

# THL3514

## 24-channel Constant Current LED Driver with LVDS Interface

### DESCRIPTIONS

The THL3514 is an LED driver with 24 channel constant current sink outputs. The constant current values for three output groups are determined by external resistors. The embedded oscillator and PWM controller individually generates 256-step brightness set by the dedicated registers for each channel.

The serial interface of 2-pair LVDS lines (clock and data) features high-level noise tolerance, high-speed, and long-distance transmission.

The LVDS allowing cascaded and multidrop connection offers the maximum flexibility for designers to place and connect LED drivers.

The simple and one-way communication protocol is easily-controlled and requires less CPU resources.

### APPLICATIONS

- Amusement
- LED Backlight
- LED Display
- Digital Signage
- Illumination

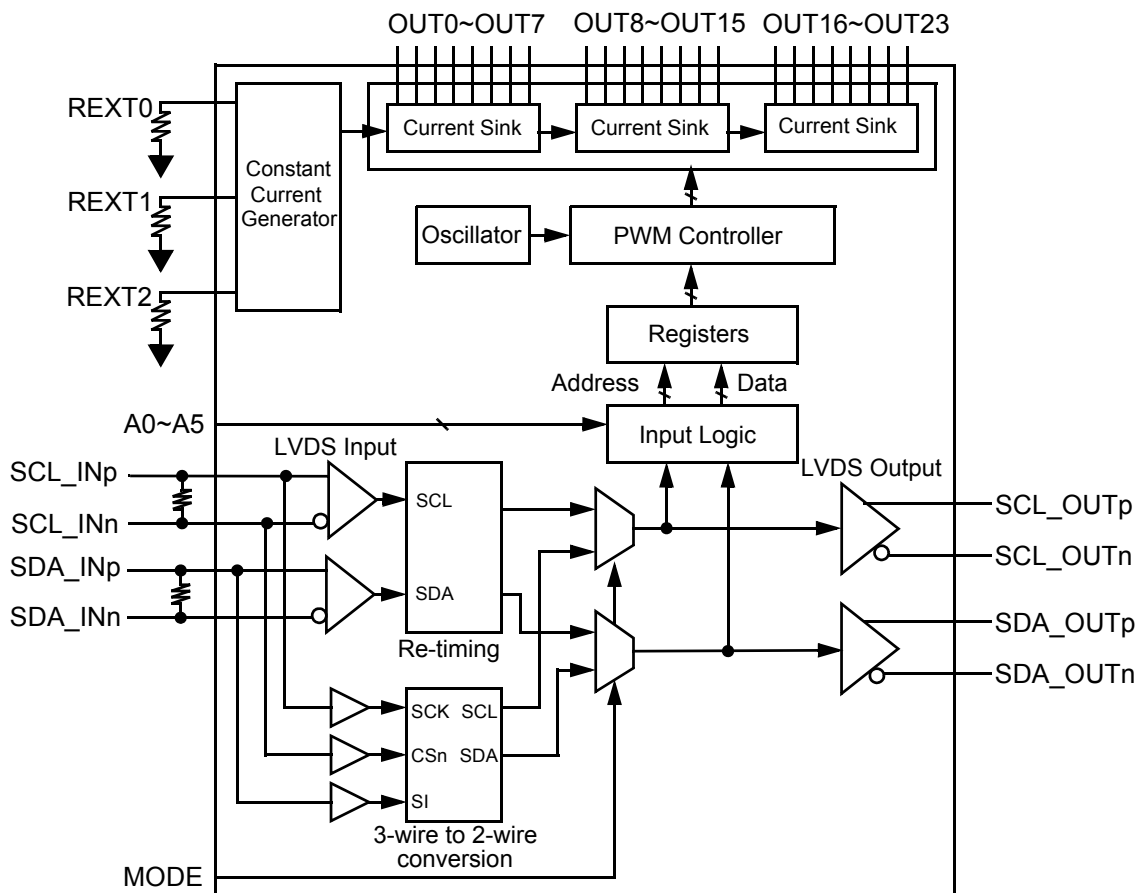
### FEATURES

- < Driver part >
  - Constant Current Output: 24 channels
  - Output Sink Current: up to 40mA/ch
  - Output voltage: up to 40V
  - Individual Brightness Control: 256 steps
  - Output disable/enable
- < Serial interface part >
  - 2-pair Serial LVDS Input or 3-wire Serial CMOS Input up to 10Mbps
  - Bridge Function Converting 3-wire Serial CMOS Input to 2-pair Serial LVDS Output
  - Repeater function of 2-pair Serial LVDS Input / Output with Waveform and Timing Correction
  - Device Address Selection up to 62 addresses
  - General call to all devices

- Protection Circuits
  - UVLO, Short Circuit Protection, Thermal Shutdown
- Supply Voltage: 3.0~5.5V
- Package: QFN 48-pin Exposed Pad
- Protection Circuits

EU RoHS Compliant

### Block Diagram



**ABSOLUTE MAXIMUM RATINGS**

| Parameter                     | Condition | Min  | Typ | Max | Unit |
|-------------------------------|-----------|------|-----|-----|------|
| VDD Supply Voltage            |           | -0.4 |     | 6.0 | V    |
| Digital Input Voltage *Note 1 |           | -0.5 |     | 6.0 | V    |
| LED Driver Output Voltage     |           |      |     | 40  | V    |
| Storage Temperature           |           | -55  |     | 150 | °C   |
| Junction Temperature, Tj      |           |      |     | 150 | °C   |

\*Note1: As for the A0 pin, the maximum value is VDD+0.5V. While power supply is not applied, the voltage on the A0 pin must be lower than 0.5V.

**RECOMMENDED OPERATING CONDITIONS**

| Parameter                         | Condition | Min | Typ | Max | Unit  |
|-----------------------------------|-----------|-----|-----|-----|-------|
| VDD Supply Voltage                |           | 3.0 |     | 5.5 | V     |
| LED Driver Output Voltage         |           |     |     | 35  | V     |
| LED Driver Output Current *Note2  |           |     |     | 40  | mA/ch |
| Operating Ambient Temperature, Ta |           | -40 |     | 85  | °C    |

\*Note2: Since overshoot of current waveform may occur depending on usage conditions, the LEDs with more than 80mA pulse forward current as absolute maximum ratings are recommended

**ELECTRICAL CHARACTERISTICS (VDD=5V, Ta=25 °C ,unless otherwise noted.)**

| Parameter                                  | Condition  | Min       | Typ  | Max      | Unit    |
|--|--|-----------|------|----------|---------|
| VDD Supply Current *Note1                  | VDD=3.3V, Iout=20mA(REXT=2.4k $\Omega$ ) without LVDS output termination resistors           |           | 11   |          | mA      |
|  | VDD=3.3V, Iout=20mA(REXT=2.4k $\Omega$ ) with LVDS output termination resistors 100 $\Omega$ |           | 18   |          | mA      |
|  | VDD=5.0V, Iout=20mA(REXT=2.4k $\Omega$ ) without LVDS output termination resistors           |           | 13   |          | mA      |
|  | VDD=5.0V, Iout=20mA(REXT=2.4k $\Omega$ ) with LVDS output termination resistors 100 $\Omega$ |           | 21   |          | mA      |
|  | VDD=5.0V, Iout=20mA(REXT=2.4k $\Omega$ ) with LVDS output termination resistors 100 $\Omega$ |           |      |          | 28      |
| Oscillator Frequency(fosc)                 |  |           | 900  |          | kHz     |
| UVLO Threshold Voltage (VDD Rising)        |  |           | 2.5  |          | V       |
| UVLO Hysteresis                            |  |           | 0.1  |          | V       |
| Constant Current Mismatch Between Channels |  |           |      | $\pm 3$  | %       |
| Constant Current Mismatch Between Devices  |  |           |      | $\pm 6$  | %       |
| LED Driver Output Leakage Current          |  |           |      | $\pm 1$  | $\mu$ A |
| Digital Input, High Level Voltage (VIH)    |  | 0.7VDD    |      |          | V       |
| Digital Input, Low Level Voltage (VIL)     |  |           |      | 0.3VDD   | V       |
| Digital Input, Hysteresis                  |  | 0.05VDD   |      |          | V       |
| Digital Input, Leakage Current             |  |           |      | $\pm 10$ | $\mu$ A |
| LVDS Input, Differential Voltage (VID)     | VIC=1.25V  | $\pm 100$ |      |          | mV      |
| LVDS Input, Leakage Current                |  |           |      | $\pm 30$ | $\mu$ A |
| LVDS Output, Differential Voltage (VOD)    | VDD=3.0V   | 240       |      |          | mV      |
|  | VDD=3.3V   |           | 350  |          | mV      |
|  | VDD=5.0V   |           | 420  |          | mV      |
|  | VDD=5.5V   |           |      | 480      | mV      |
| LVDS Output, Common Mode Voltage (VOC)     |  | 1.1       | 1.25 | 1.4      | V       |

