Three-Channel Linear LED Driver with Analog and PWM Dimming

DESCRIPTION

TS19605CA20H is a three-channel Linear LED driver with analog and PWM dimming control. This device targets at automotive lighting applications. It provides high-side drivers for LED current configured with the maximum current up to 150mA per channel. By cascade external PNP transistor can reach up to 400mA per channel.

TS19605CA20H operates with a wide input range of 4.5V to 70V and low quiescent current in standby mode. It is designed with various protection functions such as under voltage lockout (UVLO), LED-String open load voltage protection (OLP) and short circuit protection (SCP), I_{SET} pin open/short protection and over-temperature protection (OTP). Diagnostic features are provided to meet automotive requirements.

APPLICATION

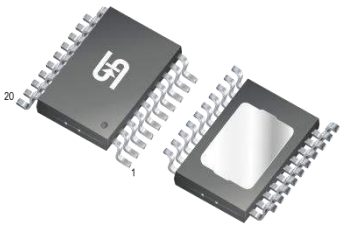
- Automotive LED Lighting:
  - Daytime Running Lamp (DRL) / Interior light
  - Stop or Tail / Position / Fog / Turn Light
- Industrial LED Applications
- General RGB or White LED Drivers

FEATURES

- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: -40°C to 125°C
  - Device HBM ESD classification level H1C
  - Device CDM ESD classification level C6
- Wide input voltage range: 4.5V to 70V
- Max. output current: 150mA per channel
  - Adjustable by external resistor
  - Accuracy: ±4% per channel when I_{OX} @ 200mA
  - Accuracy: ±6% per device when I_{OX} @ 200mA
  - Up to 400mA per channel @ $V_{DROPOUT}$≤1V
- Dimming function of PWM and Analog
- V_{REF} pin for outside cascade structure to share the power dissipation with full loading
- Diagnostic functionalities (LED-string Open/Short, I_{SET} pin Open/Short, over temperature, supply voltage)
- LED-String voltage feedback per channel for Single-LED Short Detection (SSD)
- Separate fault pin for Single-LED Short Failure
- RoHS Compliant
- Halogen-Free according to IEC 61249-2-21

Pb-Free RoHS COMPLIANT HALOGEN FREE

TSSOP-20EP

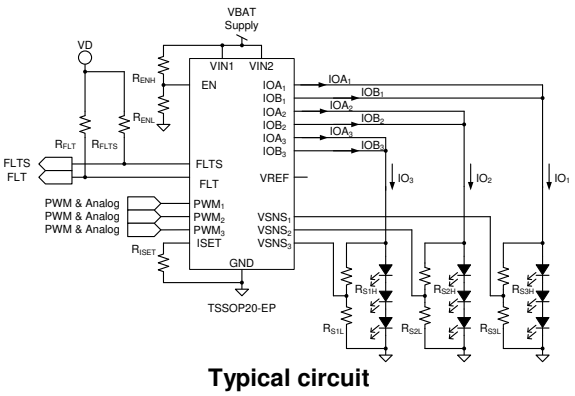


Pin Definition:

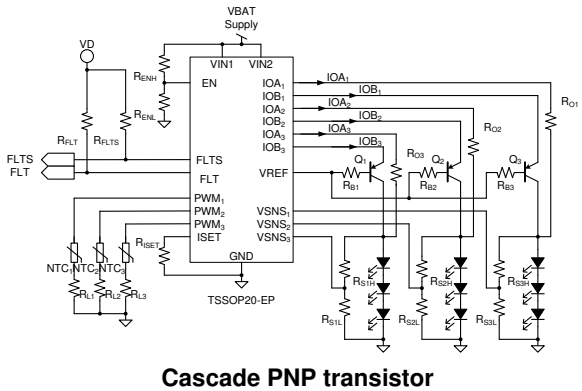
1. VIN_1	6. PWM_2	11. FLTS	16. IOA_2
2. EN	7. PWM_3	12. FLT	17. IOB_1
3. GND	8. $VSNS_1$	13. IOB_3	18. IOA_1
4. ISET	9. $VSNS_2$	14. IOA_3	19. VIN_2
5. PWM_1	10. $VSNS_3$	15. IOB_2	20. VREF

