APPLICATION MANUAL

2 Channel Step-up DC-DC Converter IC for White LED Driver
TK61220AQ4

CONTENTS

2 Channel Step-up DC-DC Converter IC for White LED Driver
TK61220AQ4

1. DESCRIPTION

The TK61220AQ4 is a 2ch step-up DC-DC converter White LED driver IC. The IC has 2 independent step-up circuits that drive 2 external MOSFETs allowing many LEDs per channel.
If ch1 stops operating due to an open in the ch1 LED string, ch2 will continue to operate and vise versa. Each channel is independently driven with the appropriate voltage increasing efficiency and reducing overall heat generation.
LED brightness control is available using PWM dimming or bias current dimming. UVLO, over-voltage protection circuit, FET over-current protection circuit and LED over-current protection circuit are built in. An external resistor and capacitor can set oscillator frequency.

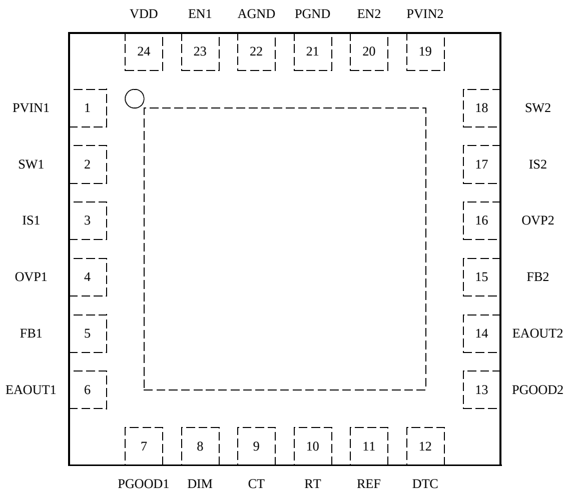
2. FEATURES

- ■ Each channel can be operated independently
- ■ External n-channel power MOSFET
- ■ Bias current dimming, PWM dimming
- ■ Oscillator frequency, Max 2.2MHz
- ■ Maximum duty cycle can be set
- ■ Synchronize parallel operation between two or more ICs
- ■ UVLO, over-voltage, FET over-current, LED over-current protection
- ■ Non-lead small package less than 1.0mm

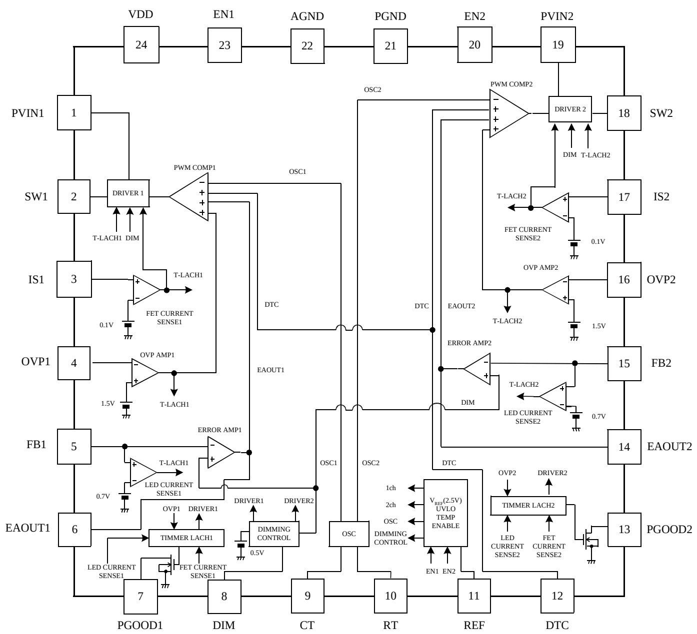
3. APPLICATIONS

- ■ LED backlight for displays
- ■ General Illumination, White LED driver
- ■ Step up DC-DC converter

4. PIN CONFIGURATION



5. BLOCK DIAGRAM



6. ABSOLUTE MAXIMUM RATINGS

T_a=25°C

Parameter	Symbol	Rating	Units	Conditions
Absolute Maximum Ratings				
VDD Pin Voltage	$V_{DD,MAX}$	-0.3 ~ 16.0	V	
PVIN1 Pin Voltage	$V_{PVIN1,MAX}$	-0.3 ~ 16.0	V	
PVIN2 Pin Voltage	$V_{PVIN2,MAX}$	-0.3 ~ 16.0	V	
SW1 Pin Voltage	$V_{SW1,MAX}$	-0.3 ~ V_{DD}+0.3	V	
SW2 Pin Voltage	$V_{SW2,MAX}$	-0.3 ~ V_{DD}+0.3	V	
EN1 Pin Voltage	$V_{EN1,MAX}$	-0.3 ~ 16.0	V	
EN2 Pin Voltage	$V_{EN2,MAX}$	-0.3 ~ 16.0	V	
PGOOD1 Pin Voltage	$V_{PGOOD1,MAX}$	-0.3 ~ 16.0	V	
PGOOD2 Pin Voltage	$V_{PGOOD2,MAX}$	-0.3 ~ 16.0	V	
IS1 Pin Voltage	$V_{IS1,MAX}$	-0.3 ~ 16.0	V	
IS2 Pin Voltage	$V_{IS2,MAX}$	-0.3 ~ 16.0	V	
OVP1 Pin Voltage	$V_{OVP1,MAX}$	-0.3 ~ 16.0	V	
OVP2 Pin Voltage	$V_{OVP2,MAX}$	-0.3 ~ 16.0	V	
DIM Pin Voltage	$V_{DIM,MAX}$	-0.3 ~ 16.0	V	
FB1 Pin Voltage	$V_{FB1,MAX}$	-0.3 ~ 6.0	V	*2
FB2 Pin Voltage	$V_{FB2,MAX}$	-0.3 ~ 6.0	V	*2
EAOUT1 Pin Voltage	$V_{EAOUT1,MAX}$	-0.3 ~ 6.0	V	*2
EAOUT2 Pin Voltage	$V_{EAOUT2,MAX}$	-0.3 ~ 6.0	V	*2
REF Pin Voltage	$V_{REF,MAX}$	-0.3 ~ 6.0	V	*2
DTC Pin Voltage	$V_{DTC,MAX}$	-0.3 ~ 6.0	V	*2
RT Pin Voltage	$V_{RT,MAX}$	-0.3 ~ 6.0	V	*2
CT Pin Voltage	$V_{CT,MAX}$	-0.3 ~ 6.0	V	*2
Storage Temperature Range	T_{stg}	-40 ~ +125	°C	
Power Dissipation	P_D	2500	mW	*1
Operating Condition				
Operating Temperature Range	T_{OP}	-40 ~ +105	°C	
Operating Voltage Range	V_{OP}	3.0 ~ 14.5	V	VDD Pin, PVIN1 Pin, PVIN2 Pin
Maximum Operating Frequency	f_{MAX}	2.2	MHz	

*1 P_D must be decreased at the rate of 25.0mW/°C for operation above 25°C on TK61220AQ4's evaluation board.
*2 Please does not apply a voltage greater than V_{REF} during IC operation.
The maximum ratings are the absolute limitation values with the possibility of the IC breakage.
When the operation exceeds this standard quality can not be guaranteed.

7. ELECTRICAL CHARACTERISTICS

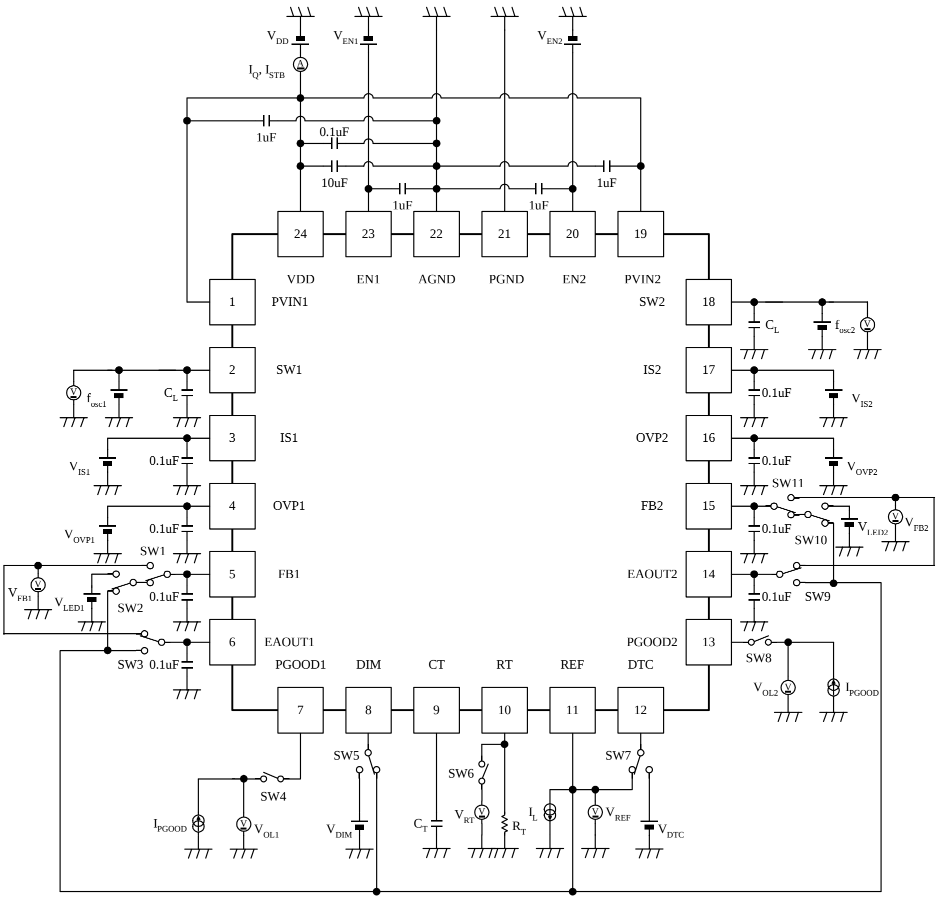
V_{DD}=5V, T_a=25°C, R_T=16kΩ, C_T=22pF, C_L=1000pF

