect reliability.

4. Recommended operating conditions

Parameter	Condition	Min	Typ	Max	Unit
Supply voltage（VDD）		4.5	-	5.5	V
LED driver output voltage（Vout）		-	-	35	V
LED driver output current（Iout） *	OUTCTL=H	4	-	40	mA/ch
	OUTCTL=L	-	-	80	mA/ch
Ambient operating temperature （Ta）		-40	-	85	℃

＊: Since overshoot may occur in the current waveform depending on the conditions of use, use LEDs with an absolute maximum pulse forward current rating of 100 mA or more.

5. Electrical characteristics (Unless otherwise noted, VDD=5V、Ta=25 ℃)

Parameter	Condition	Min	Typ	Max	Unit
Current consumption（IDD）		-	35	47	mA
PWM frequency (fOSC)		-	625	-	kHz
Power on reset / UVLO release voltage		-	4.0	-	V
Power on reset / UVLO detection voltage		-	3.8	-	V
LED driver output current inter-channel error	OUTCTL=H Iout=40mA	-	-	±6	%
LED driver output current device-to-device error		-	-	±6	%
LED driver output ON-resistance	OUTCTL=L	-	10	-	Ω
LED driver output off-leakage current	VLED > Vout	-	-	±1	μA
Digital input high-level voltage（V_{IH}）		0.7VDD	-	-	V
Digital input low-level voltage（V_{IL}）		-	-	0.3VDD	V
Digital input hysteresis voltage		0.05VDD	-	-	V
Digital input leakage current		-	-	±1	μA
Digital input capacitance	CSI, SCLI, SDAI	-	5	10	pF
Digital output high-level voltage（V_{OH}）	Except I2C I_{OH}=-8mA	0.85VDD	-	-	V
Digital output low-level voltage（V_{OL}）	I_{OH}=8mA	-	-	0.15VDD	V

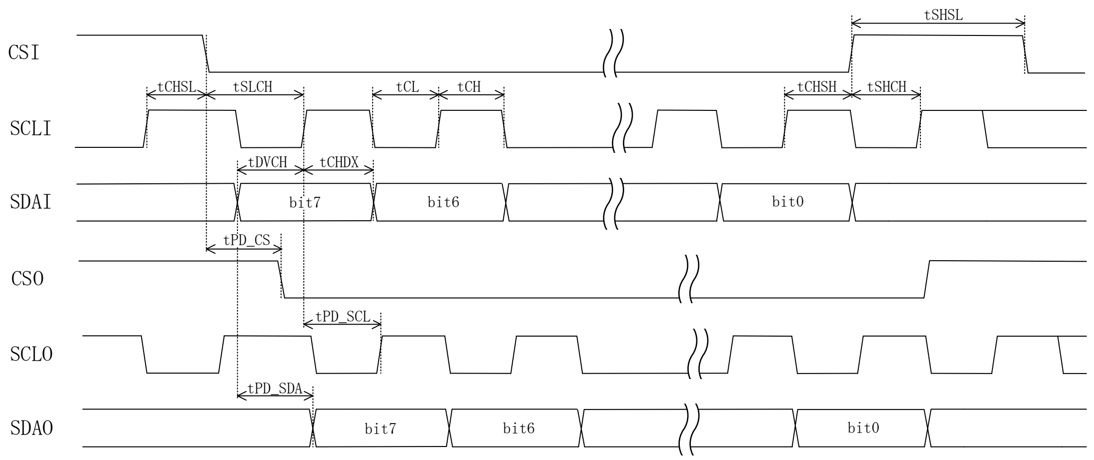
6. Switching characteristics

6.1. 3-wire/2-wire serial interface (Unless otherwise noted, VDD=5V、Ta=25 °C)

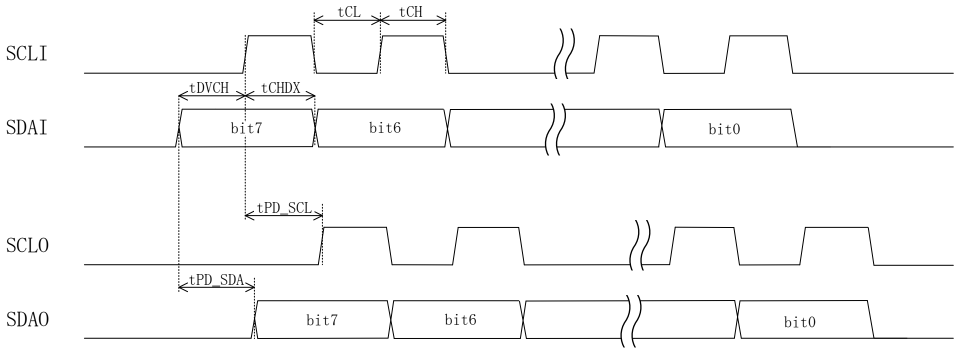
Symbol	Parameter	Condition	Min	Typ	Max	Unit
fSCK	SCLI frequency		-	-	10	MHz
tCH	SCLI High time		40	-	-	ns
tCL	SCLI Lowtime		40	-	-	ns
tDVCH	SDAI setup time		10	-	-	ns
tCHDX	SDAI hold time		10	-	-	ns
tCHSL	CSI Not Active hold time		40	-	-	ns
tSLCH	CSI Active setup time		40	-	-	ns
tCHSH	CSI Active hold time		40	-	-	ns
tSHCH	CSI Not Active setup time		40	-	-	ns
tSHSL	CSI Not Active time		200	-	-	ns
tPD_CS	CSI→CSO delay time	$C_{[Load]}$ = 10pF, Input： V_{IL},V_{IH} Output：0.5VDD	-	-	12.5	ns
tPD_SCL	SCLI→SCLO delay time		-	-	12.5	ns
tPD_SDA	SDAI→SDAO delay time		-	-	12.5	ns
tSKEW	SCLO, SDAO skew time	※See note	-		1	ns
tr	CSO, SCLO, SDAO rise time	$C_{[Load]}$ = 10pF, VDD:20% - 80%	-	-	10	ns
tf	CSO, SCLO, SDAO fall time		-	-	10	ns

※When the skew time between SCLI and SDAI input signals is 0ns and the load capacitance (C[Load]) leading to SCLO and SDAO is the same.

