IS32BL3556

4-CHANNEL, 120MA BOOST LED BACKLIGHT DRIVER FOR AUTOMOTIVE LCD PANELS

Preliminary Information
February 2017

GENERAL DESCRIPTION

The IS32BL3556 is a step-up controller with an integrated switching FET for driving white LED arrays in LCD panel backlight applications. The boost controller is a current mode, fixed frequency architecture with the switching frequency set by an external resistor. The integrated boost controller generates the minimum output voltage to keep all LEDs illuminated at the set current. The current in each of the 4 channels is programmed to a specific value with an external current set resistor and matched to within 1%.

LED dimming is achieved using an external digital PWM signal to either adjust the internal ISET current or pulse-width-modulate the LED intensity. The LED sinks have a fast response to a PWM input making it possible to achieve a high contrast ratio of 10,000:1.

A synchronization pin can be used to synchronize multiple IS32BL3556 devices or to synchronize with the external PWM source in the range of 580 kHz to 2.3MHz. The high switching frequency allows the IS32BL3556 to operate above the AM radio band.

The IS32BL3556 integrates a control block to drive an external P-Channel FET to disconnect the input supply from the system whenever a fault is detected. It has safety protection features to prevent damage during fault conditions. Protection features include output short and overvoltage, open or shorted diode, open or shorted LED pin, shorted boost switch, shorted FSET or ISET resistor, and IC over temperature. A dual level cycle-by-cycle current limit function provides soft start and protects the internal current switch against high current overloads.

The IS32BL3556 is available in a thermally enhanced eTSSOP-20 package.

FEATURES

- Input voltage range is 4.75V to 40V for start/stop, cold crank and load dump requirements
- Excellent input voltage transient response
- Sync function to synchronize boost converter switching frequency up to 2.3MHz, allowing operation above the AM band
- Single resistor primary OVP minimizes VOUT leakage
- Fully integrated LED current sinks and boost converter up to 55V
- LED current of 120mA per channel
- 1% LED to LED matching accuracy
- Internal secondary OVP for redundant protection
- Drives up to 12 series LEDs in 4 parallel strings
- 10000:1 PWM dimming at 100Hz
- PWM and analog dimming inputs
- Provides driver for external PMOS input disconnect switch
- Built-in protection features:
  - Shorted boost switch
  - Shorted FSET or ISET resistor
  - Shorted output
  - Open or shorted LED
  - Open boost Schottky
  - Over temperature (OTP)
- AEC-Q100 qualified (pending)