Parameter	Symbol	Value			Units	Conditions
		MIN	TYP	MAX		
Quiescent Supply Current	I_Q	-	1.0	1.5	mA	*4
Standby Supply Current	I_{STB}	-	0.01	1.0	μA	$V_{EN\ 1}$=$V_{EN\ 2}$=0.3V
REF Voltage	V_{REF}	2.45	2.50	2.55	V	I_L=0mA
V_{REF} Load Regulation	LoaReg	-	10	30	mV	I_L=0~1mA
EN Voltage High Voltage	V_{EN_H}	1.2	-	14.5	V	
EN Voltage Low Voltage	V_{EN_L}	0	-	0.3	V	
Undervoltage Lockout Section						
Threshold Voltage	V_{UVLO}	2.6	2.7	2.8	V	V_{DD} falling
Hysteresis	V_{UVLO_HYS}	-	0.18	-	V	
Oscillator Section						
Oscillator Frequency	f_{OSC}	0.91	1.0	1.09	MHz	V_{DTC}=1V
RT Voltage	V_{RT}	0.45	0.5	0.55	V	
Over Voltage Protection Section						
Threshold Voltage	V_{OVP}	1.35	1.5	1.65	V	V_{OVP} rising
LED Over Current Protection Section						
Threshold Voltage	V_{LED}	0.63	0.7	0.77	V	V_{LED} rising, *5
FET Over Current Protection Section						
Threshold Voltage	V_{IS}	0.08	0.1	0.12	V	V_{IS} rising
PGOOD Section						
Output Low Voltage	V_{OL}	-	0.2	0.4	V	I_{PGOOD}=1mA, V_{LED}=0.77V *1, *5
Error Amplifier Section						
Feedback Voltage	$V_{FB\ 1}$	0.481	0.5	0.519	V	V_{DIM}=2.0V, *2
	$V_{FB\ 2}$	0.481	0.5	0.519	V	V_{DIM}=14.5V, *2
	$V_{FB\ 3}$	-	0.01	0.1	V	V_{DIM}=0.2V, *2
	$V_{FB\ 4}$	0.481	0.5	0.519	V	*2, *3
Voltage Gain	A_V	-	60	-	dB	
Band Width	BW	-	1.5	-	MHz	A_V=0dB
EAOUT Output Voltage High Level	$V_{EAOUT\ H}$	2.35	2.49	-	V	V_{FB}=0V, *3
EAOUT Output Voltage Low Level	$V_{EAOUT\ L}$	-	0.01	0.1	V	*3, *4
Driver Section						
Driver Rise Time	t_r	-	40	-	nS	
Driver Fall Time	t_f	-	25	-	nS	
Pull Down Resistance	R_{Out}	-	20	-	kΩ	

*1 Timer latch turns on, and measures.
*2 FB pin connects to EAOUT pin, and measures.
*3 DIM pin connects to REF pin, and measures.
*4 FB pin connects to REF pin, and measures.
*5 EAOUT pin connects to REF pin, and measures.

8. TEST CIRCUIT

■ Test Circuit



R_T=16kΩ, C_T=22pF, C_L=1000pF

■ Measurement Conditions

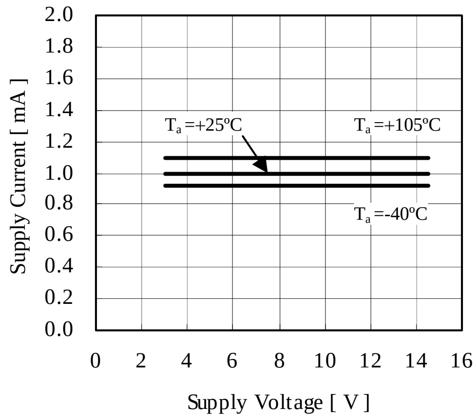
Parameter	0V Setting	Connects to REF Pin	Measurement Pin	Conditions
Quiescent Supply Current	V_{IS}, V_{OVP}	FB, DTC		
Standby Supply Current	V_{IS}, V_{OVP}	FB, DTC		V_{EN1}=V_{EN2}=0.3V
Overvoltage Protection Threshold Voltage	V_{IS}, V_{FB}	DTC	SW	V_{OVP} input
LED Overcurrent Protection Threshold Voltage	V_{IS}, V_{OVP}	DTC, EAOUT	SW	V_{FB} input
FET Overcurrent Protection Threshold Voltage	V_{OVP}, V_{FB}	DTC	SW	V_{IS} input
PGOOD Output Low Voltage *1	V_{IS}, V_{OVP}	DTC, EAOUT	PGOOD	I_{PGOOD}=1mA

*1 After the LED overcurrent protection turns on, it inputs 1mA into the PGOOD pin and measures the PGOOD pin voltage.

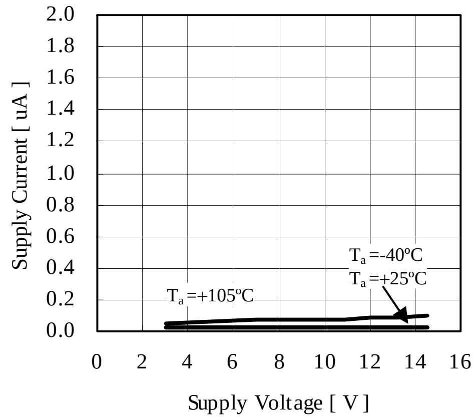
9. TYPICAL CHARACTERISTICS

V_{DD}=5V, T_a=25°C, R_T=16kΩ, C_T=22pF, C_L=1000pF

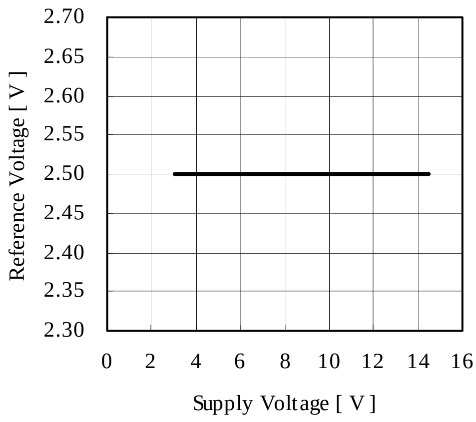
■ Quiescent Supply Current vs. Supply Voltage



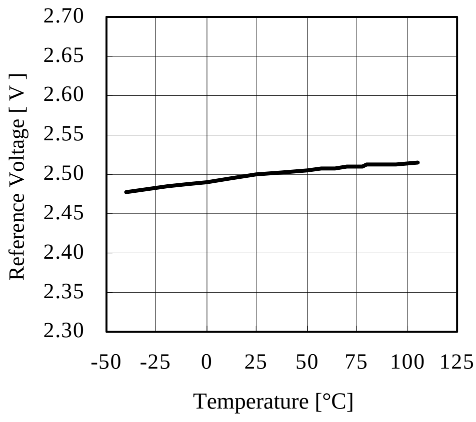
■ Shutdown Supply Current vs. Supply Voltage



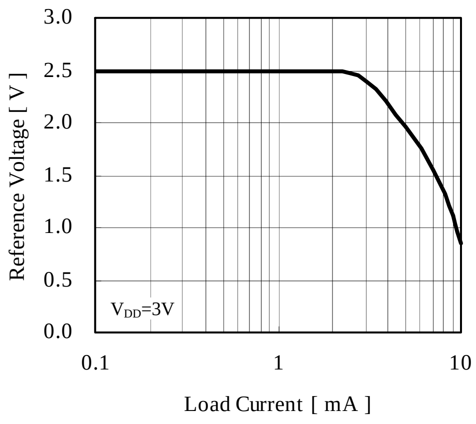
■ Reference Voltage vs. Supply Voltage



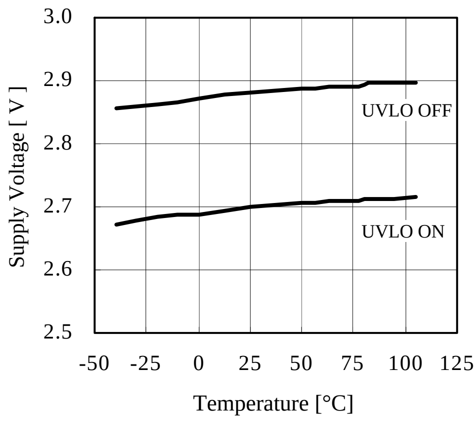
■ Reference Voltage vs. Temperature



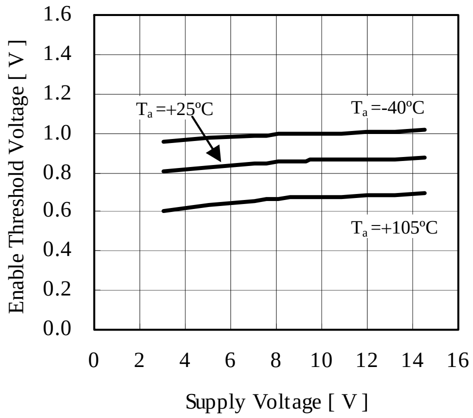
■ Reference Voltage vs. Load Current



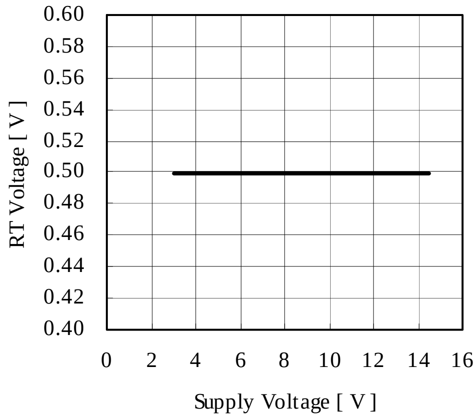
■ Supply Voltage vs. Temperature



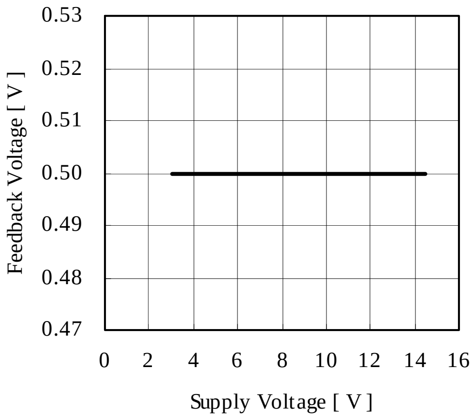
■ Enable Threshold Voltage vs. Supply Voltage