＜3-wire serial interface timing diagram＞



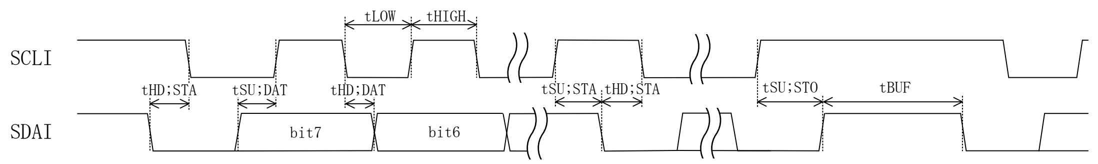
＜2-wire serial timing diagram＞



6.2. I2C interface (Unless otherwise noted, VDD=5V、Ta=25 ℃)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
fSCL	SCLI frequency		-	-	1000	kHz
tHD;STA	Start Condition hold time	Repeated start	0.26	-	-	us
tSU;STA	Repeated Start Condition setup time		0.26	-	-	us
tLOW	SCLI Low time		0.5	-	-	us
tHIGH	SCLI High time		0.26	-	-	us
tHD;DAT	Data hold time		0	-	-	us
tSU;DAT	Data setup time		50	-	-	ns
tSU;STO	Stop Condition setup time		0.26	-	-	us
tBUF	Bus release time between STOP-START Condition		0.5	-	-	us
tr	SCLI, SDAI rise time	-	-	-	120	ns
tf	SCLI, SDAI fall time	-	-	-	120	ns

＜I2C interface timing diagram＞



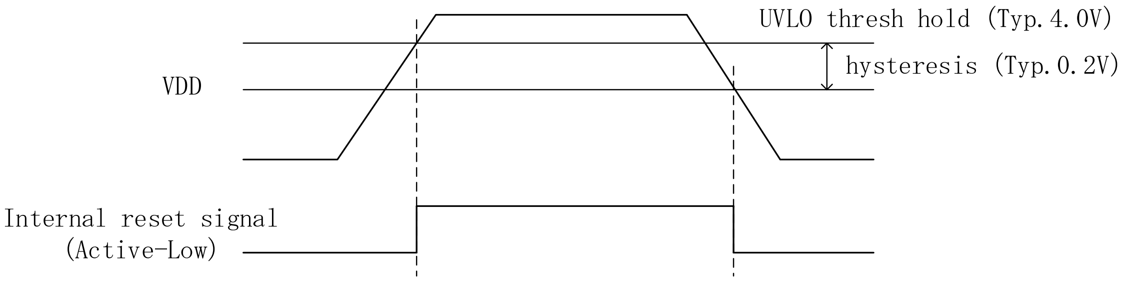
7. Reset and protect function

7.1. Power on reset

The internal state is reset when power is turned on.. All registers are set to their initial values.

7.2. UVLO

UVLO (Under Voltage Locked Out) circuit is built in to prevent malfunction under low supply voltage conditions. Until the supply voltage reaches VDD 4.0V (typ.), the internal logic circuit is held in reset state and the LED driver output is Hi-Z. The UVLO circuit has a hysteresis and when VDD drops to 3.8V (typ.) it enters the above UVLO state, the internal logic is reset and the register is set to its initial value.



7.3. Thermal shutdown

A thermal shutdown circuit is built in to prevent device failure due to heat. When the junction temperature Tj exceeds the absolute maximum rating of 150°C, the thermal shutdown circuit operates and the LED DRIVER OUTPUT is switched off. The thermal shutdown circuit has hysteresis and automatically returns to normal operation when Tj drops.

However, depending on the operating environment and the duration of the abnormal condition, it may not always be possible to prevent device failure or degradation.

8. LED driver output

8.1. Driver output type

Both constant-current and open-drain outputs are supported and can be selected by setting the OUTCTL pin.

8.2. Current value setting in constant current output

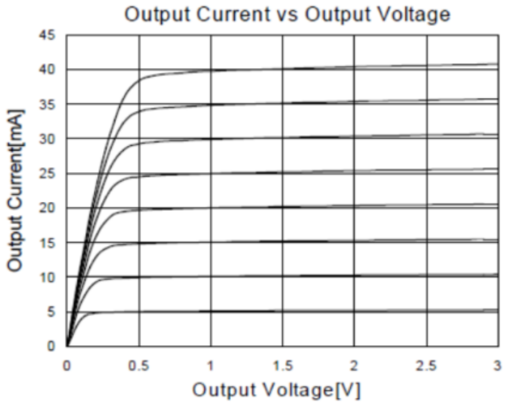
The current value of LED driver output at constant current output setting is set by the external resistor connected between terminals REXTA, REXTB, REXTC and GND. The external resistor value REXT is calculated by the following.

$$REXT[k\Omega] = \frac{0.6[V]}{Iout[mA]} \times 80 \qquad \text{(Typical value @Iout=20mA)}$$

<Example> REXT = 0.6[V]/20[mA]×80 = 2.4kΩ(@Iout=20mA)

Considering the variation of the LED supply voltage VLED and the forward voltage VF of the LED, the following voltages should be applied to the output pins.

＜”Reference”　Output current－voltage characteristics（Typ.）＞



Vout > 0.4V @Iout=10mA
Vout > 0.6V @Iout=20mA
Vout > 0.8V @Iout=40mA

<Example>
Iout=20mA
LED(VF(Max) = 3.8V) 2pcs series connection

VLED ≧ VF ＋ Vout = 3.8V × 2pcs + 0.6V = 8.2V

8.3. Setting current value at open-drain output

The current value of the LED driver output at the open-drain output setting is set by the current limiting resistor connected in series with the LED. A general method of calculating the value of the current limiting resistor is given in the open-drain output reference circuit example in Section 11.2.
In open-drain output mode, the REXT pin is not used and should be left unconnected.

8.4. Brightness adjustment

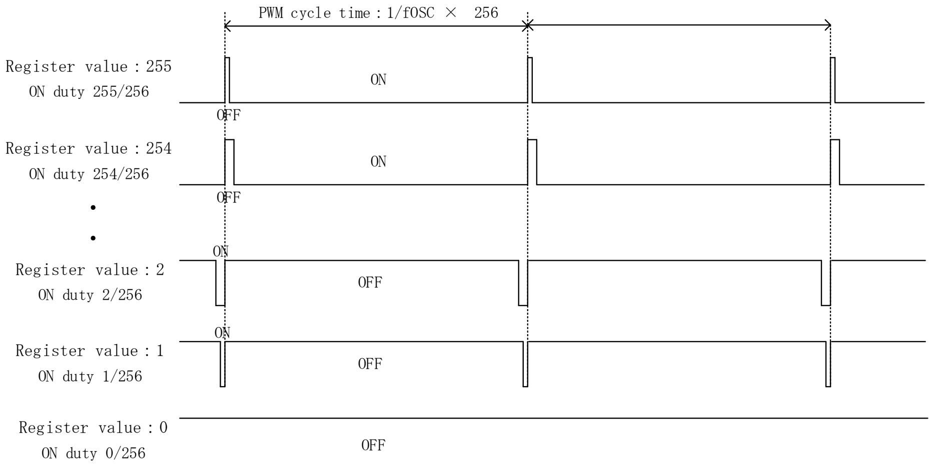
The LED brightness adjustment is set in the register for each LED driver output channel in Max 256 steps (128 steps for 2-wireserial system). Brightness adjustment is performed by setting the duty ratio of the PWM control pulse. The ON duty ratio of the PWM control pulses is determined by the following formula.

Brightness = Percentage of ON period = Brightness adjustment register value ／ 256

*Resister Value 0～255 (For 2-wire serial, even values only.)