3-wire Serial CMOS Level Input (MODE=High)

| Symbol | Parameter                 | Condition | Min | Typ | Max | Unit |
|--------|---------------------------|-----------|-----|-----|-----|------|
| fSCK   | SCK Frequency             |           |     |     | 10  | MHz  |
| tCH    | SCK High Time             |           | 40  |     |     | ns   |
| tCL    | SCK Low Time              |           | 40  |     |     | ns   |
| tDVCH  | SI Setup Time             |           | 10  |     |     | ns   |
| tCHDX  | SI Hold Time              |           | 10  |     |     | ns   |
| tCHSL  | CSn Not Active Hold Time  |           | 40  |     |     | ns   |
| tSLCH  | CSn Active Setup Time     |           | 40  |     |     | ns   |
| tCHSH  | CSn Active Hold Time      |           | 40  |     |     | ns   |
| tSHCH  | CSn Not Active Setup Time |           | 40  |     |     | ns   |
| tSHSL  | CSn Not Active Time       |           | 200 |     |     | ns   |

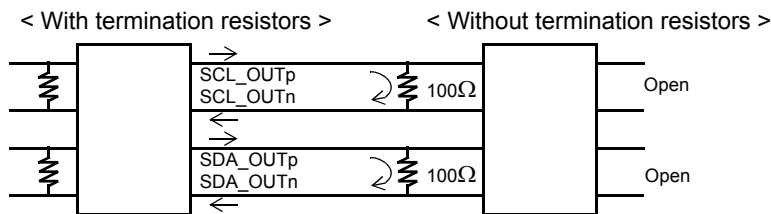
2-pair Serial LVDS Output

| Symbol | Parameter                  | Condition | Min | Typ | Max | Unit |
|--------|----------------------------|-----------|-----|-----|-----|------|
| tr, tf | SCL, SDA Transition Time   | *2        |     |     | 10  | ns   |
| tSTAH  | Header Condition Hold Time |           | 6   | 10  | 20  | ns   |
| tDSU   | SDA Setup Time             |           | 6   | 10  | 20  | ns   |
| tDHO   | SCL Falling Edge Hold Time |           | 5   |     |     | ns   |
| tPWE   | End Pulse Width            |           | 25  | 40  | 70  | ns   |
| tPD    | SCL Propagation Delay      |           |     |     | 30  | ns   |

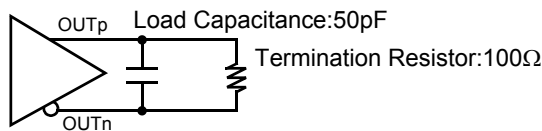
2-pair Serial LVDS Input (MODE=Low)

| Symbol | Parameter                  | Condition | Min | Typ | Max | Unit |
|--------|----------------------------|-----------|-----|-----|-----|------|
| fSCL   | SCL Frequency              |           |     |     | 10  | MHz  |
| tDAH   | SCL High Time              |           | 25  |     |     | ns   |
| tDAL   | SCL Low Time               |           | 25  |     |     | ns   |
| tSTAH  | Header Condition Hold Time |           | 4   |     |     | ns   |
| tDSU   | SDA Setup Time             |           | 4   |     |     | ns   |
| tDHO   | SCL Falling Edge Hold Time |           | 3   |     |     | ns   |

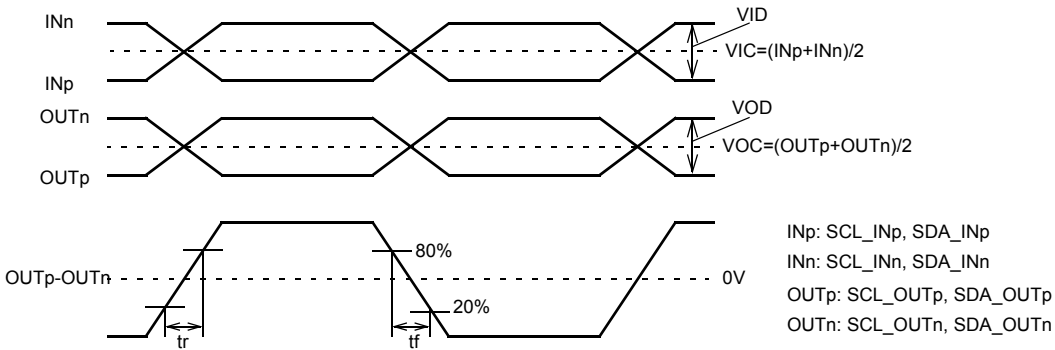
\*1. In cascading connection, termination resistors are necessary for LVDS outputs. In this case, 2.4mA to 4.8mA current flows at each resistor depending on the power supply voltage. Therefore, the current consumption is larger than the case without the termination resistors.