Notes: MSL 3 (Moisture Sensitivity Level) per J-STD-020

TYPICAL APPLICATION CIRCUIT



Typical circuit



Cascade PNP transistor

ABSOLUTE MAXIMUM RATINGS (T_A = 25°C unless otherwise specified) (Note 1)			
PARAMETER	**SYMBOL**	**LIMIT**	**UNIT**
Power input voltage - Battery power supply	V_{VIN1}/V_{VIN2}	-0.3 to 75	V
EN input voltage	V_{EN}	-0.3 to 75	V
Current channel output voltage	V_{IOAX}/V_{IOBX}	-0.3 to 75	V
V_{REF} bias voltage	V_{REF}	V_{VIN2}-2	V
FLT/FLT_S signal voltage	V_{FLT}, V_{FLTS}	-0.3 to 22	V
ISET input voltage	V_{ISET}	-0.3 to 5.5	V
PWM/Analog signal input voltage	V_{PWMX}	-0.3 to 5.5	V
Current channel sense input voltage	V_{VSNSX}	-0.3 to 5.5	V
Junction Temperature Range	T_J	-40 to +150	°C
Storage Temperature Range	T_{STG}	-65 to +150	°C
ESD Rating (Human Body Mode)	HBM	±2	kV
ESD Rating (Charged Device Mode)	CDM	±1	kV

THERMAL PERFORMANCE (Note 2)			
PARAMETER	**SYMBOL**	**LIMIT**	**UNIT**
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	145	°C/W
Thermal Resistance Junction to Ambient (Note 2-1)	$R_{\theta JA}$	45	°C/W
Thermal Resistance Junction to Case	$R_{\theta JC}$	48	°C/W
Thermal Resistance Junction to Case (Note 2-1)	$R_{\theta JC}$	15	°C/W

RECOMMENDED OPERATING CONDITION (T_A = 25°C unless otherwise specified) (Note 3)			
PARAMETER	**SYMBOL**	**LIMIT**	**UNIT**
Power input voltage - Battery power supply	V_{VIN1}/V_{VIN2}	5 to 70	V
EN input voltage	V_{EN}	0 to 70	V
Current channel output voltage	V_{IOAX}/V_{IOBX}	0 to 70	V
V_{REF} bias voltage	V_{VREF}	V_{VIN2}-2	V
FLT/FLT_S signal voltage	V_{FLT}, V_{FLTS}	0 to 20	V
ISET output voltage	V_{ISET}	0 to 5	V
PWM/Analog signal input voltage	V_{PWMX}	0 to 5	V
Current channel sense input voltage	V_{VSNSX}	0 to 5	V
Storage Temperature Range	T_{STG}	-55 to +150	°C
Operating Junction Temperature Range	T_J	-40 to +150	°C
Operating Ambient Temperature Range	T_{OPA}	-40 to +125	°C

ELECTRICAL SPECIFICATIONS (V_{IN}= 14V, T_J = -40°C to 150°C unless otherwise specified)						
PARAMETER	**SYMBOL**	**CONDITION**	**MIN**	**TYP**	**MAX**	**UNIT**
Supply Voltage						
V_{IN} Turn-on Threshold	V_{VIN_ON}	V_{EN} = 5V	4.2	4.8	5.4	V
V_{IN} Hysteresis	V_{VIN_HYS}	V_{EN} = 5V	0.26	0.33	0.4	V
EN Turn-on Threshold	V_{EN_ON}		1.3	1.65	2	V
Quiescent Current	I_Q	V_{EN} = 5; V_{IN} = 4.2V	10	12.5	26	μA
Shutdown Current	I_{SD}	V_{EN} = 0; V_{IN} = 14V	40	--	80	μA
Operating Supply Current	I_{CC}	Not including IO_X & I_{SET} R_{ISET} =1.2kΩ; VIO_X=10V	0.5	--	2	mA
Shutdown Current in Fault mode	I_{Fault}		0.55	--	1.3	mA
Regulator (Note 4, 5)						
Output Current Range	IOA_X/IOB_X	$VIOA_X$ & $VIOB_X$ = V_{VIN2}-1	4	--	400	mA
Channel Accuracy	$\Delta I_{O(channel)}$	R_{ISET} = 1.2kΩ	-4	--	+4	%
Device Accuracy	$\Delta I_{O(device)}$	R_{ISET} = 1.2kΩ	-6	--	+6	%
Ratio of IO_2 to Setting Current	$K_{I\ (CH2)}$	R_{ISET} = 1.2kΩ	--	180	--	--
IO Setting Reference Voltage	V_{ISET}	R_{ISET} = 1.2kΩ	1.1	1.3	1.5	V
V_{IN}-Base Reference Voltage	V_{REF}	I_{VREF} = 0mA;	2.07	--	2.6	V
Driver capability of V_{REF}	ΔV_{REF}	I_{VREF} = ±20mA	-5	--	5	%
Fault Flag (FLT & FLTS)						
Logic Input High Threshold	$V_{IH\_FLT(S)}$		2	--	--	V
Logic Input Low Threshold	$V_{IL\_FLT(S)}$		--	--	0.7	V
Logic Output High threshold	$V_{OH\_FLT(S)}$	1μA Source Current	2	--	--	V
Logic Output Low Threshold	$V_{OL\_FLT(S)}$	500μA Sink Current	--	--	0.7	V
Strong Pull-up Current	I_{PU}	$V_{FLT(S)}$ = 3V	500	750	1000	μA
Strong Pull-down Current	I_{PD}	$V_{FLT(S)}$ = 2V	4	8	16	μA
Comparator ($VSNS_X$)						
Comparator Reference Voltage	$VSNS_{X\_REF}$	IO_X = 10mA; VIO_X = 6V V_{VIN} > 9V	1	1.2	1.4	V
$VSNS_X$ Hysteresis	$VSNS_{X\_HYS}$		--	130	--	mV
Signal Short Detection Enable	VIN_{SSEN}	IO_X = 10mA; VIO_X = 6V $VSNS_X$ < 1V	7.9	9	10.1	V
VIN for Short Circuit Hysteresis	VIN_{SSEN_HYS}		--	1	--	V
Protection						
Open Load Detection Voltage	V_{OLVX}	V_{OLV} = V_{IN} - VIO_X	155	315	465	mV
Open Load Detection Hysteresis	V_{OLX_HYS}	V_{OLV} = V_{IN} - VIO_X	--	140	--	mV
Short Detection Voltage	V_{SCPX}	IO_X =10mA	0.85	0.95	1.05	V
Short-detection deglitch	T_{DG}	I_{FLT}=10mA	1	2	3	ms
		During PWM; count the number of ms continuous cycles when VIO_X < V_{SCPX}	7	--	8	ms
I_{SET} Open Detection	R_{ISET_OPEN}	VFLT pull low	--	--	200	kΩ