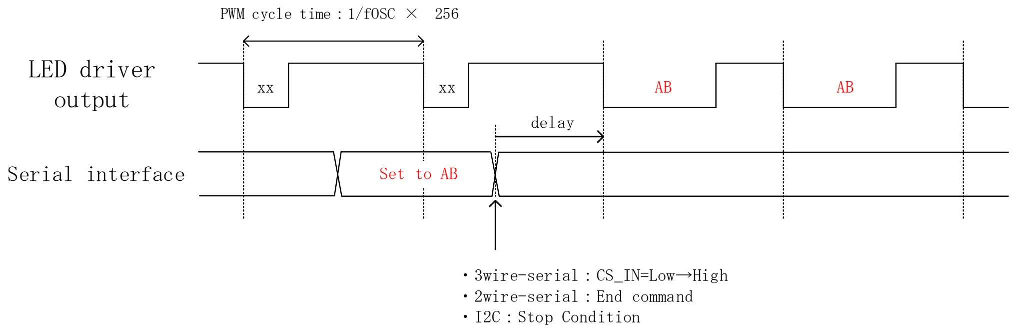
The higher the set value, the greater the proportion of ON periods and the higher the brightness. Register value 255 (254 for 2-wireserial) is set to Max brightness, but the LED driver outputs an OFF pulse with the minimum PWM pulse according to the set value. If the register value is 0, the outputs remain their OFF (Hi-Z) and the LEDs turn off the light.

＜Brightness adjustment by PWM pulse width＞



The value written to the register is reflected in the LED driver output at the start of the next PWM cycle after the serial access is completed (3-wireserial: CSI=Low to High, 2-wireserial: End command, I2C bus: Stop Condition). This result in a maximum delay time from register setting completion to LED driver output of 256 minimum PWM pulse widths (1/fOSC).

＜Delay time from brightness setting to LED driver output＞

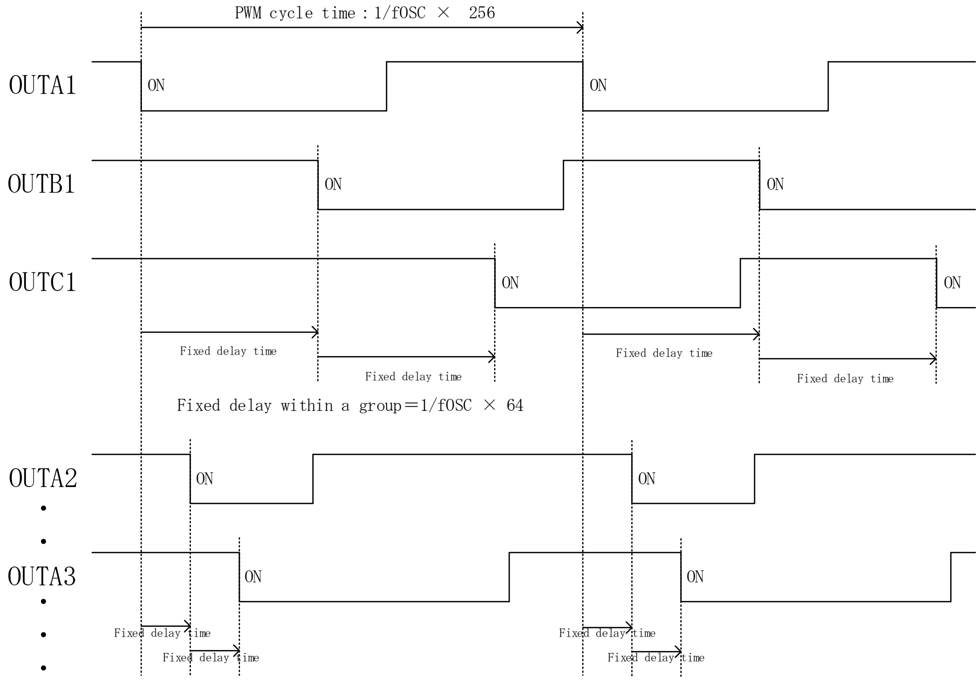


8.5. Phase control of PWM output pulse

To reduce switching noise, the start position of the PWM pulses can be changed for each channel or group.
This phase control method is selected from three options by register setting (R00[3:2]).

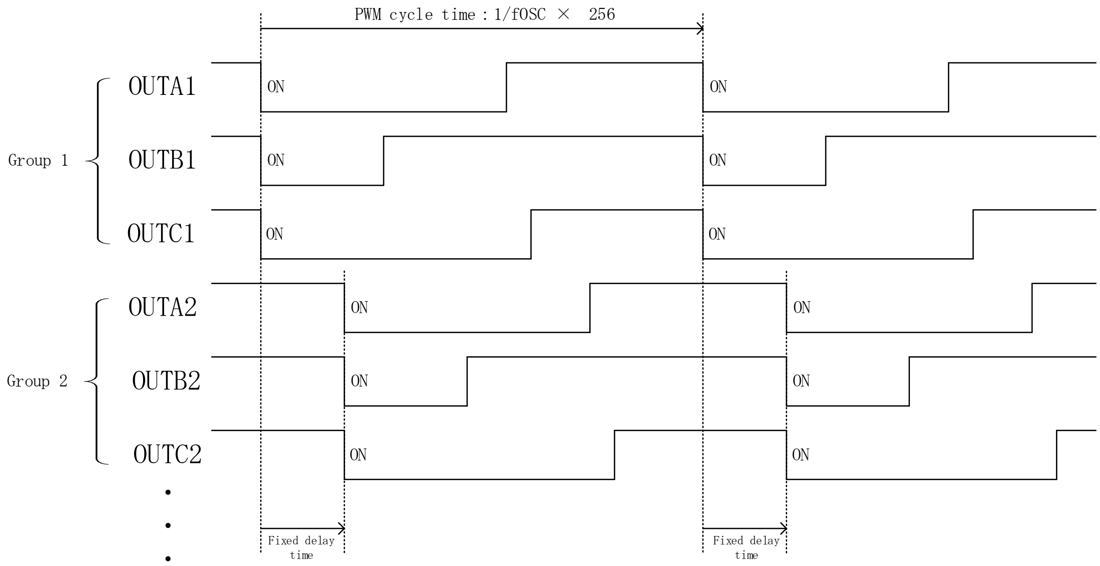
・Per-channel control（R00[3:2]=0）
Adjacent channels start PWM pulses in different phases.

＜Per-channel control＞



・3ch group control（R00[3:2]=1）
PWM pulses are started in different phases for each group from Group 1 to Group 8.

