16-Channel Constant Current LED Driver With 16-Bit PWM Control and Dot-Correct

Features

- 16 constant-current output channels
- Constant output current invariant to load voltage change:
  3~45mA@V_{DD}=5V
  3~30mA@V_{DD}=3.3V
- Excellent channel output current accuracy:
  - Between channels: <±1,5%(typ.); between ICs: <±3%(typ.)
- Visual effect control
  - 8-bit dot-correction
  - 7-bit linear programmable output current gain
  - 16-bit or 12-bit grey scale control
  - Random PWM technology to improve refresh rate
- Error detection control
  - In-message error detection: on-the-fly, data-in error-out
  - Compulsory individual LED open/short-circuit detection:
    full panel, data independent silent error detection in 690ns
  - Configurable short-circuit detection threshold voltage
  - Thermal protection
- EMI reduction
  - Staggered delay of output, preventing from current surge
- Maximum data clock frequency: 30MHz
- Maximum grey scale clock frequency: 33MHz
- 3V~5.5V Supply Voltage

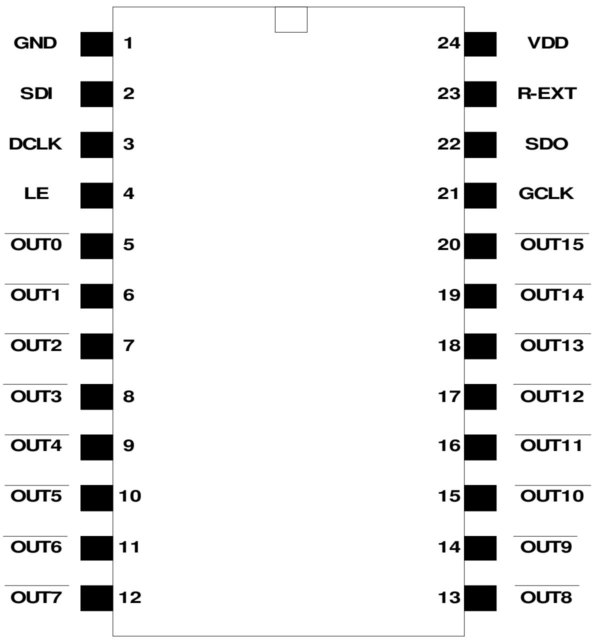
Application

- Full-color LED display

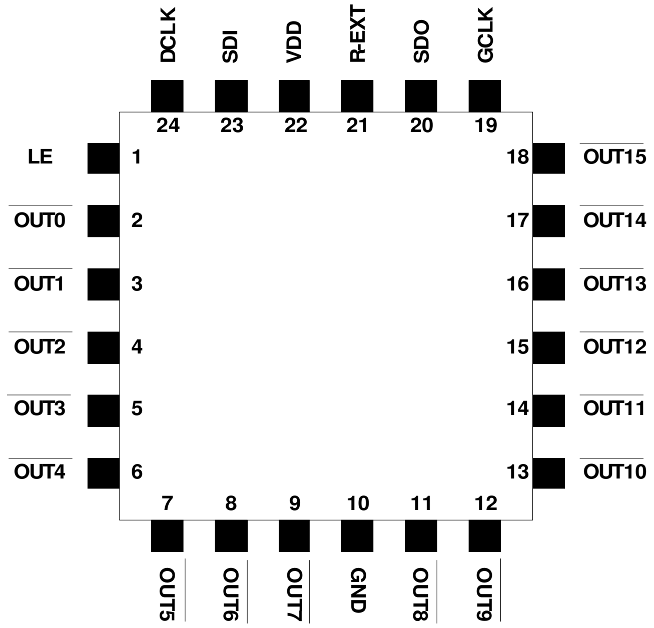
General Description

IT1504 is a 16-channel constant current LED driver with selectable 16-/12-bit grey scale control and 8-bit dot correction. The constant current for each output channel is from 3mA to 45mA. The current is set by an external resistor. IT1504 shares the data input and data output to extend the functionality, such as in-message error detection, compulsory error detection, thermal protection, and current gain control in LED display systems.
With random PWM technology, IT1504 improves the PWM by breaking the “on” time into several random period “on” time, therefore IT1504 is able to increase visual refresh quality. Besides, IT1504 provides 16-bit grey scale control to enrich the color of image, allowing to present video images with 65,536 grey scales. IT1504 also provides 8-bit dot correction to calibrate the brightness and color of LEDs individually. Furthermore, the preset current of IT1504 also can be adjusted by 128 steps for LED global brightness.
With in-message error detection, IT1504 can detect individual LED for both open- and short-circuit errors on-the-fly without extra components. In addition, to have a better system reliability, IT1504 is built with thermal protection functions.

Pin Configurations



IT1504SP

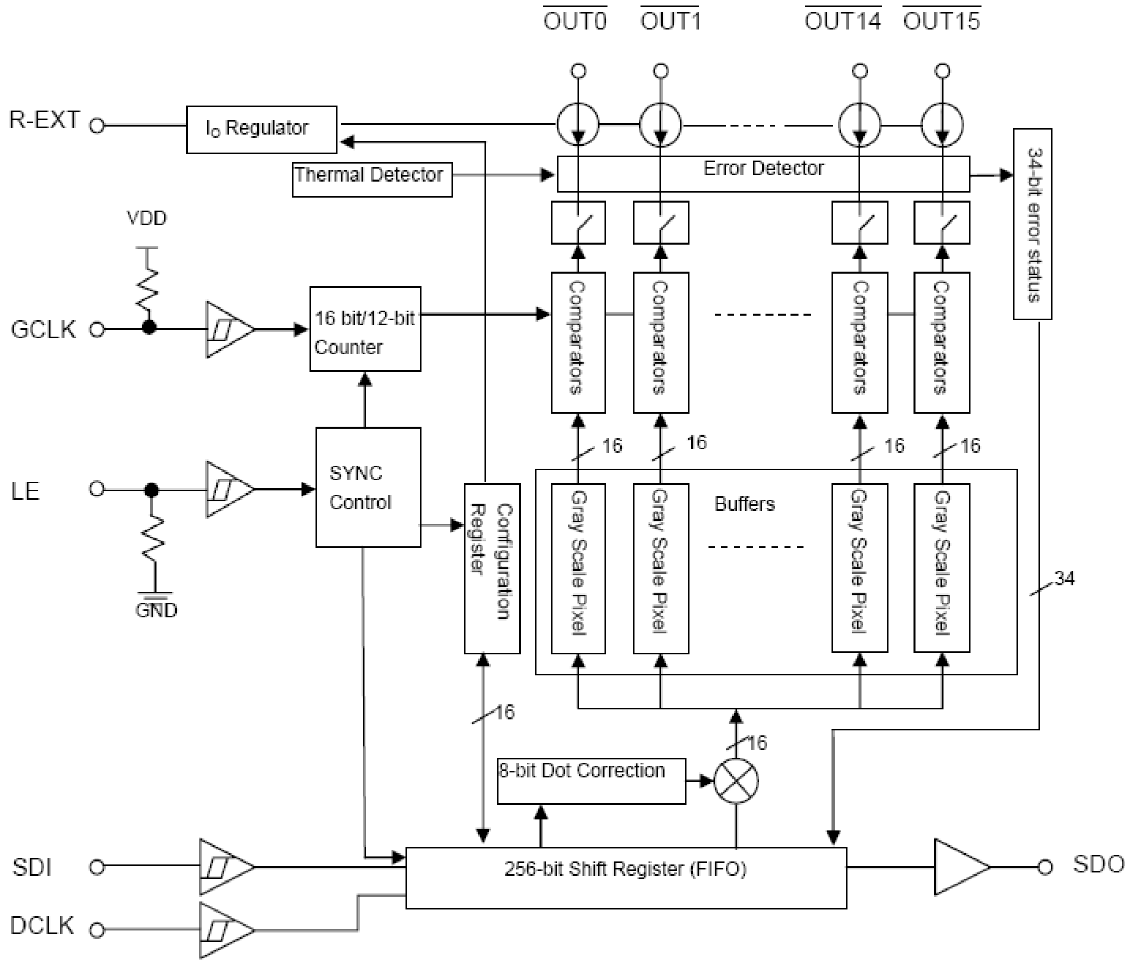


IT1504QF

Terminal Description

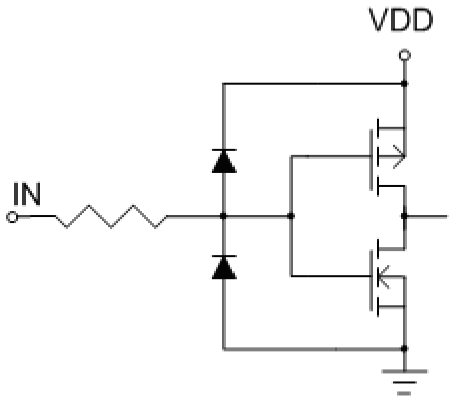
Pin Name	Description
GND	Ground terminal for control logic and current sink.
SDI	Serial-data input to the shift register.
DCLK	Clock input terminal used to shift data on rising edge and carries command information when LE is asserted.
LE	Data strobe terminal and controlling command with DCLK.
$\overline{\text{OUT0}}$ ~ $\overline{\text{OUT15}}$	Constant current output terminals.
GCLK	Grey scale clock terminal. Clock input for grey scale. The grey scale display is counted by grey scale clock comparing with input data.
SDO	Serial-data output to the receiver-end SDI of next driver IC.
R-EXT	Input terminal used to connect an external resistor for setting up output current for all output channels.
VDD	3.3V/5V supply voltage terminal.