APPLICATIONS

- LCD Monitor
- LCD Display Module
- LCD TV
- Car infotainment
- Cluster

TYPICAL APPLICATION CIRCUIT

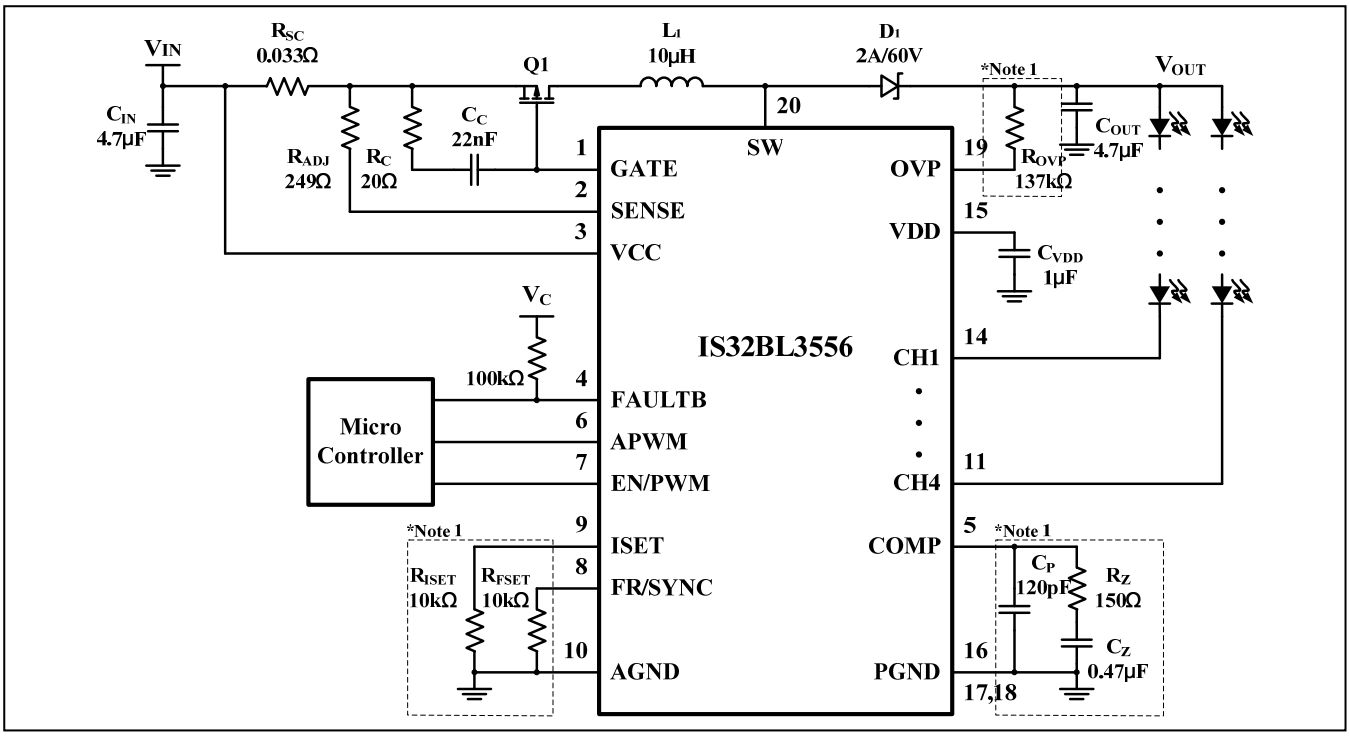


Figure 1 Typical Application Circuit with PMOS Disconnect

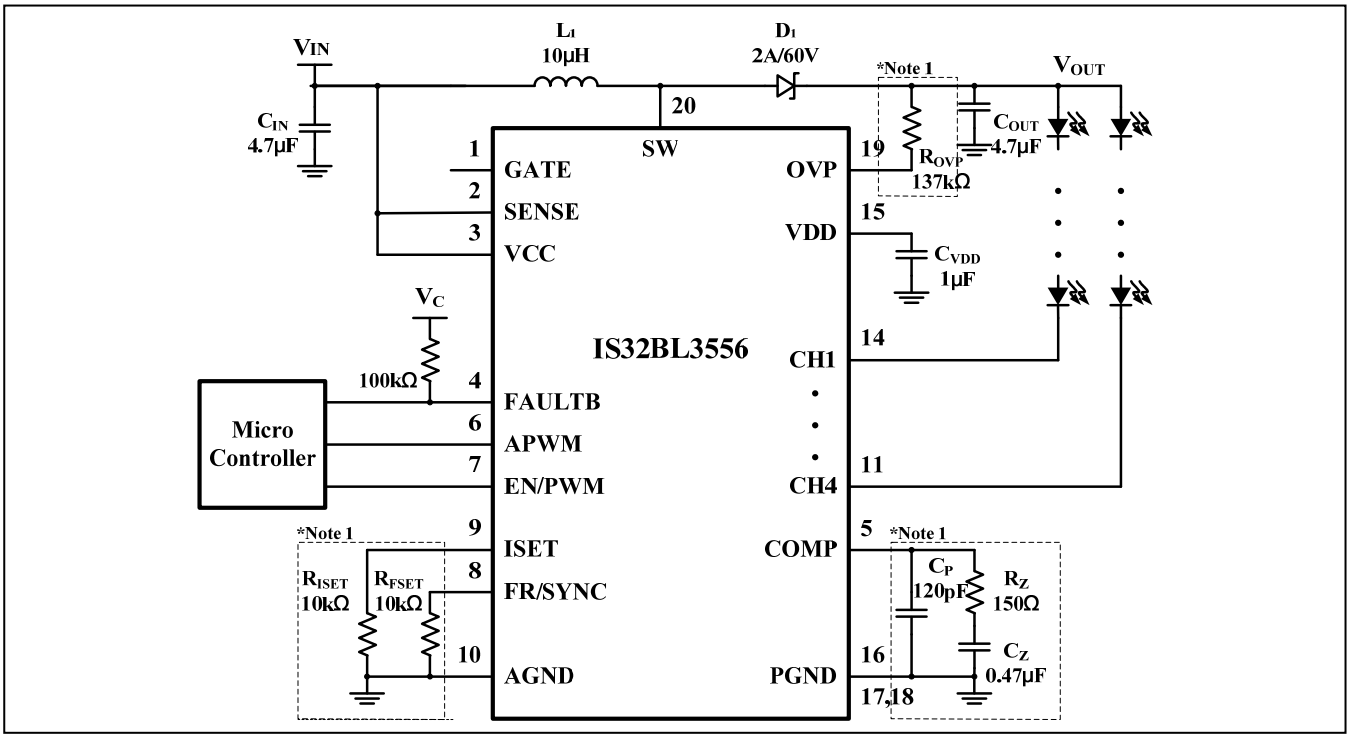
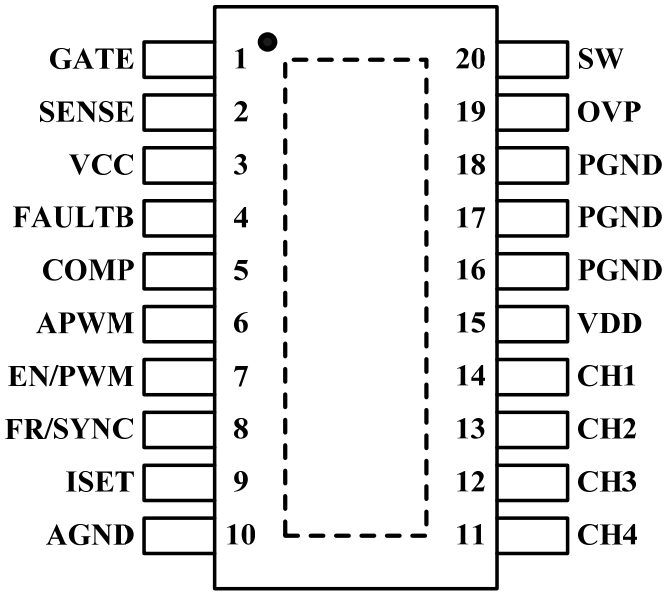


Figure 2 Typical Application Circuit without PMOS

Note 1: Value of those devices need to adjust according different applications.

PIN CONFIGURATION

Package	Pin Configuration (Top View)
eTSSOP-20	

PIN DESCRIPTION

No.	Pin	Description
1	GATE	Driver's output for the gate of external P-channel FET.
2	SENSE	Connect the negative sense side of the current sense resistor R_{SC} from this pin. The threshold voltage is measured as V_{CC} - V_{SENSE}. There is also a fixed current sink to allow for trip threshold adjustment.
3	VCC	Power supply input. Bypass VCC to GND with a capacitor to keep the DC input voltage constant.
4	FAULTB	Open drain fault flag to indicate a fault condition. Connect a 100kΩ resistor between this pin and the required logic level voltage.
5	COMP	Soft-start and control loop compensation. Connect a series R_Z-C_Z network from this pin to ground for control loop compensation.
6	APWM	Analog trimming option for dimming. Applying a digital PWM signal to this pin adjusts the internal ISET current.
7	EN/PWM	PWM signal input for LED dimming, used to control the LED intensity by using pulse width modulation. Also used to enable the IS32BL3556.
8	FR/SYNC	Frequency and synchronization pin. A resistor R_{FR} from this pin to ground sets the switching frequency. This pin can also be used to synchronize two or more IS32BL3556s in the system. The maximum synchronization frequency is 2.3MHz.
9	ISET	LED current adjust input. Connect a resistor R_{ISET} between ISET pin and GND to set the reference current through each LED string.
10	AGND	LED signal ground.
11~14	CH4~CH1	Connect the cathodes of the LED strings to these pins. All unused pins should be connected with a 1.54kΩ resistor to ground.
15	VDD	Output of internal LDO; connect a 1μF decoupling capacitor between this pin and ground.
16~18	PGND	Power ground for internal NMOS.
19	OVP	Over voltage protection pin; connect the R_{OVP} resistor from VOUT to this pin to adjust the overvoltage protection.
20	SW	The drain of the internal NMOS switch of the boost converter.
	Thermal Pad	Connect to GND.

ORDERING INFORMATION

Automotive Range: -40°C to +125°C

Order Part No.	Package	QTY
IS32BL3556-ZLA3-TR	eTSSOP-20, Lead-free	2500/Reel
IS32BL3556-ZLA3		70/Tube

ABSOLUTE MAXIMUM RATINGS

Voltage in CHx, OVP pins	-0.3V ~ +55V
Voltage in VCC, SENSE, GATE, FAULTB pins	-0.3V ~ +40V
Voltage in ISET, FR/SYNC, APWM, COMP pins	-0.3V ~ +5.5V
Voltage in SW pin, continuous Voltage in SW pin, t<50ns	-0.6V ~ 65V -1.0V
All other pins	-0.3V ~ +6.0V
Package thermal resistance, $R_{\theta JA}$, on 2-layer PCB, 3 in^2 on 4-layer PCB based on JEDEC standard	48.5°C/W 34°C/W
Operating junction temperature, T_J	150°C
Storage temperature range, T_{STG}	-55°C ~ +150°C
ESD (HBM) ESD (CDM)	±2kV ±750V

Note:
Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition 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.

