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AP2152

3CH High Power WLED Driver

DESCRIPTION

The AP2152 is a 3 channel white LED driver IC. It is composed of a current mode DC/DC boost converter with an internal power MOSFET and 3 channel constant current sources, which can drive up to 10 LEDs per channel for a maximum of 30 LEDs.

The AP2152 achieves ±0.8% typ. LED current matching between each channel when the LED current is set at 75.8mA. The LED current can be run up to a maximum of 120mA with the appropriate external set resistor on the ISET pin.

The AP2152 operates over a wide input voltage range from 4.25V to 35V, and the switching frequency goes up to a maximum of 2.5MHz with the appropriate external set resistor on the RT pin. The switching frequency can also be synchronized with an external signal.

The AP2152 provides the LED dimming function via an external PWM signal, with a frequency range from 100Hz to 20KHz.

The AP2152 provides LED open protection, LED short protection, OVP pin short protection, channel short protection, over voltage protection, over current protection, thermal protection and UVLO.

FEATURES

- **White LED driving number: Maximum 30 pieces (10 pieces in series x 3 in parallel)**
- **LED current matching: ±0.8% typ. (I_{LED}=75.8mA)**
- **LED maximum current: 120mA**
- **Maximum switching frequency: 2.5MHz**
- **PWM dimming frequency by applying external signal: Maximum 20kHz**
- **Input voltage range: 4.25V~35V**
- **Built-in 45V power MOSFET**
- **Error flag through serial interface**
- **Synchronize with External frequency**
- **Master – Slave configuration**
- **LED open protection**
- **LED short protection**
- **OVP pin short protection**
- **Output channel short protection**
- **Overvoltage protection (OVP)**
- **Over current protection**
- **Thermal protection**
- **UVLO**
- **20 pin HTSSOP with heat-sink package**