\*2. SCL, SDA Transition Time Measurement Condition

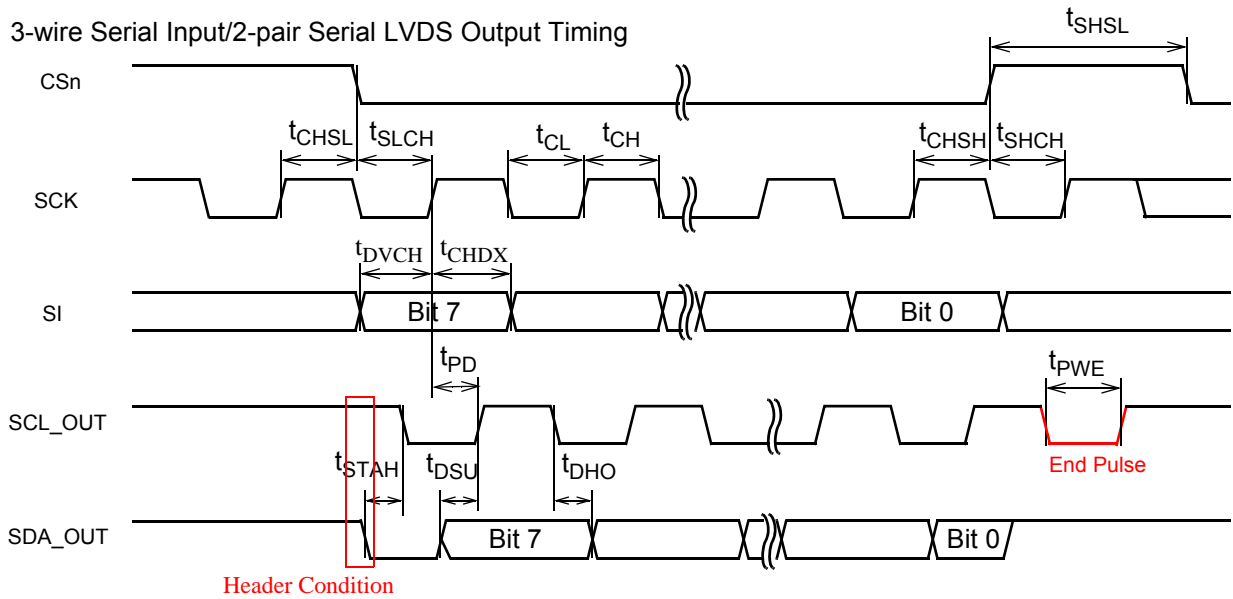


**LVDS Spec**

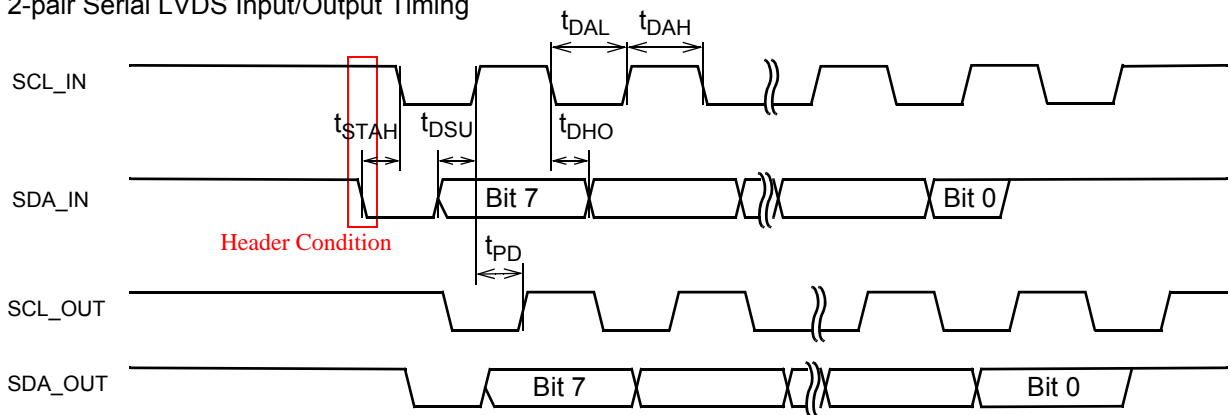


**Timing Diagram**

**3-wire Serial Input/2-pair Serial LVDS Output Timing**



**2-pair Serial LVDS Input/Output Timing**

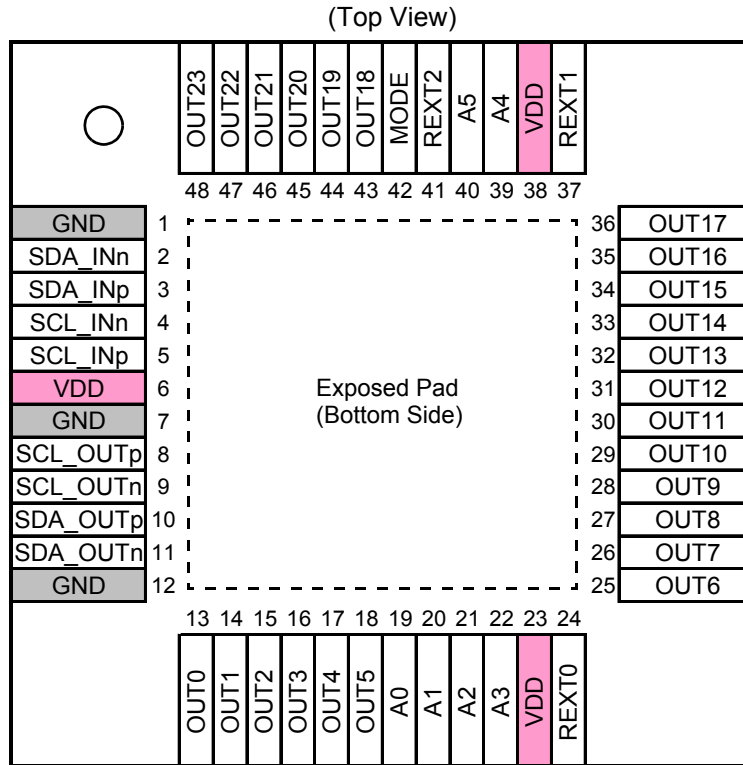


**\* Abbreviation**

This document refers to the differential signals in unipolar shorthand; for example, SCL\_IN, SDA\_IN, SCL\_OUT, and SDA\_OUT mean (SCL\_INp - SCL\_INn), (SDA\_INp - SDA\_INn), (SCL\_OUTp - SCL\_OUTn), and (SDA\_OUTp - SDA\_OUTn) respectively.

\* A falling transition of the SDA\_IN while the SCL\_IN is high is defined as "Header Condition". Please refer to the section "2-pair Serial LVDS Input" for details.

**PIN CONFIGURATIONS**



\* The exposed pad is connected to GND inside the device. The exposed pad should be soldered to GND on the PCB.

**PIN DESCRIPTION**

| Pin Name     | Type                         | Description   |
|--------------|------------------------------|---|
| MODE         | Digital Input                | Serial Interface Input Mode Select<br>Low: 2-pair Serial LVDS Input<br>High: 3-wire Serial CMOS Input   |
| SCL_INp(SCK) | LVDS Input/<br>Digital Input | MODE=Low: 2-pair Serial LVDS Clock Input - Positive<br>MODE=High: 3-wire Serial Clock Input (SCK)       |
| SCL_INn(CSn) | LVDS Input/<br>Digital Input | MODE=Low: 2-pair Serial LVDS Clock Input - Negative<br>MODE=High: 3-wire Serial Chip Select Input (CSn) |
| SDA_INp(SI)  | LVDS Input/<br>Digital Input | MODE=Low: 2-pair Serial LVDS Data Input - Positive<br>MODE=High: 3-wire Serial Data Input (SI)          |
| SDA_INn      | LVDS Input/<br>Digital Input | MODE=Low: 2-pair Serial LVDS Data Input - Negative<br>MODE=High: Reserved (Connect to Low)              |
| SCL_OUTp     | LVDS Output                  | 2-pair Serial LVDS Clock Output - Positive  |
| SCL_OUTn     | LVDS Output                  | 2-pair Serial LVDS Clock Output - Negative  |
| SDA_OUTp     | LVDS Output                  | 2-pair Serial LVDS Data Output - Positive   |
| SDA_OUTn     | LVDS Output                  | 2-pair Serial LVDS Data Output - Negative   |
| OUT0-OUT23   | Constant Current Output      | LED Driver Output Channel 0 - 23  |
| REXT0        | Analog Output                | Resistor connection for the constant current outputs (OUT0-OUT7)  |
| REXT1        | Analog Output                | Resistor connection for the constant current outputs (OUT8-OUT15)                                       |
| REXT2        | Analog Output                | Resistor connection for the constant current outputs (OUT16-OUT23)                                      |
| A0-A5        | Digital Input                | Device address input Bit0 - 5   |
| VDD          | —                            | Power supply  |
| GND          | —                            | Ground  |

## REGISTER NOTATION

Address is noted in hex with the prefix “R”. For example, R00 is a register of address 00.  
 Bit location is noted by “[ ]”. For example, R00[5:0] is bit 5 down to bit 0 of address 00.  
 Register value is noted in binary with the suffix “b”. For example, R00[5:0]=000000b  
 Register value is noted in decimal without a suffix. For example, R04[7:0]=160  
 Register value is noted in hex with the suffix “h”. For example, R04=A0h