ELECTRICAL CHARACTERISTICS (NOTE 1, 2)

T_J = -40°C ~ +125°C, V_{CC} =12V. Typical value is T_J = 25°C, unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Input Supply						
V_{CC}	Input voltage	(Note 3,4)	4.75		40	V
V_{UVLO_R}	UVLO start threshold	V_{CC} rising (Note 3)			4.35	V
V_{UVLO_F}	UVLO stop threshold	V_{CC} falling (Note 3)			3.90	V
V_{UVLO_HY}	UVLO hysteresis	(Note 2)	300	450	600	mV
I_{CC}	Quiescent current	$V_{EN/PWM}$= V_{IH}, f_{SW}= 1.5MHz, no load (Note 3)		5.5	10	mA
I_{SD}	Shutdown current	V_{CC}= 12V, $V_{EN/PWM}$= $V_{FR/SYNC}$= 0V (Note 3)		5.0	10	μA
Input Logic Levels (EN/PWM and APWM)						
V_{IL}	Input logic level-low	VCC throughout operating input voltage range (Note 3)			0.4	V
V_{IH}	Input logic level-high	VCC throughout operating input voltage range (Note 3)	1.5			V
$R_{EN/PWM}$	EN/PWM pin open drain pull-down resistor		60	100	140	kΩ
R_{APWM}	APWM pull-down resistor		60	100	140	kΩ

ELECTRICAL CHARACTERISTICS (CONTINUED)

T_J = -40°C ~ +125°C, V_{CC} =12V. Typical value is T_J = 25°C, unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
APWM						
f_{APWM}	APWM frequency	V_{IH}= 1.5V, V_{IL}= 0.4V (Note 2,3)	20		1000	kHz
Overvoltage Protection						
V_{OVP1}	OVP threshold	OVP connected to V_{OUT} (Note 3)	7.7	8.1	8.5	V
I_{OVPS}	OVP sense current	(Note 3)	188	199	210	µA
I_{OVPL}	OVP leakage current	(Note 3)		0.1	1	µA
V_{OVP2}	Secondary over voltage protection	(Note 3)		60		V
Boost Switch						
R_{SW}	Switch on-resistance	I_{SW}= 0.750A, V_{CC} = 12V(Note 3)	75	300	600	mΩ
I_{SW_LKG}	Switch leakage current	V_{SW}= 16V, $V_{EN/PWM}$= V_{IL}(Note 3)		0.1	1	µA
I_{SW_LIM1}	Switch current limit	(Note 3)	3.0	3.5	4.2	A
I_{SW_LIM2}	Secondary switch current limit	Higher than maximum I_{SW_LIM1} for all conditions, device latches when detected (Note 2)		7.0		A
t_{SW_ON}	Minimum switch on-time	(Note 3)		200		ns
t_{SW_OFF}	Minimum switch off-time	(Note 3)		50		ns
Oscillator Frequency						
f_{SW}	Oscillator frequency	R_{FR}= 7.2kΩ (Note 3)	1.85	2	2.15	MHz
		R_{FR}= 10kΩ (Note 3)	1.35	1.5	1.65	MHz
		R_{FR}= 20kΩ (Note 3)	0.675	0.75	0.875	MHz
$V_{FR/SYNC}$	FR/SYNC pin voltage	R_{FR}= 10kΩ		1.0		V
f_{FR}	FR frequency range	(Note 2)	200		2300	kHz
Synchronization						
f_{SY}	Synchronized PWM frequency	(Note 2)	580		2300	kHz
t_{SY_OFF}	Synchronization input minimum off-time	(Note 2)	150			ns
t_{SY_ON}	Synchronization input minimum on-time	(Note 2)	150			ns
V_{SY_H}	SYNC input logic voltage	FR/SYNC pin, high level (Note 3)	2.0			V
V_{SY_L}		FR/SYNC pin, low level (Note 3)			0.4	V
Thermal Protection (TSD)						
T_{SD_TH}	Thermal shutdown threshold	Temperature rising (Note 2)		165		°C
T_{SD_HY}	Thermal shutdown hysteresis	(Note 2)		20		°C

ELECTRICAL CHARACTERISTICS (CONTINUED)

T_J = -40°C ~ +125°C, V_{CC} =12V. Typical value is T_J = 25°C, unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
FAULTB Pin						
V_{FAULT_PD}	FAULTB pull-down voltage	I_{FAULTB}= 1mA (Note 3)			0.5	V
I_{FAULT_L}	FAULTB pin leakage current	V_{FAULTB}= 5V			1	μA
LED Current Sinks						
Err_{CH}	CHx accuracy	I_{SET}= 100μA (Note 3)			3	%
ΔI_{CH}	CHx matching	I_{SET}= 100μA (Note 3)			1	%
V_{CH}	CHx regulation voltage	V_{CH1}= V_{CH2}= V_{CH3}= V_{CH4}, I_{SET}= 100μA (Note 3)	620	720	820	mV
A_{ISET}	I_{SET} to I_{CHx} current gain	I_{SET}= 100μA (Note 3)	970	1000	1030	A/A
V_{SET}	ISET pin voltage		0.99	1.00	1.01	V
I_{SET}	Allowable I_{SET} current	(Note 3)	20		120	μA
V_{CH_S}	V_{CH} short detect	While LED sinks are in regulation, sensed from CHx pin to ground (Note 3)	4.6	5.1	5.6	V
I_{CH_SS}	Soft start CHx current	Current through each enabled CHx pin during soft start		12		mA
t_{PWM_OFF}	Maximum PWM dimming until off-time (Note 2)	Measured while $V_{EN/PWM}$ = low, during dimming control and internal references are powered-on (exceeding t_{PWM_OFF} results in shutdown)		32,750		f_{SW} cycles
t_{PWM_ON}	Minimum PWM on-time	First cycle when powering-up device (Note 3)		0.75	2	μs
t_{PWMH_ON}	PWM high to LED-on delay	Time between PWM enable and LED current reaching 90% of maximum (Note 3)		0.9	1	μs
t_{PWML_OFF}	PWM low to LED-off delay	Time between PWM enable going low and LED current reaching 10% of maximum (Note 3)		0.9	1	μs

ELECTRICAL CHARACTERISTICS (CONTINUED)

T_J = -40°C ~ +125°C, V_{CC} =12V. Typical value is T_J = 25°C, unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
GATE Pin						
I_{G_SINK}	GATE pin sink current	V_G= V_{CC}		-104		µA
t_{G_FAULT1}	Gate fault shutdown greater than 1–2X current			8,192		f_{SW} cycles
V_G	Gate voltage	Gate to source voltage measured when gate is on		-6.7		V
SENSE Pin						
I_{ADJ}	SENSE pin sink current	(Note 3)	18.8	20.3	21.8	µA
V_{SENSE1}	SENSE trip point	Measured between VCC and SENSE, R_{ADJ}= 0Ω (Note 3)	94	104	114	mV
V_{SENSE2}	SENSE 2X trip	2X V_{SENSE} trip, instantaneous shutdown, R_{ADJ}= 0Ω (Note 2)		180		mV

Note 1: For input and output current specifications, negative current is defined as coming out of the node or pin (sourcing); positive current is defined as going into the node or pin (sinking).