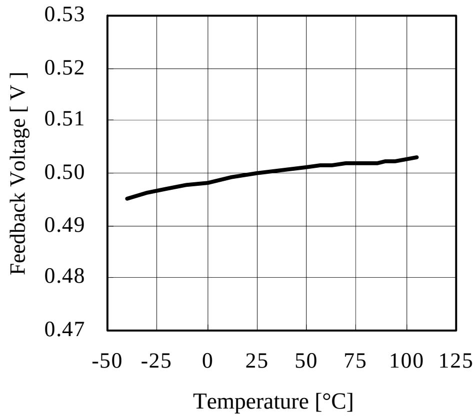
■ RT Voltage vs. Supply Voltage



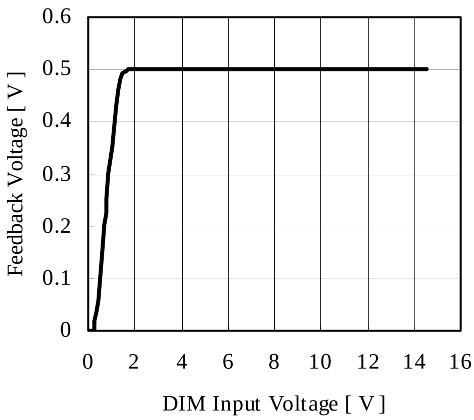
■ Feedback Voltage vs. Supply Voltage



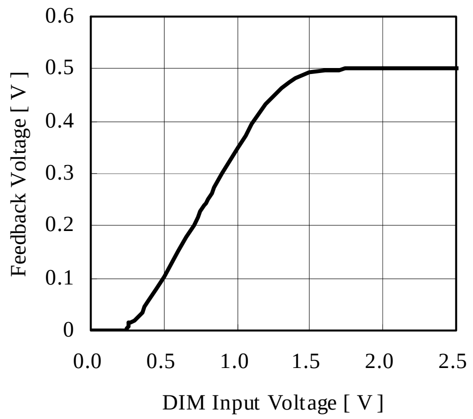
■ Feedback Voltage vs. Temperature



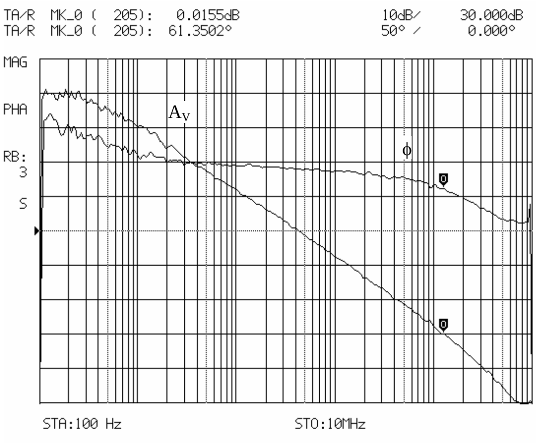
■ Feedback Voltage vs. DIM Input Voltage 1

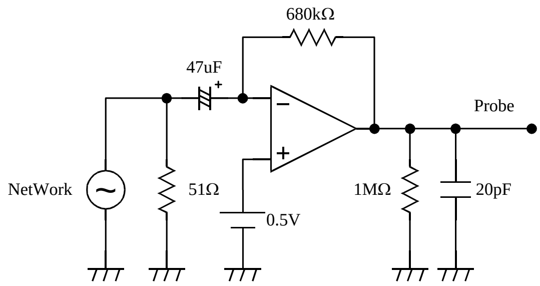


■ Feedback Voltage vs. DIM Input Voltage 2



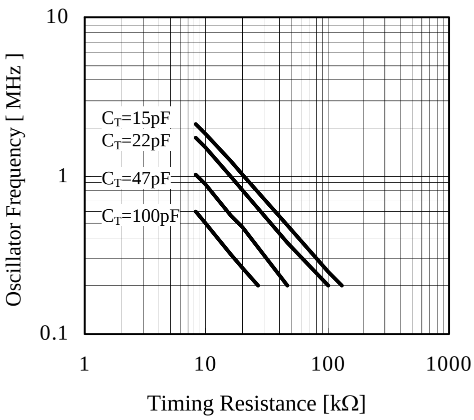
■ Error Amplifier Gain and Phase vs. Frequency



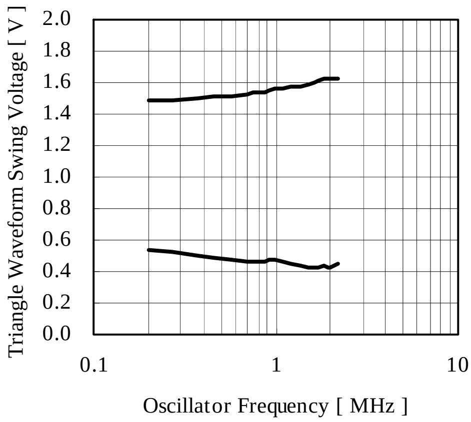


Input=-70dBm
RBW=3Hz

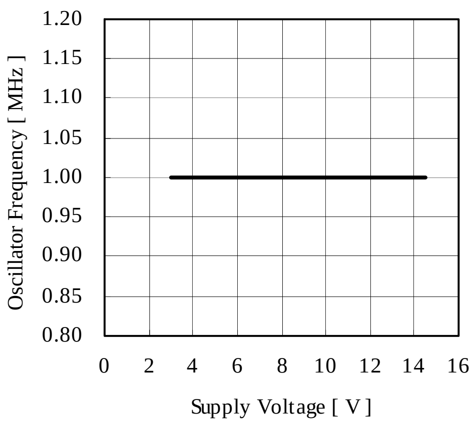
■ Oscillator Frequency vs. Timing Resistance



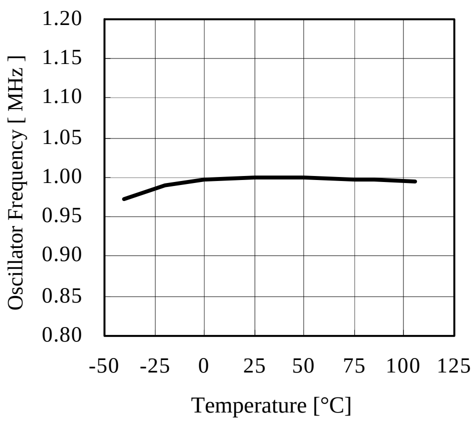
■ Triangle Waveform Swing Voltage vs. Oscillator Frequency



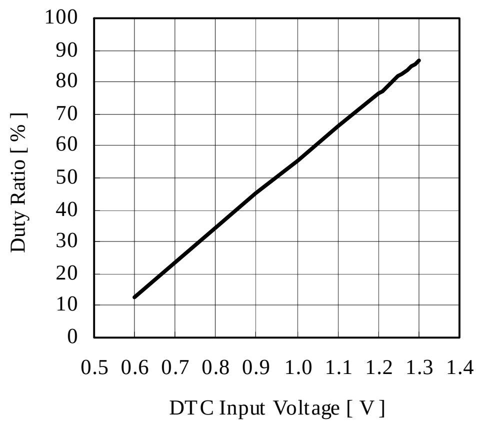
■ Oscillator Frequency vs. Supply Voltage



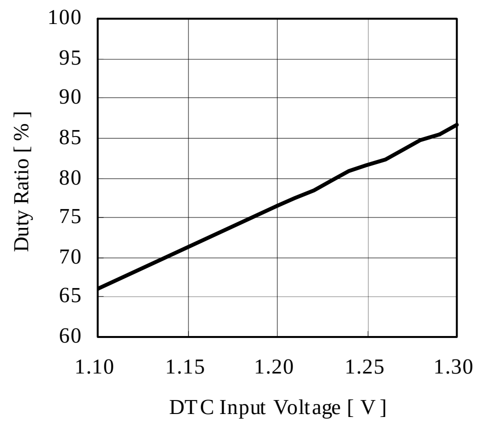
■ Oscillator Frequency vs. Temperature



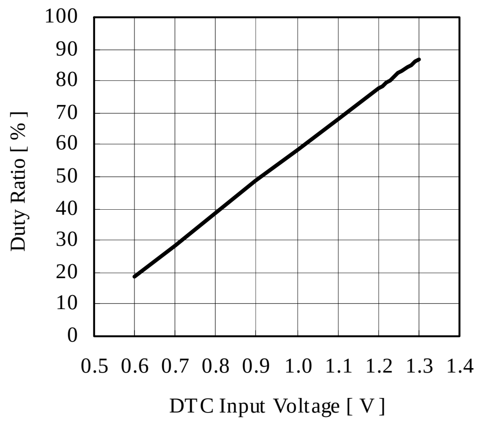
■ Duty Ratio vs. DTC Input Voltage 1 (f_{OSC}=0.5MHz)