APPLICATIONS

- **Display backlight**
- **Lighting equipment**

BLOCK DIAGRAM

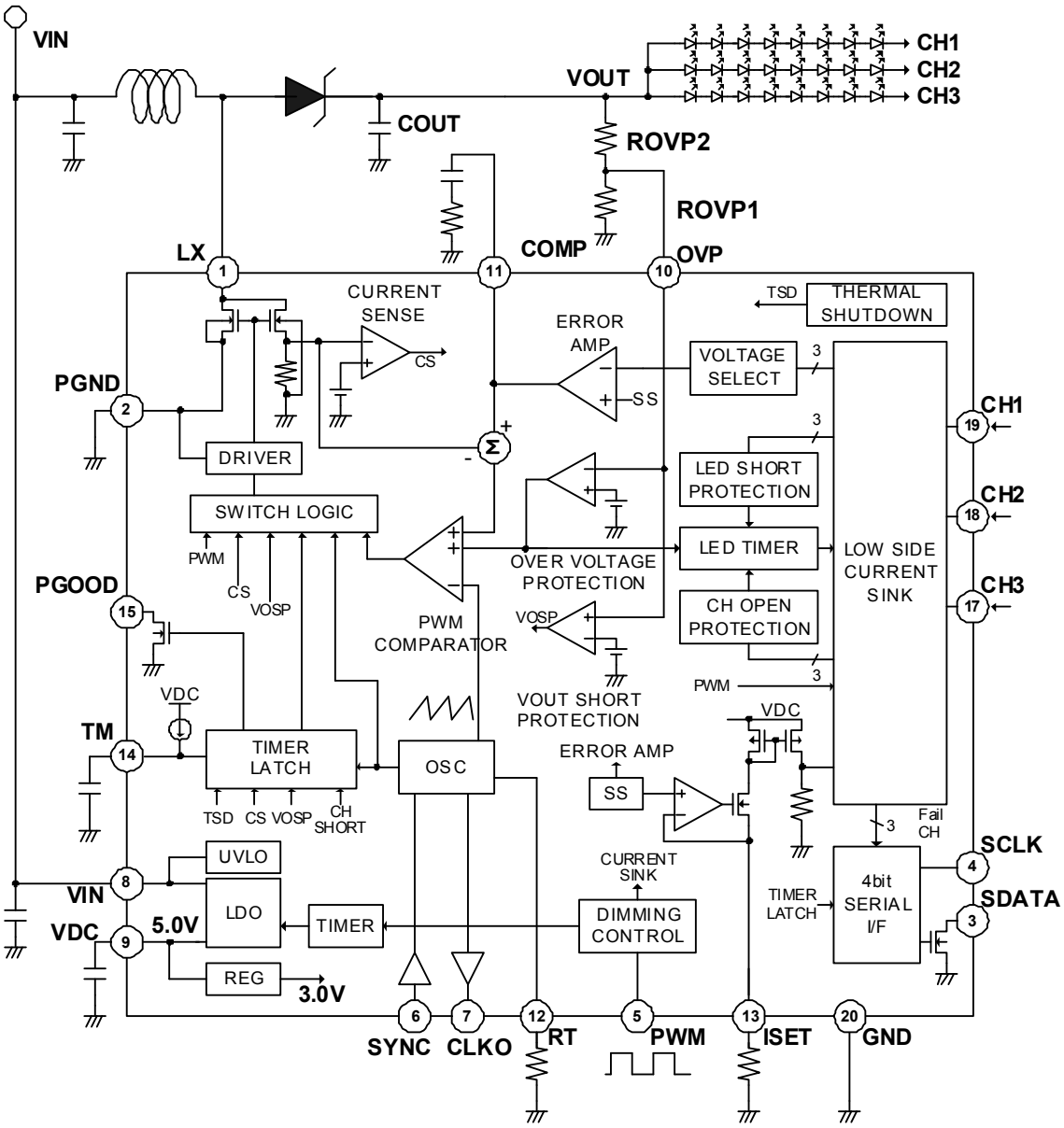


Figure 1. AP2152 Block Diagram

PIN LAYOUT and APPLICATION CIRCUIT EXAMPLE

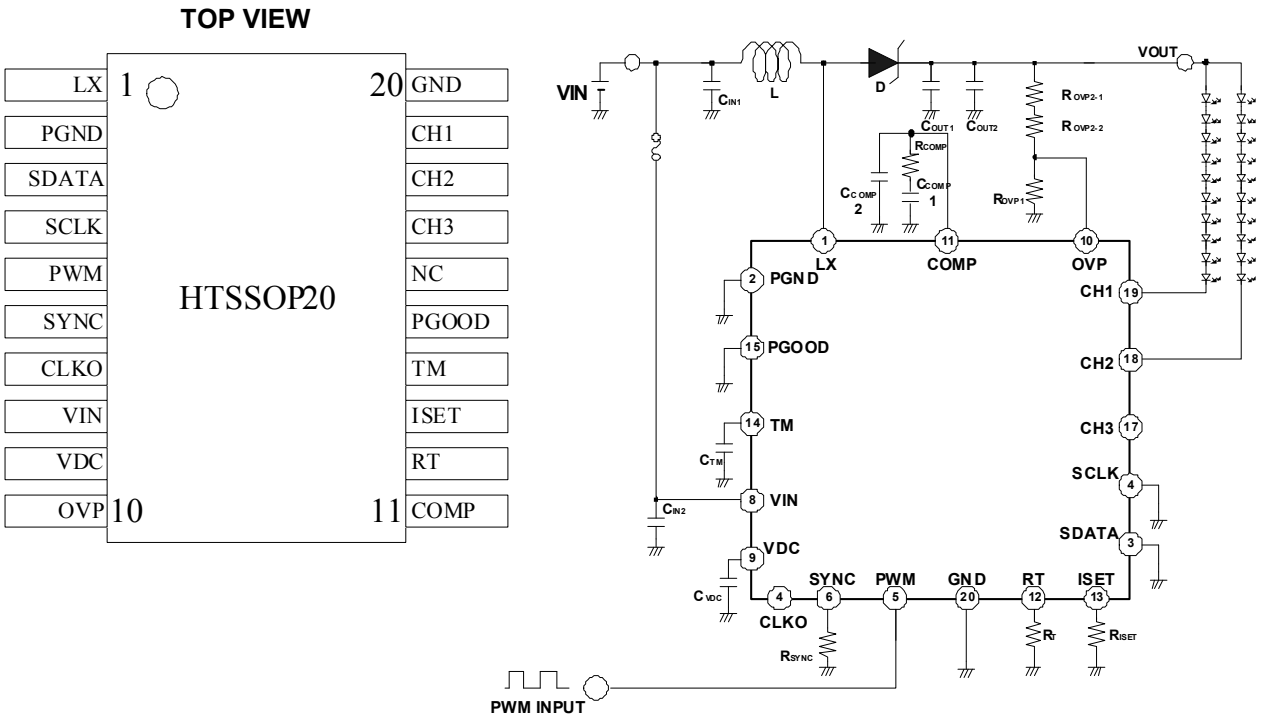


Figure 2. AP2152 Pin Layout and a circuit example

PIN DESCRIPTION

Pin No.	Pin Name	Function
1	LX	Power MOSFET pin. Nch MOSFET open-drain. If 2.6A or higher current is detected on this pin, over-current protection circuit is activated.
2	PGND	GND for power MOSFET
3	SDATA	Data output from serial interface. Nch open-drain output. The output data will be synchronized with the clock input on the SCLK pin.. When the data function is unnecessary please connect to GND.
4	SCLK	Clock input for serial interface. When the clock function is unnecessary please connect to GND.
5	PWM	PWM dimming signal input pin. Built-in 200kΩ pull down resistor. This also functions as the enable input, and if this pin goes to a high level, the IC is changed from the stand-by state to the enable state, the internal LDO is activated, and the boost operation begins. If this pin goes to a low level, the internal timer starts counting, 30msec later the IC goes into the standby state.
6	SYNC	Clock input pin for synchronous operation. Built-in 1MΩ pull-down resistor. If the synchronous operation is unnecessary, please connect to GND.
7	CLKO	Internal clock output pin. If the clock function is unnecessary, please keep this pin open.
8	VIN	Power input pin. Internal LDO input to provide power for internal circuits. 1.0μF should be connected between the VIN pin and GND.
9	VDC	Internal LDO output pin. 5V output by regulating from VIN. Maximum output current is 30mA. 1.0μF should be connected between the VDC pin and GND.
10	OVP	Over voltage protection detection circuit input pin. The voltage at the OVP pin is the LED Anode voltage divided by the resistor divider. If the voltage exceeds 1.2V, the boosted LED anode voltage will be suppressed. If the voltage goes below 0.1V, the OVP pin short protection circuit is activated.
11	COMP	DC/DC boost converter phase compensation pin. A resistor and a capacitor should be connected between the COMP pin and GND.

Pin No.	Pin Name	Function
12	RT	Switching frequency set pin. Oscillation frequency can be set by connecting a resistor between the RT pin and GND. Please refer to section 2.4 “Switching frequency setting/Function of synchronizing with external clock”.
13	ISET	LED driving current set pin. LED current can be set by connecting a resistor between the ISET pin and GND. Please refer to section 2.3 “LED current setting”.
14	TM	Capacitor connection pin for timer. If an abnormality occurs in the IC, this pin outputs 10μA constant current. If this pin voltage exceeds 2.0V, the IC ceases its operation. By returning to the standby state, the timer is reset and the IC can be released. When the timer is unnecessary, please connect to GND. Please refer to section 2.6 “Timer latch (TM) setting”.
15	PGOOD	Power Good pin. N channel open-drain, it keeps OFF when normal operation. If an abnormality occurs in the IC, the operation is latched off by timer latch function and internal FET turns ON. Please refer to “Protections description” for the detail of Power Good pin status described later. When the power good function is unnecessary, please connect to GND.
16	NC	NC pin.
17	CH3	WLEDs constant current circuit 3. CH3 is open drain, and provides constant current to the LEDs. If this constant current channel is unnecessary, please keep this pin open.
18	CH2	WLEDs constant current circuit 2. CH2 is open drain, and provides constant current to LEDs. If this constant current channel is unnecessary, please keep this pin open.
19	CH1	WLEDs constant current circuit 1. CH1 is open drain, and provides constant current to LEDs. If this constant current channel is unnecessary, please keep this pin open.
20	GND	GND pin for internal circuits.
-	THERMAL PAD	For heat radiation, connection to GND is recommended. This is electrically isolated from the internal circuit.

ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit	Condition
VIN voltage	V_{IN}	-0.3 to +45	V	*1
LX, CH1-3 Voltage	V_{LX}, V_{CH}	-0.3 to +45	V	*1
SDATA, SCLK, PWM,VDC, PGOOD, SYNC voltage	-	-0.3 to +6	V	*1
OVP, COMP, RT, ISET, TM, CLKO voltage	-	-0.3 to (V_{DC} + 0.3)	V	*1*4
CH1-3 current	I_{CH}	140	mA	
PGOOD current	I_{GOOD}	20	mA	
Power Dissipation	P_D	2500	mW	*2, *3
Operating Temperature Range	T_{OP}	-40 ~ +105	°C	
Storage Temperature Range	T_{STG}	-55 ~ +150	°C	

Note:

*1. All voltages refer to GND pin (GND, PGND) as zero (reference) voltage.

*2. PD must be decreased at the rate of 23.3mW/°C for operation above 25°C.

*3. Mounted on a 50 mm × 50 mm x 1 mm double sided FR-4 board.

*4. The maximum value is limited to 6.0V if V_{DC} exceeds 5.7V.

Note: The maximum ratings are the absolute limitation values with the possibility of damage/breakage. When operation exceeds this standard, quality cannot be guaranteed.

ELECTRICAL CHARACTERISTICS

V_{IN}=12V, GND=PGND=0V, R_{ISET}=36kΩ, R_T=91kΩ, PWM=5V, T_A=+25°C unless otherwise specified.
Items marked by● are guaranteed by design in the range of -30℃ to +85℃.