## REGISTER MAP

| Address  | Default | Function                      | Description                             |
|----------|---------|-------------------------------|---|
| R00[7]   | 0       | PWM Phase Control Mode        | 0: Normal Mode<br>1: Group Control Mode |
| R00[6]   | 0       | LED Output Enable             | 0: Output Disable<br>1: Output Enable   |
| R00[5:0] | -       | -                             | internal fixation                       |
| R01[7:0] | 00h     | Individual Brightness - OUT0  | Individual Brightness=Value/256         |
| R02[7:0] | 00h     | Individual Brightness - OUT1  |   |
| R03[7:0] | 00h     | Individual Brightness - OUT2  |   |
| R04[7:0] | 00h     | Individual Brightness - OUT3  |   |
| R05[7:0] | 00h     | Individual Brightness - OUT4  |   |
| R06[7:0] | 00h     | Individual Brightness - OUT5  |   |
| R07[7:0] | 00h     | Individual Brightness - OUT6  |   |
| R08[7:0] | 00h     | Individual Brightness - OUT7  |   |
| R09[7:0] | 00h     | Individual Brightness - OUT8  |   |
| R0A[7:0] | 00h     | Individual Brightness - OUT9  |   |
| R0B[7:0] | 00h     | Individual Brightness - OUT10 |   |
| R0C[7:0] | 00h     | Individual Brightness - OUT11 |   |
| R0D[7:0] | 00h     | Individual Brightness - OUT12 |   |
| R0E[7:0] | 00h     | Individual Brightness - OUT13 |   |
| R0F[7:0] | 00h     | Individual Brightness - OUT14 |   |
| R10[7:0] | 00h     | Individual Brightness - OUT15 |   |
| R11[7:0] | 00h     | Individual Brightness - OUT16 |   |
| R12[7:0] | 00h     | Individual Brightness - OUT17 |   |
| R13[7:0] | 00h     | Individual Brightness - OUT18 |   |
| R14[7:0] | 00h     | Individual Brightness - OUT19 |   |
| R15[7:0] | 00h     | Individual Brightness - OUT20 |   |
| R16[7:0] | 00h     | Individual Brightness - OUT21 |   |
| R17[7:0] | 00h     | Individual Brightness - OUT22 |   |
| R18[7:0] | 00h     | Individual Brightness - OUT23 |   |

## FUNCTIONAL DESCRIPTION

### External reference resistor

The constant current value of LED driver output channels are determined by the resistors connected between REXT0, REXT1, REXT2 and GND. The external resistor value is calculated by the following equation.

$$REXT[k\Omega] = \frac{0.6 [V]}{I_{out} [mA]} \times 80 \quad (\text{Typical Value at } I_{out}=20\text{mA})$$

For example, when  $I_{out}=20\text{mA}$ ,  $REXT=0.6/20 \times 80=2.4[k\Omega]$

### Writing to registers

The device includes 25-byte registers (R00-R18) for setting. Writing to registers is executed through the serial interface and the value is maintained as long as power is applied. The register value can not be read.

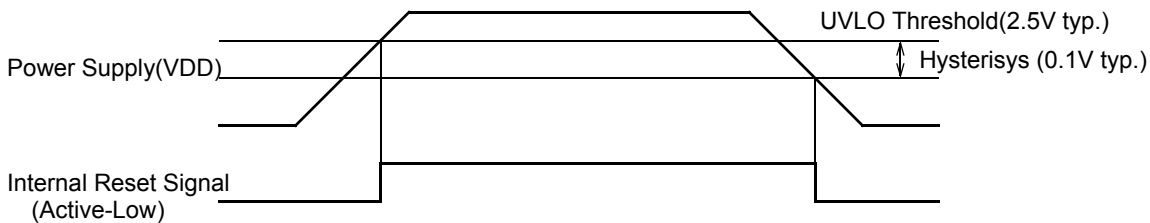
Writing to registers should be invoked after the power supply (VDD) of all the devices in cascading and multidrop connection gets stable above 3.0V.

Then after power-up, if using 2-pair serial LVDS input, initialization of 2-pair serial LVDS input must be done before writing to registers. However, in case all the registers are continuously rewritten, in other words repeatedly refreshed, the initialization of 2-pair serial LVDS input is not necessary after power-up and instantaneous interruption.

Please refer to the section “Initialization of 2-pair Serial LVDS Input” for details.

### UVLO

The device has an internal UVLO (Under-Voltage Locked-Out) circuit to prevent the device from malfunction at low supply voltage. Until power supply (VDD) has reached 2.5V (typical value), the UVLO holds the internal logic circuit in a reset condition, and keeps the LED driver outputs and LVDS outputs in Hi-Z state. The UVLO circuit has hysteresis. If power supply falls below 2.4V (typical value), the device gets into the above UVLO state in which the internal logic circuit is reset and the registers are reset to default value.



### Short Circuit Protection

The device includes short circuit protection circuits for each pin of the external reference resistors, REXT0-REXT2 to prevent the LED driver outputs from driving excessive current. If LED driver outputs turn on with the REXT0-REXT2 pin shorted to such as GND, overcurrent flowing in output transistors may cause permanent damage to the device.

The short circuit protection is a function to shutdown outputs immediately when the device detects short circuit condition on REXT0-REXT2 pin. If short circuit condition is resolved, normal operation automatically resumes.

However, this function can not always prevent breakdown or damage to the device depending on usage situation and duration of abnormality.

### Thermal Shutdown

The device includes thermal shutdown circuit to prevent damages caused by excessive heat. If the junction temperature exceeds the absolute maximum rating ( $T_j=150^\circ \text{C}$ ), the thermal shutdown circuit turn off all LED driver outputs. The thermal shutdown circuits has hysteresis. If  $T_j$  falls enough, normal operation automatically resumes.

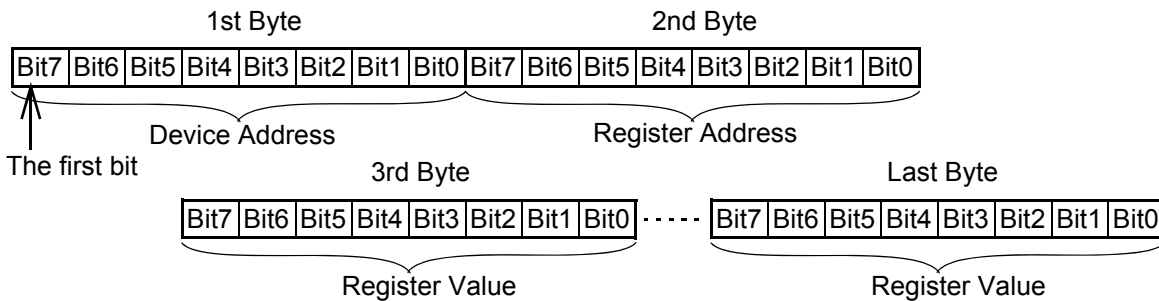
However, this function can not always prevent breakdown or damage to the device depending on usage situation and duration of abnormality.

### Serial Communication Protocol

2-pair serial LVDS input or 3-wire serial CMOS level input is selected as a serial interface for register setting by the MODE pin. The 2-pair serial LVDS input and 3-wire serial CMOS level input share input pins (SCL\_INp/SCL\_INn, SDA\_INp/SDA\_INn) which are used as 2-pair serial LVDS input when the MODE pin is set to low, and used as 3-wire serial CMOS level input when the MODE pin is set to high.

- The serial interface is clock synchronous and used only for writing to registers (one-way communication).
- The data length is 8-bit in MSB first bit order. As for how to recognize the first bit, please refer to the section “2-pair serial LVDS input” and “3-wire serial CMOS level input”.
- The first 8 bits that includes the first bit is defined as “1st byte” and the next 8 bits as “2nd byte” and so on.
- “1st Byte” is assigned to the device address. If device address is set to 00h, all the devices are selected to be written except the device which has a device address 00111111 by the A5-A0 pins.
- “2nd Byte” is assigned to the register address.
- The bytes after “3rd Byte” is assigned to register values to write. The register address is incremented every time 8-bit register value is written. For example, the value of “3rd Byte” is written to the register at the address indicated in “2nd byte”, and the value of “4th byte” is written to the register at the address (“2nd byte”+1).
- Don’t write except the registers R00-R18

#### < Serial Data >



### Device Address Setting

The lower 6 bits out of 8-bit serial interface device address are set by the A0-A5 pin. The higher 2 bits are fixed at 00.

For example,

in case A5=Low, A4=Low, A3=Low, A2=Low, A1=Low, A0=High,  
the device address is set to 00000001 (01h).

- If the A0-A5 pins are all set to high, the register of the device can not be written. Please set all the A0-A5 pins to high in order to use only 2-pair to 2-pair repeater function or 3-wire to 2-pair bridge function without using LED driver outputs.
- Since the device address 00000000 (00h) is the one to be used for writing to all devices, basically don’t use it.
- Please set device addresses within the range from 00000001 (01h) to 00111110 (3Eh) in normal use.