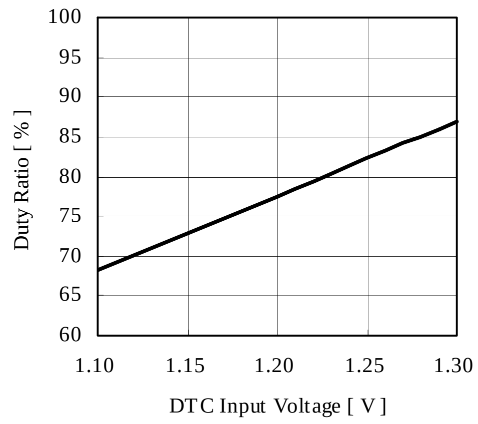
■ Duty Ratio vs. DTC Input Voltage 2 (f_{OSC}=0.5MHz)



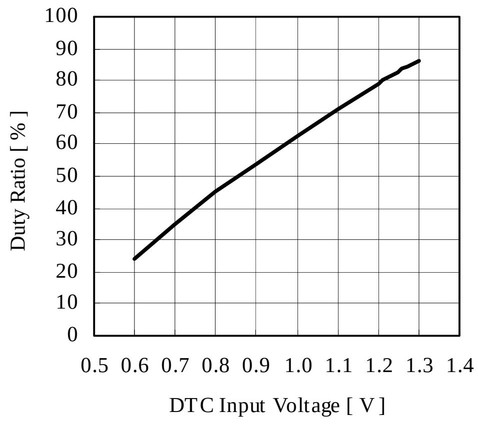
■ Duty Ratio vs. DTC Input Voltage 3 (f_{OSC}=1MHz)



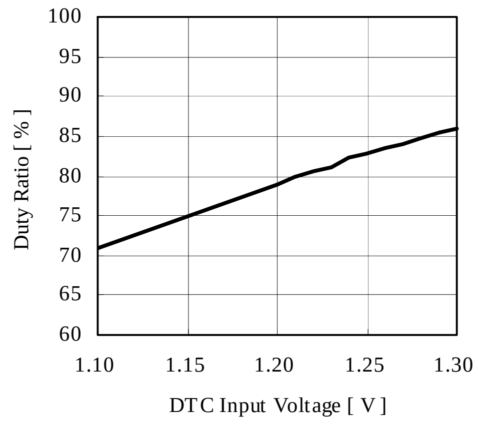
■ Duty Ratio vs. DTC Input Voltage 4 (f_{OSC}=1MHz)



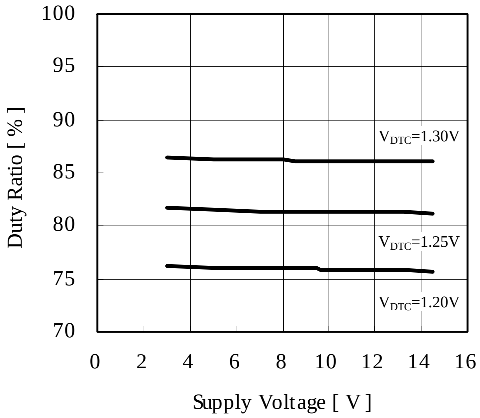
■ Duty Ratio vs. DTC Input Voltage 5 (f_{OSC}=2MHz)



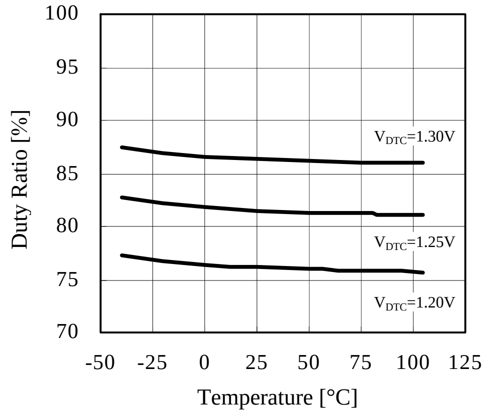
■ Duty Ratio vs. DTC Input Voltage 6 (f_{OSC}=2MHz)



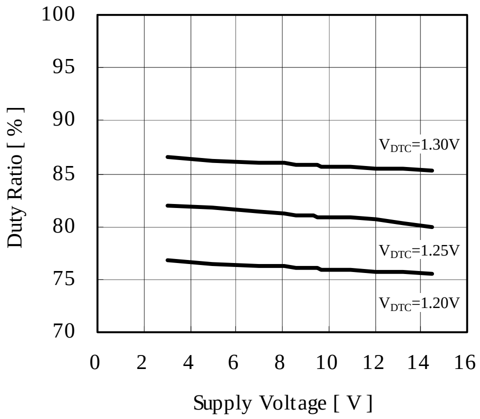
■ Duty Ratio vs. Supply Voltage 1 (f_{OSC}=0.5MHz)



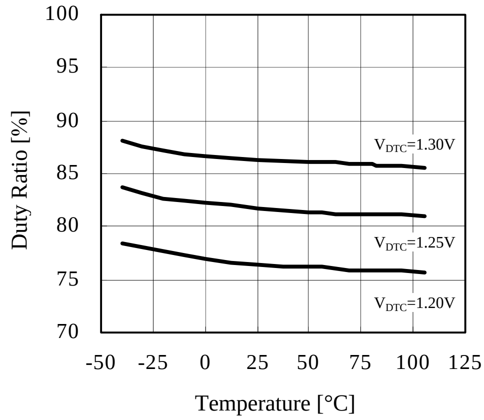
■ Duty Ratio vs. Temperature 1 (f_{OSC}=0.5MHz)



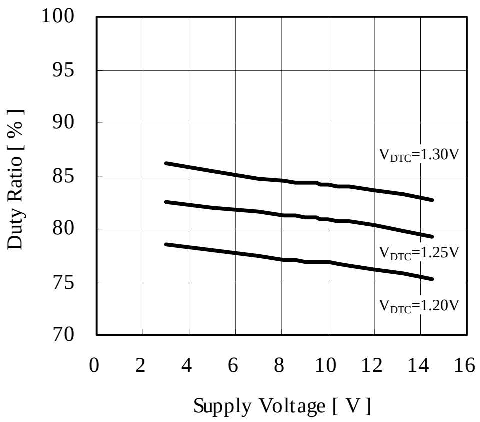
■ Duty Ratio vs. Supply Voltage 2 (f_{OSC}=1MHz)



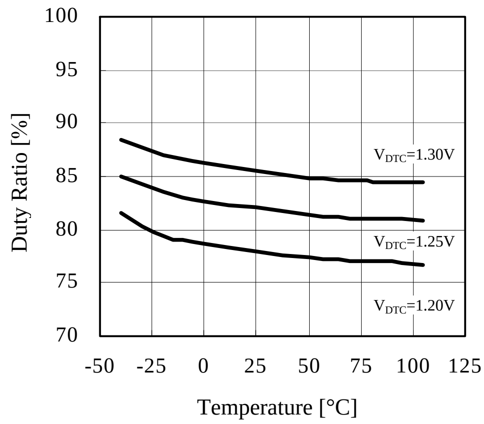
■ Duty Ratio vs. Temperature 2 (f_{OSC}=1MHz)



■ Duty Ratio vs. Supply Voltage 3 (f_{OSC}=2MHz)

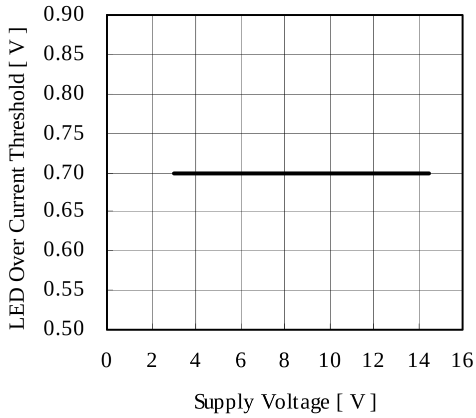


■ Duty Ratio vs. Temperature 3 (f_{OSC}=2MHz)

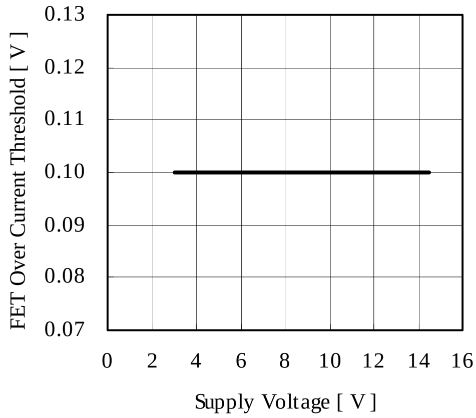


* V_{DTC}=1.20V (Resistance between REF pin-DTC pin: 39kΩ, Resistance between DTC pin-GND pin: 36kΩ)
* V_{DTC}=1.25V (Resistance between REF pin-DTC pin: 36kΩ, Resistance between DTC pin-GND pin: 36kΩ)
* V_{DTC}=1.30V (Resistance between REF pin-DTC pin: 36kΩ, Resistance between DTC pin-GND pin: 39kΩ)