Parameter	Symbol		Value			Unit	Condition
			MIN	TYP	MAX		
DC/DC Converter							
Input voltage Range	V_{IN}	●	4.25		35	V	
Supply Current(SW ON)	I_{DD}			5	10	mA	
Standby Current	I_{STB}			5.0	10	μA	After start up PWM =0V *1
UVLO Voltage	V_{UVLO}		3.75	4.0	4.25	V	UVLO On V_{IN}
UVLO Hysteresis Width	V_{HYS_UVLO}			0.2		V	UVLO Off V_{IN}
Switching Frequency	F_{OSC}		1.86	2.0	2.14	MHz	R_T=55kΩ
		●	1.80	2.0	2.17	MHz	
			1.21	1.3	1.39	MHz	R_T=91kΩ
		●	1.18	1.3	1.42	MHz	
LX On Resistance	R_{LX}			400	800	mΩ	I_{LX}=+30mA
LX Off Leak Current	I_{LEAK_LX}			0.1	1.0	μA	V_{LX}=45V
Maximum On Duty	D_{MAX}		90	95		%	F_{OSC}=1.3MHz
LX Minimum On Time	T_{LX_MIN}	●			50	ns	
COMP Output High Voltage	V_{OH_COMP}		4.55	4.9		V	I_{COMP}=-10μA
COMP Output Low Voltage	V_{OL_COMP}			0.1	0.2	V	I_{COMP}=+10μA
Error Amp Reference Voltage	V_{REF_EA}		680	800	920	mV	R_{ISET}=36 kΩ
		●	600	800	1000	mV	
Current Sink Circuit and Dimming Part							
LED Current Range	I_{LED}	●	10		120	mA	
LED Current	I_{LED_TYP1}		73.15	75.8	78.46	mA	R_{ISET}=36kΩ $I_{LED\_TYP}(mA) = \frac{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}}{2}$
		●	72.39	75.8	79.21	mA	R_{ISET}=36kΩ $I_{LED\_TYP}(mA) = \frac{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}}{2}$
	I_{LED_TYP2}		28.8	30.0	31.2	mA	R_{ISET}=91kΩ $I_{LED\_TYP}(mA) = \frac{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}}{2}$
		●	28.5	30.0	31.5	mA	R_{ISET}=91kΩ $I_{LED\_TYP}(mA) = \frac{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}}{2}$
	I_{LED_TYP3}	●	62.08	65.0	67.93	mA	R_{ISET}=42kΩ $I_{LED\_TYP}(mA) = \frac{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}}{2}$

Electrical Characteristics (continuation)

Parameter	Symbol		Value			Unit	Condition
			MIN	TYP	MAX		
LED Current Accuracy Between Channels	ΔI_{LED1}		-2.5	±0.8	+2.5	%	R_{ISET}= 36kΩ, I_{LED_TYP}=75.8mA $\triangle I_{LED}(\%) = \frac{I_{CH(1-3)MAX} - I_{CH(1-3)MIN}}{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}} \times 100$
	ΔI_{LED2}		-5.0	±1.5	+5.0	%	R_{ISET}= 91kΩ, I_{LED_TYP}=30.0mA $\triangle I_{LED}(\%) = \frac{I_{CH(1-3)MAX} - I_{CH(1-3)MIN}}{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}} \times 100$
	ΔI_{LED3}	●	-2.5	±0.8	+2.5	%	R_{ISET}= 42kΩ, I_{LED_TYP}=65.0mA $\triangle I_{LED}(\%) = \frac{I_{CH(1-3)MAX} - I_{CH(1-3)MIN}}{I_{CH(1-3)MAX} + I_{CH(1-3)MIN}} \times 100$
LED Current Delay Time	tr	●		1	2	μs	LED Current Rising Time to PWM Input R_T=55kΩ
	tf	●		0.5	1		LED Current Falling Time to PWM Input R_T=55kΩ
LDO							
Output Voltage	V_{DC}		4.75	5.0	5.25	V	V_{IN}=12V, I_{DC}=10mA
		●	4.50	5.0	5.50	V	
Protection Function							
OVP Reference Voltage	V_{OVP}	●	1.15	1.2	1.25	V	
LED Short Criterion Voltage	V_{SHT}		10.8	12	13.2	V	CH1~CH3 pin
LX Limited Current	I_{LX_LIMIT}			2.6		A	
PGOOD On Resistance	R_{PGOOD}				100	Ω	I_{PGOOD}=+10mA
TM Voltage	V_{TM}		1.9	2.0	2.1	V	
TM Constant Output Current	I_{TM}		8	10	12	μA	TM=1.0V
Switching Frequency Range	F_{OSC}	●	0.2		2.5	MHz	
Input High Level Voltage	V_{IH}	●	2.1			V	PWM, SCLK, SYNC
Input Low Level Voltage	V_{IL}	●			0.7	V	PWM, SCLK, SYNC
CLKO Output High Level Voltage	V_{OH_CLKO}		4.0			V	I_{CLKO}=-1mA
CLKO Output Low Level Voltage	V_{OL_CLKO}				0.3	V	I_{CLKO}=+1mA

*1.
Normally, when 4.25V is applied to VIN for shorter than 100μs, while the PWM pin is kept at a low level, the IC will be in the standby mode.
However, if 4.25V is applied to VIN for longer than 300μs, the current consumption of the IC is about 900μA. In order to get the IC into standby mode, after inputting a H level to the PWM pin for more than 36μs , a L level needs to be maintained for more than 50ms.

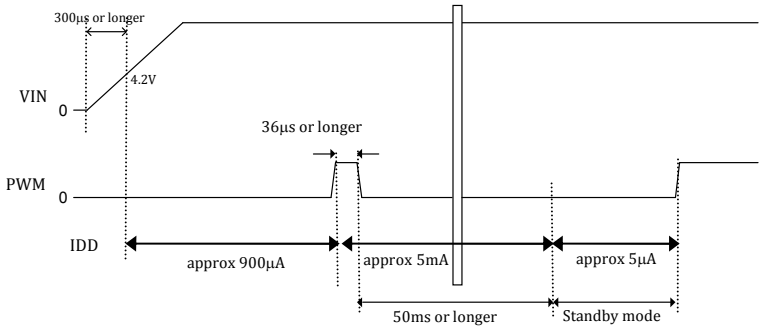


Figure 3. Power Supply Rising Time and Standby mode

Interface (AC Timing)

Parameter	Symbol		Value			Unit	Condition
			MIN	TYP	MAX		
PWM							
PWM Minimum High Time 1	T_{PWM_MIN1}			15	30	μs	Before Startup
		●		15	36	μs	Before Startup
PWM Minimum High Time 2	T_{PWM_MIN2}	●		5	7	μs	After Startup
Shutdown Time	T_{SD}	●	20	30	50	ms	
PWM Dimming Frequency Range	F_{PWM}		0.1		20	kHz	$F_{PWM} \leq F_{OSC}$ / 65
SYNC							
SYNC Input Frequency Range	F_{SYNC}	●	0.21		2.5	MHz	
SYNC Input Duty	D_{SYNC}	●	20		80	%	
Serial Timing							
SCLK Cycle	t_{SCKP}		10			μs	
SCLK Pulse Width	t_{SCKW}		5			μs	
SDATA Delay	t_{SDTW}		3			μs	

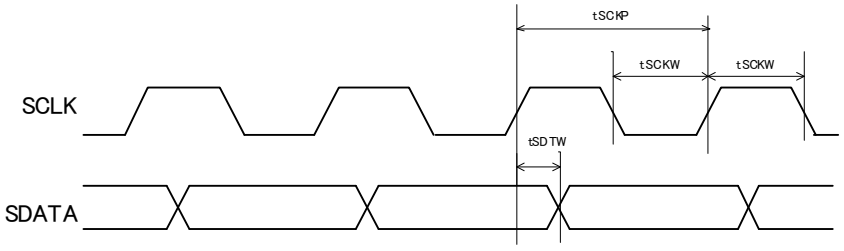


Figure 4. Serial Interface Wave Form

OPERATION

1) Operation Outline

The AP2152 is composed of a current mode DC/DC boost convertor, 3 LED constant current source channels, an LDO, and several protection circuits. It can drive a single LED line to three LED lines connected together with a common anode. (Any unused channel should be left open)
This current mode DC/DC boost convertor has a built-in a power MOSFET, and the switching frequency is determined by an external resistor or an external clock signal. The LED anode voltage is optimized by monitoring each channel's voltage and the channel voltage that has the highest forward voltage is chosen. This voltage is used to control the DC/DC boost convertor's output voltage . constant current circuits for driving the LEDs are set by an external resistor, and PWM dimming is possible by applying a PWM signal to the PWM pin. The latch-off time for the protection circuits, such over current protection, channel short protection, and thermal protection can be set. There is also a PGOOD pin to output the latch-off status.