Note 2: Ensured by design and characterization, not production tested.

Note 3: Indicates specifications guaranteed by design and characterization over the full operating temperature range with T_A = T_J = -40°C ~ 125°C

Note 4: Minimum V_{CC}= 4.75V is only required at startup. After startup is completed, the IC is able to function down to V_{CC}= 4V.

TYPICAL PERFORMANCE CHARACTERISTICS

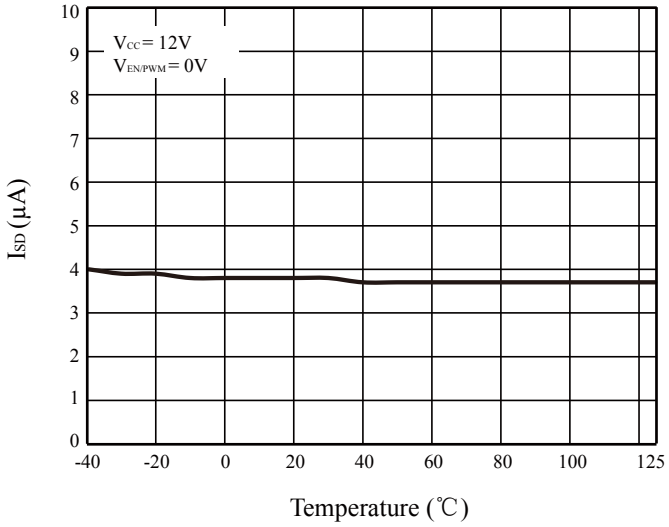


Figure 3 I_{SD} vs. Temperature

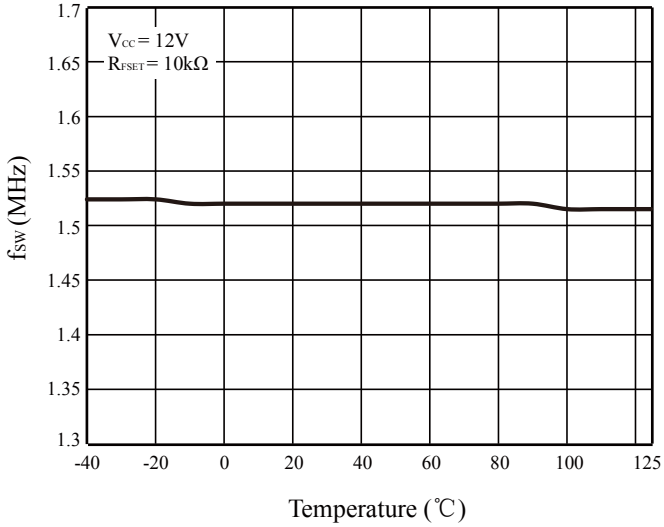


Figure 4 f_{SW} vs. Temperature