Block Diagram

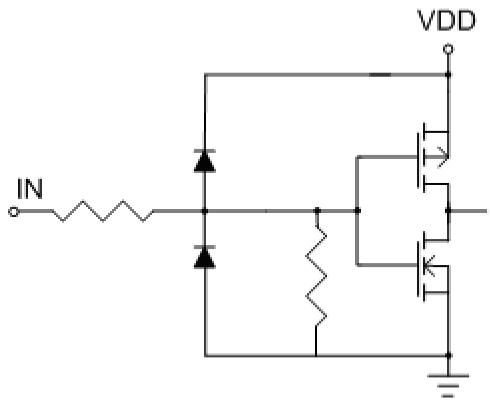


Equivalent Circuits of Inputs and Outputs

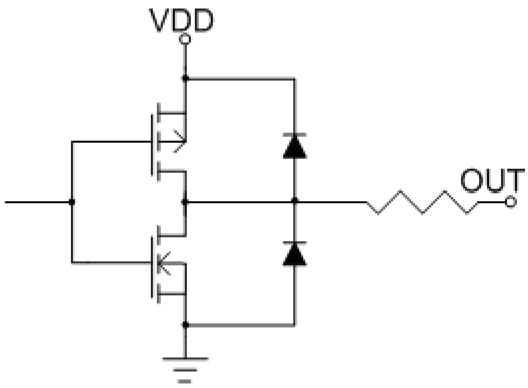
GCLK, DCLK, SDI terminal



LE terminal



SDO terminal



Maximum Ratings

Characteristics		Symbol	Rating	Unit
Supply Voltage		V_{DD}	0~7	V
Input Pin Voltage(SDI)		V_{IN}	-0.4~ V_{DD}+0.4	V
Output Current		I_{OUT}	+50	mA
Sustaining Voltage at OUT Port		V_{DS}	-0.5~17	V
GND Terminal Current		I_{GND}	+1280	mA
Power Dissipation (On PCB,Ta=25°C)	IT1504SP Type	P_D	3.5	W
	IT1504QF Type		3.1	
Thermal Resistance (On PCB,Ta=25°C)	IT1504SP Type	$R_{th(j-a)}$	67	°C/W
	IT1504QF Type		42	
Operating Temperature		T_{opr}	-40~+85	°C
Storage Temperature		T_{stg}	-55~+150	°C

Electrical Characteristics (V_{DD}=5V, Ta=25°C)

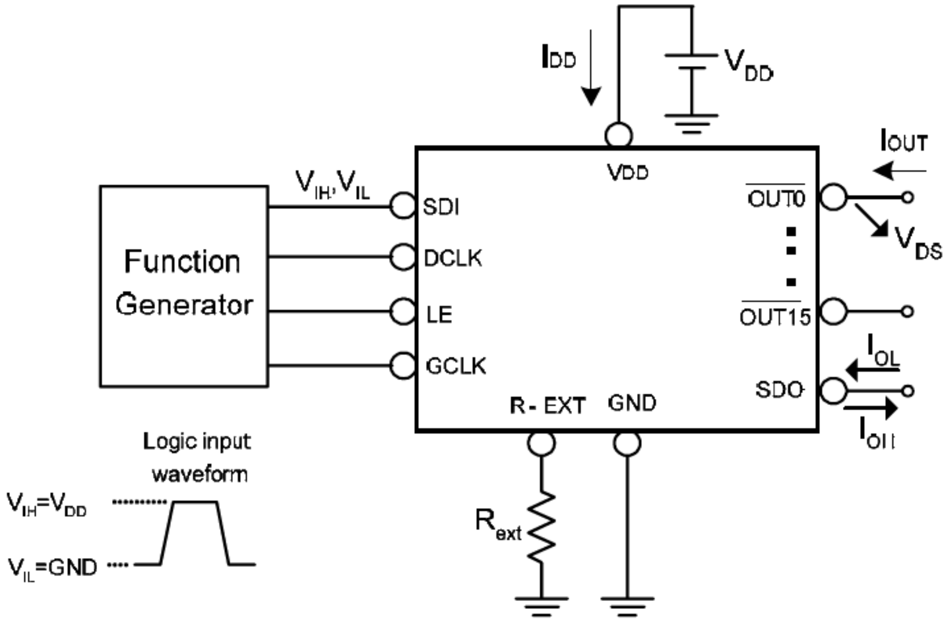
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage Range	V_{DD}	-	4.5	5.0	5.5	V
Output Voltage	V_{OUT}	-	-	-	17	V
Output Current	I_{OUT}	DC Output Channel	3	-	45	mA
	I_{OH}	SDO	-	-	-1	mA
	I_{OL}	SDO	-	-	1	mA
Output Leakage Current	I_{OUT}	V_{OUT}=17.0V	-	-	0.5	μA
Current Skew(Channel)	dI_{OUT1}	I_{OUT} =25.8mA,V_{DS}=1V; R_{EXT}=560Ω	-	±1.5	±3	%
		I_{OUT}=45mA,V_{DS}=1V; R_{EXT}=310Ω	-	±1.5	±3	%
Current Skew(IC)	dI_{OUT2}	I_{OUT} =25.8mA,V_{DS}=1V; R_{EXT}=560Ω	-	±3	±6	%
		I_{OUT}=45mA,V_{DS}=1V; R_{EXT}=310Ω	-	±3	±6	%
Output Current vs. Output Voltage Regulation*	%/dV_{DS}	V_{DS} within 1.0V and 3.0V, R_{EXT}=560Ω@25.8mA	-	±0.1	-	%/V
Output Current vs. Supply Voltage Regulation*	%/dV_{DD}	V_{DD} within 4.5V and 5.5V	-	±1	-	%/V
Input Voltage	V_{iH}	T_a=-40°C ~85°C	0.7V_{DD}	-	V_{DD}	V
	V_{iL}	T_a=-40°C ~85°C	GND	-	0.3V_{DD}	V
Output Voltage(SDO)	V_{OH}	I_{OH}=-1.0mA	4.6	-	-	V
	V_{OL}	I_{OL}=1.0mA	-	-	0.4	V
LED Open Error Detection Threshold	$V_{DS,TH}$	-	-	0.3	0.35	V
Pull-down Resistor of LE	R_{IN}(down)	-	250	450	800	KΩ
Supply Current (DCLK=GCLK= 0Hz) OFF	I_{DD}(off)1	R_{EXT}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =OFF	-	3	5	mA
	I_{DD}(off)2	R_{EXT}=560Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =OFF	-	8	11	mA
	I_{DD}(off)3	R_{EXT}=310Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =OFF	-	9.1	13	mA
Supply Current (DCLK=GCLK= 0Hz) ON	I_{DD}(on)1	R_{EXT}=560Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	8	11	mA
	I_{DD}(on)2	R_{EXT}=310Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	9.1	13	mA
Supply Current (DCLK=GCLK= 30MHz, SDI=15MHz) ON	I_{DD}(on)1	R_{EXT}=560Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	24.5	-	mA
	I_{DD}(on)2	R_{EXT}=310Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	28.3	-	mA
Thermal Flag Temperature 1	T_{TF1}	Junction Temperature	-	140	-	℃
Thermal Flag Temperature 2	T_{TF2}	Junction Temperature	-	160	-	℃

***One channel on.**

Electrical Characteristics (V_{DD}=3.3V, Ta=25°C)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage Range	V_{DD}	-	3.0	3.3	3.6	V
Output Voltage	V_{OUT}	-	-	-	17	V
Output Current	I_{OUT}	DC Output Channel	3	-	45	mA
	I_{OH}	SDO	-	-	-1	
	I_{OL}	SDO	-	-	1	
Output Leakage Current	I_{OUT}	V_{OUT}=17.0V	-	-	0.5	μA
Current Skew(Channel)	dI_{OUT1}	I_{OUT}, R_{EXT}=560Ω	-	±1.5	±3	%
		I_{OUT}=45mA,V_{DS}=1V, R_{EXT}=310Ω	-	±1.5	±3	%
Current Skew(IC)	dI_{OUT2}	I_{OUT}, R_{EXT}=560Ω	-	±3	±6	%
		I_{OUT}=45mA,V_{DS}=1V, R_{EXT}=310Ω	-	±3	±6	%
Output Current vs. Output Voltage Regulation*	%/dV_{DS}	V_{DS} within 1.0V and 3.0V, R_{EXT}=560Ω@25.8mA	-	±0.1	-	%/V
Output Current vs. Supply Voltage Regulation*	%/dV_{DD}	V_{DD} within 3.0V and 3.6V	-	±1	-	%/V
Input Voltage	V_{iH}	T_a=-40°C ~85°C	0.7V_{DD}	-	V_{DD}	V
	V_{iL}	T_a=-40°C ~85°C	GND	-	0.3V_{DD}	
Output Voltage(SDO)	V_{OH}	I_{OH}=-1.0mA	2.9	-	-	V
	V_{OL}	I_{OL}=1.0mA	-	-	0.4	
LED Open Error Detection Threshold	$V_{DS,TH}$	-	-	0.3	0.35	V
Pull-down Resistor of LE	R_{IN}(down)	-	250	450	800	KΩ
Supply Current (DCLK=GCLK=0Hz) OFF	I_{DD}(off)1	R_{EXT}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =OFF	-	2.7	4.5	mA
	I_{DD}(off)2	R_{EXT}=560Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =OFF	-	7.4	10.2	
	I_{DD}(off)3	R_{EXT}=310Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =OFF	-	8.6	11.4	
Supply Current (DCLK=GCLK=0Hz) ON	I_{DD}(on)1	R_{EXT}=560Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	7.4	10.2	
	I_{DD}(on)2	R_{EXT}=310Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	8.6	11.4	
Supply Current (DCLK=GCLK=30MHz,SDI=15MHz) ON	I_{DD}(on)1	R_{EXT}=560Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	13.4	-	
	I_{DD}(on)2	R_{EXT}=310Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =ON	-	15.2	-	
Thermal Flag Temperature 1	T_{TF1}	Junction Temperature	-	140	-	℃
Thermal Flag Temperature 2	T_{TF2}	Junction Temperature	-	160	-	℃