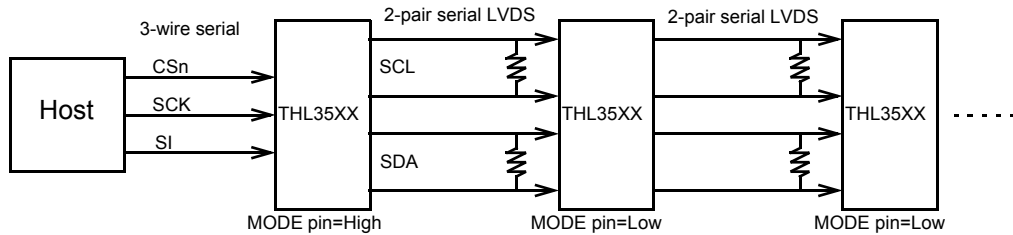
### Serial Interface Connection

THL3514 is protocol compatible with LED drivers series of opendrain outputs and constant current outputs so that can be mixed in cascade and multidrop connection scheme .(Please note that multiple LVDS outputs can not be connected to each other.)

\*LED drivers series of opendrain outputs and constant current outputs are referred to collectively as THL35XX hereafter.

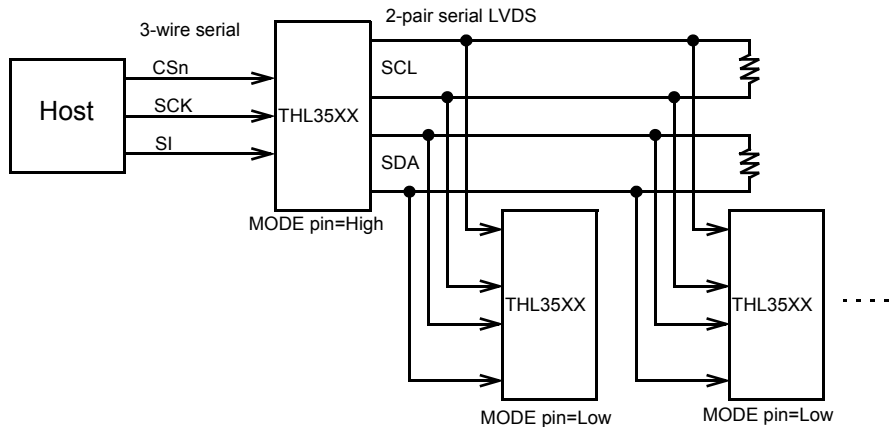
### Cascade Connection by 2-pair serial LVDS

The THL35XX can convert 3-wire serial output from the host such as micro-controller or CPU to 2-pair serial LVDS, which is connected to the 2-pair serial LVDS input of a following device in a point-to-point topology. As for the maximum number of devices to be cascaded, please refer to an application note.



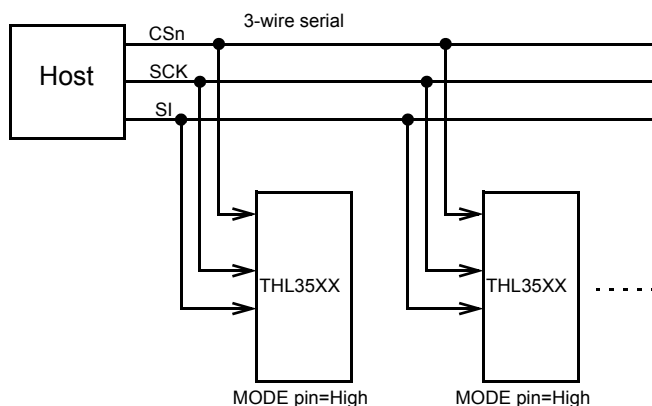
### Multidrop Connection by 2-pair serial LVDS

The THL35XX can convert 3-wire serial output from the host such as micro-controller or CPU to 2-pair serial LVDS, which is connected to the 2-pair serial LVDS input of following multiple devices in a multidrop topology. As for the maximum number of devices to be multidropped, please refer to an application note.



### Multidrop Connection by 3-wire serial

3-wire serial output from the host such as micro-controller or CPU is connected to following multiple devices in a multidrop topology.

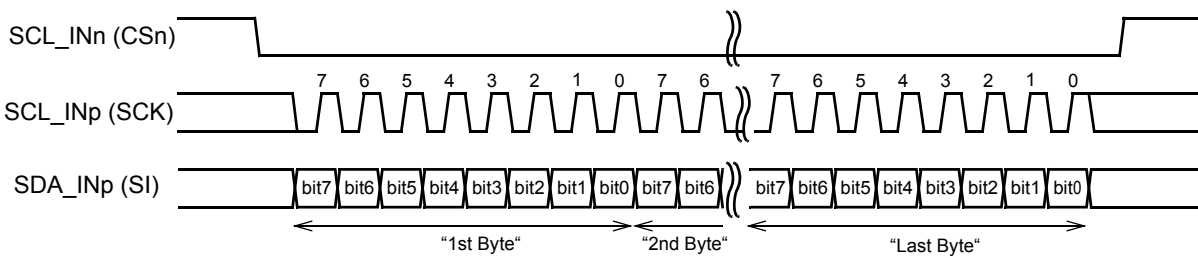


### 3-wire Serial CMOS Level Input

When the MODE pin is set to high, the serial interface for writing to registers becomes 3-wire serial CMOS level input. The chip select (CSn), serial clock (SCK), serial data (SI) of 3-wire serial CMOS level input are input to the SCL\_INn pin, the SCL\_INp pin, the SDA\_IN pin respectively. The SDA\_INn must be tied to low.

- While the CSn stays low, the data input SI is latched by rising edges of the clock input SCK.
- The data latched by the first clock rising edge after the CSn falls is assigned the “first bit“.
- The “Last Byte” is written to a register when the CSn rises after Bit0 (in other words, “Last Byte” will not be written to a register until the CSn rises).
- If the CSn rises in the middle of a byte, the byte is not written to a register, then the communication resumes from “1st Byte” when the CSn falls next.

< 3-wire Serial CMOS Level Input >

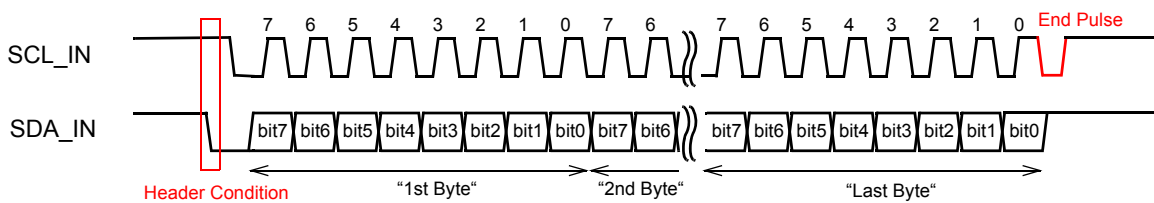


### 2-pair serial LVDS

When the MODE pin is set to low, the serial interface for writing to registers becomes 2-pair serial LVDS input (SCL\_INp/SCL\_INn, SDA\_INp/SDA\_INn).

- The data input SDA\_IN is latched by rising edges of the clock input SCL\_IN.
- A falling transition of the SDA\_IN while the SCL\_IN is high is defined as “Header Condition“, and the data latched by the first clock rising edge after the “Header Condition” is assigned the “first bit“. Except “Header Condition“, the transitions of the data input SDA\_IN are allowed while the clock input SCL\_IN is low.
- The “Last Byte” is written to a register at the reception of an active-low pulse “End Pulse” (actually, “Last Byte” is written to a register at the rising edge of the “End Pulse“). When the “End Pulse” rises, the data output SDA\_OUT must be high.
- If the “Header Condition” is received in the middle of a byte, the byte is not written to a register, then the communication resumes from “1st Byte“.