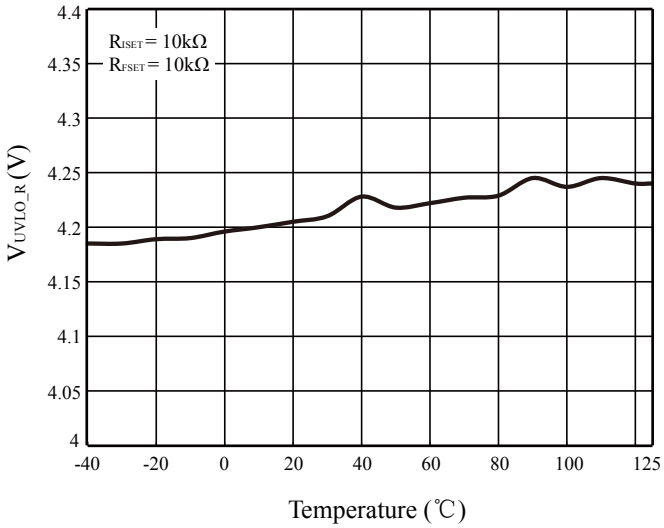


Figure 5 V_{UVLO_R} vs. Temperature

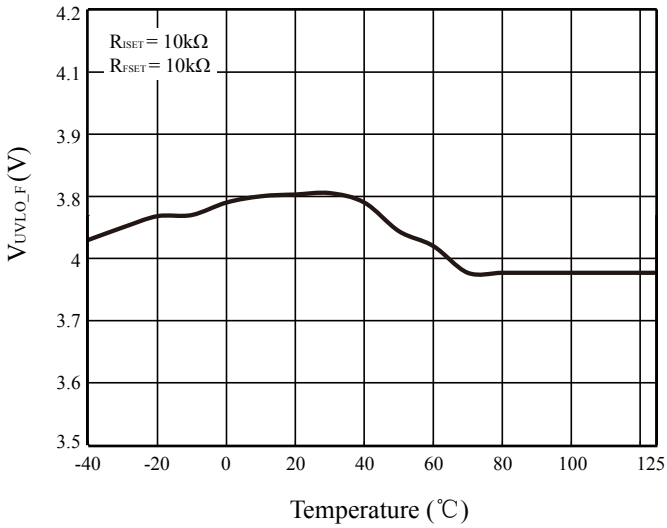


Figure 6 V_{UVLO_F} vs. Temperature

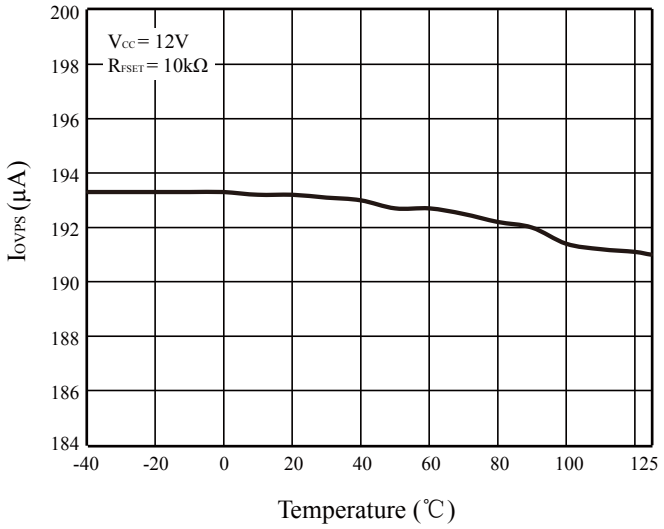


Figure 7 I_{OVPS} vs. Temperature

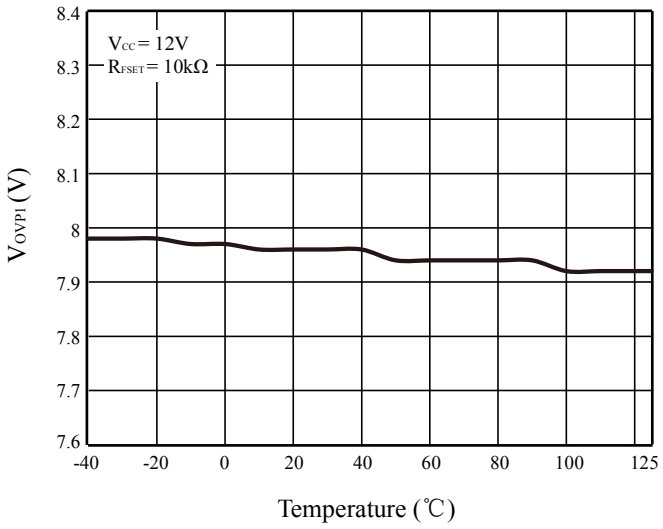


Figure 8 V_{OVP1} vs. Temperature

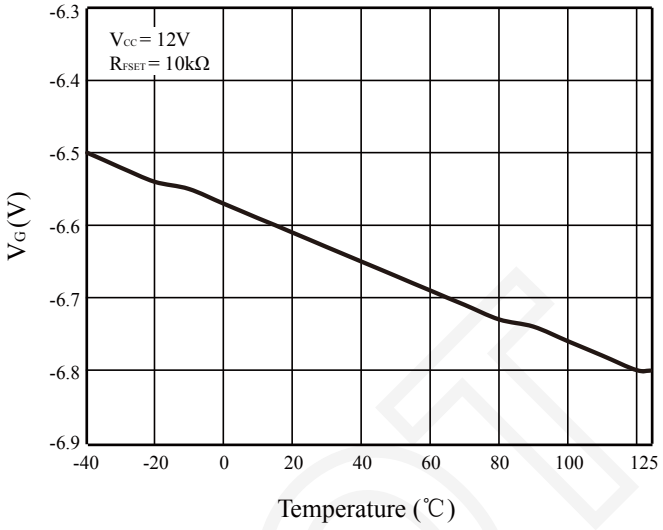


Figure 9 V_G vs. Temperature

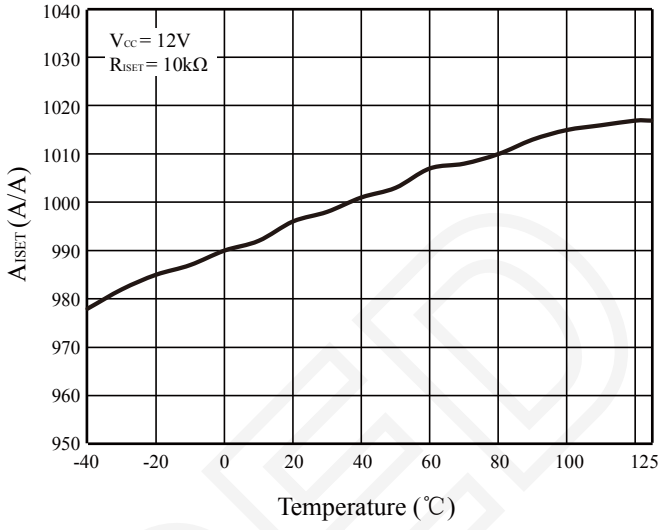


Figure 10 A_{ISET} vs. Temperature

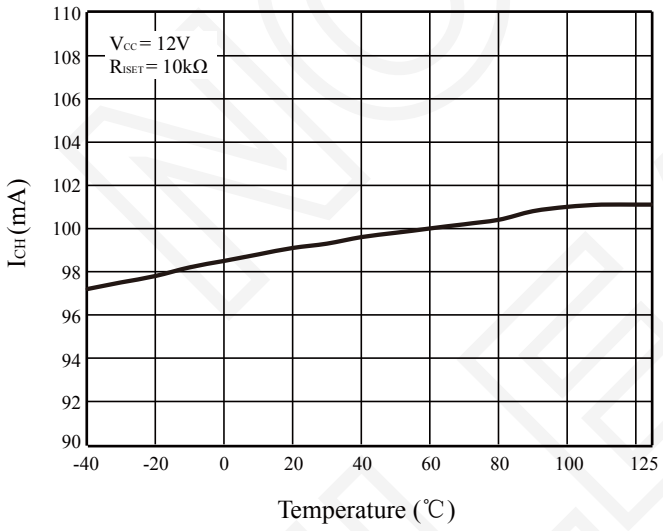