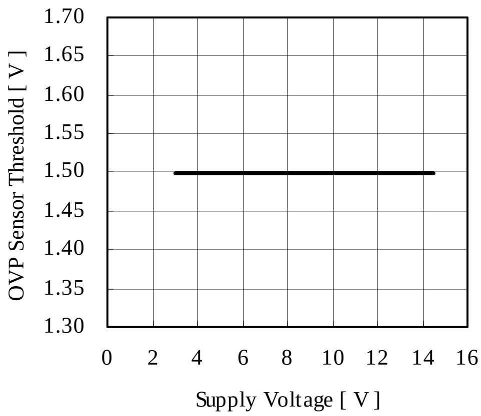
■ LED Over Current Threshold vs. Supply Voltage



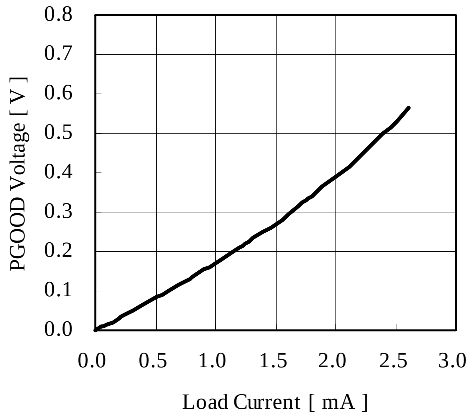
■ FET Over Current Threshold vs. Supply Voltage



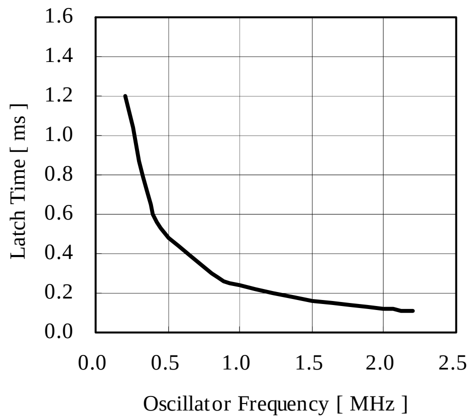
■ OVP Sensor Threshold vs. Supply Voltage



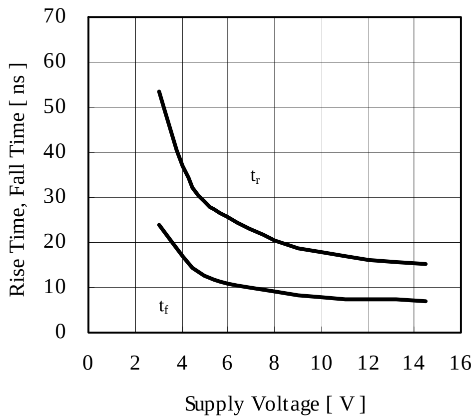
■ PGOOD Voltage vs. Load Current



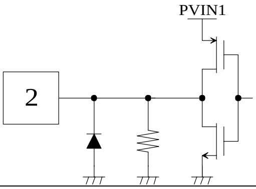
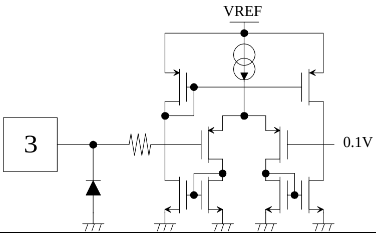
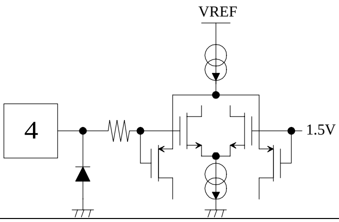
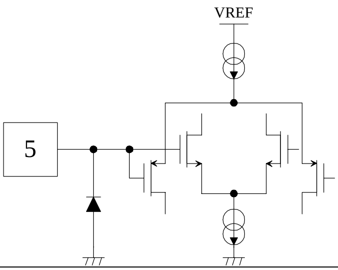
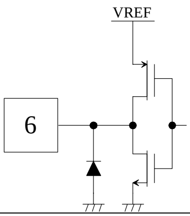
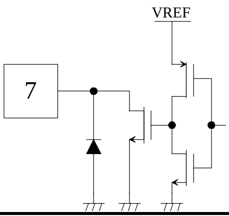
■ Latch Time vs. Oscillator Frequency

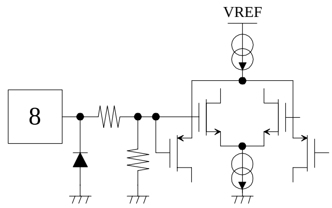
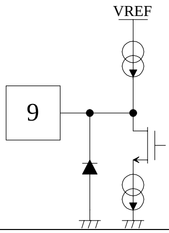
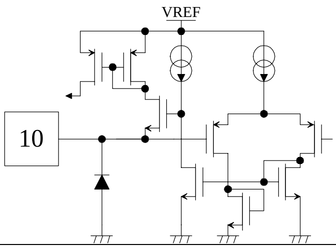
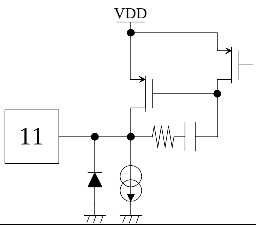
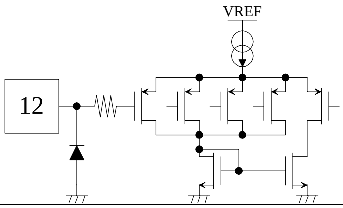
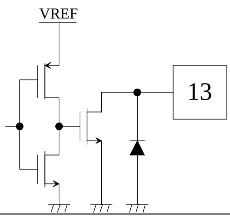
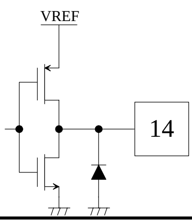


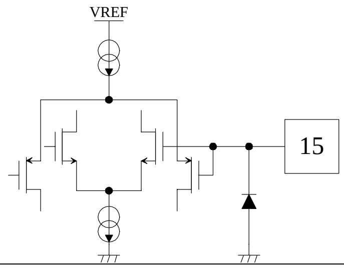
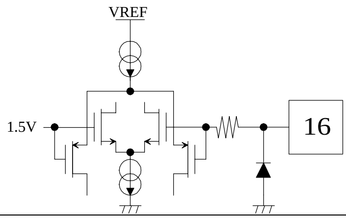
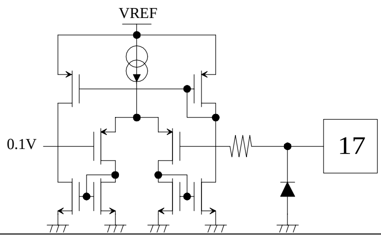
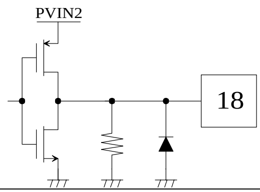
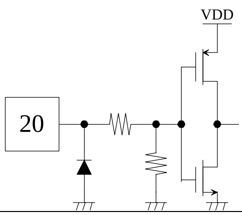
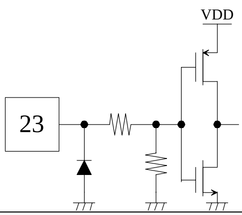
■ Rise Time and Fall Time vs. Supply Voltage



10. PIN DESCRIPTION

Pin No	Pin Description	Internal Equivalent Circuit	Description
1	PVIN 1	-	This pin is the power supply pin for the ch1 driver. PVIN1 is not connected with PVIN2 and VDD inside the IC.
2	SW 1		This pin is the driver output pin for the ch1 external MOSFET gate drive. Pull-down resistor (about 20kΩ) is built in.
3	IS 1		This pin is the ch1 resistor connection pin for over-current detection.
4	OVP 1		This pin is the ch1 resistor connection pin for over-voltage detection.
5	FB 1		This pin is the ch1 error amplifier inverting input pin. This pin outputs the PWM control signal detecting the output level of the DC-DC converter. The output of the DIMMING CONTROL part is connected to the non-inverting input. Because it connects the return resistance and the capacitance to the EAOUT pin and the FB pin, it can set the optional loop gain. Stable phase compensation setting is possible.
6	EAOUT 1		This pin is the ch1 error amplifier output pin.
7	PGOOD 1		This pin is the ch1 protection state output pin. This pin is an open drain and can sink 1mA. When the timer latch functions, output of this pin is a "L" level.

Pin No	Pin Description	Internal Equivalent Circuit	Description
8	DIM		This pin is the bias current dimming and PWM dimming pin. Pull-down resistor (about 300kΩ) is built in. The FB pin voltage changes in a constant ratio when a voltage between 0V and 2V is applied to the DIM pin. The LED current varies with the FB pin voltage. When the applied voltages exceed 2.0V, the FB pin voltage becomes a fixed 0.5V. The FB voltage difference between FB1 and FB2 in the fixed state is less than ±2.5% (±12.5mV).
9	CT		This pin is the capacitor connection pin for triangle oscillator frequency setting. One side of a capacitor connects with GND. Please use capacitors greater than 15pF. When the pin voltage becomes less than 0.3V, the driver output turns Off.
10	RT		This pin is the resistor connection pin for triangle oscillator frequency setting. One side of a resistor connects with GND. Please use resistors greater than 8.2kΩ. Oscillator frequency is expressed in the following equation by a combination of R_T and C_T. It must be 200kHz or more. $f_{osc}=1/((2\times(C_T+4pF)\times R_T)+160ns)$
11	REF		This pin is the reference voltage V_{REF}=2.5V output pin for the outside supply.
12	DTC		This pin is the dead time control pin. The DTC pin voltage is set by dividing the REF pin voltage by a resistor.
13	PGOOD 2		This pin is the ch2 protection state output pin.
14	EAOUT 2		This pin is the ch2 error amplifier output pin.