The AP2152 flowchart at startup is shown in Figure 5.

When all CH pins are used, applying a PWM signal begins the DC/DC boost convertor operation. The LED anode voltage rises, and if the LED current of all the CH reaches 1/10 of the set current, the soft-start circuit is activated and the LED current gradually increases in approximately 1ms, and LEDs are lit.

If there are any unused CH pins, the LED open detection circuit is activated at the beginning of the DC/DC boost converter operation as soon as the PWM signal is applied. When the LED anode voltage reaches the OVP preset value, the OVP state is detected. If a CH pin has not reached 1/10 of the LED set current, an open state is recognized, and the LED constant current circuit will cease. For CH pins connected to LEDs, the LED current reaches 1/10 of the set current, the normal connection is recognized, and the LEDs are lit after the soft-start operation.

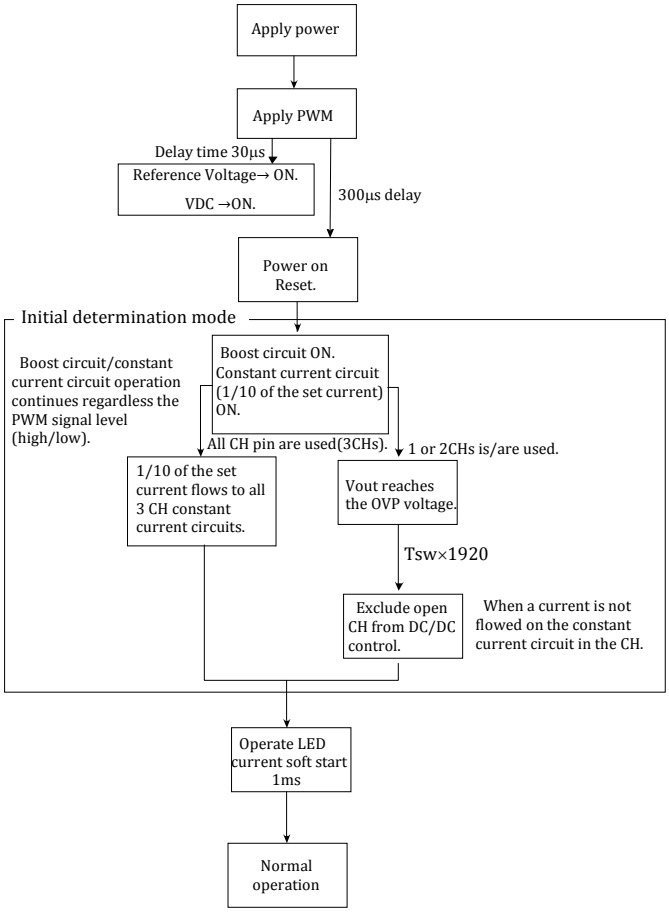


Figure 5. Flowchart at startup

2) Functions

2-1) PWM Input circuit

The AP2152 achieves PWM dimming by applying a PWM signal to the PWM pin. The PWM pin is also used as the enable function of the IC.

At startup, if a high level PWM signal is applied to the PWM pin and maintained for more than 36us, the standby mode will be released. If the high level of PWM signal within the range of 50Hz~20kHz($F_{PWM} \leq F_{OSC} / 65$), is applied longer than 7us to the PWM pin after releasing the standby mode, the operation mode is maintained and direct PWM dimming by PWM signal is simultaneously conducted. The LED current will be the set current configured by the R_{ISET} resistor during a high level of the PWM dimming signal, and the current will be 0mA during a low level of the PWM dimming signal.

If a low level PWM signal is maintained longer than 50ms after the LED is lit, the IC will be in the standby mode.

2-2) 5V Regulator

The AP2152 has a built in low dropout linear regulator to supply voltage for the internal circuits. If a low level is applied to the PWM pin, the VDC is approximately 0V, and if a high level is applied to the PWM pin, the VDC outputs 5V. The VDC pin, the output of the LDO, outputs 5V while the supply voltage ranges from 6V to 35V. If the supply voltage is less than 6V, the output voltage decreases depending on the supply voltage. If the supply voltage goes below the UVLO voltage, the IC ceases operation. If the supply voltage is between the UVLO voltage and 6V, the IC operates but the characteristics are not guaranteed.

Please connect 1uF capacitor between the VDC pin and GND.

2-3) LED current setting

The AP2152 has 3 channel LED constant current circuits built in. By connecting 10 LEDs in series per channel, a maximum of 30 LEDs can be driven. Maximum LED current per channel is 120mA. The LED current can be set in the range from 10mA to 120mA by connecting an external resistor R_{ISET} between the ISET pin and GND. If the ISET pin is affected by noise, the LED current becomes unstable, so R_{ISET} should be placed as close to the IC as possible. The ISET pin sets the LED current for all channels. (CH1~CH3)

The following shows the approximate expression for the LED current and the R_{ISET} connected to the ISET pin. Please check the LED current (thoroughly) when designing the actual board.

$$ILED(mA) = \frac{2730}{R_{ISET}(k\Omega)}$$

2-4) Switching frequency setting/Synchronize with external clock

The AP2152 can set the DC/DC boost converter switching frequency in the range from 0.2MHz to 2.5MHz by connecting an external resistor RT between the R_T pin and GND. If the RT pin is affected by noise, the switching frequency becomes unstable, so R_T should be placed as closer to the IC as possible.

The AP2152 switching frequency can be synchronized to an external clock signal. If an external clock signal is applied to the SYNC pin, the switching frequency synchronizes to the external clock's rising edge. If a low level is applied to the SYNC pin for approximately 10us during the synchronization operation, it becomes self-oscillating.

(If low level is applied to the SYNC pin in the synchronization operation for approximately 10us, it becomes self-oscillation operation.)

The external clock frequency and the switching frequency set by R_T should be the same.

The following shows the approximate expression of the switching frequency and R_T on the RT pin. Please check (thoroughly) when designing the actual board.

$$F_{OSC}(MHz) = \frac{10^3}{7.695 \times R_T(k\Omega) + 80}$$

2-5) Over voltage protection (OVP)/OVP pin short protection

In order not to exceed the internal MOSFET breakdown voltage, the AP2152 has built in over voltage protection. The OVP pin monitors the LED anode voltage divided by the resistor divider. If the OVP pin voltage exceeds 1.20V, the IC ceases boost operation. The LED constant current source maintains operation. If the OVP pin voltage becomes less than 1.20V, the boost operation is resumed.
The over current protection function prevents damage by suppressing an overvoltage condition (excessive LED anode voltage) when the load is reduced. This can occur when there is an open condition across one of the LED lines or when the supply voltage fluctuates rapidly.

$$\text{OVP Voltage} = (1 + \frac{R_{ovp2}}{R_{ovp1}}) \times \text{OVP Reference Voltage}$$

OVP reference voltage 1.2V (typ)

The OVP set voltage should be set more than the total voltage of the maximum forward voltage of the LED line plus the error amplifier reference voltage to correctly detect an LED open condition. However the total voltage needs to be less than the Nch power MOSFET maximum rating voltage.
The OVP pin short protection is built in. It is activated when the OVP pin voltage becomes less than 0.1V, which is caused by an open across the external Schottkey diode. If the OVP pin short protection is activated, the boost DC/DC convertor operation and the LED constant current circuit ceases, the internal FET for PGOOD is turned on.