Test Circuit for Electrical Characteristics



Switching Characteristics (V_{DD}=5.0V, Ta=25°C)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Setup Time	SDI-DCLK↑	t_{SU0}	V_{DD}=5.0V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=700Ω V_{DS}=1V R_L=150Ω C_L=10pF C_1=100nF C_2=10μF C_{SDO}=10pF V_{LED}=4.0V	1	-	-	ns
	LE↑-DCLK↑	t_{SU1}		1	-	-	ns
	LE↓-DCLK↑	t_{SU2}		5	-	-	ns
Hold Time	DCLK↑-SDI	t_{H0}		3	-	-	ns
	DCLK↑-LE↓	t_{H1}		7	-	-	ns
Propagation Delay Time	DCLK-SDO	t_{PD0}		-	29	33	ns
	GCLK- $\overline{OUT4n}$ *	t_{PD1}		-	35	-	ns ns
	LE-SDO**	t_{PD2}		-	30	40	ns
Stagger Delay Time	$\overline{OUT4n+1}$ *	t_{DL1}		-	5	-	ns ns
	$\overline{OUT4n+2}$ *	t_{DL2}		-	10	-	ns
	$\overline{OUT4n+3}$ *	t_{DL3}		-	15	-	ns
Pulse Width	LE	$t_{W(L)}$		5	-	-	ns
In-message Error Detection Duration (Count by GCLK)		t_{EDD}		25	-	-	GCLK
Compulsory Error Detection Duration Time***		t_{ERR-C}		700	-	-	ns
Data Clock Frequency		F_{DCLK}		-	-	30	MHz
Grey Scale Clock Frequency		F_{GCLK}		-	-	33	MHz
Output Rise Time of Output Ports		t_{OR}		-	18.4	-	ns
Output Fall Time of Output Ports		t_{OF}		-	30.4	-	ns

*There will be one GCLK latency at the first PWM output data. Refer to the Timing Waveform, where n=0,1,2,3.

**In timing of “Read Configuration” and “Read Error Status Code”, the next DCLK rising edge should be t_{PD2} after the falling edge of LE.

***Users have to leave more time than the maximum error detection time for the error detection.

**** With uniform output current.

Switching Characteristics (V_{DD}=3.3V, Ta=25°C)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Setup Time	SDI-DCLK↑	t_{SU0}	V_{DD}=3.3V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=700Ω V_{DS}=1V R_L=150Ω C_L=10pF C_1=100nF C_2=10μF C_{SDO}=10pF V_{LED}=4.0V	1	-	-	ns
	LE↑-DCLK↑	t_{SU1}		1	-	-	ns
	LE↓-DCLK↑	t_{SU2}		5	-	-	ns
Hold Time	DCLK↑-SDI	t_{H0}		3	-	-	ns
	DCLK↑-LE↓	t_{H1}		7	-	-	ns
Propagation Delay Time	DCLK-SDO	t_{PD0}		-	46	55	ns
	GCLK- $\overline{OUT4n}$ *	t_{PD1}		-	43	-	ns
	LE-SDO**	t_{PD2}		-	40	50	ns
Stagger Delay Time	$\overline{OUT4n+1}$ *	t_{DL1}		-	7	-	ns
	$\overline{OUT4n+2}$ *	t_{DL2}		-	14	-	ns
	$\overline{OUT4n+3}$ *	t_{DL3}		-	21	-	ns
Pulse Width	LE	$t_{W(L)}$		5	-	-	ns
In-message Error Detection Duration (Count by GCLK)		t_{EDD}		25	-	-	GCLK
Compulsory Error Detection Duration Time***		t_{ERR-C}		690	-	-	ns
Data Clock Frequency		F_{DCLK}		-	-	20	MHz
Grey Scale Clock Frequency****		F_{GCLK}		-	-	25	MHz
Output Rise Time of Output Ports		t_{OR}		-	24	-	ns
Output Fall Time of Output Ports		t_{OF}		-	31	-	ns

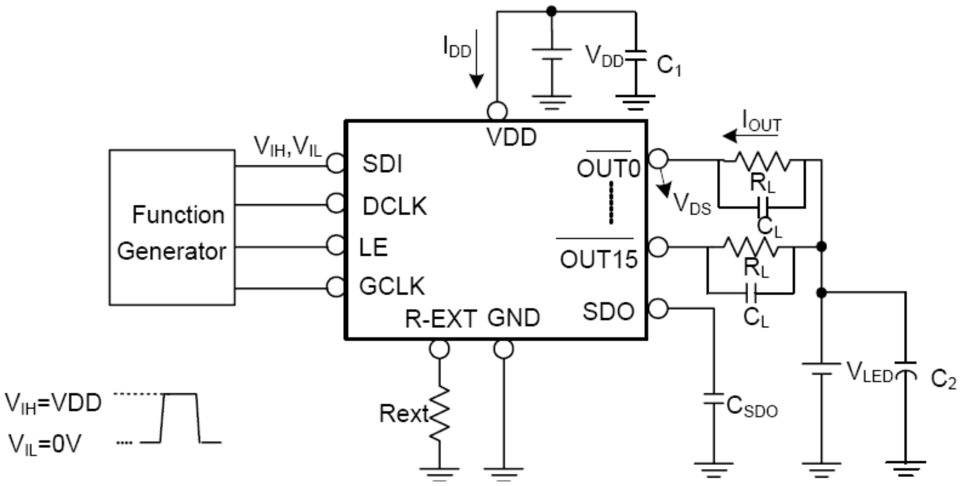
*There will be one GCLK latency at the first PWM output data. Please refer to the Timing Waveform, where n=0,1,2,3.

**In timing of “Read Configuration” and “Read Error Status Code”, the next DCLK rising edge should be t_{PD2} after the falling edge of LE.

***Users have to leave more time than the maximum error detection time for the error detection.

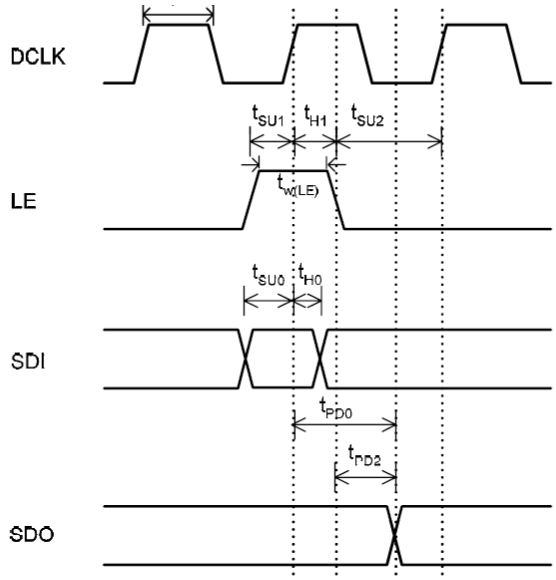
**** With uniform output current.

Test Circuit for Switching Characteristics

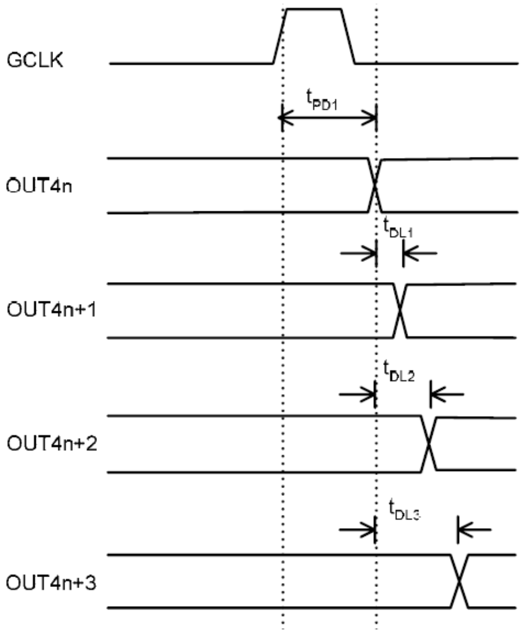


Timing Waveform

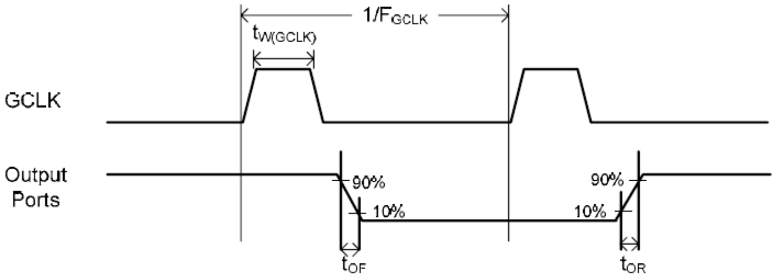
(1)



(2)



(3)



Principle of Operation

Users should set the operation modes in the configuration register through the "write configuration" command before sending grey scale data. The control command and configuration register are summarized in the following two tables.