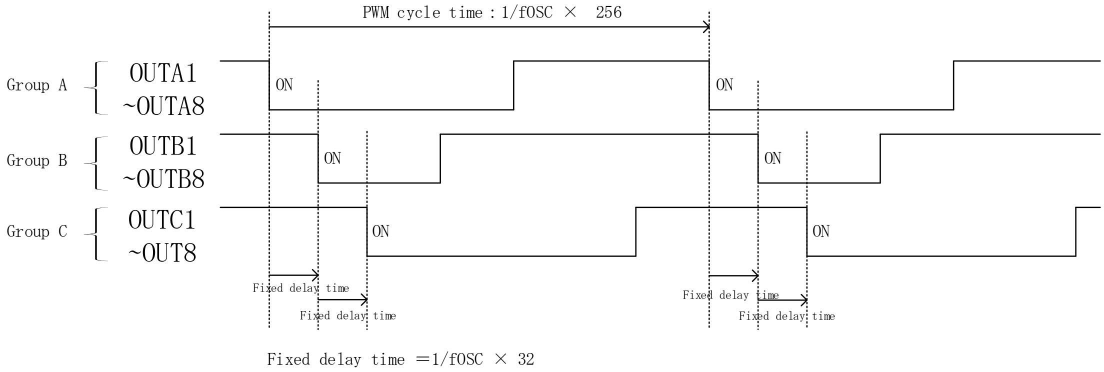
＜3ch Group control＞



・8ch group control（R00[3:2]=2）

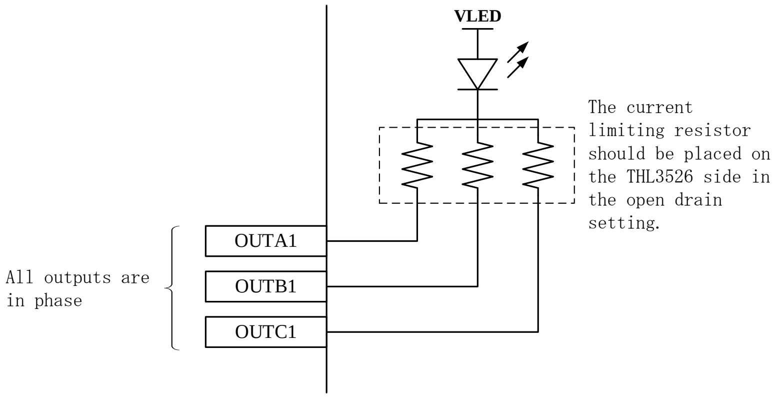
PWM pulses are started in different phases for each group (Group A/B/C).

＜8ch group control＞



When driving LEDs with LED driver channels in parallel, set the PWM phase control mode to Group control and drive the channels with the same phase in parallel. When connected in parallel in open-drain output mode, the current-limiting resistor should be connected to the THL3526 side to suppress current variations for each channel.

＜Parallel drive of LED driver outputs＞



8.6. LED driver output enable

All LED DRIVER OUTPUT channels can be disabled by register setting (R00[1]). When output is disabled (R00[1]=0), all LED DRIVER OUTPUT channels are in OFF (Hi-Z) state and LEDs are off.

After the power-on reset is released, the initial state is disable and the LEDs are off.

When using multiple THL3526, the output of all devices can be enabled simultaneously by setting R00[1]=1 at device address "00h" after completing the luminance setting with the output disabled.

9. Serial interface

9.1. Register access

The THL3526 has 25-byte registers. Writing to the registers uses the serial interface. Register values are maintained while power is applied. Register values can be read only when the I2C interface is selected. Writing to the registers should be started after the supply voltages (VDD) of all devices connected by cascade or multi-drop connections have stabilized at 4.5 V or higher.

9.2. Protocols

・The serial interface is clock synchronous.

・Data length is 8 bits, MSB first.

・The first 8 bits including the first bit are defined as "1st Byte" and the next 8 bits as "2nd Byte".

・The "1st byte" specifies the device address. When the device address is set to 00h, register writes are performed to all THL3526.（Except for THL3526 whose device address is set to 3Eh.）。

・During write operation, "2nd Byte" specifies the address of the register. "3rd byte" and thereafter, specifies the register value to be written. The register address value is auto incremented (+2) for each 8-bit register value written. The value specified by "3rd Byte" is written to the address specified by "2nd Byte", and the value specified by "4th Byte" is written to the address "2nd Byte + 2".

・The register value is set when bit 0 of each register is written.

・The register address is auto-incremented to hold the next address of the last register written or read.

・After specifying the register address in the 2nd Byte, if no write or read operation is performed to the register, the register address specified in the 2nd Byte is retained.

・During read operation, the "2nd Byte" reads out the register value of the register address that was held during the previous write operation. Thereafter, the register address is auto incremented each time the 8-bit register value is read, and the register values are sequentially read out.

・The auto increment of register addresses continues to increment after R30 as long as register accesses continue.

・Do not specify register addresses other than those shown in the register map.

＜Serial data（write）＞

1st Byte								2nd Byte								
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	・ ・ ・
Device address								Register address								

3rd Byte									Last Byte							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	・・・・・	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Register value									Register value							

＜Serial data（read）＞

1st Byte								2nd Byte								
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	・ ・ ・
Device address								Register address								

3rd Byte									Last Byte							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	・・・・・	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Register value									Register value							

9.3. Device address

Pins A0 to A4 specify device addresses.

（Example）Pin settings A4=Low、A3=Low、A2=Low、A1=Low、A0=High

The device address in 2-wire/3-wire serial is set to 00000010b (02h) and in I2C to 0000001b (01h).

＜Device address＞

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0	0	A4	A3	A2	A1	A0	0/1

・Bit 0 is fixed at 0 in 2-wire/3-wire serial, and 0 is a write command and 1 is a read command in I2C.

・In 2-wire/3-wire serial mode, writing registers to the device with pins A0 to A4 all set high is prohibited. When using only the repeater function without using the LED driver output, select 2-wire or 3-wire serial and set all A0 to A4 to High.

・Do not use the device address 00000000b (00h) with all pins A0 to A4 Low, as it is the device address for writing to all devices.

9.4. 3-wire serial

When the 3-wire serial is selected at the MODE pin, the pins CSI, SCLI, and SDAI are enabled. The chip select, serial clock, and serial data of the 3-wire serial should be input to pins CSI, SCLI, and SDAI, respectively.

・The data input SDAI is sampled on the rising edge of the clock input SCLI while CSI is in the Low period.

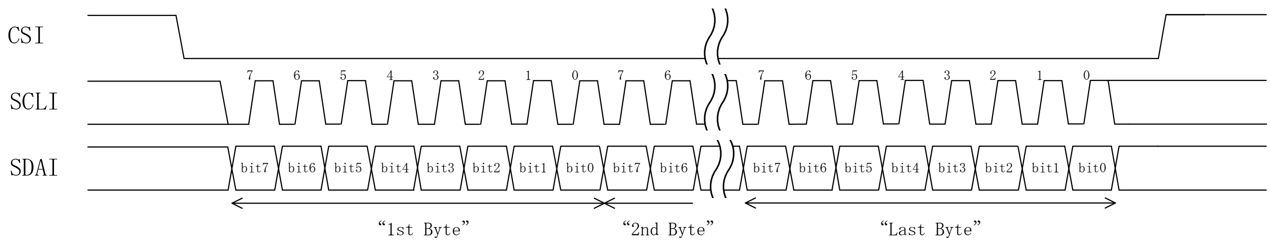
・The SDAI sampled on the first SCLI rising edge after the falling edge of CSI is the first bit.

・If CSI rises in the middle of a Byte, that Byte is not set in the register and communication starts from the beginning ("1st Byte") at the fall of the next CSI.