Figure 11 I_{CH} vs. Temperature

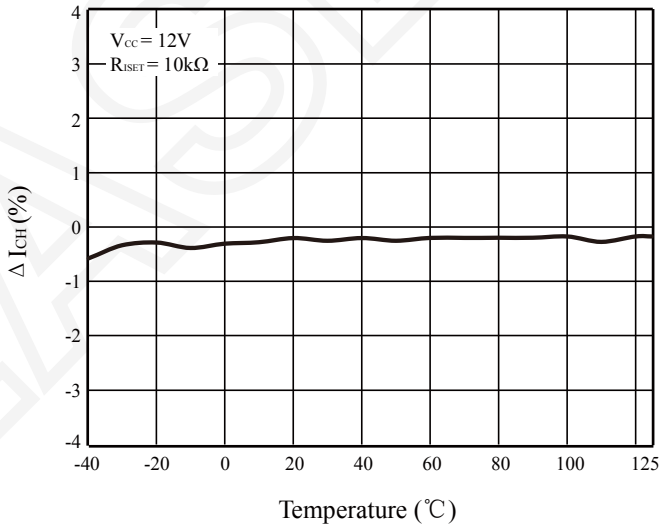


Figure 12 ΔI_{CH} vs. Temperature

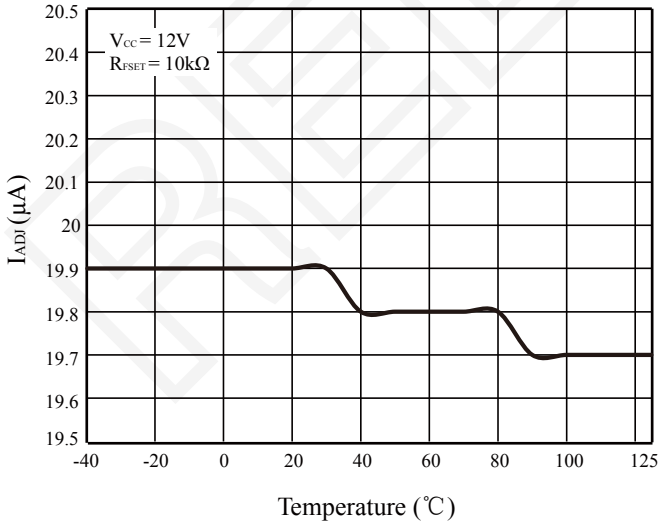


Figure 13 I_{ADJ} vs. Temperature

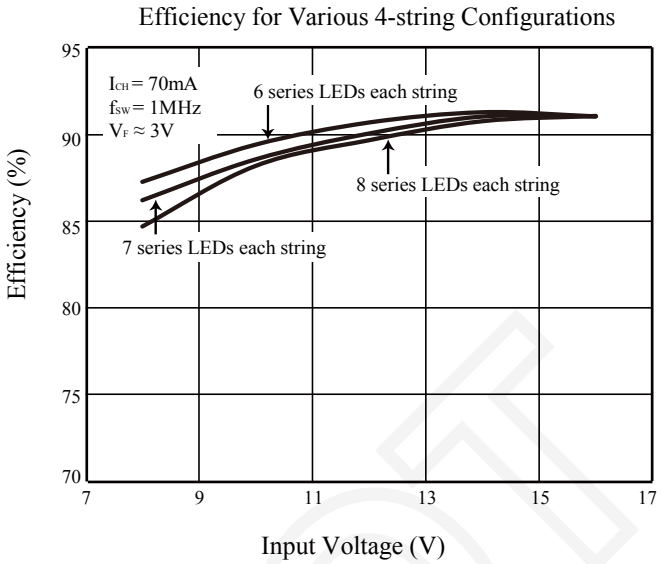


Figure 14 Efficiency vs. Voltage of String Configurations

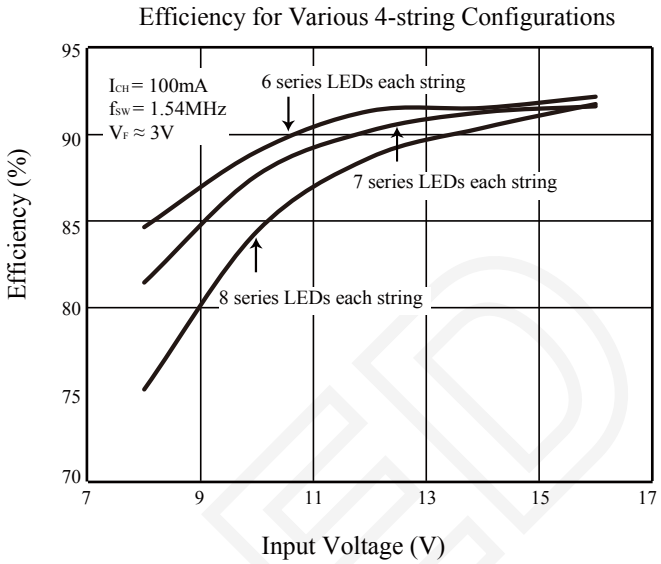


Figure 15 Efficiency vs. Voltage of String Configurations

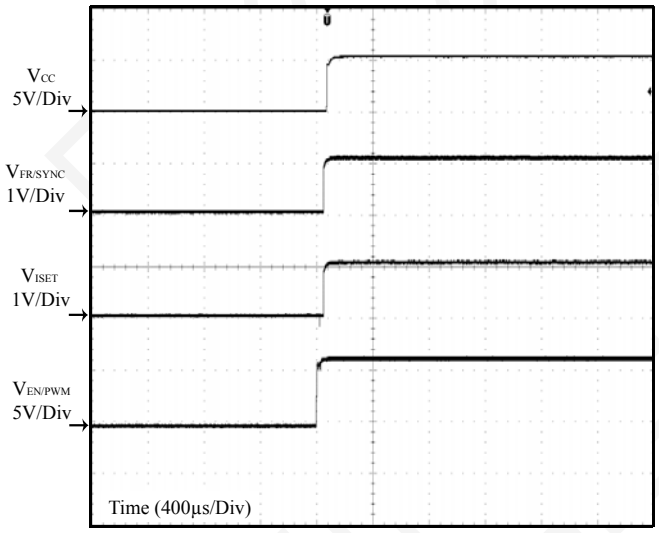


Figure 16 Power-Up

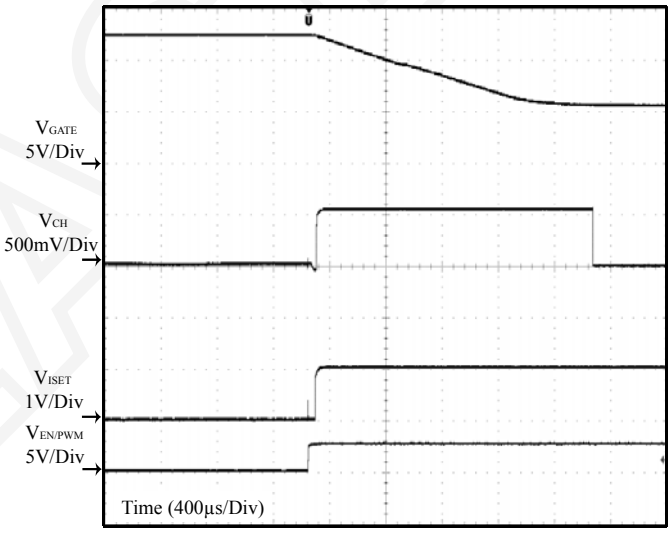


Figure 19 Power-Up

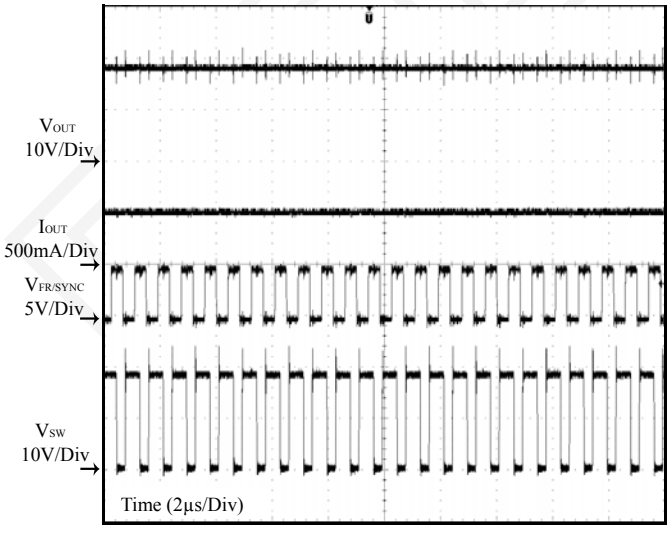