Control Command

	Signals Combination		Description
Command Name	**LE**	**Number of DCLK Rising Edge when LE is asserted**	**The Action after a Falling Edge of LE**
Latch Data	High	0	Latch the serial data to the latch for gray scale or dot correction or configuration register or stop compulsory error detection
Dot correction	High	1	Enter the dot correction mode; the shift register is set to be 128 bits
Enable output	High	3	Enable output channels and activate the PWM counter
Compulsory error detection	High	4	Start compulsory error detection
Write Configuration	High	5	Write 16-bit configuration register
Read Configuration	High	6	Read the configuration register value
Disable output	High	7	Disable output channels and reset the PWM counter
12-bit grey scale	High	192(12x16)	Set the 12-bit grey scale mode
16-bit grey scale	High	256(16x16)	Set the 16-bit grey scale mode

Note: Please do not use the number of DCLK which are not specified in the table. Otherwise, it could cause malfunction on the LED drivers.

Definition of Configuration Register

MSB															LSB
F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0

e.g. Default Value

F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	1	00		0	1111111						

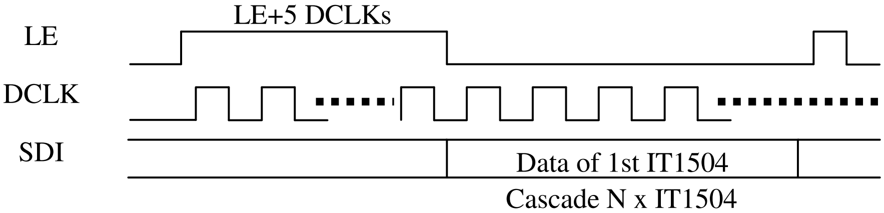
Bit	Attribute	Definition	Value	Function
F	Read/Write	PWM grey scale mode	0	12 bits
			1(Default)	16 bits
E	Read/Write	PWM algorithm	0	Conventional PWM
			1(Default)	Random PWM, divide the duty into 64 parts
D	Read/Write	PWM data synchronization	0	Manual synchronization
			1(Default)	Auto synchronization
C	Read/Write	PWM counting mode	0(Default)	Continuous counting mode
			1	One-shot counting mode
B	Read/Write	Thermal shutdown	0	Disable thermal shutdown
			1(Default)	Enable thermal shutdown
A	Read/Write	Error detection	0	Disable both in-message and compulsory error detections
			1(Default)	Enable both in-message and compulsory error detections
9~8	Read/Write	Threshold voltage of short-circuit detection	00(Default) 01 10 11	2'b00: Disable short-circuit detection 2'b01: $0.43xV_{DD}\pm0.1(V)$ 2'b10: $0.53xV_{DD}\pm0.1(V)$ 2'b11: $0.73xV_{DD}\pm0.1(V)$
7	Read/Write	Reserved	0(Default)	Reserved. The value must be "0".
6~0	Read/Write	Output current gain adjustment	1111111 (Default)	Output current; $I=I_O$xCurrent Gain[6:0]/127; $I_O=(V_{R-EXT}/R_{ext})x23$

Shift Register

The effective length of the shift register in IT1504 is auto-adjusted among 256/192/128/16 bits according to different modes of input data.

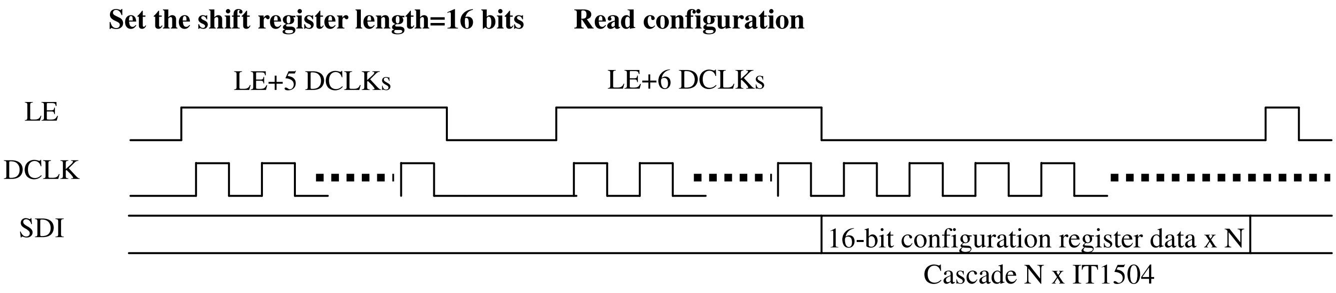
Write Configuration Register

IT1504 can write the configuration register when receiving one LE pulse containing 5 DCLKs, and then send 16-bit configuration setting to each LED driver. The following waveform shows the input signal waveform when cascading N pieces of IT1504:



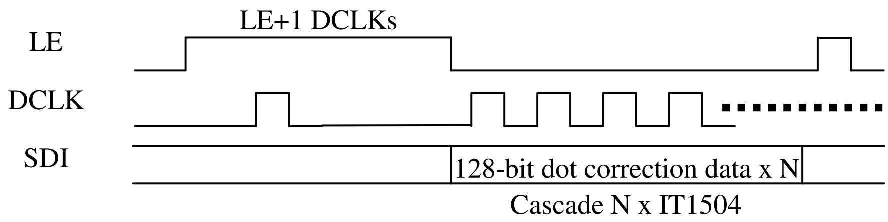
Read Configuration Register

IT1504 can read the configuration register when receiving one LE pulse containing 5 DCLKs in order to set the shift register length to 16 bits, and then send one LE pulse containing 6 DCLKs to read the configuration setting. After the command, 16-bit configuration of each IT1504 will be shifted out sequentially from the Nth IT1504 to the 1st IT1504. The following waveform shows the output signal waveform when cascading N pieces of IT1504:



Input the Dot Correction Data

IT1504 can input the dot correction data when receiving one LE pulse containing one DCLK, and then send 128-bit dot correction data to each LED driver. The following waveform shows the input signal waveform when cascading N pieces of IT1504:



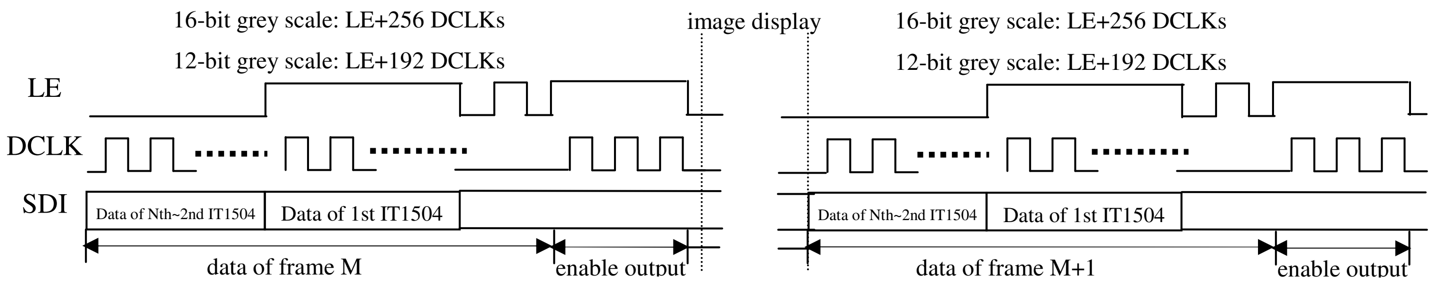
Enable and Disable Output

IT1504 can disable output channels when receiving one LE pulse containing 7 DCLKs. The output channels will be enabled again when receiving one LE pulse containing 3 DCLKs. This "enable" command can also reactivate the IC from thermal shutdown when the junction temperature decreases.

Set the PWM Grey Scale Mode

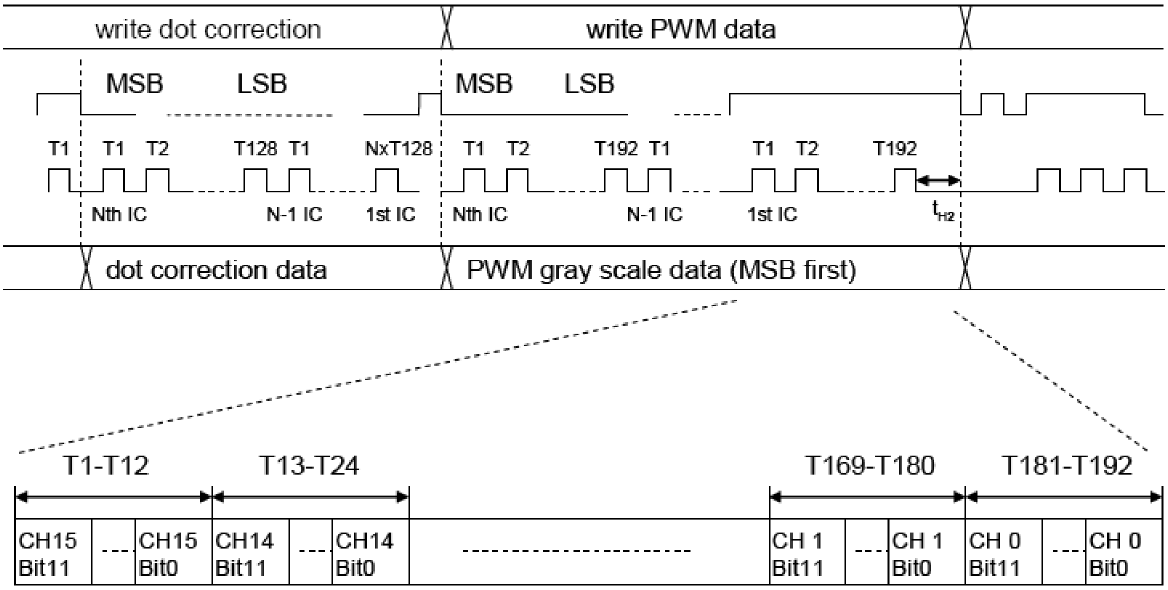
IT1504 provides a selectable 16-bit or 12-bit grey scale mode by setting bit "F" of the configuration register. For 16-bit grey scale mode, the bit "F" is set to "1" (default), and for 12-bit grey scale mode, the bit "F" is set to "0".