ELECTRICAL SPECIFICATIONS (V_{IN}= 14V, T_J = -40°C to 150°C unless otherwise specified)						
PARAMETER	**SYMBOL**	**CONDITION**	**MIN**	**TYP**	**MAX**	**UNIT**
I_{SET} Short Detection	R_{ISET_SHORT}	VFLT pull low	400	--	--	Ω
Dimming						
PWM Dimming High Threshold Voltage	V_{OH_PWMX}		2.5	--	--	V
PWM Dimming Low Threshold Voltage	V_{OL_PWMX}		--	--	0.7	V
Analog Dimming Threshold Voltage of 100% Current Level	V_{MAX_PWMX}		--	2.4	2.48	V
Analog Dimming Threshold Voltage of 1% Current Level	V_{MIN_PWMX}		0.72	0.8	--	V
PWM_X Source Current	I_{PWMX}	V_{PWMX} = 2.5V	250	300	350	μA
Thermal Section (Note 6, 7)						
Thermal Shutdown	TSD		--	165	--	°C
Temperature Hysteresis	T_{HYS}		--	15	--	°C

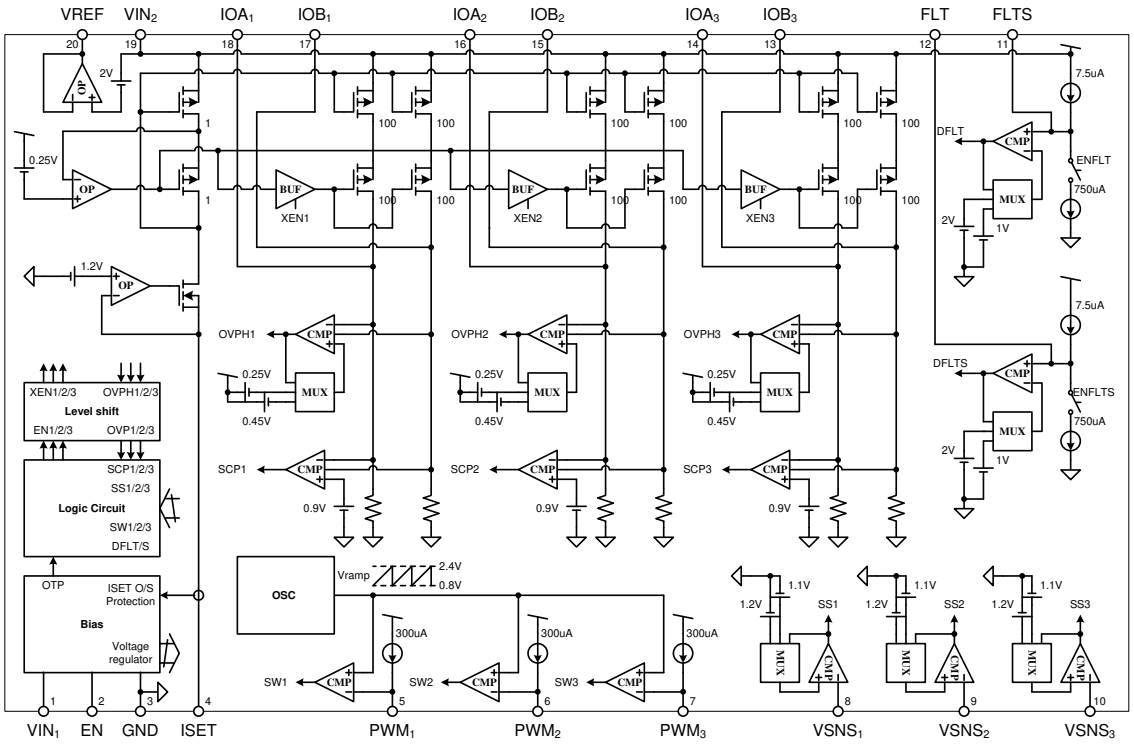
Note:

1. Stresses listed as the above “Absolute Maximum Ratings” may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
2. Thermal resistance is specified with the component mounted on a test board in free air with low effective thermal conductivity at T_A=25°C.
   2-1: Mounted on aluminum 4oz PCB
3. The device is not guaranteed to function outside its operating conditions.
4. Channel accuracy: $I_{(IOUTx)}$ - $I_{(avg)}$ / $I_{(avg)}$
   4-1: $I_{(AVG)}$ = [$I_{(IOUT1)}$ + $I_{(IOUT2)}$ + $I_{(IOUT3)}$] / 3
5. Device accuracy: $I_{(IOUTx)}$ - $I_{(setting)}$ / $I_{(setting)}$
   5-1: $I_{(setting)}$ is the target current set by R_{ref}.
6. Guaranteed by design.
7. Auto Recovery type.

ORDERING INFORMATION

ORDERING CODE	PACKAGE	PACKING
TS19605CA20H RLG	TSSOP-20EP	2,500pcs / 13” Reel

FUNCTION BLOCK



PIN DESCRIPTION

PIN NO.	NAME	FUNCTION
1	V_{IN1}	Battery power input voltage for bias circuit
2	EN	Enable and shut down pin
3	GND	Ground return for all internal circuitry
4	I_{SET}	Connect external resistor to GND to set output current of each channel
5	PWM_1	PWM/Analog dimming voltage input of Channel 1
6	PWM_2	PWM/Analog dimming voltage input of Channel 2
7	PWM_3	PWM/Analog dimming voltage input of Channel 3
8	$VSNS_1$	LED string voltage sense input 1
9	$VSNS_2$	LED string voltage sense input 2
10	$VSNS_3$	LED string voltage sense input 3
11	FLTS	Single LED short fault terminal
12	FLT	Fault terminal
13	IOB_3	Current output terminal 3 of B channel
14	IOA_3	Current output terminal 3 of A channel
15	IOB_2	Current output terminal 2 of B channel
16	IOA_2	Current output terminal 2 of A channel
17	IOB_1	Current output terminal 1 of B channel
18	IOA_1	Current output terminal 1 of A channel
19	V_{IN2}	Battery power input voltage for driver circuit
20	V_{REF}	V_{IN}-Base reference voltage
-	EP	Exposed Pad. Connect EP to a large-area ground plane for effective power dissipation. Do not use as the IC ground connection