Figure 18 Normal Operation

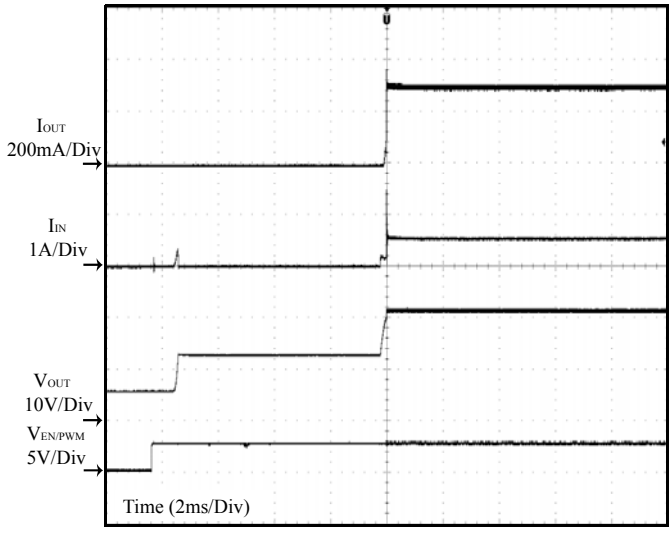


Figure 17 Startup by EN/PWM

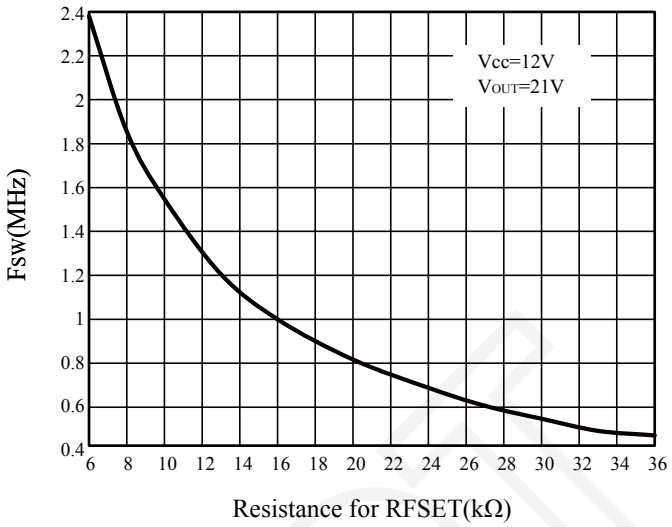


Figure 20 Switching frequency vs. R_{FSET}

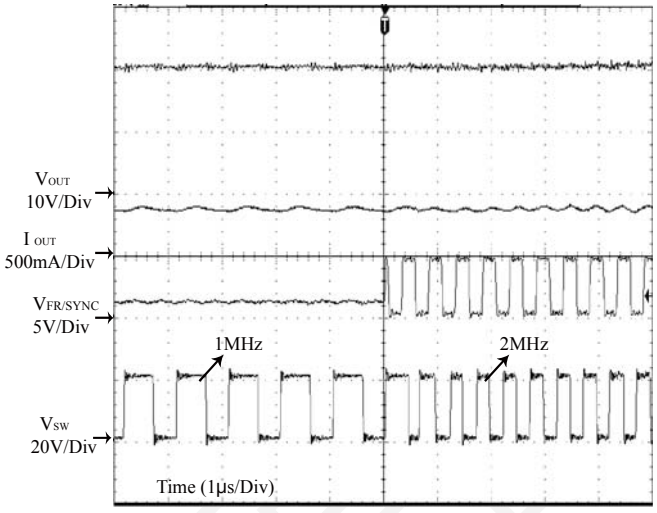


Figure 21 Transition of synchronization

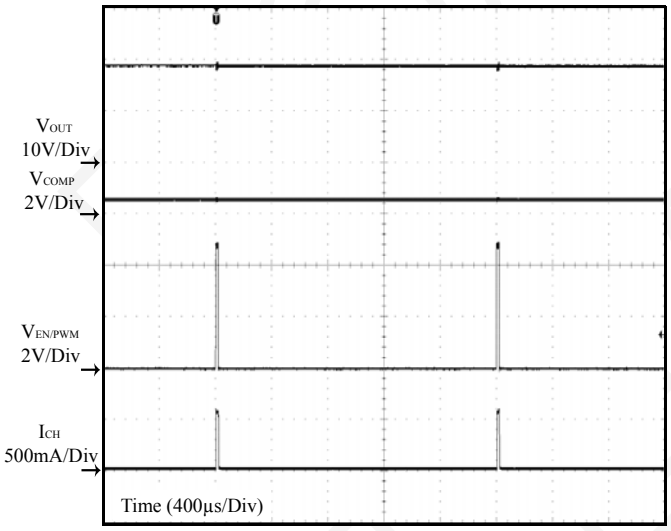


Figure 22 PWM Dimming Of Low Duty Cycle

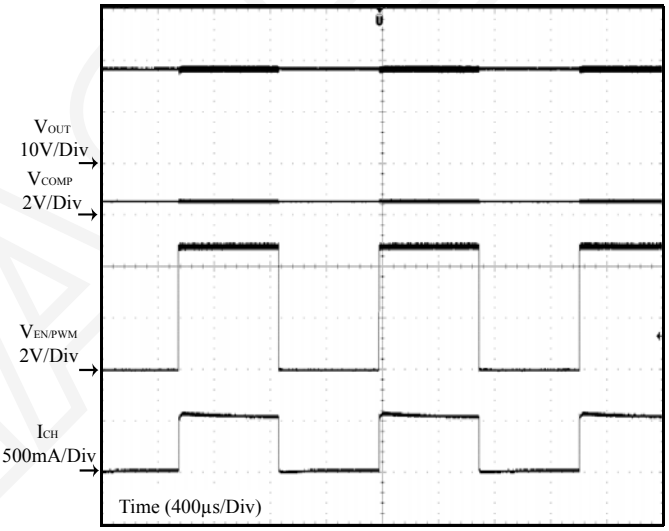


Figure 23 PWM Dimming Of High Duty Cycle

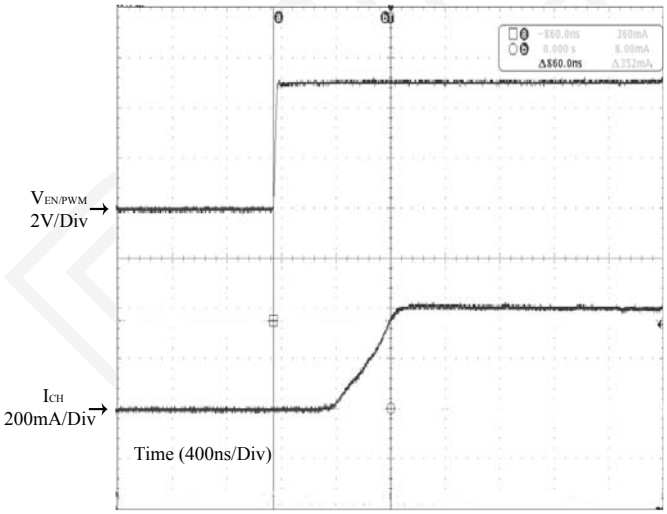


Figure 24 EN/PWM Rising