Users need to set the grey scale mode before sending the data, and then send the data from Nth IT1504 to the 1st IT1504. IT1504 will enter 16-bit grey scale mode when receiving one LE containing 256 DCLKs or 192 DCLKs respectively. To latch the data, the command of one LE pulse containing 0 DCLK should be sent after the grey scale mode. Then IT1504 will enable the output when receiving one LE pulse containing 3 DCLKs. The following waveform shows the input signal waveform when cascading N pieces of IT1504:



Grey Scale Data Format

The data input sequence of both 16-bit and 12-bit grey scale data are the same, and the following waveform illustrates the sequence:



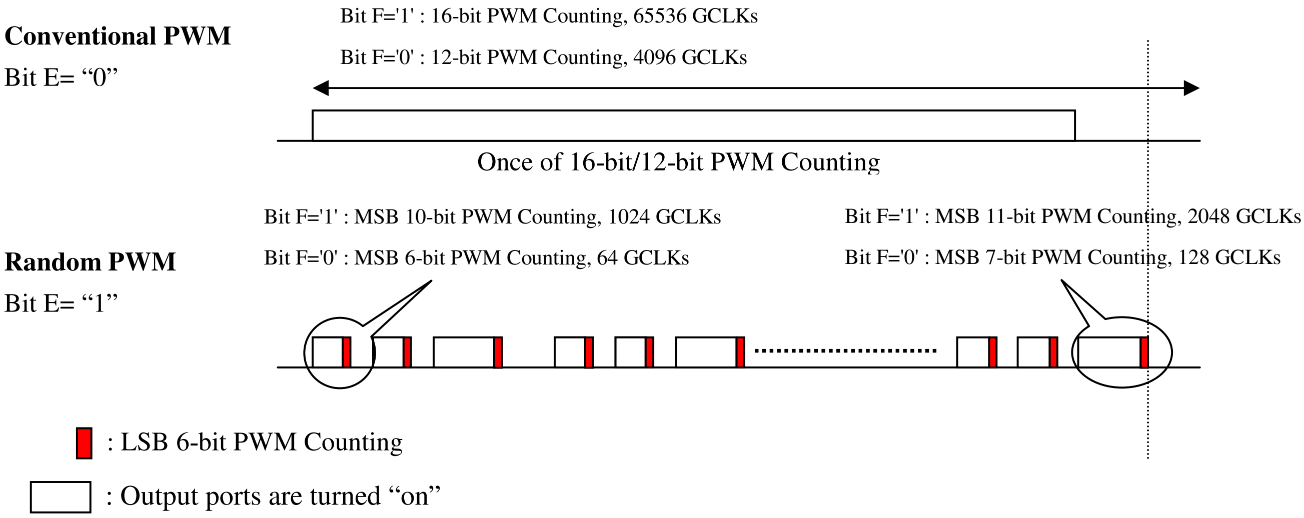
t_{H2}: At the end of grey scale mode, DCLK↓–LE↓ should be no less than 10ns.

Set the PWM Counting Mode

PWM Algorithm

IT1504 defines the different counting algorithms that support random PWM technology. With random PWM, the total PWM cycles can be broken down into MSB (Most Significant Bits) and LSB (Least Significant Bits) of grey scale cycles, and the MSB information can be dithered across different period of refresh cycles.

IT1504 is flexible for either the conventional PWM algorithm or random PWM algorithm by setting bit "E" of the configuration register. For random PWM algorithm, the bit "E" is set to "1" (default), and for conventional PWM algorithm, the bit "E" is set to "0":



Synchronization of PWM Cycle

IT1504 is also flexible for either manual synchronization or auto synchronization by setting bit “D” of the configuration register.

For auto synchronization, the bit “D” is set to “1” (default). IT1504 will automatically process the synchronization of previous data and next data for PWM counting. The next image data will be updated to output buffers and start PWM counting when the previous data finishes one internal PWM cycle. This prevents the lost count of image data resolution and guarantees the data accuracy.

For manual synchronization, the bit “D” is set to “0”. Once the next input data is correctly recognized, IT1504 will stop the present PWM cycle and restart a new PWM cycle to show the new data immediately.

PWM Counting Mode

Users can set either continuous counting mode or one-shot counting mode by setting bit “C” of the configuration register.

For the continuous counting mode, the bit “C” is set to “0” (default). In the continuous counting mode, IT1504 will continuously repeat the PWM cycles and turn on the output channels according to the image data until the next image data is correctly recognized.

For the one-shot counting mode, the bit “C” is set to “1”. In the one-shot counting mode, IT1504 will run the PWM cycle for each image data one time, and then stop the output channels until the next image data is correctly recognized.

Error Detection Principle

IT1504 provides two error detection functions: in-message error detection and compulsory error detection. Users can read the open-/short-circuit error reports, thermal flag, and R_{EXT} open flag from SDO. For all the detection functions, “0” indicates abnormal state and “1” indicates normal state.

In-message Error Detection

Users can set the in-message error detection by bit “A” of configuration register. To enable the in-message error detection, the bit “A” is set to “1” (default). To disable the in-message error detection, the bit “A” is set to “0”.

The open-/short-circuit error will be reported only when output channels are turned on in 10 GCLKs, and the error reports will be put into the shift register after the grey scale data is latched.

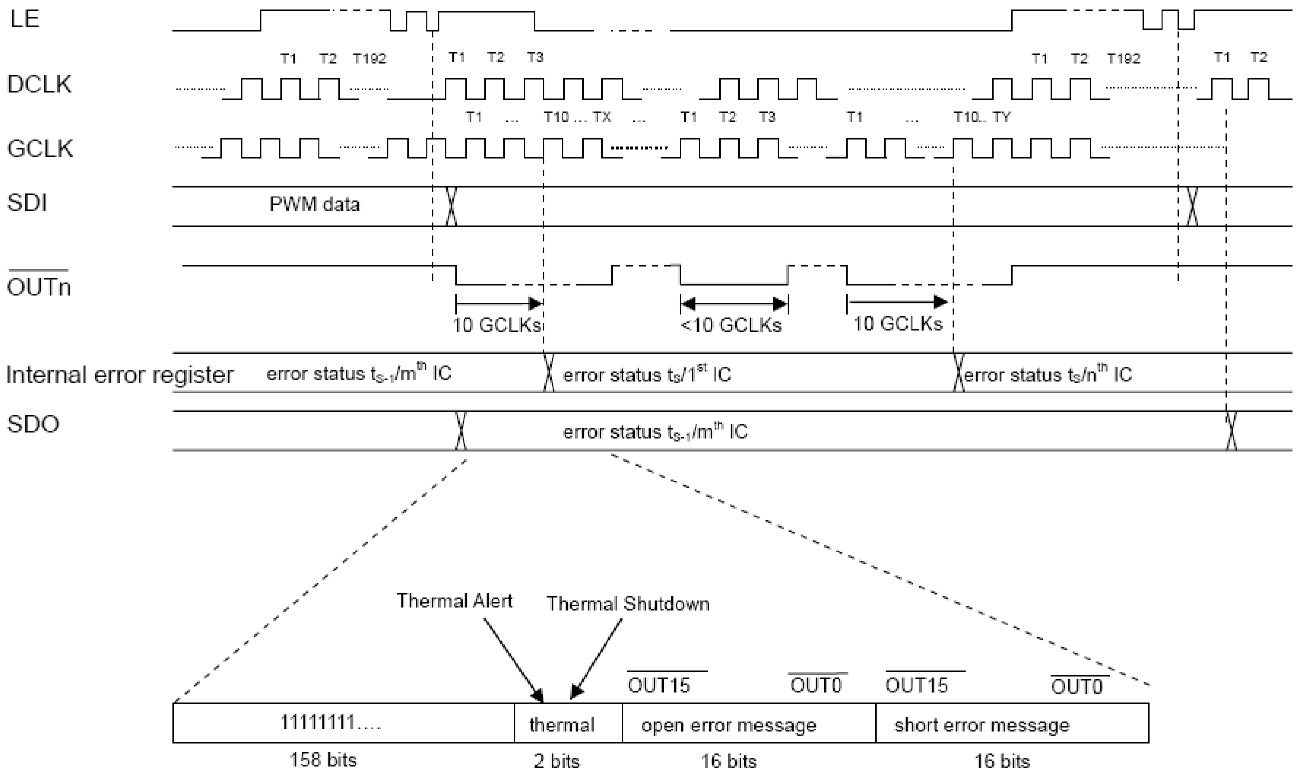
Since the PWM output duty cycle of IT1504 is the product of grey scale data and dot correction data. If the random PWM algorithm is selected, the open/short circuit in-message error detection will be performed while the product of grey scale data and dot correction data is from 640 to 65,535 in the 16-bit grey scale mode or from 640 to 4,095 in the 12-bit grey scale mode. If the normal PWM algorithm is selected, the open/short circuit error will be reported when the product of grey scale data and dot correction data is larger than 10.

IT1504 will judge if the turn-on time is enough or not to deliver the error report. If the turned-on time is too short, IT1504 will report normal state coded as “1”.

Error data (N)=error data(N-1) presents detection result.