・Signals input to CSI, SCLI, and SDAI are output from CSO, SCLO, and SDAO, respectively.

・Register values cannot be read.

＜3-wire serial＞



9.5. 2-wire serial

When 2-wire serial is selected at the MODE pin, the CSI pin is disabled and SCLI and SDAI are enabled. Serial clock and serial data of 2-wire serial should be input to terminals SCLI and SDAI, respectively.

・Samples SDAI at the rising edge of SCLI.

・The start command is defined as "1111111111b". When "0" is received after a sequence of 8 or more consecutive "1 "s, "111111111111b" immediately before "0" is recognized as the start command, and 8-bit data starting from "0" is recognized as the 1st byte.

・If the end command is defined as "10000001b" and the end command is received, the communication ends immediately and waits for the next start command.

・If a start command is detected in the middle of a Byte, that Byte is discarded and communication starts from the beginning ("1st Byte").

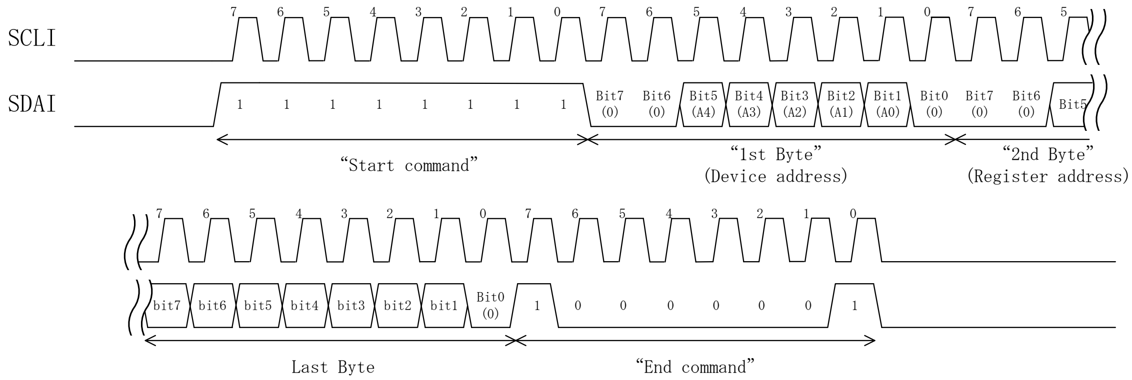
・If an end command is detected in the middle of a byte due to noise or other causes, the byte is discarded and communication is terminated immediately.

・Do not set bit 0 to "1" except for the start and end commands; a byte with bit 0 set to "1" is invalid and the register address is not incremented.

・Signals input to SCLI and SDAI are output from SCLO and SDAO, respectively.

・Register values cannot be read.

＜2-wire serial＞

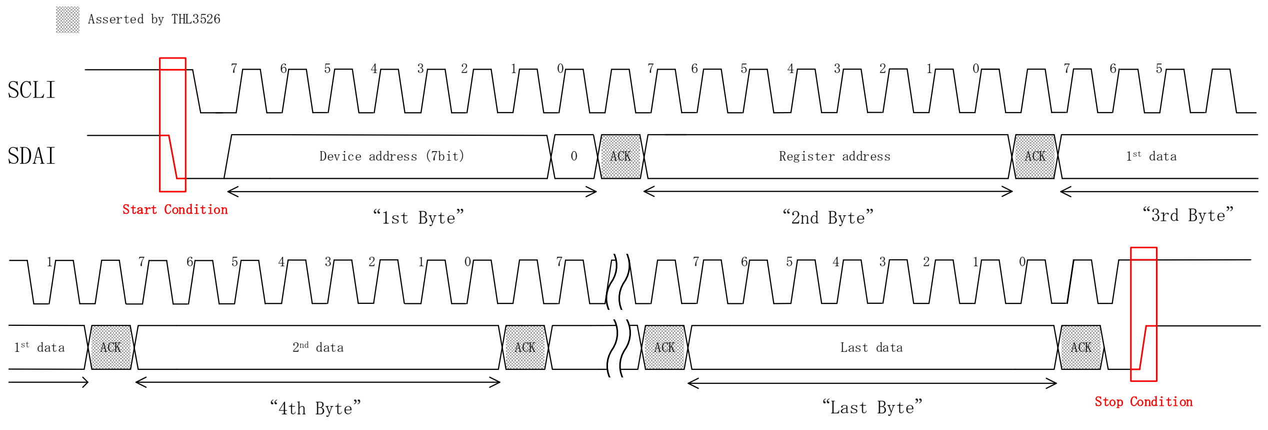


9.6. I2C

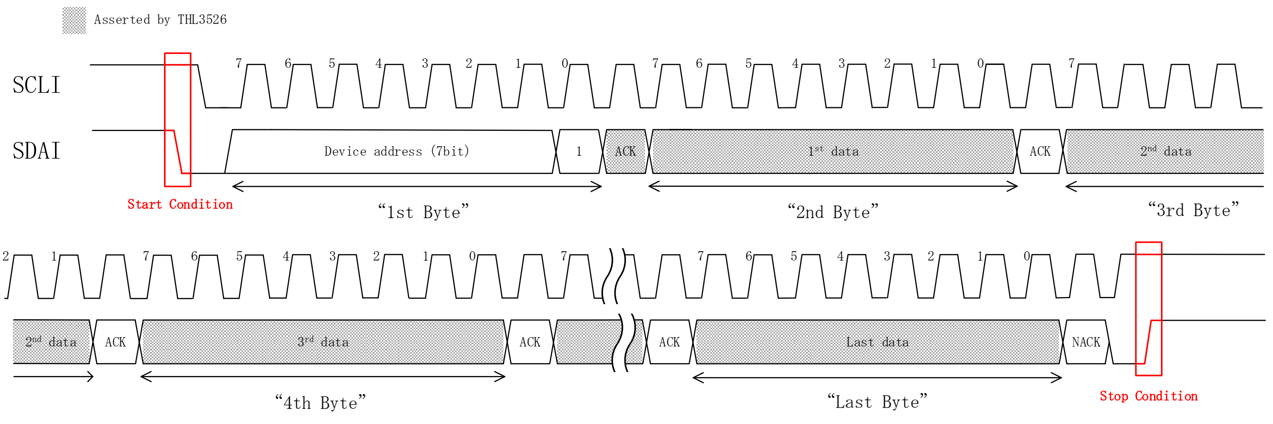
When I2C is selected with the MODE pin, the CSI pin is disabled and SCLI and SDAI are enabled. Serial clock and serial data should be input to terminals SCLI and SDAI, respectively.

- Samples SDAI at the rising edge of SCLI.
- The "Start Condition" is defined as the falling edge of the data input SDAI when the clock input SCLI is High, and the data sampled at the first rising edge of the clock after the "Start Condition" is the first bit.
- The "Stop Condition" is defined as the detection of the rising edge of SDAI when SCLI is High, and communication is completed at the "Stop Condition".
- Except for "Start Condition" and "Stop Condition", SDAI can only be transitioned during the period when SCLI is Low.
- If a "Start Condition" is detected in the middle of a Byte, that Byte is not set in the register and communication starts from the beginning ("1st Byte").
- When not communicating, both SCLI and SDAI must be kept High.
- The upper 7 bits of "1st Byte" are the device address, and the least significant bit is a register write when 0, and a register read when 1.