TYPICAL PERFORMANCE CURVES

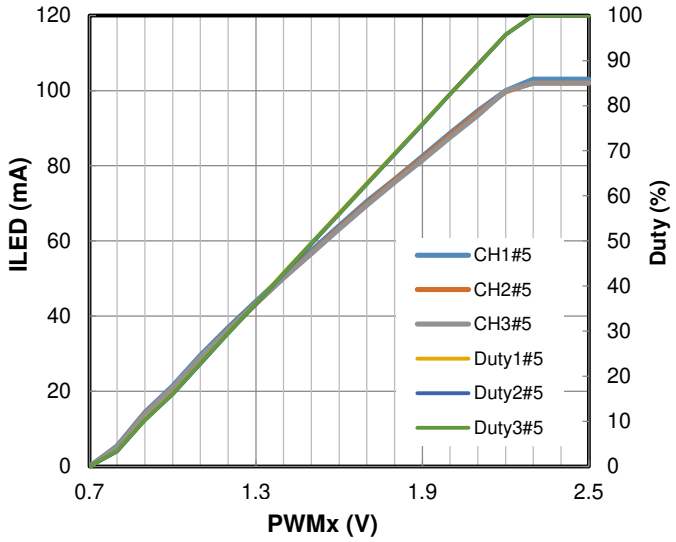


Figure 1. I_{LED} vs. Analog Dimming

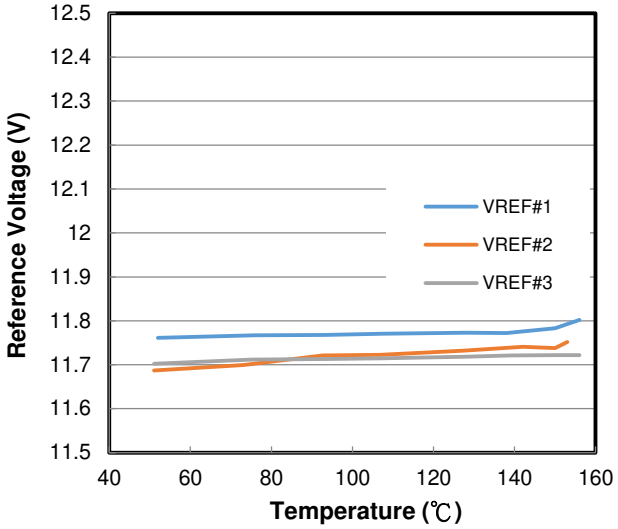


Figure 2. V_{REF} vs. Temperature

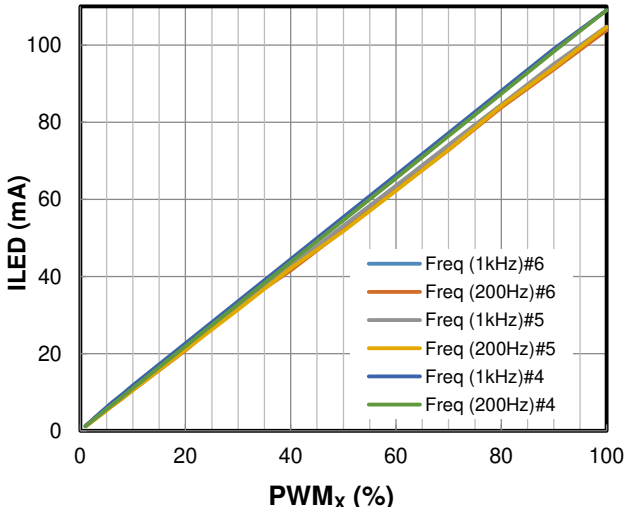


Figure 3. I_{LED} vs. PWM Dimming

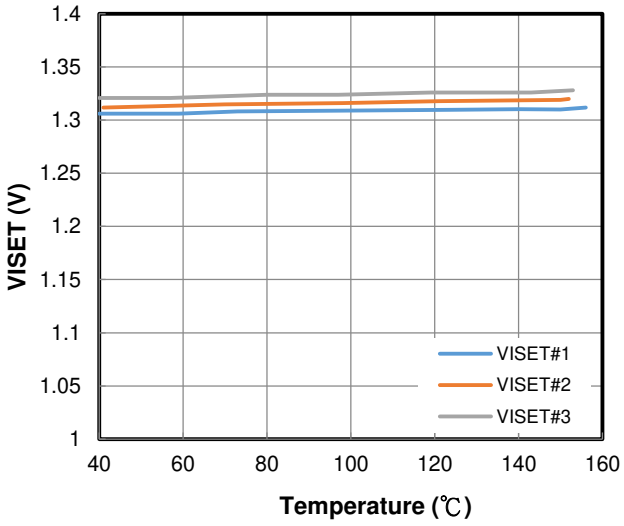


Figure 4. V_{ISET} vs. Temperature

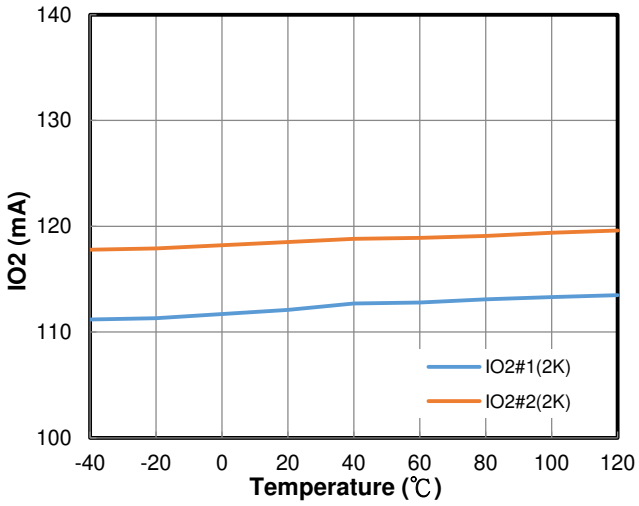


Figure 5. IO2 vs. Temperature

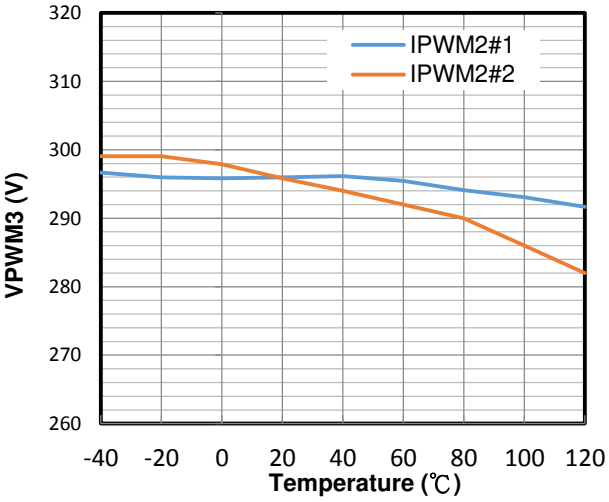


Figure 6. IPWMX vs. Temperature

APPLICATION INFORMATION

TS19605CA20H is a 3 channel Linear LED driver with PWM and Analog dimming. It designs with constant source current of PWMX pin for linear current decrease by NTC resistor or difference each current level by resistor. The device has wide input operation voltage from 4.5 to 70V and provide three high side drivers for LED current configured. the driver current can up to 400mA per channel by cascade external PNP transistor. The device also provides V_{IN}-base reference voltage V_{REF} for cascade structure of PNP base current to share the power dissipation or use shunt resistor to share power dissipation.

TS19605CA20H monitor the fault conditions from the thermal, I_{OX}, V_{SNSX} and I_{SET} pin to report its status on the FLT and FLTS terminal. The Fault condition Include thermal shutdown, LED load open/short, single LED short and I_{SET} pin open/short. Two separate fault terminals allow maximum flexibility of fault-mode reporting to the MCU in case of an error.

Pin Definitions