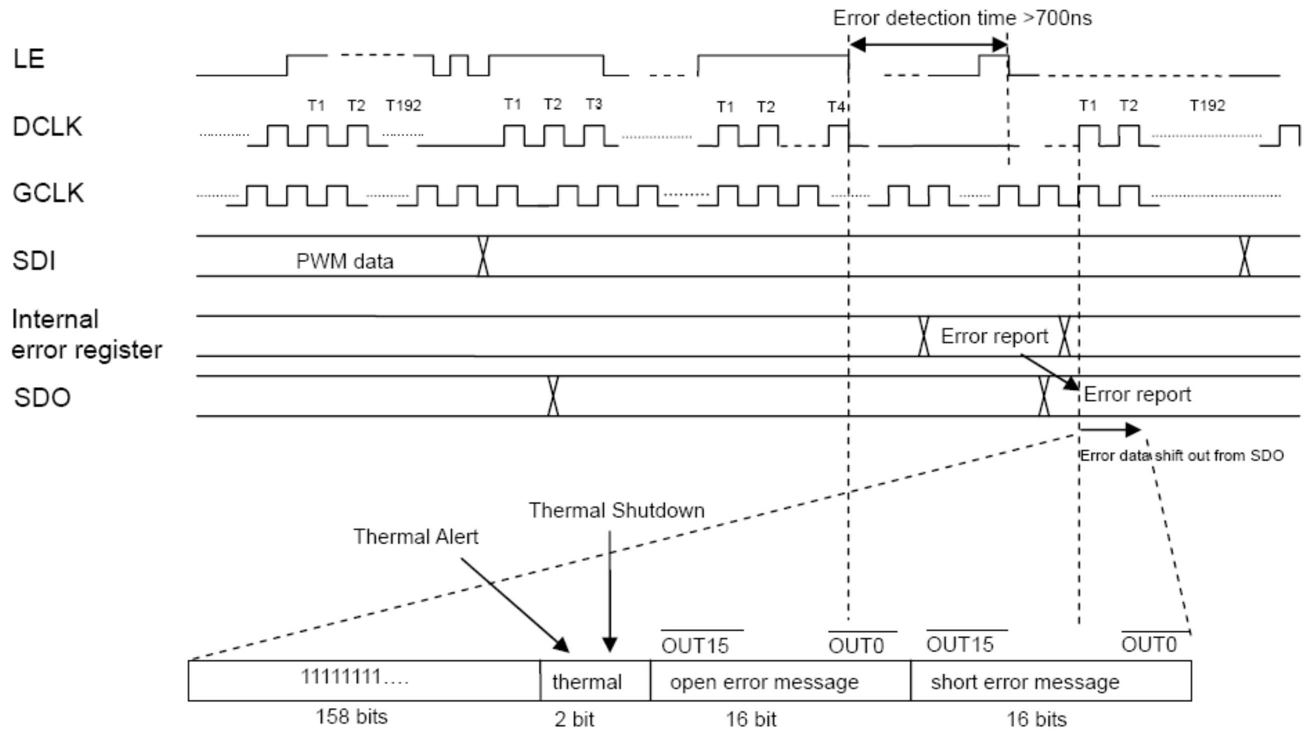
It will be reset to 1 until the error data is read out.

Please see the example of the following diagram of 12-bit grey scale mode for the control sequence and data output format of all error reports.



Compulsory Error Detection

IT1504 can also perform the compulsory error detection when receiving one LE pulse containing 4 DCLKs and stop the compulsory error detection when receiving one LE pulse containing 0 DCLK. The output channels will be forced to turned on within 690ns (between the LE falling edges) to perform the compulsory error detection. The error report will be pushed out after compulsory error detection operation time (690ns). IT1504 will shift out both open and short error reports from SDO simultaneously. The following is an illustration of the timing sequence of compulsory error detection of 12-bit grey scale mode.

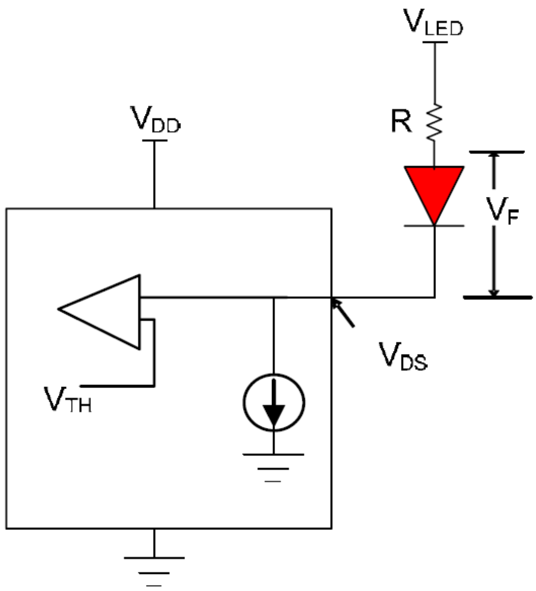


Setting the Threshold Voltage for Compulsory Short-Circuit Detection

Users can set the threshold voltage (V_{TH}) for compulsory short-circuit detection by bit [9:8] of configuration register as summarized below:

2'b00: Disable the short-circuit detection (default)
2'b01: 0.43xVDD± 0.1(V)
2'b10: 0.53xVDD± 0.1(V)
2'b11: 0.73xVDD± 0.1(V)

IT1504 provides settable V_{TH} for different LED configuration. If the detected voltage is larger than V_{TH}, the IT1504 identifies the LED as short-circuit. For example, if each output channel of IT1504 drives one red LED, the V_{TH} should be set larger. If each output channel of IT1504 drives several white LEDs, the V_{TH} should be set smaller. The system should consider the accumulated V_F of the LEDs to set a suitable V_{TH}.



Thermal Protection

Users can set the thermal protection by bit "B" of configuration register. To enable the thermal shutdown function, the bit "B" is set to "1" (default). To disable the thermal shutdown function, the bit "B" is set to "0".

IT1504 provides two thermal flags:

Thermal flag 1 is over-temperature alarm, and thermal flag 2 is thermal shutdown. When the IC junction temperature is over 140℃, thermal flag 1 will report "0". When the IC junction temperature is under 120℃, thermal flag 1 will recover to "1".

When the IC junction temperature is over 160℃, the thermal flag 2 will become "0" and IT1504 will turn off the output current of all channels automatically. IT1504 will turn on the output channels when receiving one LE pulse containing 3 DCLKs.

Adjust the Output Current Gain

Users can adjust output current gain by bit [6:0] of configuration register. The default current gain value is 7b'1111111.

The output current; $I=I_0$ x Current Gain [6:0]/127, where I_0=(VR-EXT/Rext)x23

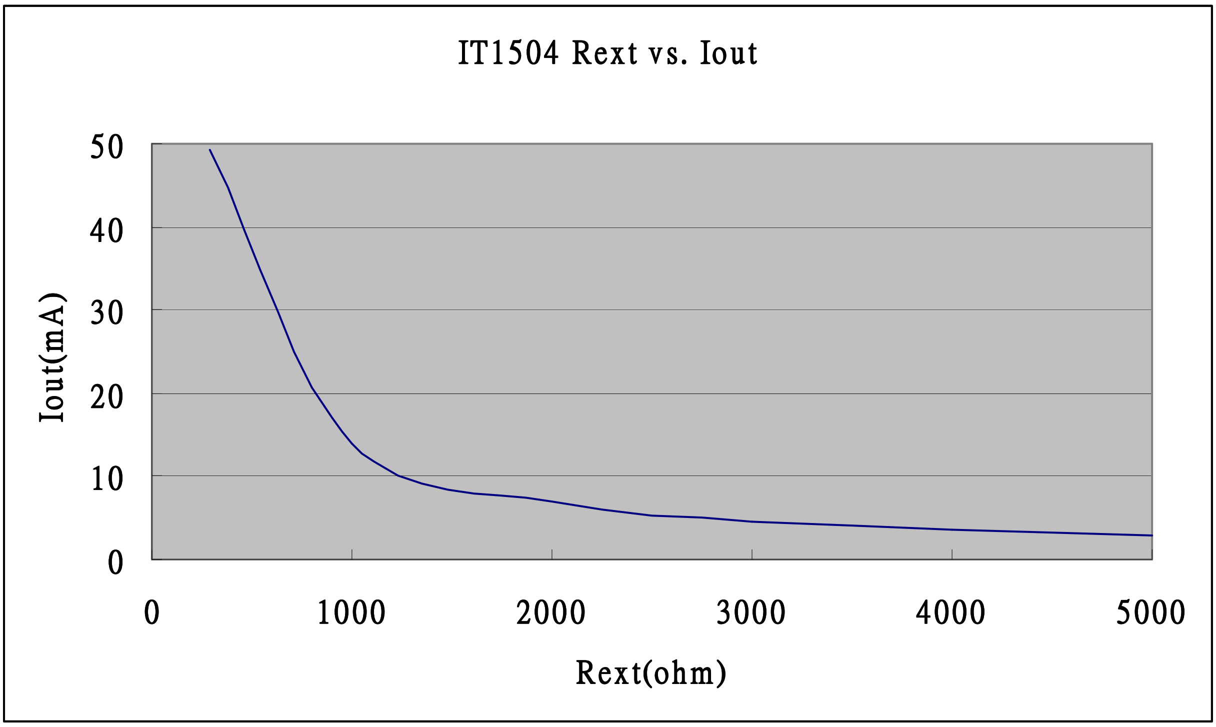
The current gain value is proportional to the output current. In other words, current gain value versus output current is linear. This function helps users to tune the output current by software in stead of by hardware for daily operation.

Setting Output Current

The output current (I_{OUT}) is set by an external resistor, Rext. The default relationship between I_{OUT} and Rext is shown in the following figure.