＜I2C（write）＞



＜I2C（Read）＞



9.7. 3-wire／2-wire serial bus repeater（Except for I2C）

THL3526 has a built-in buffer for 3-wire/2-wire serial interface, and signals input to CSI/SCLI/SDAI are output from CSO/SCLO/SDAO respectively through the buffer. Through this buffer, multistage cascade connection of THL3526 is possible.
※This function is not available when I2C is selected.

In cascade connections, variations for delay that occurs when serial signals pass through buffer circuits and wiring between devices and variations in buffer output state transition times result in skew between serial clock and serial data, limiting the number of connection stages.

＜計算例＞

a. Number of cascade connection	: N
b. Serial clock cycle time	: 1000ns（1MHz）
c. THL3526 output skew time（tSKEW）	: Max 1ns
d. Device-to-device wiring delay variation	: 0.3ns（example）
e. THL3526 buffer output transition time（tr/tf）	: Max10ns
f. THL3526 serial inputs Setup/Holdtime（tDVCH,tCHDX）	: Min10ns
g. Skew time per stage of cascade connection	: c + d + e = 0.2ns + 0.3ns + 10ns = 11.3ns
h. THL3526 serial input skew allowable Time	: (b – f * 2)/2 = (1000ns – 20ns)/2 = 490ns

$h - g \times a = 490\text{ns} - 11.3\text{ns} \times N > 0$
$N < 43.3$

In the above calculation example, 43 stages can theoretically be cascaded, but as the serial clock frequency is increased, the number of connectable stages decreases 7 stages at 5 MHz and 3 stages at 10 MHz.

Note that the above does not take into account the skew time between the serial clock and serial data input to the first stage. If the maximum delay (skew) of serial data output relative to serial clock output at the serial interface of the controller is 40ns, the following.

First-stage input skew time ＋ $g \times N$ ＜ h
$40\text{ns} + 11.3\text{ns} \times N < 490\text{ns}$
$N < 38.9$

Theoretically, 38 stages can be connected at 1 MHz and 4 stages at 5 MHz, but cascade connection is not possible at 10 MHz.

9.8. Register map

Notation

Addresses are written in hexadecimal with an "R" at the beginning. (Example) R00: Register at address 00h

Bit positions are indicated using "[]". (Example) R00[5:0] Bits 5 to 0 at address 00h

When register values are expressed in binary, a "b" is added at the end. （Example） R00[5:0]=111110b

When register values are expressed in decimal, nothing is appended to the end. （Example）R04[7:0]=160

When register values are expressed in hexadecimal, add "h" at the end. （Example）R04=A0h

Address	Initial	Function	Description
R00[7:4]	0	-	Fixed internally
R00[3:2]	0	LED driver output phase control mode	0: Per-channel 1: 3ch Group 2: 8ch Group 3: Prohibition
R00[1]	0	LED driver output enable	0: Disable 1: Enable
R00[0]	0	-	Do not set "1".
R02[7:0]	00h	OUTA1brightness adjustment	Brightness = Register value / 256 ※The register values that can be set depend on the serial communication method selected. 3-wireserial／I2C : 0 ~ 255（256 steps） 2-wireserial : Only even values from 0 to 255（128 steps）
R04[7:0]	00h	OUTB1 brightness adjustment	
R06[7:0]	00h	OUTC1 brightness adjustment	
R08[7:0]	00h	OUTA2 brightness adjustment	
R0A[7:0]	00h	OUTB2 brightness adjustment	
R0C[7:0]	00h	OUTC2 brightness adjustment	
R0E[7:0]	00h	OUTA3 brightness adjustment	
R10[7:0]	00h	OUTB3 brightness adjustment	
R12[7:0]	00h	OUTC3 brightness adjustment	
R14[7:0]	00h	OUTA4 brightness adjustment	
R16[7:0]	00h	OUTB4 brightness adjustment	
R18[7:0]	00h	OUTC4 brightness adjustment	
R1A[7:0]	00h	OUTA5 brightness adjustment	
R1C[7:0]	00h	OUTB5 brightness adjustment	
R1E[7:0]	00h	OUTC5 brightness adjustment	
R20[7:0]	00h	OUTA6 brightness adjustment	
R22[7:0]	00h	OUTB6 brightness adjustment	
R24[7:0]	00h	OUTC6 brightness adjustment	
R26[7:0]	00h	OUTA7 brightness adjustment	
R28[7:0]	00h	OUTB7 brightness adjustment	
R2A[7:0]	00h	OUTC7 brightness adjustment	
R2C[7:0]	00h	OUTA8 brightness adjustment	
R2E[7:0]	00h	OUTB8 brightness adjustment	
R30[7:0]	00h	OUTC8 brightness adjustment	

10. Junction temperature

The junction temperature calculated by the following calculation should not exceed the absolute Max. rating.

＜Package thermal resistance（Reference）＞

Condition	Parameter	Symbol	Value	Unit
4-layer substrate	Thermal resistance between junction and case surface	Ψjt	1.33	°C/W
	Thermal resistance from junction to ambient air	θja	28.3	°C/W
2-layer substrate	Thermal resistance between junction and case surface	Ψjt	2.4	°C/W
	Thermal resistance from junction to ambient air	θja	59.1	°C/W

＊Measured value with Exposed Pad soldered to the thermal pad on the board.

＜Junction temperature calculation method＞

Tj = Ta + θja × Ptotal ・・・(1)

Tj = Tc + Ψjt × Ptotal ・・・(2)

Ptotal = VDD × IDD + Vout × Iout × Nch × Duty ・・・(3)

Tj ：Junction temperature
Ta ：Ambient temperature
Tc ：Case temperature
Ptotal ：Power consumption（Total power consumption by power supply current and LED driver outputs）
Vout ：LED driver output voltage at LED “ON”
（Constant current output mode：VLED－VF, open-drain output mode：Iout × Driver output ON resistance）
Iout ：LED driver output current at LED “ON”
Nch ：Number of channels to be turned on simultaneously
Duty ：Ratio of output ON time by PWM control（Normally calculated at 100%.）

＜Calculation example in constant current output mode＞

θja=59.1 °C/W（2-layer substrate with Exposed Pad）
Ta=60 °C
VDD=5.0V
VLED=5.0V
IDD=47mA（See Electrical Characteristics）
Vout=VLED-VF=5V－2.1V=2.9V（RED 8ch）、Vout=5V－3.2V=1.8V（GREEN 8ch・BLUE 8ch）
Iout=20mA/ch

Ptotal(3) = 5V × 0.047A ＋2.9V × 0.02A × 8ch × 100% ＋1.8V × 0.02A × 16ch × 100%
= 1.275W
Tj(1) = 60 °C＋59.1 °C/W × 1.275W
= 135.4 °C