VIN_X Pin

Power supply input for the TS19605 during normal operation. V_{IN1} major in IC bias current, V_{IN2} is for output driver current. The device will start up when V_{VIN} reaches 4.8V (typical) and will shut down when V_{VIN} voltage is below 4.5V (typical). For the signal LED short detection function. V_{VIN} must be reaches 9V (typical) and will shut down when V_{IN} voltage is below 8V (typical).

EN Pin

The EN pin can sense V_{IN} information by voltage divider resister setting or directly connect to V_{IN} pin. The device will enable on the device when V_{EN} over 2V.

GND Pin

GND is the reference node of internal circuit.

ISET Pin

The output current could be linearly adjusted through variable resister connected between I_{SET} and GND pin.

PWM_X Pin

A PWM and Analog dimming function is applied in TS19605CA20H. The Analog dimming range is an analog voltage from 0.8V to 2.4V and the PWM dimming function is the same pin of analog dimming. The current regulation is decided by duty cycle of external PWM signal. Built-in 300μA source current to decided analog dimming voltage by resistor or NTC application.

$VSNS_X$

The $VSNS_X$ pin can sense LED string information by voltage divider resister to define the single LED short condition.

APPLICATION INFORMATION (CONTINUE)

FLT/FLTS Pin

There are two separate fault terminals (FLT/FLTS) allow maximum flexibility of fault-mode reporting to the MCU. And they are I/O terminals for many control mechanisms as below table.