Pin No	Pin Description	Internal Equivalent Circuit	Description
15	FB 2		This pin is the ch2 error amplifier inverting input pin.
16	OVP 2		This pin is the ch2 resistor connection pin for over-voltage detection.
17	IS 2		This pin is the ch2 resistor connection pin for over-current detection.
18	SW 2		This pin is the ch2 driver output pin for the external MOSFET gate drive. Pull-down resistor (about 20kΩ) is built in.
19	PVIN 2	-	This pin is the power supply pin for the ch2 driver. PVIN2 is not connected with PVIN1 and VDD inside the IC.
20	EN 2		This pin is the ch2 voltage control pin. Independent operation is possible with this pin. Pull-down resistor (about 1MΩ) is built in. If either EN1, EN2 pin is "H", the REF voltage turns On.
21	PGND	-	Power Ground. PGND is not connected with AGND inside the IC.
22	AGND	-	Analog Ground
23	EN 1		This pin is the ch1 voltage control pin. Independent operation is possible with this pin. Pull-down resistor (about 1MΩ) is built in. If either EN1, EN2 pin is "H", the REF voltage turns On.
24	VDD	-	Supply Voltage Input. VDD is not connected with PVIN1 and PVIN2 inside the IC.

11. APPLICATIONS INFORMATION

11-1. Timer Latch

The output of the FET over-current protection and the LED over-current protection and the over-voltage protection are connected, count time is 1/fosc×240. It can be resumed by either turning EN pin voltage off and on or by restoring supply voltage.

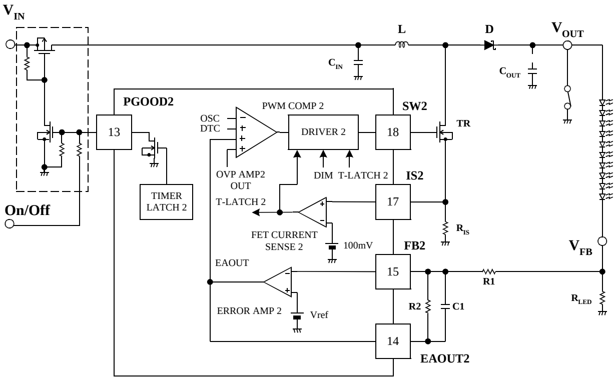
11-2. FET Overcurrent Protection

The TK61220AQ4 has built in FET over-current protection and can set the maximum current of the external FET by I_{SWMAX}=0.1/R_{IS}. When the IS pin voltage exceeds 0.1V, the driver output turns Off, and the timer latch starts counting. If it recovers while the timer is counting, the driver output turns On again. If it doesn't recover while the timer is counting, the timer latch functions, and the driver output turns Off.

Even if the timer latch functions during a short between V_{OUT}-GND, and the driver output turns Off, the over-current flows to the coil and the Schottky diode. If this state continues for a long time, it may damage the coil and the Schottky diode. If this is a concern, add the circuit shown in figure 1.

The PGOOD pin changes to an "L" level when the timer latch turns off the IC. The Pch FET at the input turns Off. The route of the coil and Schottky diode is cut. The over-current at the short state between V_{OUT}-GND can be limited.

Figure.1: Additional protection circuitry example 1



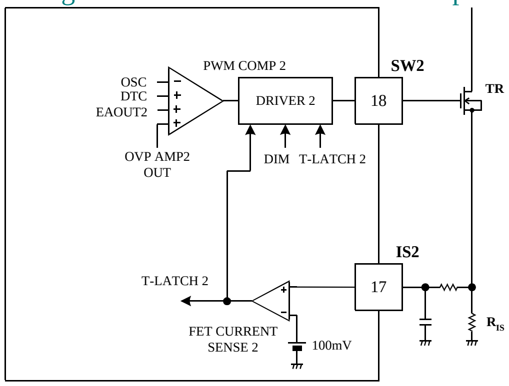
11-2-1.The IS pin setting

Because the threshold voltage of FET over-current protection is low (0.1V), the GND location of R_{IS} should be as close as possible to the IC GND. This will help reduce possible noise generation. In addition, please use wide traces because a considerable current flows in R_{IS}.

When an inrush current is generated during the start up and PWM dimming, there is a possibility of enabling the FET over-current protection. Please adjust the capacitance at the error amplifier to eliminate any inrush current during start up time.

In addition, when gate capacitance of the FET is large, the charge current of the gate flows to R_{IS} for a short time, and there is the possibility of the FET over-current protection malfunctioning. In this case please add a RC filter.

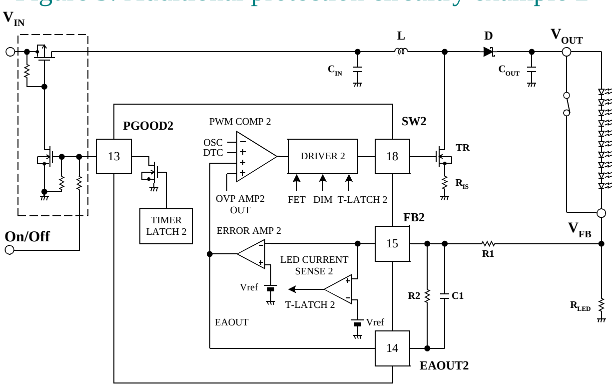
Figure.2: RC filter constitution example



11-3. LED Overcurrent Protection

The TK61220AQ4 controls the LED current by controlling a step-up DC-DC converter. $V_{IN}<V_{OUT}$ consists as a relation between the supply voltage and the output voltage. When $V_{IN}>V_{OUT}$, the IC loses control, and changes the over-current-state.
The TK61220AQ4 has built in LED over-voltage protection. When the FB pin voltage exceeds 0.7V, a timer latch starts counting. If it recovers while the timer is counting, the count of a timer is reset. If it doesn't recover while the timer is counting, the timer latch functions, and the driver output turns Off.
Even if the timer latch functions during a short between V_{OUT}-FB, and the driver output turns Off, the over-current flows to the coil and the Schottky diode. Current becomes V_{IN}/R_{LED}. It may exceed the allowable current of the coil and the Schottky diode. It exceeds power dissipation loss of R_{LED} and may damage the coil and the Schottky diode. If this is a concern, add the circuit shown in figure 3.
The PGOOD pin changes to an "L" level when the timer latch turns off the IC. The Pch FET at the input turns Off. The route of the coil and Schottky diode is cut. The over-current at the short state between V_{OUT}-FB can be limited.

Figure 3: Additional protection circuitry example 2



11-4. Overvoltage Protection

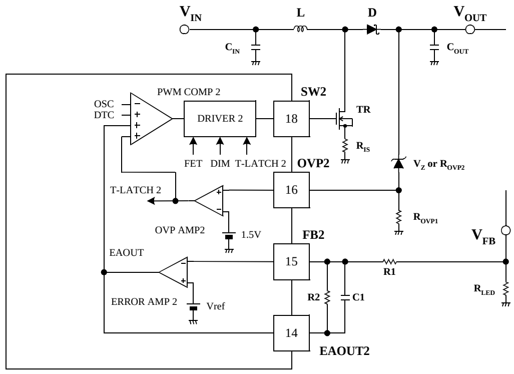
In an LED open-state, the control of the feedback loop is cut. Therefore Even if the output voltage (V_{OUT}) rises, the V_{FB} does not rise, and the output voltage will continue to rise. This condition could easily damage the external FET and the Schottky diode by exceeding their dielectric strength.
The TK61220AQ4 has built in over-voltage protection and monitors the output voltage separately from an LED control loop. When the output voltage is connected to the OVP pin, it is possible to control that the OVP pin does not exceed the voltage, which is set externally.
When the OVP pin voltage exceeds 1.5V, the IC limits the output voltage, and the timer latch starts counting. If it recovers in the count time, the count of a timer is reset. If it doesn't recover in the count time, the timer latch functions, and the driver output turns Off.
The OVP voltage can be set by two different methods. The method used will depend on the application.

If a zener diode is used: V_Z+1.5V
→There is no leak current when the IC is Off.

If resistor are used: $(1+R_{OVP2}/R_{OVP1})\times 1.5V$
→It reduces of ambient temperature, low-cost.

Please set the dielectric strength value to each constant in consideration of the output voltage when Vf of LED is the maximum.

Figure 4: Additional protection circuitry example 3



11-5. Undervoltage Lockout (UVLO)

When the supply voltage is under 2.7V the IC turns off the internal circuitry and prevent any malfunction.

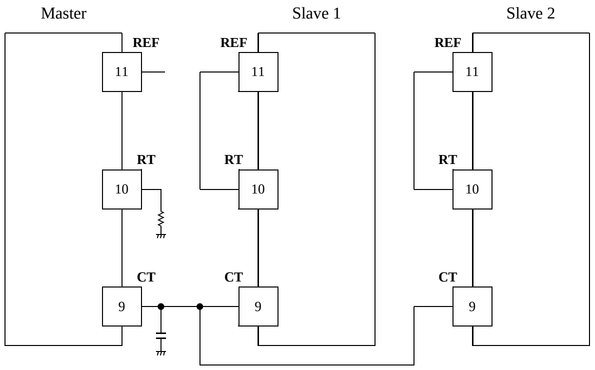
11-6. Thermal Sensor

When the chip temperature exceeds about 150°C, the driver output turns Off. Afterwards when the chip temperature decreases, the driver output turns On again.