2-6) Timer Latch (TM pin) setting

The AP2152 has a built in timer latch type protection circuit. The latch time for the protection circuit is set by connecting an external capacitor C_{TM} between the TM pin and GND. When channel short protection, over current protection, OVP pin short protection, or thermal protection is activated, C_{TM} which is connected to the TM pin is charged by a 10uA constant current. However, the TM pin becomes Hi-Z (high impedance) while PWM = low and the TM pin voltage is maintained.
When the protection circuits continue their operation, the charging of C_{TM} also continues. If the TM pin voltage reaches 2.0V, the DC/DC boost convertor and the LED constant current circuits are latched off and the internal FET for PGOOD is turned on.
In order to restart the IC after it has been turned off by the timer latch function, a low level for more than 50ms needs to be maintained on the PWM pin or the supply voltage needs to be pulled down below the UVLO voltage.
The following shows the approximate expression of the timer latch time and C_{TM} connected on the TM pin. Please check (thoroughly) when designing the actual board.
Timer latch time $T_{TM}(ms) = 200 \times C_{TM}(\mu F)$

2-7) Thermal protection

The AP2152 has a built in thermal protection circuit. If the IC goes into and maintains a high temperature state, the IC will be latched off, therefore the IC needs to be operating below the thermal protection circuit minimum (activation) temperature of 125°C.

2-8) LED open protection

The AP2152 can be operated with one, two or three channels connected. There is not a problem if a CH pin is left open. .
For this operation, the AP2152 has a built in LED open detection circuit. If an open CH pin is detected, the CH pin becomes a high impedance and is excluded from the control circuit of the DC/DC boost converter.
If all three CH pins are open, the DC/DC boost converter and the LED constant current circuits are completely turned off. If a capacitor is connected in parallel with the LED line and the LED line is opened, the open detection circuit may not work correctly.

2-9) LED short protection and Cout setting

The AP2152 has a built in LED short protection circuit. If an LED is broken as a short state and the CH pin voltage exceeds 10.8V, the corresponding constant current circuit will be ceased.

If there is an unused CH pin, the LED anode voltage increases up to the OVP setting voltage by the LED open detection circuit. In this case, the CH pin temporarily increases and becomes the same state as the LED short protection, in order to distinguish this case from LED short protection operation, the opened CH pin is excluded using the IC internal counter. For this operation, the Cout value is constrained, so Cout should be determined using the following formula.

LED short protection count time > CH pin voltage rising time (10.8V or higher)

$$①\text{LED short protection count time} = \frac{1}{Fsw} \times 1920$$

$$②\ \text{CH pin voltage rising time} = \frac{Cout \times (Vovp(max) - LEDVf(min) - 10.8V)}{Iout \times 0.95}$$

2-10) PGOOD function

The PGOOD pin is an Nch open drain output. The internal FET on the PGOOD pin stays off when the supply voltage is 0V (If the PGOOD pin is connected to a pull-up resistor, the PGOOD pin becomes high level) If the supply voltage reaches to approximately 2V, the internal circuits are biased and the internal PGOOD FET turns on. If the supply voltage is more than UVLO and the PWM pin is high, the standby circuit will be released, the IC recognizes as normal operation and the internal PGOOD FET turns off. If a protection circuit is activated after normal operation, the internal PGOOD turns on. (Relationship between protection function and the PGOOD pin state is later described in “Protection Function”). By applying a PWM low level for longer than 50ms, the IC will be reset and the internal PGOOD FET turns on in a standby state.

When the LED anode is shorted to GND, the internal PGOOD FET immediately is turned on by the OVP pin short circuit protection and the PGOOD signal can be used to cut the path from VIN to the LED anode. (Refer to Figure 7)

The AP2152 employs a timer latch method for protection functions. If the FET over current protection, thermal protection, CH short protection, LED open protection, or LED short protection is activated, the IC is latched off and turns off the LEDs.

For example, when the PGOOD pin is monitored by a microcomputer and an abnormal state (PGOOD pin with pull-up resistor is low level) is detected, the microcomputer controls a restart sequence after the IC is reset, so a highly stable system configuration is possible.

Internal Nch FET on PGOOD pin operation

●Turn off during normal operation

●Turn on when abnormal operation

Timer latch off (Over current, CH short, Thermal protection), all CH are open or short, UVLO

●Turn on when in standby state while supply voltage (VIN) is applied. Turn off when VIN is less than 2V

●Turn on without delay by timer circuit when OVP pin short is detected.