< 2-pair serial LVDS input >



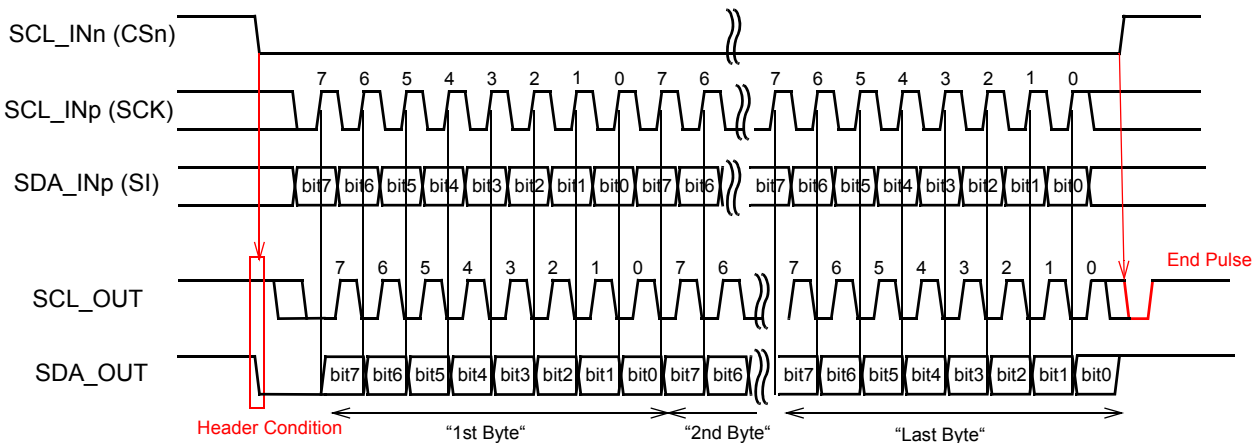
\* The 3-wire to 2-pair bridge function can convert 3-wire serial output from the host such as micro-controller or CPU to 2-pair serial LVDS. Please refer to the section “3-wire to 2-pair bridge function” for details.

### 3-wire to 2-pair bridge function

When the MODE pin is set to high, the serial interface for writing to registers becomes 3-wire serial CMOS level input (CSn, CK, SI), which is converted to 2-wire serial and transferred to the LVDS output pins.

- While the CSn is active low, the data input SI is latched and transferred to the LVDS output SDA\_OUT on the rising edges of the clock input SCK. There is about 10ns setup time between the clock output SCL\_OUT and the data output SDA\_OUT.
- When the CSn falls, "Header Condition" is generated on 2-pair LVDS output.
- After the CSn rises, an active-low pulse "End Pulse" (the pulse width: 40ns typ) is added on the clock output SCL\_OUT.
- When the CSn rises, the data output SDA\_OUT is forced high. In the result, the low to high transition of the clock output SCL\_OUT "End Pulse" occurs while the data output SDA\_OUT is high

< 3-wire to 2-pair bridge >

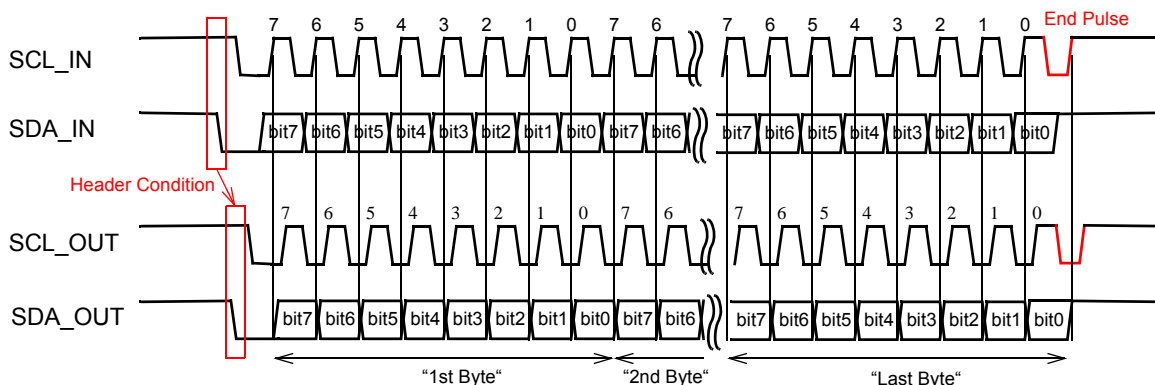


### 2-pair to 2-pair repeater function

When the MODE pin is set to low, the serial interface for writing to registers becomes 2-pair serial LVDS input (SCL\_INp/SCL\_INn, SDA\_INp/SDA\_INn). The timing between the clock and the data is compensated and then they are transferred to the LVDS output pins.

- The data input SDA\_IN is latched and transferred to the LVDS output SDA\_OUT on the rising edges of the clock input SCL\_IN. There is about 10ns setup time between the clock output SCL\_OUT and the data output SDA\_OUT.
- The "Header Condition" is regenerated and transferred to the output.

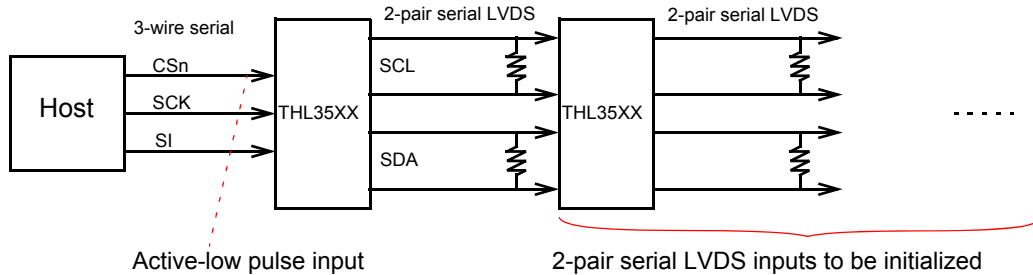
< 2-pair to 2-pair repeater function >



### Initialization of 2-pair Serial LVDS Input

After power-up, if using 2-pair serial LVDS input, initialization of 2-pair serial LVDS input must be done before writing to registers. Without the initialization of 2-pair serial LVDS input, the first writing to registers (“1st Byte”-“Last Byte”) may possibly fail. However, the initialization of 2-pair serial LVDS input is not necessary in case failure in the first writing to registers can be allowed; for example, in case all the registers (R00-R18) are continuously rewritten, in other words repeatedly refreshed.

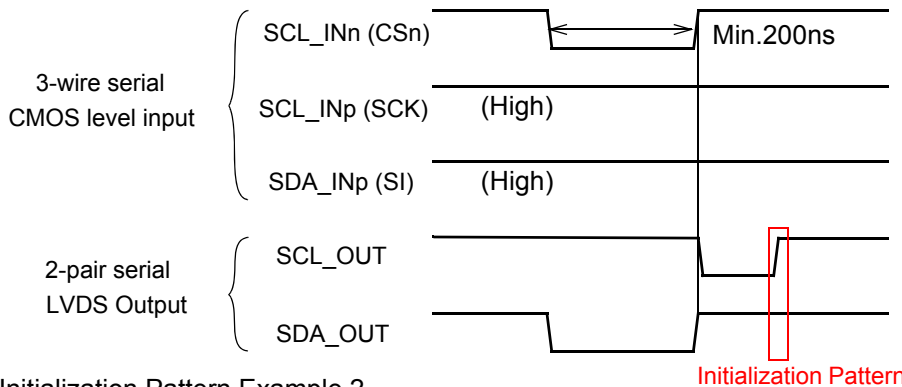
In order to initialize 2-pair serial LVDS input, please input active-low pulse (pulse width: 200ns min.) of the CSn into 3-wire serial CMOS level input of the first device which converts 3-wire to 2-pair. In consequence, the 2-pair serial LVDS input of all the following devices are initialized. In cascading connection, it takes the propagation delay of all stages in cascaded chain to finish the initialization of 2-pair serial LVDS input.