Fault Table

Fault Type	Fault Select	Condition	FAULT (V)	FAULTS (V)	IO_X (V)	IO_X (V)	IO_X (V)	Failure Removed	Fault Clear
SHORT	FAULT & FAULTS Floating	IO_X Short GND V(VIN) > 5V; V(IOUTX) < 0.9V	Pulled Low	Pulled Low	OFF	OFF	OFF	Latch	Restart (EN)
		IO_X Single LED short V(VIN) > 9V; V(VSNSX) < 1.2V	Pulled High	Hiccup	ON	ON	ON	Latch	Restart (EN)
	FAULT & FAULTS Externally Pulled High	IOX Short GND V(VIN) > 5V; V(IOUTX) < 0.9V	Pulled High	Pulled Low	OFF	ON	ON	Latch	Restart (EN)
		IO_X Single LED short V(VIN) > 9V; V(VSNSX) < 1.2V	Pulled High	Pulled High	ON	ON	ON	Latch	Restart (EN)
OPEN	FAULT Floating	Iout1 OPEN; V(VIN) > 5V V(VIN)-V(IOX) <300mV	Pulled Low	Pulled High	OFF	OFF	OFF	Auto recover	Auto recover
	FAULT Externally Pulled High	Iout1 OPEN; V(VIN) > 5V V(VIN)-V(IOX) < 300mV	Pulled High	Pulled High	OFF	ON	ON	Auto recover	Auto recover
Thermal shutdown	FAULT Floating	V(VIN) > 5V Temperature >165°C	Pulled Low	Pulled Low	OFF	OFF	OFF	Temperature < 155°C	Auto recover
ISET Pin open or short	FAULT Floating	RREF > 200kΩ V(VIN) > 5V	Pulled Low	Pulled Low	OFF	OFF	OFF	Latch	Restart (EN)
	FAULT Floating	RREF < 400Ω V(VIN) > 5V	Pulled Low	Pulled Low	OFF	OFF	OFF	Latch	Restart (EN)

IO_X Pin

This is the current output pin to driver LED load. The output current can be expressed as below.

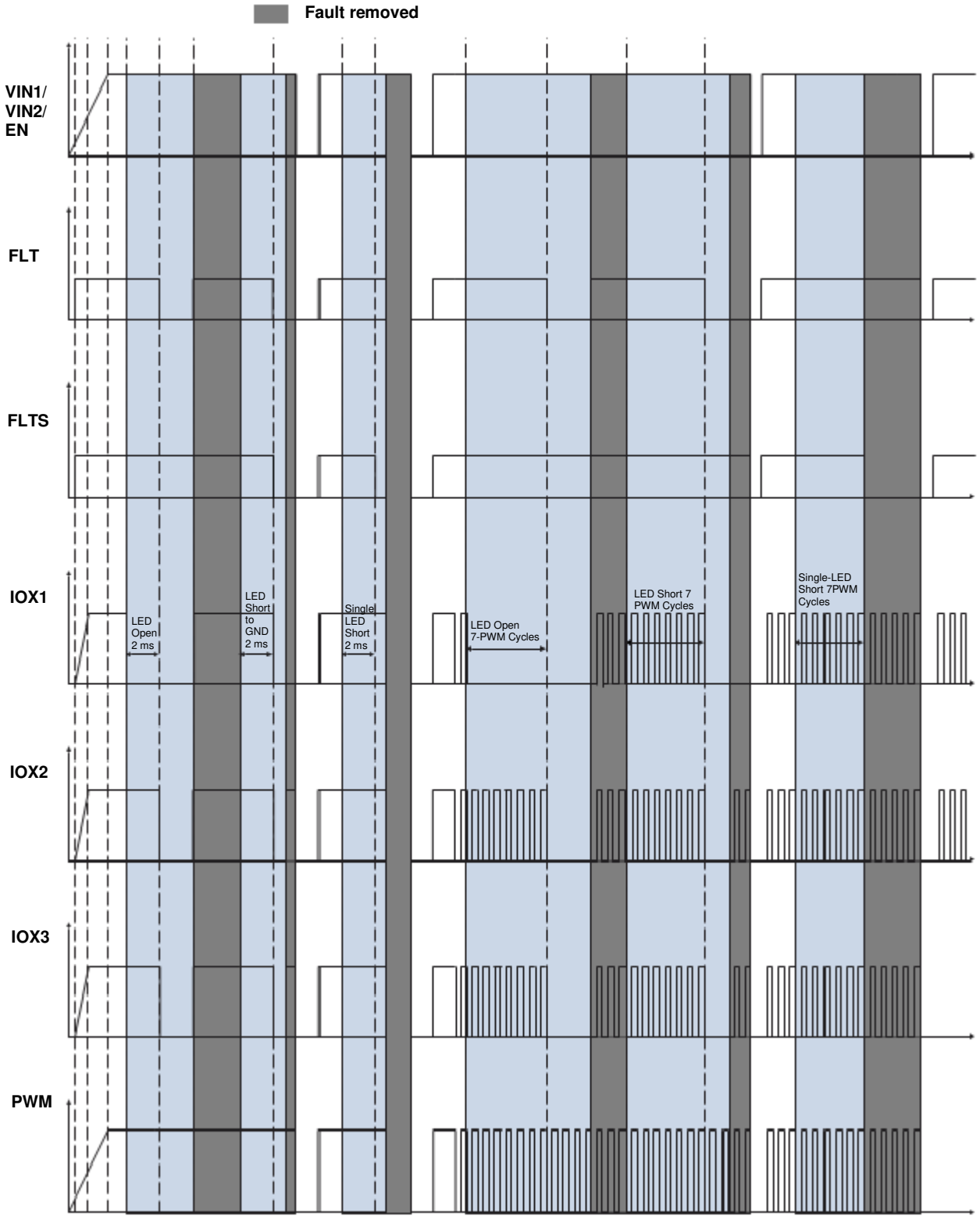
$$IOA_X = IOB_X = 0.5 \times K_I \times \frac{V_{ISET}}{R_{ISET}} = 0.5 \times IO_X$$