VIN → PWM

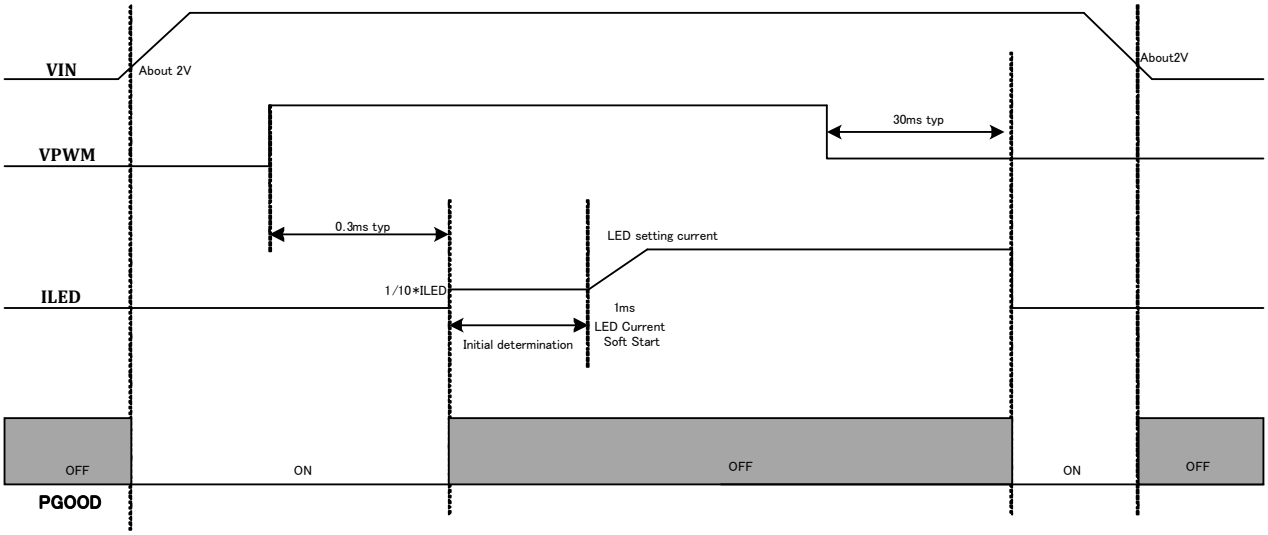


Figure6. PGOOD pin operation

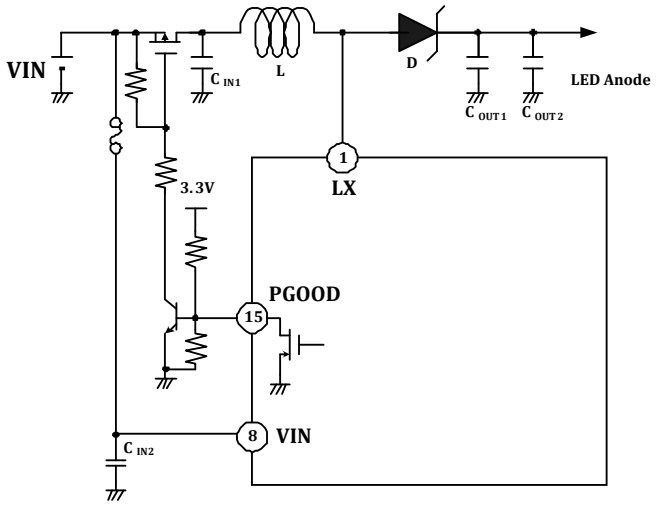


Figure7. Cut off VIN-LED anode path by using an external FET (example)

2-11) Serial interface

The AP2152 has a built in read only serial interface. By inputting a CLK signal to the SCLK pin, data can be read from the SDATA pin synchronizing with the CLK rising edge. The SDATA pin is an Nch open drain output. The pin needs to be pulled-up to the external power supply.

	SDATA	State
CH1	Low	LED OPEN or SHORT ⇒ CH1 shutoff
CH2	Low	LED OPEN or SHORT ⇒ CH2 shutoff
CH3	Low	LED OPEN or SHORT ⇒ CH2 shutoff
TM	Low	Shut-off state by timer latch

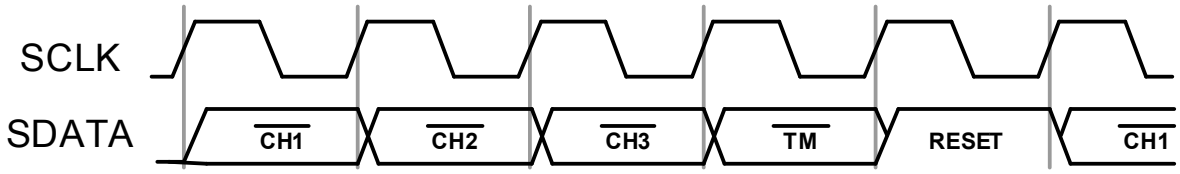


Figure8. Serial Interface Timing Chart

3) Protection Function

Protection	Description	Detection time Shut-off state	Detection condition	Release condition	PGOOD
Thermal	When the IC temperature rises and reaches the detection condition and exceeds the detection time, the DC/DC boost converter and the LED constant current circuit are latched off.	T_{TM} *2 Latch off	125℃min	*1	ON
Over current	Internal Nch power MOSFET drain current is monitored by using an internal detection resistor. If exceeding the detection condition, the power MOSFET is turned off. And if exceeding the detection time, the DC/DC boost converter and the LED constant current circuit are latched off.	T_{TM} *2 Latch off	2.6A	*1	ON
Over voltage (OVP)	If the OVP pin voltage reaches the detection condition, the DC/DC boost converter is immediately shut off. In this case, the LED constant current circuit is still operating	LED anode voltage control Auto-release	More than 1.2V	1.2V or less	OFF
OVP pin short	If the OVP pin reaches the detection condition caused by the OVP pin shorted to GND, the LED anode shorted to GND or the Schottky diode open, the DC/DC boost converter and the LED constant current circuit are immediately shut off and the internal PGOOD FET is turned on. If the OVP pin voltage reaches the release condition, normal operation is resumed. If exceeding the detection time, the DC/DC boost converter and the LED constant current circuit are latched off.	Cease all Auto-release ↓ T_{TM} *2 Latch off	Lass than 0.1V	More than 0.1V ↓ *1	ON
UVLO	To prevent malfunction of the IC when the VIN voltage reaches the detection condition. Circuits excluding the UVLO circuit stop the operation. If the VIN voltage returns to the release condition, the IC resumes normal operation.	Cease all Auto-release	3.75Vmin	4.45Vmax	ON
LDO short	To prevent malfunction and over heating of the IC when the VDC pin shorts to GND. The LDO current is limited to low levels. If the short state goes away, the IC resumes normal operation.	Cease all Auto-release	More than 30mA	30mA or less	OFF
CH short	When the CH pin shorts to GND, the voltage reaches the detection condition, and exceeds the detection time, the DC/DC boost converter and the LED constant current are ceased.	T_{TM} *2 Latch off	0.1V	*1	ON
LED open	If the CH pin is opened due to an LED disconnection or destruction as an open state, the CH pin is latched off.	Internal timer each CH Latch off	Less than LED set current when OVP Voltage	*1	OFF *3
LED short	If the CH pin voltage reaches the detection condition due to destruction by an LED short, the CH pin is latched off.	Internal timer each CH Latch off	12V	*1	OFF *4
ISET short	To prevent heat generation due to increases in the LED current when the ISET pin shorts to GND, the Nch power MOSFET operation is ceased. If the short state goes away, the IC resumes the normal operation.	Cease Nch Power MOSFET Auto-release	ISET pin GND short	ISET pin normal 1V	OFF
RT short	To prevent heat generation due to increases in the switching frequency when the RT pin shorts to GND, the Nch power MOSFET operation is ceased. If the short state goes away, the IC resumes the normal operation.	Cease Nch Power MOSFET Auto-release	RT pin GND short	RT pin Normal 1V	OFF

Note:

*1. In order to release the latch off state, the PWM pin should be maintained at a low level for 50ms or longer or the supply voltage should be pulled down less than the UVLO voltage.

*2. Set time by external capacitor on the TM pin. Refer to the timer latch setting.

*3. OFF when 1 CH or 2 CHs out of 3 CHs is/are open state, ON when all 3 CHs are open state.

*4. OFF when 1 CH or 2 CHs out of 3 CHs is/are short state, ON when all 3 CHs are short state.

APPLICATION (example)

Input voltage	Vin=8.5V~16V
LED	2 lines in parallel
LED anode voltage	9 LEDs in series 22.3V-32.6V
LED current	55mA/line