#### < Initialization of 2-pair Serial LVDS Input >

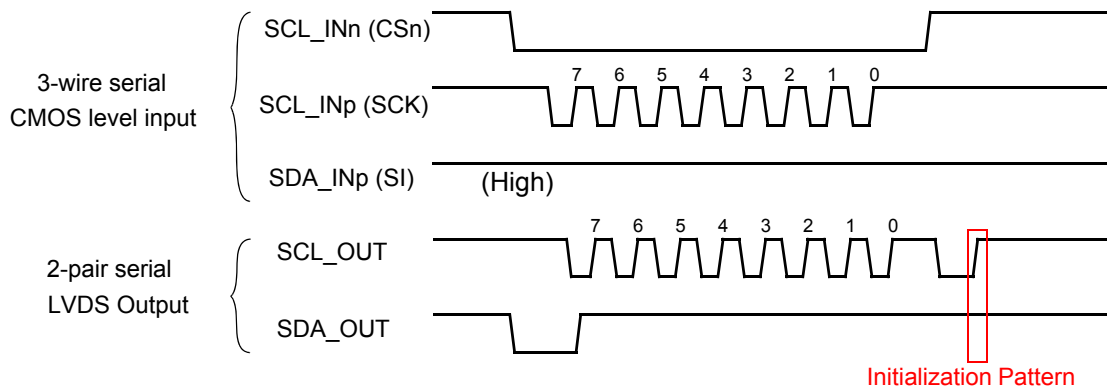
##### Initialization Pattern Example 1

Input active-low pulse input to the CSn



##### Initialization Pattern Example 2

Input 1st Byte (Device Address)=FFh

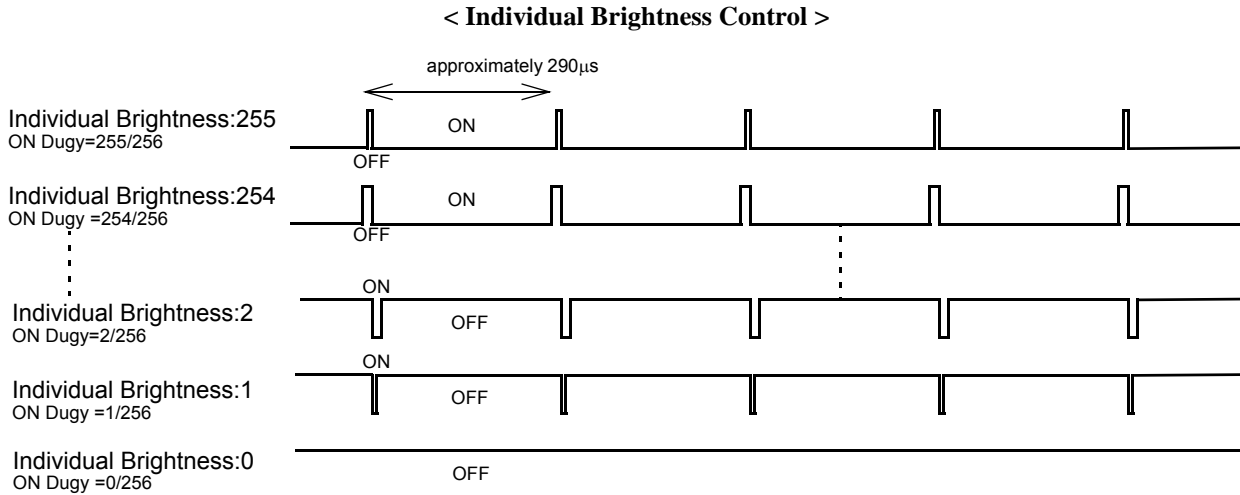


### Individual Brightness Control

The Brightness for each LED output channel (OUT0-OUT23) are individually programmable in 256 steps by the register configuration (R01-R15). The individual Brightness is controlled by PWM duty cycle. The ratio of ON time for the constant current outputs is expressed in the following equation.

$$\text{ON time ratio} = \text{Individual Brightness Control Register Value} / 256$$

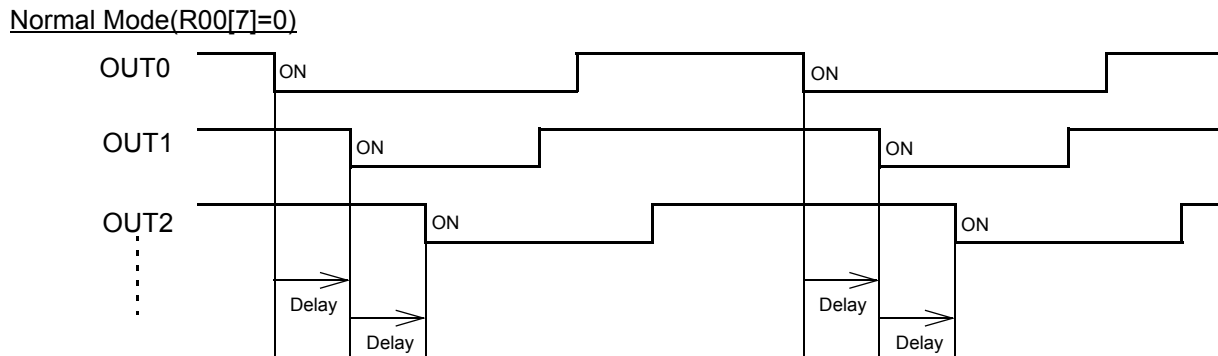
The bigger setting value results in the larger ON time ratio, therefore higher brightness. When the register value is 0, the output current sink is held OFF, therefore the LED turns off.



### PWM Phase Control Mode

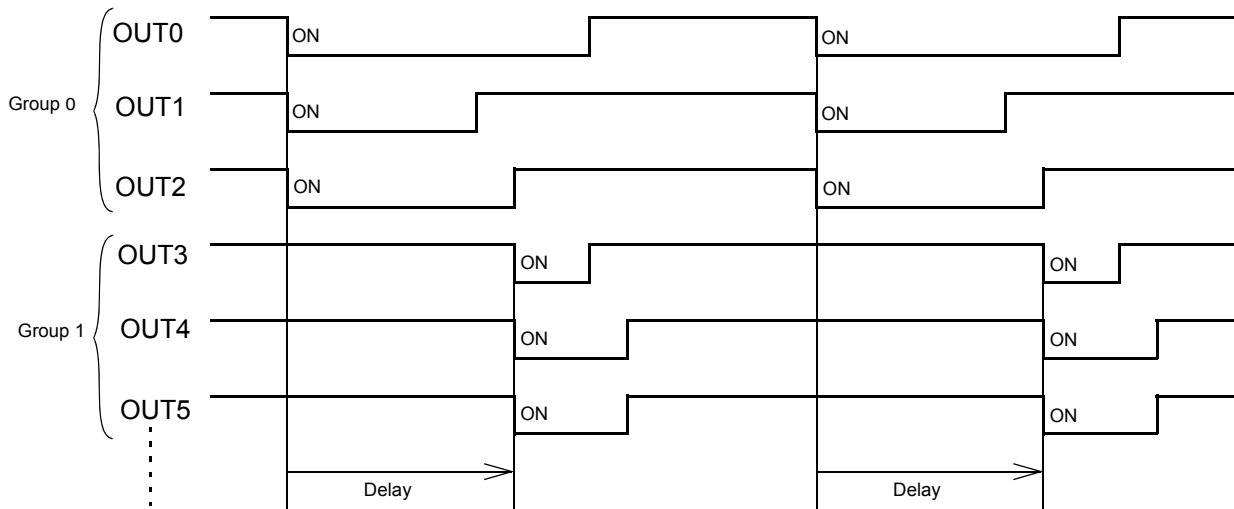
The PWM pulse start position of each channel is controlled in different phases to reduce switching noise. The phase control mode is selectable in 2 ways by the register configuration (R00[7]). In normal mode (R00[7]=0), the PWM pulse start positions of all channels are different from each other. In group control mode (R00[7]=1), the PWM pulse start positions of 2 or 3 channel groups are different from each other.

**< PWM Phase Control Mode >**



< PWM Phase Control Mode >

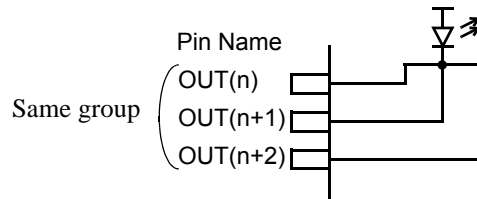
Group Control Mode(R00[7]=1)



When multiple LED output channels need to be connected in parallel to drive, the PWM phase control mode must be set to group control mode (R00[7]=1), and the channels in the same group must be connected in parallel to drive.