Where:

- K_I is the ratio of current factor
- V_{ISET} is the internal reference voltage (1.2V)
- R_{ISET} is the sensing resistor connected between ISET pin and the GND

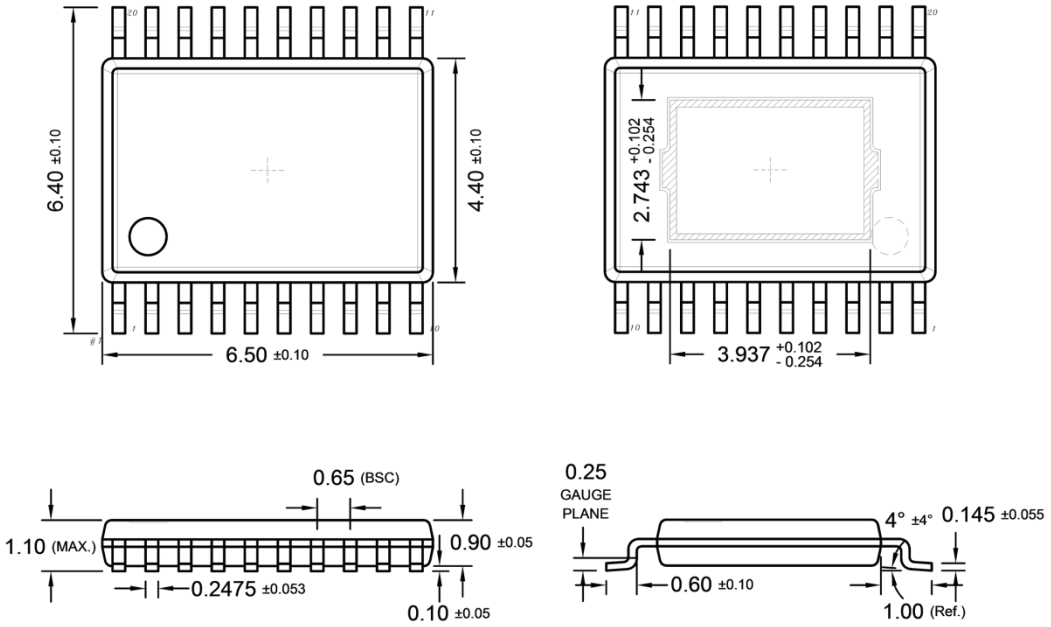
APPLICATION INFORMATION (CONTINUE)

Detail Timing Diagram

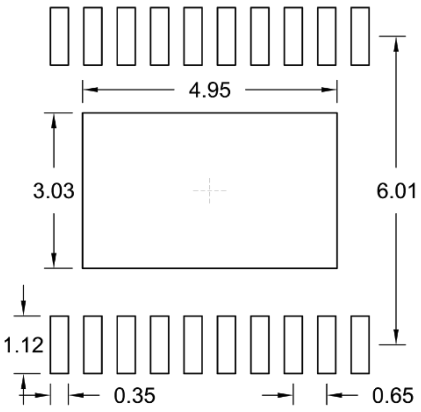


PACKAGE OUTLINE DIMENSIONS (Unit: Millimeters)

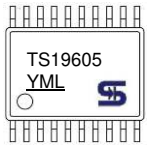
TSSOP-20EP



SUGGESTED PAD LAYOUT (Unit: Millimeters)



MARKING DIAGRAM



Y = Year Code

M = Month Code for Halogen Free Product

O	=Jan	**P**	=Feb	**Q**	=Mar	**R**	=Apr
S	=May	**T**	=Jun	**U**	=Jul	**V**	=Aug
W	=Sep	**X**	=Oct	**Y**	=Nov	**Z**	=Dec

L = Lot Code (1~9, A~Z)

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