Also, the output current can be calculated from the equation:
$V_{R-EXT}=0.61$; $I_{OUT}=(V_{R-EXT}/Rext)x23xG/127$

Where Rext is the resistance of the external resistor connected to R-EXT terminal and V_{R-EXT} is its voltage. G is the digital current gain, which is set by the bit[6:0] of the configuration register. The default value of G is 127. For your information, the output current is about 25mA when Rext=560Ω and 45mA when Rext =310Ω if G is set to default value 127. The formula and setting for G are described in further section.

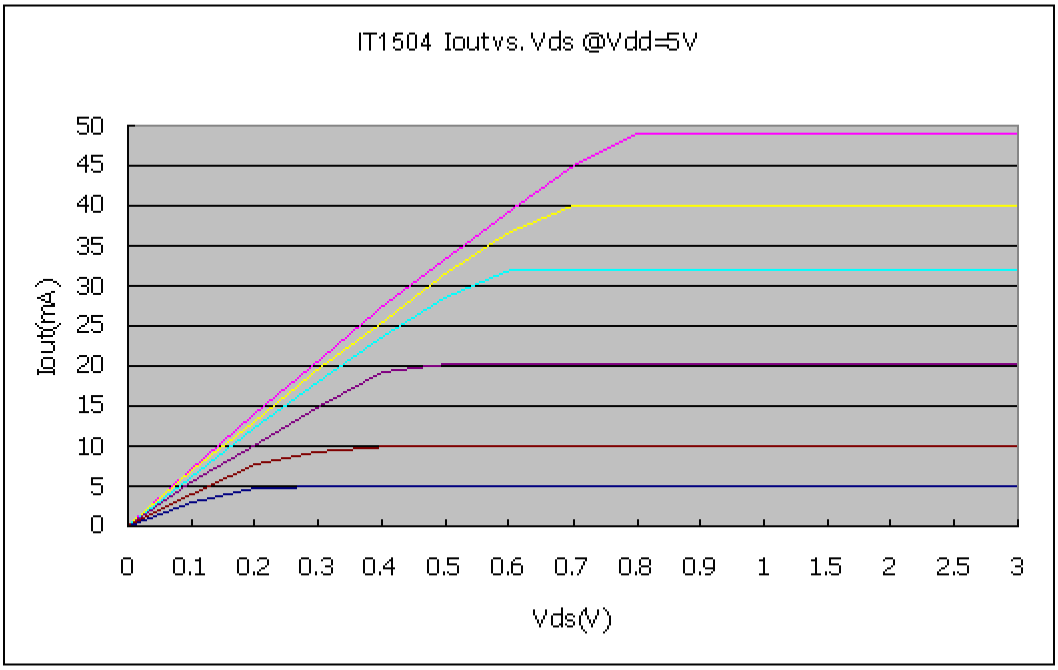


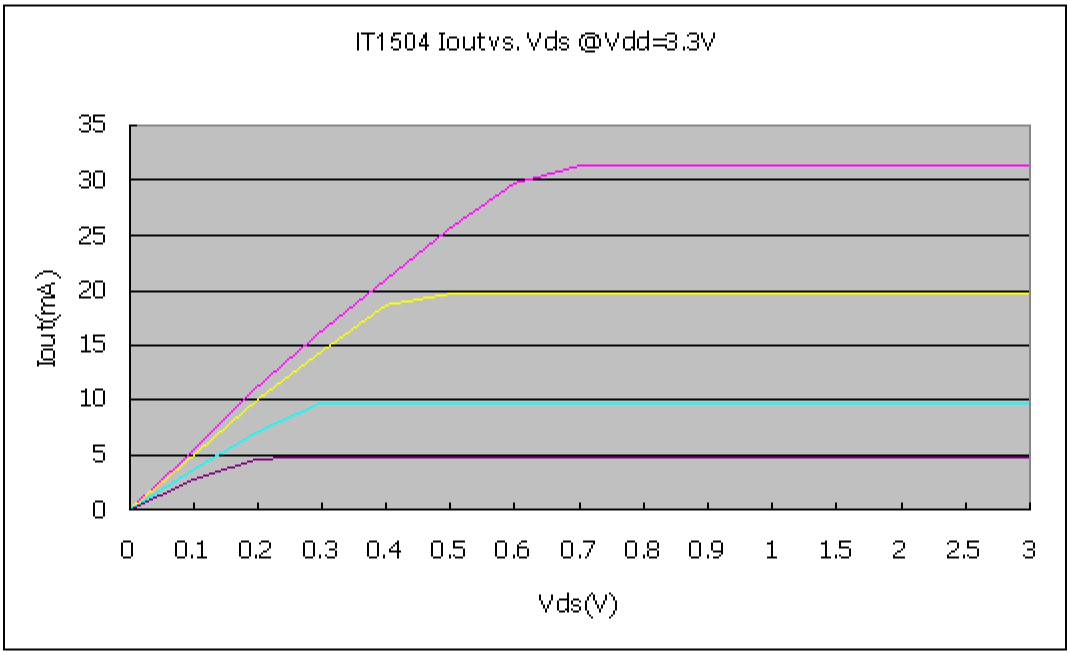
Constant Current

In LED display application, IT1504 provides nearly no variation in current from channel to channel and from IC to IC. This can be achieved by:

1) The typical current variation between channels is less than ±1.5%, and that between ICs is less than ±3%.

2) In addition, the current characteristic of output stage is flat and users can refer to the figure as shown below. The output current is kept constant regardless of the variations of LED forward voltages (VF). This guarantees LED to to be performed on the same brightness as user's specification.





Staggered Delay of Output

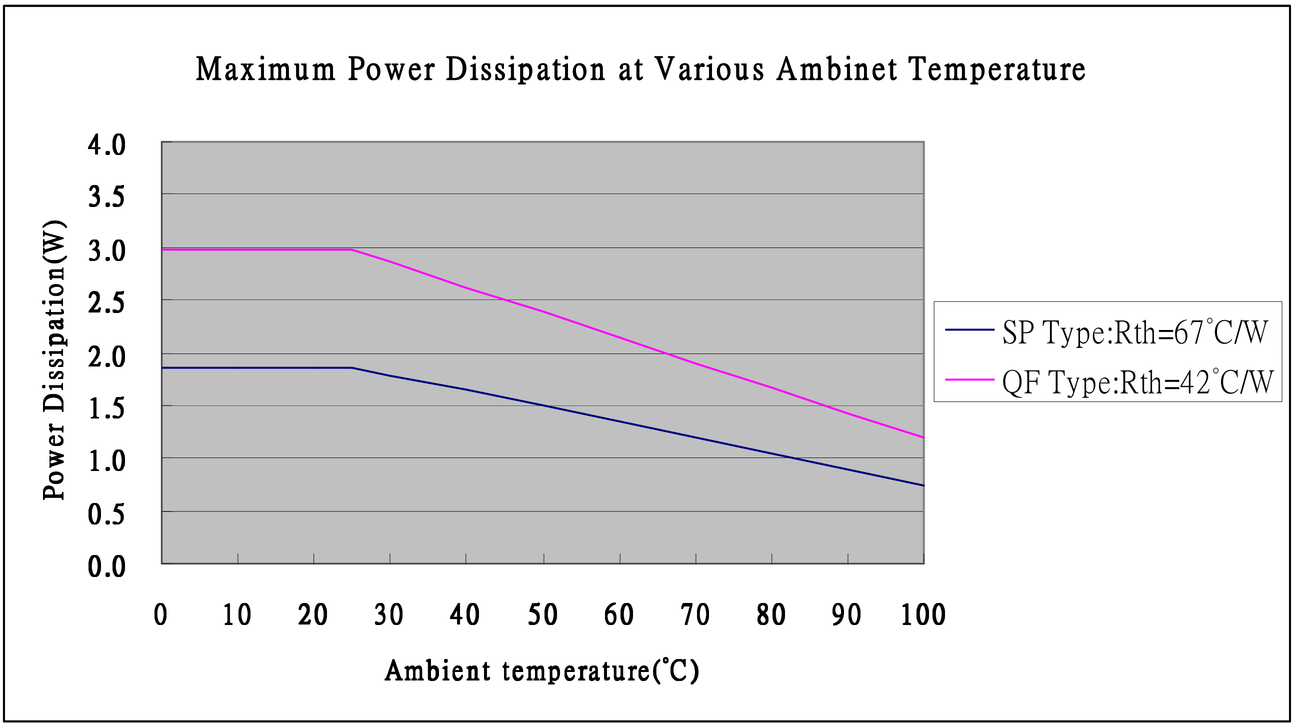
IT1504 has a built-in staggered circuit to perform delay mechanism. Among output ports exist a graduated 5ns delay time among $\overline{OUT4n}$, $\overline{OUT4n+1}$, $\overline{OUT4n+2}$ and $\overline{OUT4n+3}$, by which the output ports will be divided to four groups at a different time so that the instant current from the power line will be lowered.

Package Power Dissipation(P_D)

This maximum allowable package power dissipation is determined as $P_D(max)=(T_j-T_a)/R_{th(j-a)}$. When 16 output channels are turned on simultaneously, the actual package power dissipation is
$P_D(act)=(I_{DD}\times V_{DD})+(I_{OUT}\times Duty\times V_{Ds}\times 16)$. Therefore, to keep $P_D(act) \leq P_D(max)$, the allowable maximum output current as a function of duty cycle is:
$I_{OUT}=\{[(T_j-T_a)/R_{th(j-a)}]-(I_{DD}\times V_{DD})\}/V_{Ds}/Duty/16$, where $T_j=150$℃.