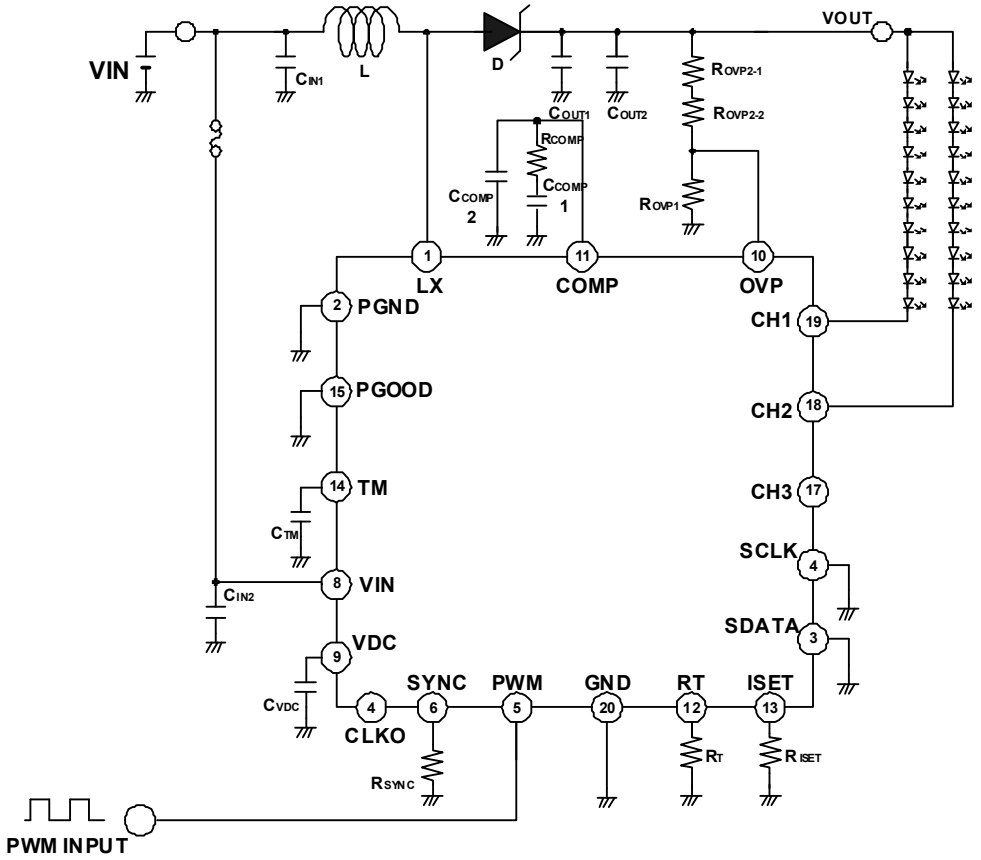


Figure 9. External circuit connection example

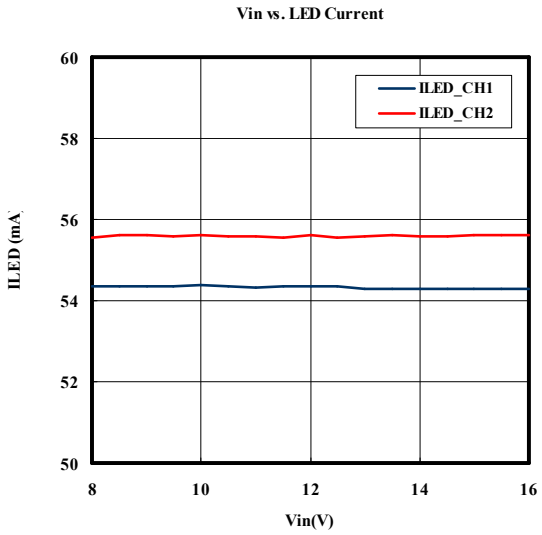
A recommended BOM

	Symbol	P/N	Value	Maker	Note
Resistor	R_T	-	55kΩ ±0.5%	-	SW frequency 2MHz
	R_{OVP1}	-	30kΩ ±0.5%	-	OVP voltage 37.2V
	R_{OVP2-1}	-	430kΩ ±0.5%	-	OVP voltage 37.2V
	R_{OVP2-2}	-	470kΩ ±0.5%	-	OVP voltage 37.2V
	R_{ISET}	-	49.7kΩ ±0.5%	-	LED current 55mA
	R_{COMP}	-	1kΩ ±1%	-	Phase compensation
	R_{SYNC}	short	0Ω	-	Self resonant freq.
Capacitor	C_{IN1}	GRM31CR71H475K	4.7uF/50V	MURATA	Input capacitor
	C_{IN2}	CM21X5R105M50A	1.0uF/50V	KYOCERA	Capacitor for the IC
	C_{VDC}	CM05X5R105M06A	1.0uF/6.3V	KYOCERA	For VDC stability
	C_{TM}	CM05X5R104M10A	0.1uF/10V	KYOCERA	Timer latch setting
	C_{COMP1}	CM05X5R473M16A	0.047uF/16V	KYOCERA	Phase compensation
	C_{COMP2}	open	-	-	-
	$C_{OUT1,\ 2}$	GRM31CR71H225K	2.2uF/50V	MURATA	Output capacitor
Diode	D	-	60V, Io=1A	-	-
Inductor	L	#A921CY-150M	D63LCB 15uH	TOKO	-

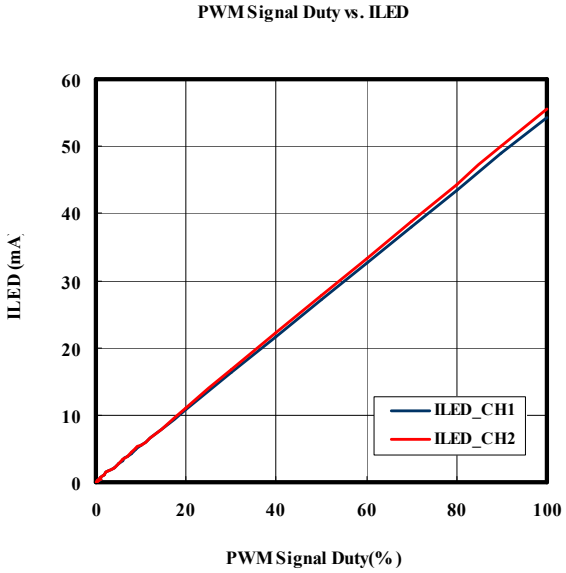
Values in this table are for reference only.

Characteristics Ta=25°C, PWM=3.3V (reference only)

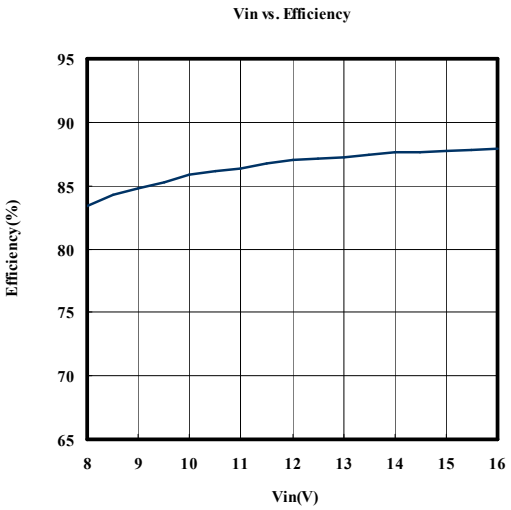
LED current vs. Supply voltage



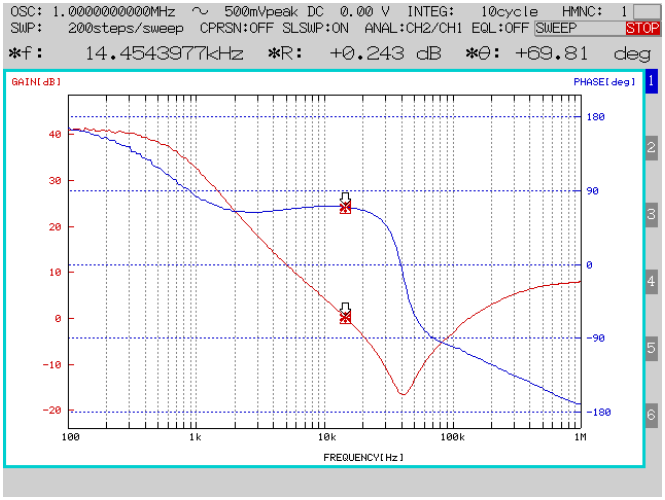
LED current vs. PWM Duty VIN=12V、PWM 200Hz