< Grouping of Group Control Mode >

| Group  | Output Channel      |
|--------|---------------------|
| Group0 | OUT0, OUT1, OUT2    |
| Group1 | OUT3, OUT4, OUT5    |
| Group2 | OUT6, OUT7, OUT8    |
| Group3 | OUT9, OUT10, OUT11  |
| Group4 | OUT12, OUT13, OUT14 |
| Group5 | OUT15, OUT16, OUT17 |
| Group6 | OUT18, OUT19, OUT20 |
| Group7 | OUT21, OUT22, OUT23 |

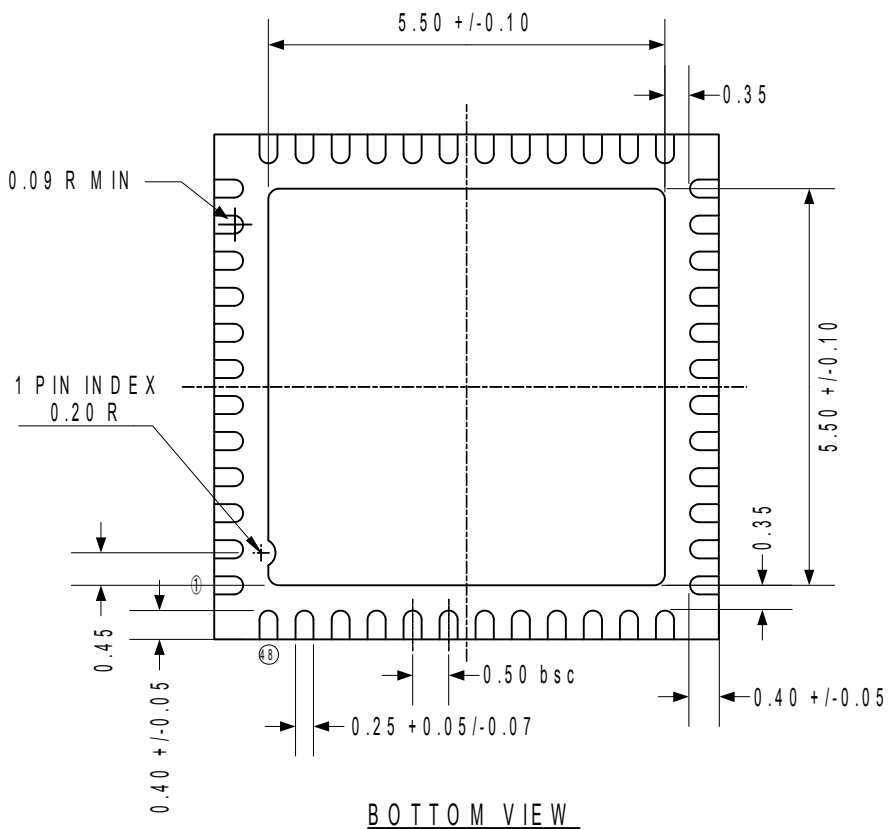
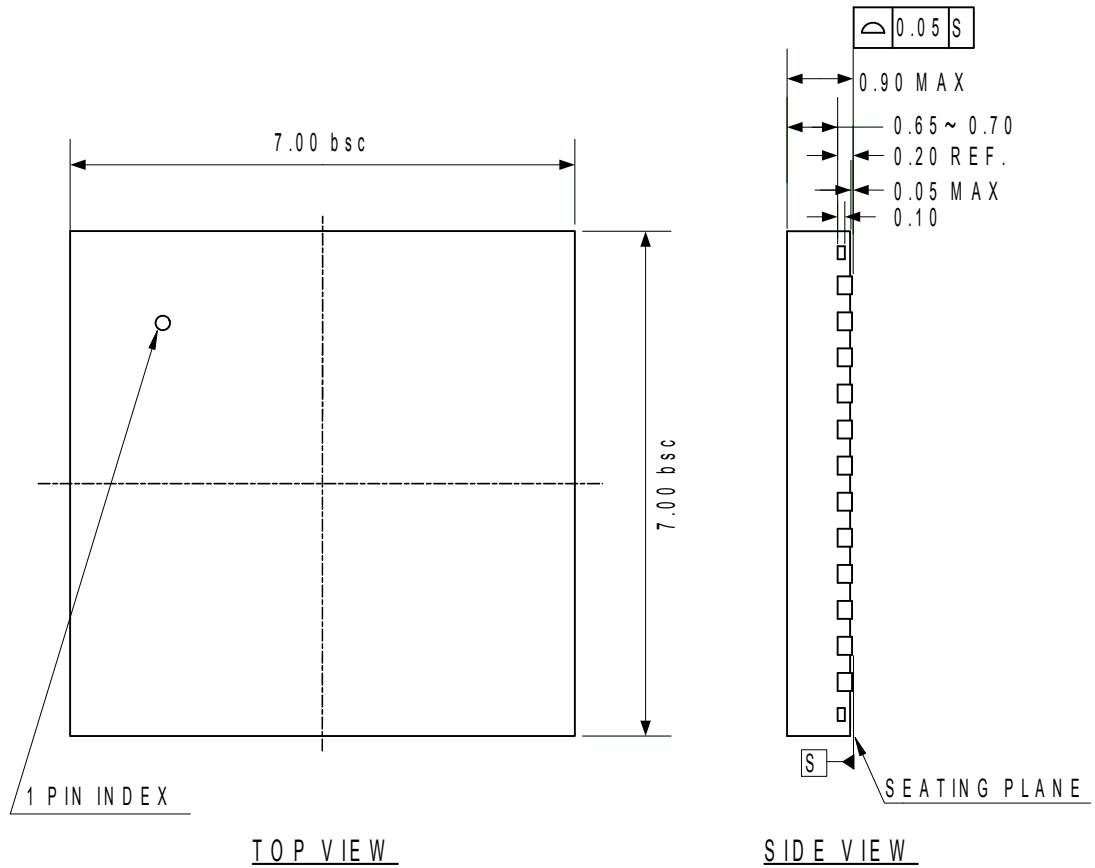


**LED Driver Output Enable**

All of the LED driver outputs can be disabled by register configuration (R00[6]). When disabled (R00[6]=0), all of the LED driver outputs go into OFF (Hi-Z) state, LEDs turn off.

### Package Dimensions

QFN 48-pin



Unit: mm

## Notices and Requests

1. The product specifications described in this material are subject to change without prior notice.
2. The circuit diagrams described in this material are examples of the application which may not always apply to the customer's design. We are not responsible for possible errors and omissions in this material. Please note if errors or omissions should be found in this material, we may not be able to correct them immediately.
3. This material contains our copy right, know-how or other proprietary. Copying or disclosing to third parties the contents of this material without our prior permission is prohibited.
4. Note that if infringement of any third party's industrial ownership should occur by using this product, we will be exempted from the responsibility unless it directly relates to the production process or functions of the product.
5. This product is presumed to be used for general electric equipment, not for the applications which require very high reliability (including medical equipment directly concerning people's life, aerospace equipment, or nuclear control equipment). Also, when using this product for the equipment concerned with the control and safety of the transportation means, the traffic signal equipment, or various Types of safety equipment, please do it after applying appropriate measures to the product.
6. Despite our utmost efforts to improve the quality and reliability of the product, faults will occur with a certain small probability, which is inevitable to a semi-conductor product. Therefore, you are encouraged to have sufficiently redundant or error preventive design applied to the use of the product so as not to have our product cause any social or public damage.
7. Please note that this product is not designed to be radiation-proof.
8. Customers are asked, if required, to judge by themselves if this product falls under the category of strategic goods under the Foreign Exchange and Foreign Trade Control Law.
9. The product or peripheral parts may be damaged by a surge in voltage over the absolute maximum ratings or malfunction, if pins of the product are shorted by such as foreign substance. The damages may cause a smoking and ignition. Therefore, you are encouraged to implement safety measures by adding protection devices, such as fuses.

**THine Electronics, Inc.**

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