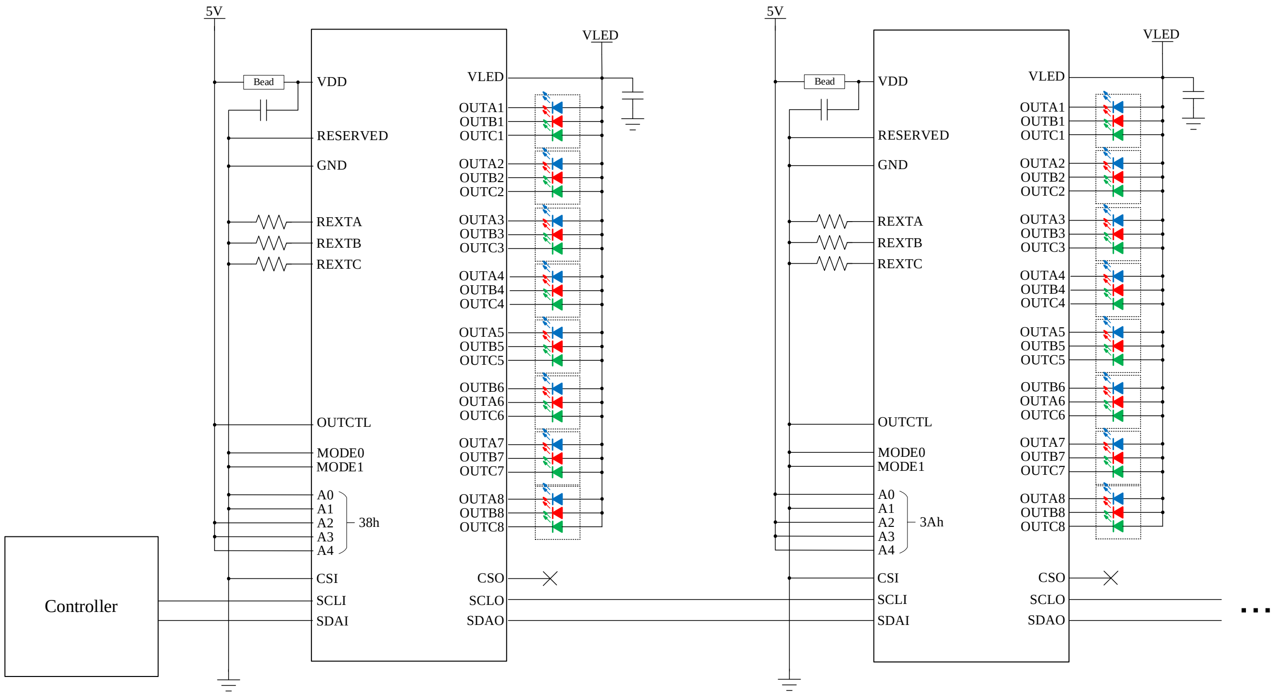
＜Calculation example in open-drain output mode＞

θja=59.1 °C/W（2-layer substrate with Exposed Pad）
Ta=60 °C
VDD=5.0V
IDD=47mA（See Electrical Characteristics）
Iout=20mA/ch
LED driver output registance：Typ.10Ω（See Electrical Characteristics）

Ptotal(3) = 5V × 0.018A ＋ (0.02A × 10Ω) ×0.02A × 24ch ×100%
= 0.331W
Tj(1) = 60 °C＋59.1 °C/W × 0.186W
= 79.6 °C

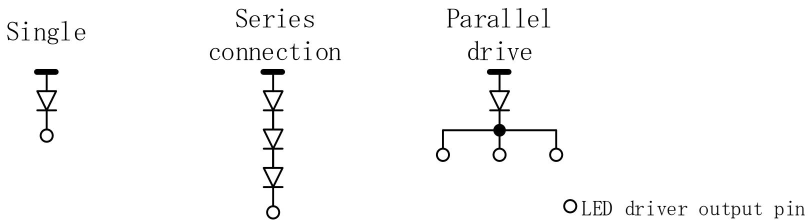
11. Circuit examples

11.1. Constant current output mode, 2-wire serial・Cascade connection



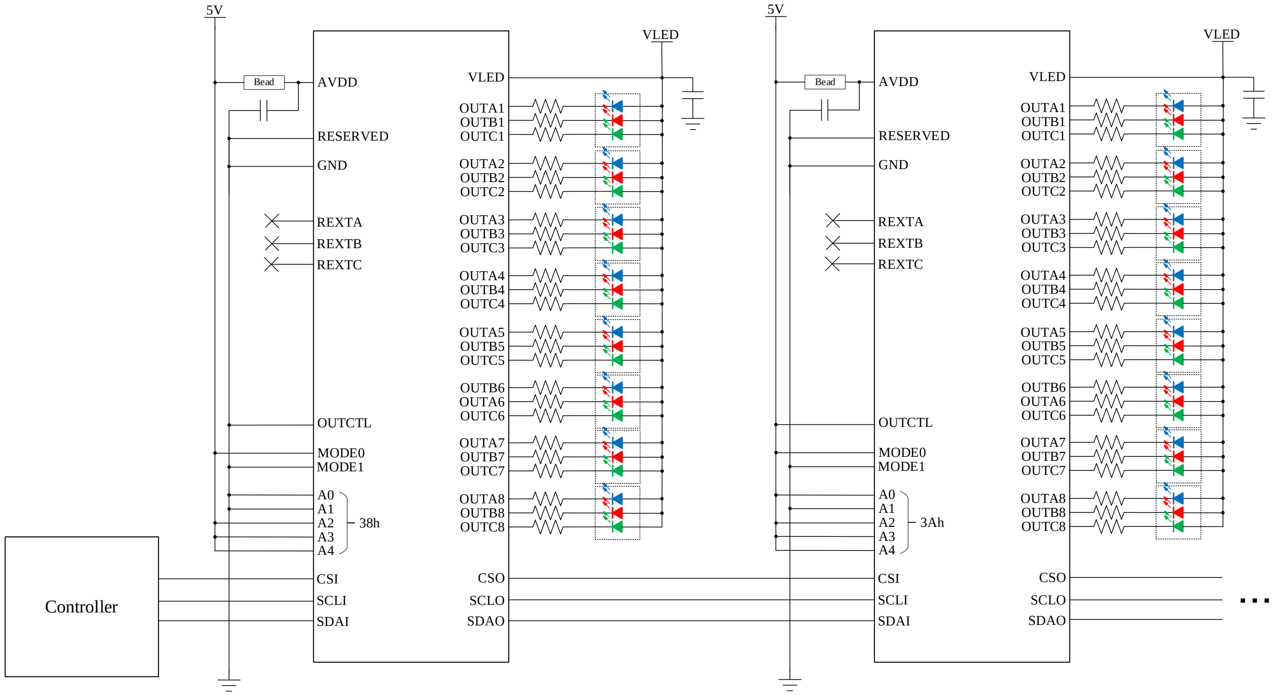
Note1. The power supply should be properly filtered using capacitors, coils, ferrite beads, etc. A 0.1uF bypass capacitor should be connected near each power supply terminal VDD.