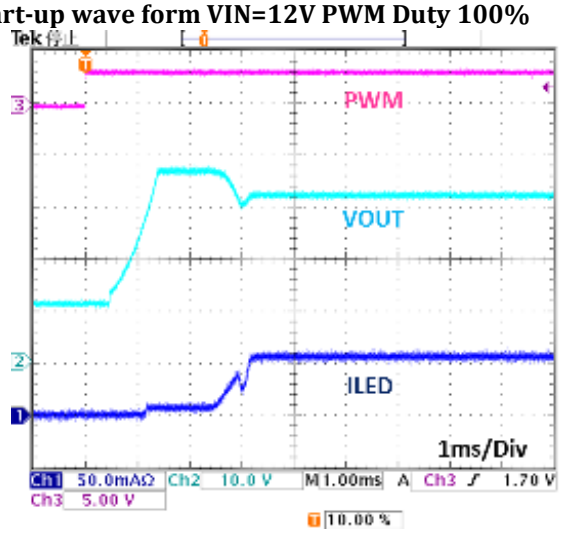
Efficiency vs. Supply voltage



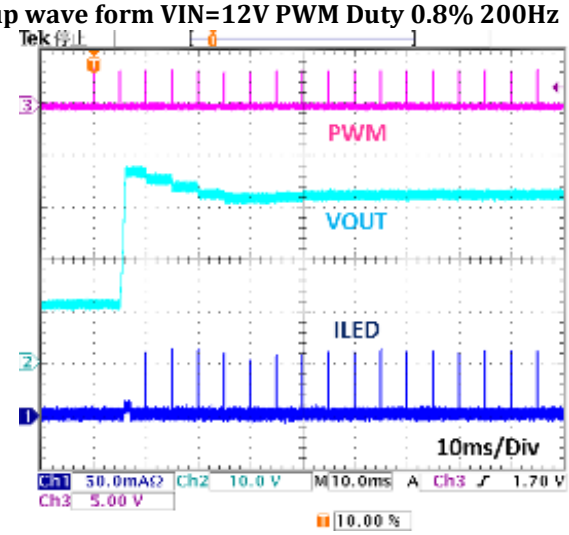
Phase margin VIN=12V



Start-up wave form VIN=12V PWM Duty 100%

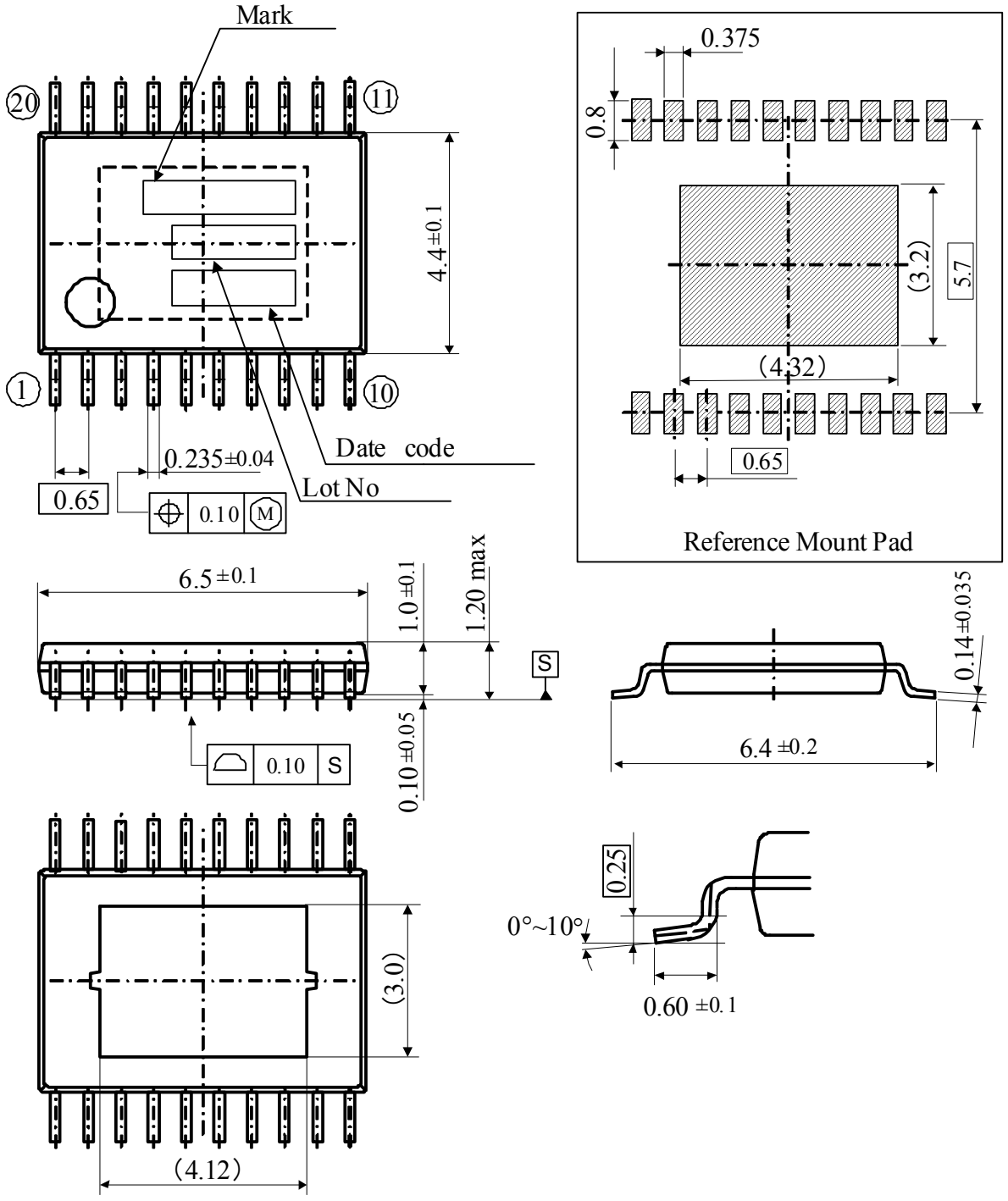


Start-up wave form VIN=12V PWM Duty 0.8% 200Hz

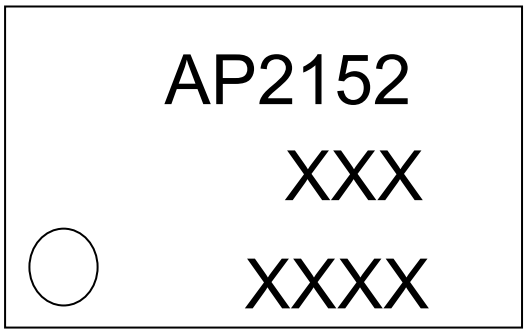


PACKAGE and MARKING

1) Dimension（20 pin HTSSOP）



2) Marking



Upper	Product name : AP2152
Center	Assembly lot number: 3 digits
Lower	Date code: 4 digits 1 digit (last digit of year) + 2 digits (weekly code) + 1 digit (lot number)