Condition: Iout=50mA, V_{DS}=1V, 16 output channels	
Device Type	$R_{th(j-a)}$(℃/W)
SP(SOP-24)	67
QF(QFN-24)	42

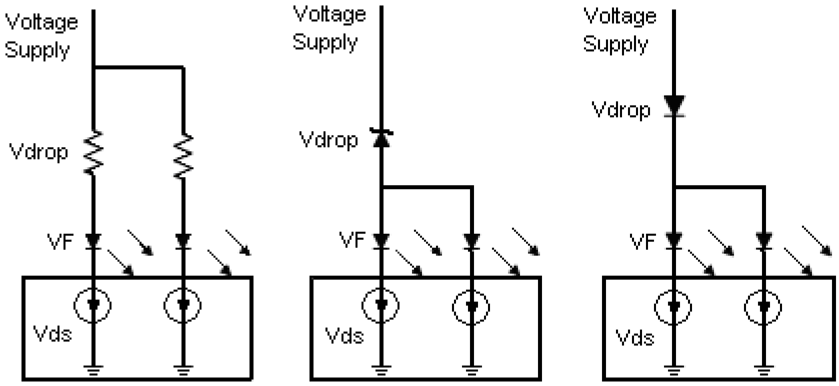
The maximum power dissipation, $P_D(max)=(Tj-Ta)/R_{th(j-a)}$, decreases as the ambient temperature increases.



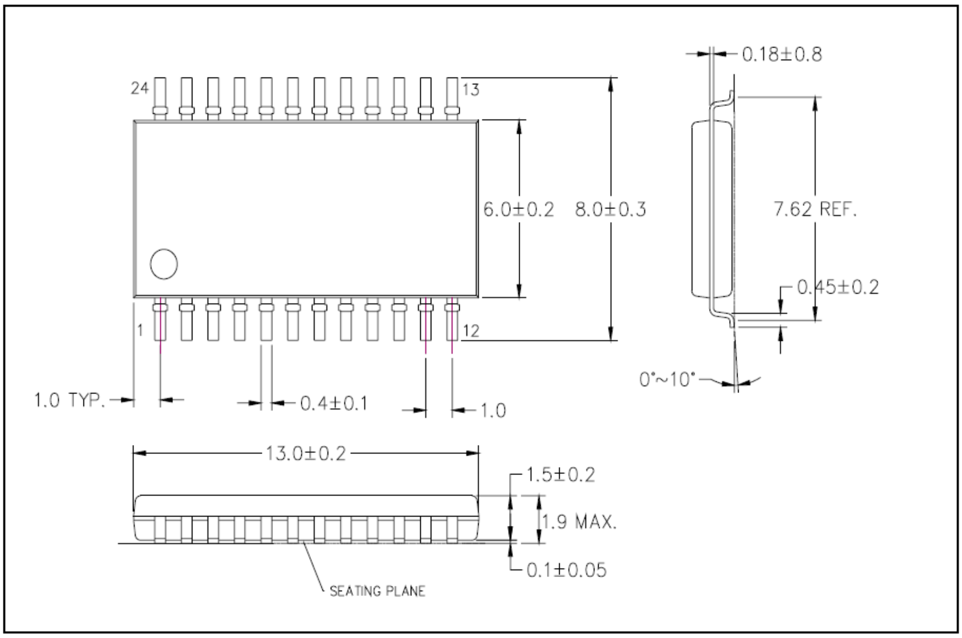
Load Supply Voltage(V_{LED})

This device is operating with the VDS of 1.0V to 1.2V with LED forward voltage(VF) of 1.2V to 4.0V. If V_{DS} be higher enough to make package power dissipation increased. It is recommended to use lowest load supply voltage or to set any serials dropping voltage as following figures.

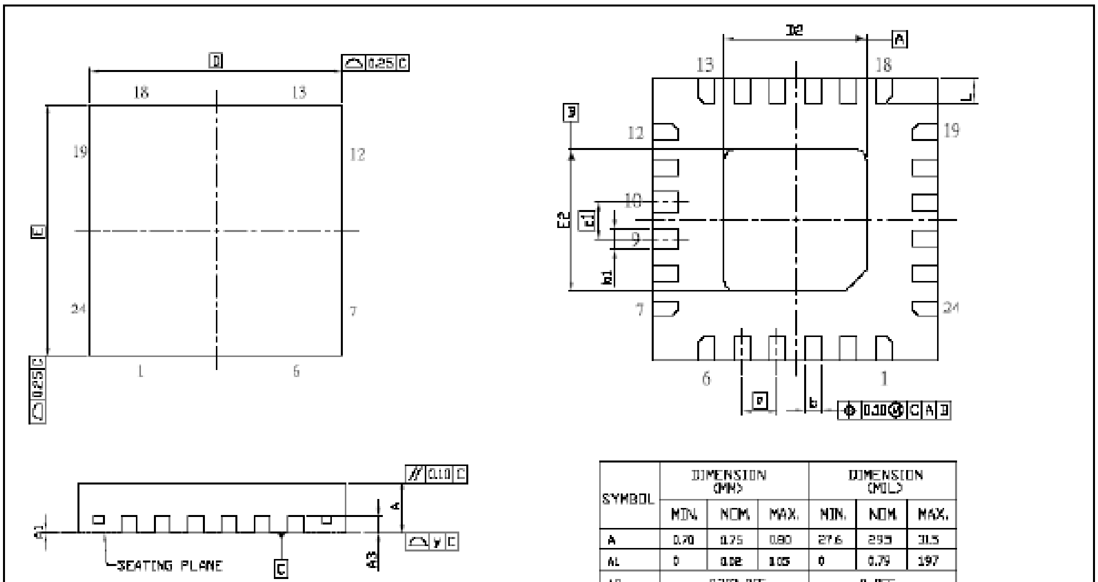
$V_{DS}=V_{LED}-V_F-V_{DROP}$



IT1504SP(SOP24-236mil) Outline Drawing



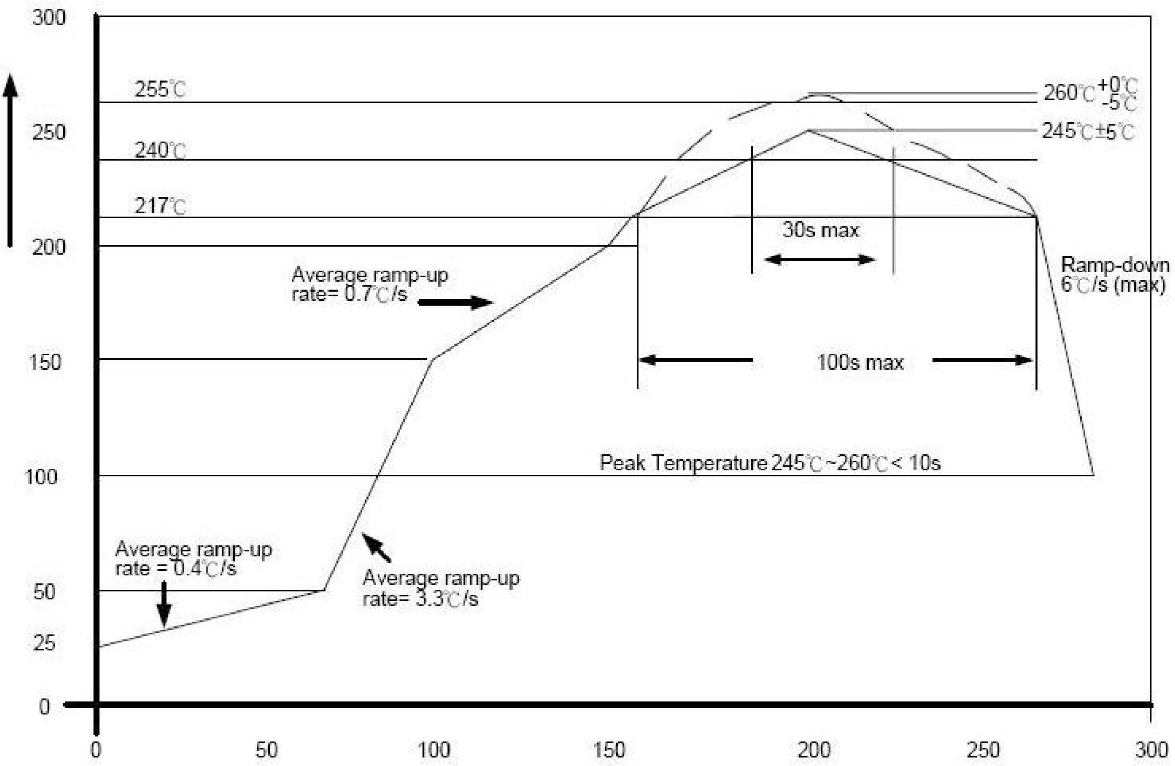
IT1504QF Outline Drawing



SYMBOL	DIMENSION (MM)			DIMENSION (MIL)		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	27.6	29.5	31.5
A1	0	0.02	0.05	0	0.79	1.97
A3	0.203 REF			8 REF		
b	0.18	0.23	0.28	7.1	9.0	11.0
D	3.90	4.00	4.10	153.5	157.5	161.4
D2	1.90	2.00	2.10	74.8	78.7	82.7
E	3.90	4.00	4.10	153.5	157.5	161.4
E2	1.90	2.00	2.10	74.8	78.7	82.7
e	0.50 BSC			19.69 BSC		
L	0.25	0.35	0.45	9.8	13.7	17.7
y	0.08			3.15		
b1	0.25	0.30	0.35	9.8	11.8	13.7
e1	0.52 REF.			20.5 REF.		

Soldering Temperature Suggestion for RoHS materials(JEDEC J-STD-020C)

Temperature(°C)



Time(sec)

——: Recommended Reflow Profile

------: Maximum Peak Temperature