11-7. Parallel Synchronization Operation

It is possible to synchronize several TK61220AQ4 by connecting them together using the CT pin. Set only one IC as the master and set other ICs as slaves.
The master IC is configured the same as a single application TK61220AQ4. Then connect the CT pin of the master IC to the CT pin of the slave IC.
The RT pin of the slave IC is connected to the REF pin. The oscillator frequency needs to be set with consideration of the wiring capacitance of the CT line. It is necessary to distribute the dimming and the EN signals to the master IC and all the slave ICs.

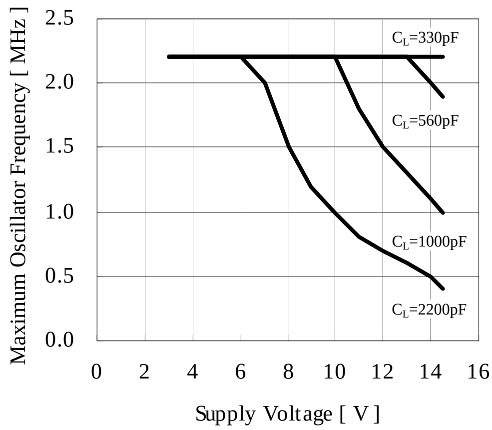
Figure.5: Parallel synchronization operation example



11-8. Notes on use

This IC might become an unstable operation below the lowest operation voltage.
Please use the relation among the supply voltage, the oscillator frequency, and the load capacitance below the solid line of Figure 6.

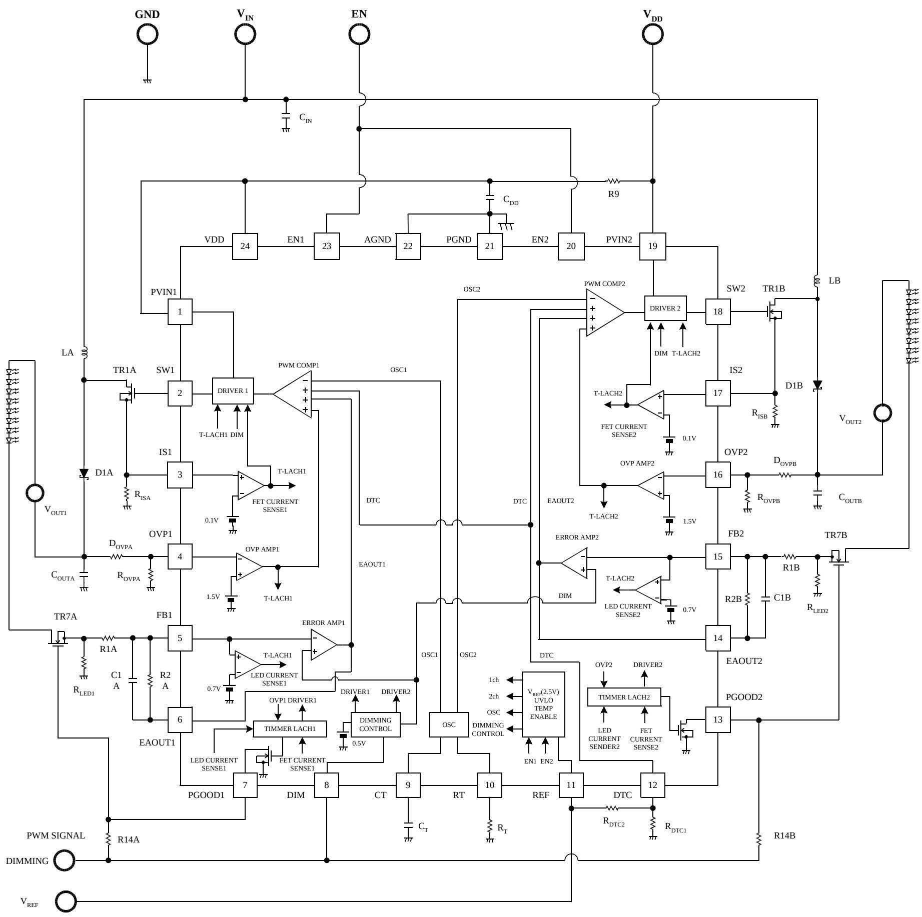
Figure.6: Oscillator Frequency vs. Supply Voltage



11-9. TK61220AQ4 16 White-LEDs Drive

Input voltage : V_{IN}=7V~16V
LED : 6~8 LEDs in series
LED current : 73.5mA(DIM pin 3.0V~14.5V condition) 100mA setting at the maximum is possible.
Inductor peak current : 1.5Amax
Oscillator frequency : 350kHz

11-9-1. Application Circuit



11-9-2. Value of component

R_{IS}: 0.047Ω
R_{LED}: 6.8Ω ±1%
R_{OVP} 82kΩ
D_{OVP}: 2MΩ
R_T: 11kΩ±1%
R_{DTC1}: 33kΩ±1%
R_{DTC2}: 33kΩ ±1%

R1: 1kΩ
R2: 470kΩ
R9: SHORT
R14: 100kΩ

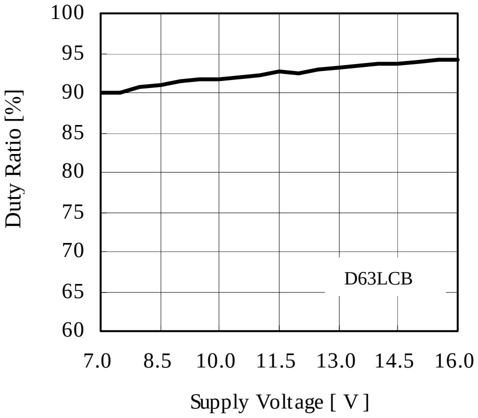
D1: 100V , Io=3A
TR1: Nch-60V, 2A, 4V drive
TR7: Nch-50V, 0.2A,2.5 drive

L: 10μH
(TOKO D63LCB Type, Part Number: A921CY-100M)

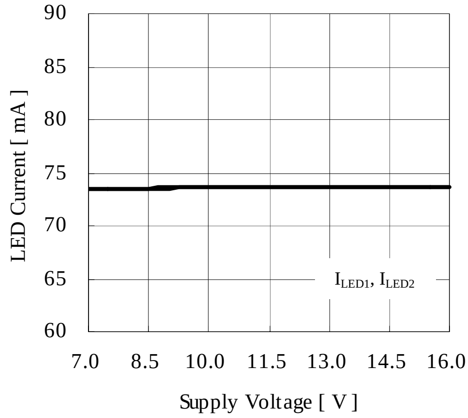
C_{IN}: 4.7μF/35V (KYOCERA CM316X5R475M35A)
C_{DD}: 4.7μF/16V (KYOCERA CM21X5R475M16A)
C_T: 120pF/50V (KYOCERA CM05CH121J50A)
C1: 0.1μF/10V (KYOCERA CM05X5R104K10A)
C_{OUT}: 0.1μF/50V

11-9-3. Characteristics

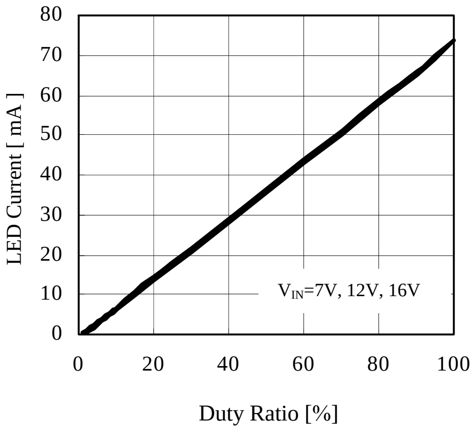
■ Efficiency vs. Supply Current (I_{LED}=73.5mA)



■ LED Current vs. Supply Current (V_{LED}=5.0V)



■ LED Current vs. Duty Ratio(PWM Signal Frequency=200Hz)



$$* \text{Efficiency} = \frac{V_{OUT1} \times I_{LED1} + V_{OUT2} \times I_{LED2}}{V_{IN} \times I_{IN}} \times 100 \quad (\%)$$

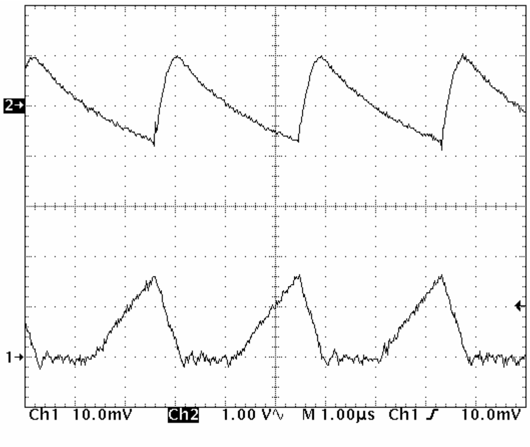
*Current loss of IC oneself is not calculated in upper expression.

$$* I_{LED} = \frac{V_{FB}}{R_{LED}} = \frac{0.5V}{6.8\Omega} = 73.5mA$$

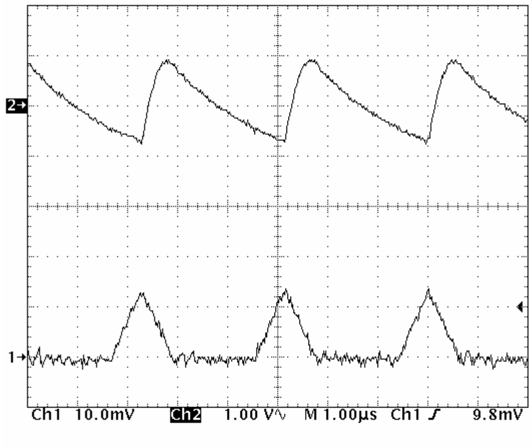
11-9-4. Operation Waveform

(Top) Output Voltage Waveform : 1V/Div(AC)
(Bottom) Inductor Current Waveform : 1A/Div