Note2. LEDs can be connected to the following



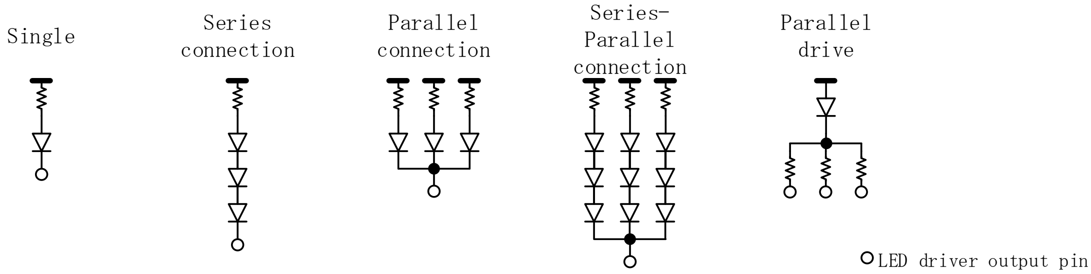
Note3. Unused LED driver output channels should be left open.

11.2. Open-drain output mode, 3-wire serial・Cascade connection

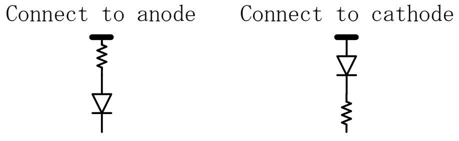


Note1. The power supply should be properly filtered using capacitors, coils, ferrite beads, etc. A 0.1uF bypass capacitor should be connected near each power supply terminal VDD.

Note2. LEDs can be connected to the following



Current-limiting resistors can be connected to either the anode or cathode side of the LED.
However, in the case of parallel drive, the current limiting resistor should be connected to the cathode side to suppress the current variation for each channel.

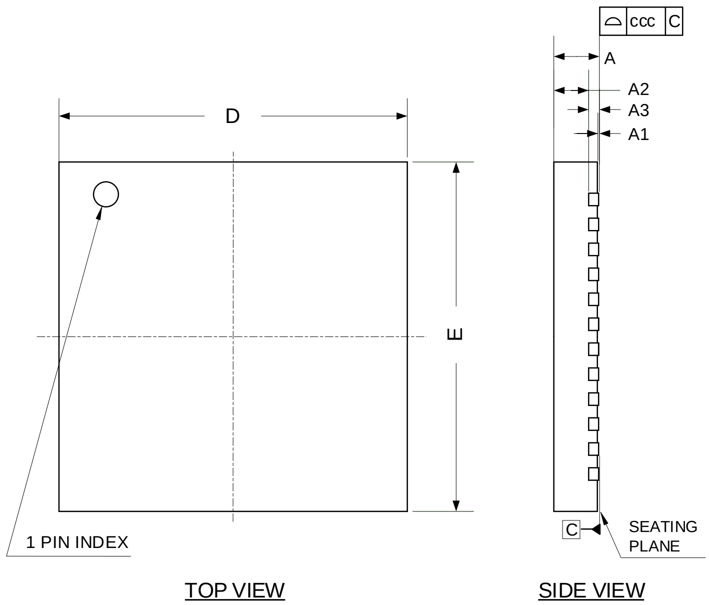


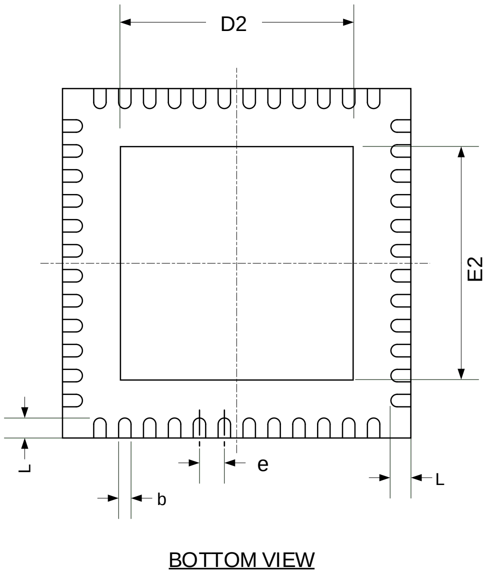
The current-limiting resistance R can be calculated simply by the following.

R=(VLED -VF)/ILED
VLED：LED supply voltage
VF ：LED forward voltage（Total voltage when connected in series）
ILED：LED current

Note3. Unused LED driver output channels should be left open.

12. Dimensions

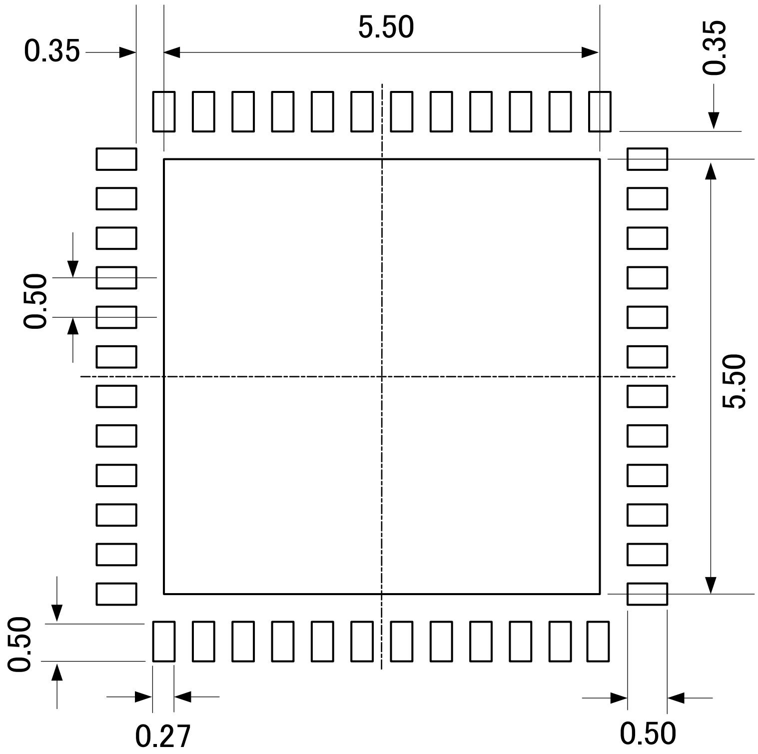




Unit : mm

Symbol	Items	Min.	Nom.	Max.
A	Mounting Height	-	-	0.90
A1	Standoff	-	-	0.05
A2	-	-	0.65	-
A3	-	(0.20)		
b	Terminal Width	-	0.25	-
D	Body Length	7.00 BSC		
D2	Exposed Length	-	5.50	-
E	Body Width	7.00 BSC		
E2	Exposed Width	-	5.50	-
L	-	-	0.40	-
e	Pitch	0.50 BSC		
ccc	Coplanarity	0.08		

13. Reference Land Pattern



The customer is responsible for adjusting the land pattern by fully considering the customer's mounting conditions (board material, solder type, reflow conditions, etc.).

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