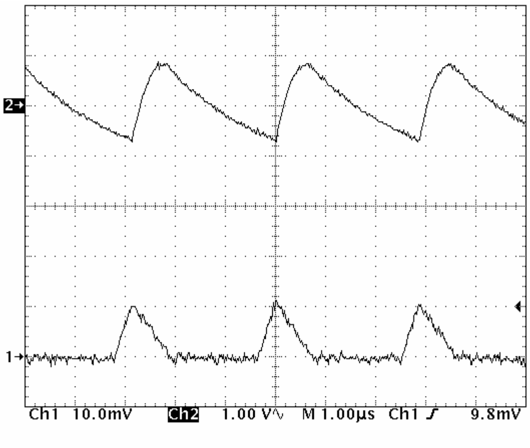
V_{IN}=7V



V_{IN}=12V



V_{IN}=16V

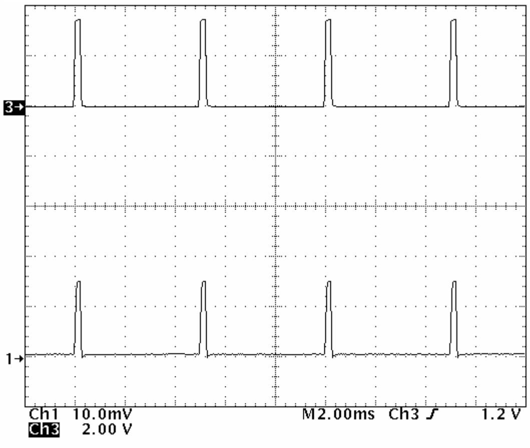


11-9-5. PWM Dimming Waveform

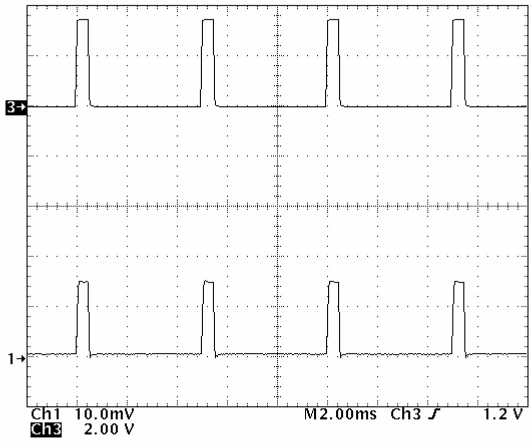
Input PWM signal into DIM pin. (V_{IN}=12V, PWM Signal Frequency=200Hz)

(Top)	DIM Pin Voltage Waveform	(PWM Signal)	: 2V/Div
(Bottom)	LED Current Waveform	(Ch1 Standard)	: 50mA/Div

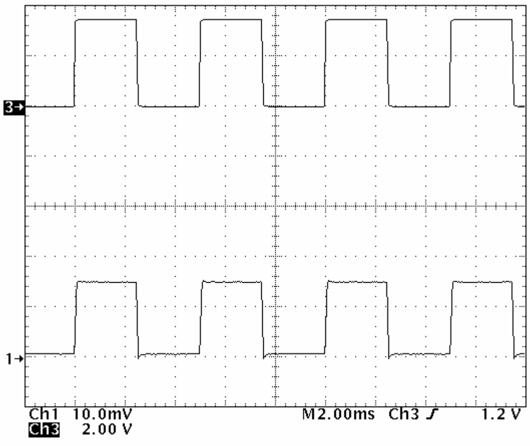
Duty Ratio=5%



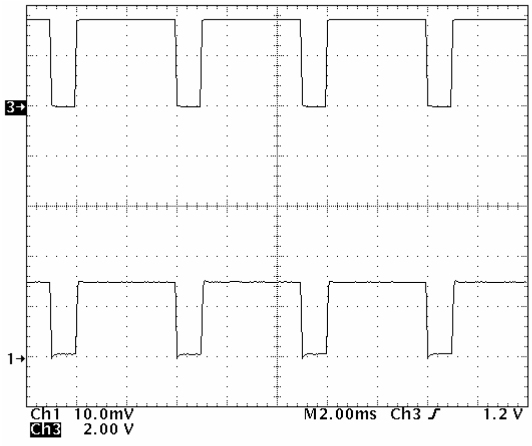
Duty Ratio=10%



Duty Ratio=50%

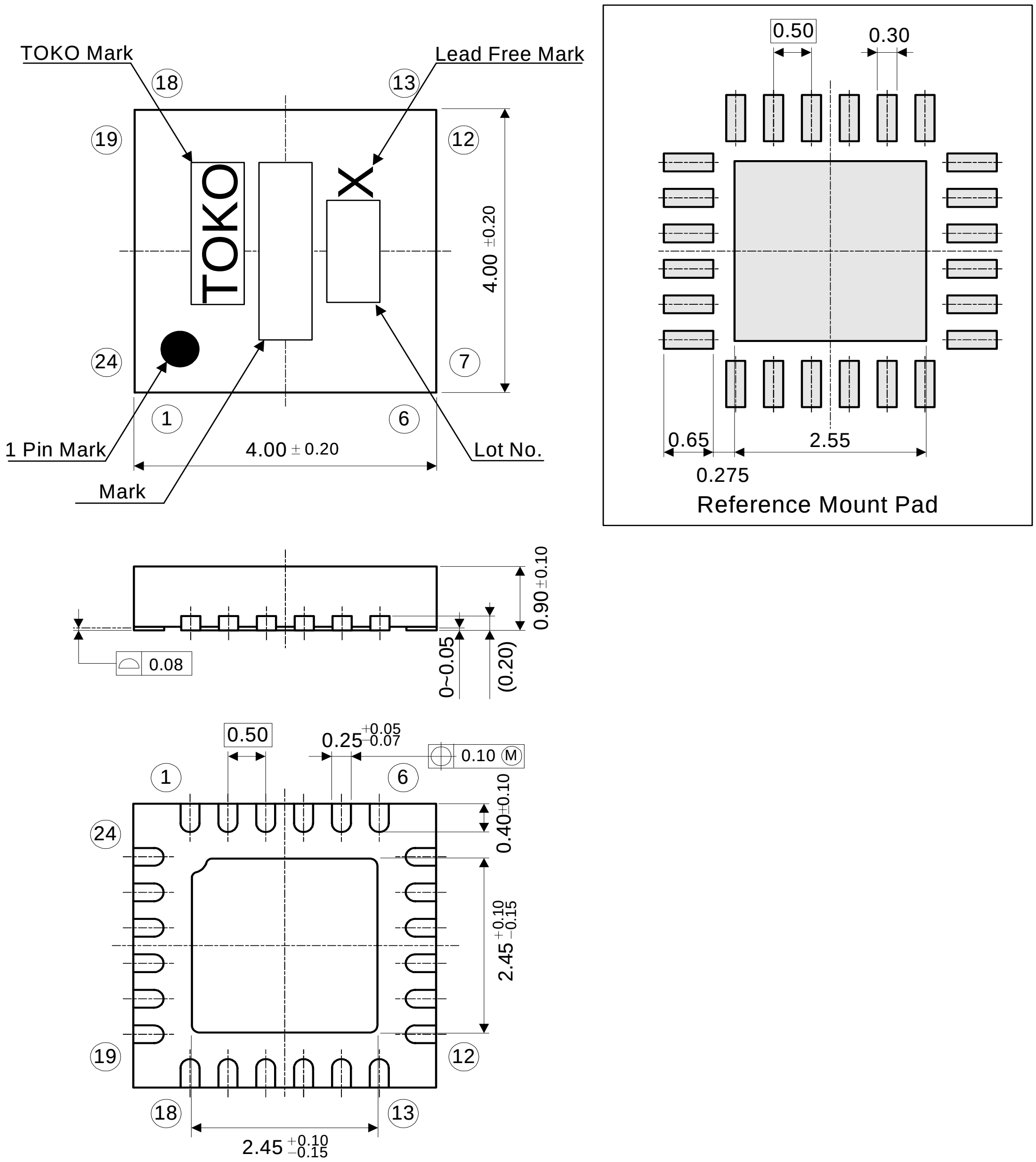


Duty Ratio=80%



12. PACKAGE OUTLINE

■ 24-Lead Quad Flat Non-Leaded Package With Heat Sink: HQFN4040-24



Unit : mm

Package Structure and Others

Package Material	:	Epoxy Resin
Terminal Material	:	Copper Alloy
Terminal Finish	:	Lead Free Solder Plating (8~25μm)
Solder Composition	:	Sn100%
Mark Method	:	Laser
Country of Origin	:	Malaysia
Mass	:	0.044g

13. NOTES

■ Please be sure that you carefully discuss your planned purchase with our office if you intend to use the products in this application manual under conditions where particularly extreme standards of reliability are required, or if you intend to use products for applications other than those listed in this application manual.

- Power drive products for automobile, ship or aircraft transport systems; steering and navigation systems, emergency signal communications systems, and any system other than those mentioned above which include electronic sensors, measuring, or display devices, and which could cause major damage to life, limb or property if misused or failure to function.
- Medical devices for measuring blood pressure, pulse, etc., treatment units such as coronary pacemakers and heat treatment units, and devices such as artificial organs and artificial limb systems which augment physiological functions.
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■ None of the ozone depleting substances(ODS) under the Montreal Protocol are used in our manufacturing process.

14. OFFICES

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