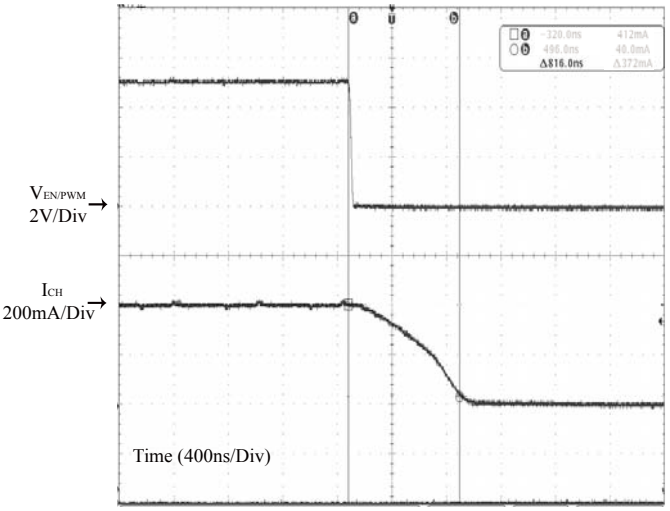


Figure 25 EN/PWM Falling

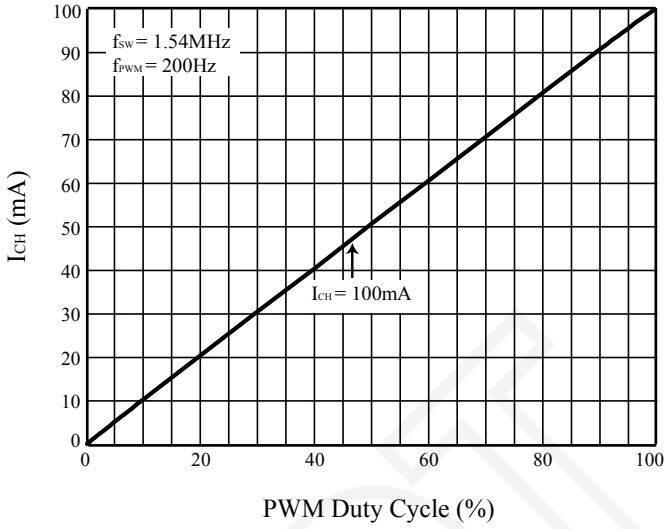


Figure 26 I_{CH} vs. PWM Duty Cycle

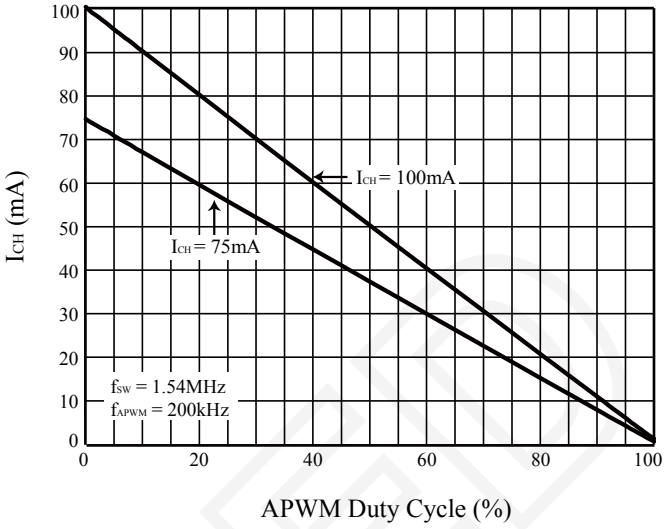


Figure 27 I_{CH} vs. APWM Duty Cycle

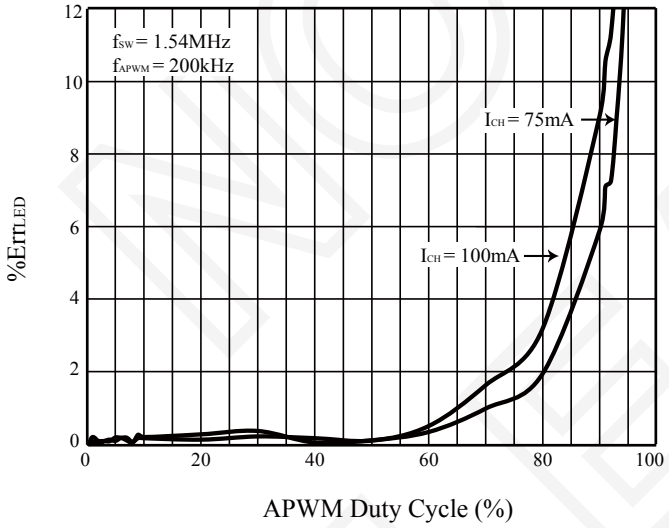


Figure 28 Percentage Error Of I_{CH} Vs. APWM Duty Cycle

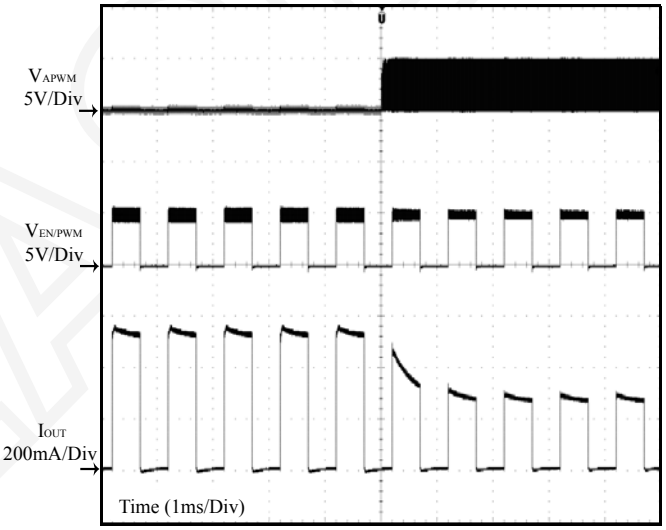


Figure 29 Signal Applied To The APWM Pin During PWM Dimming

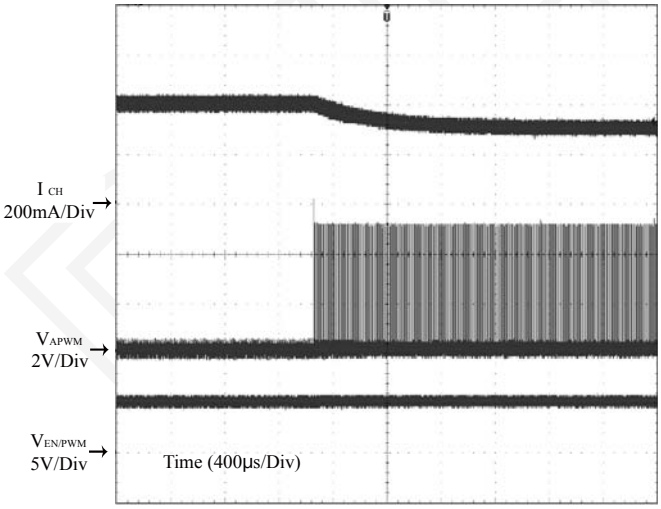


Figure 30 A 25% Duty Cycle Signal Applied To The APWM Pin

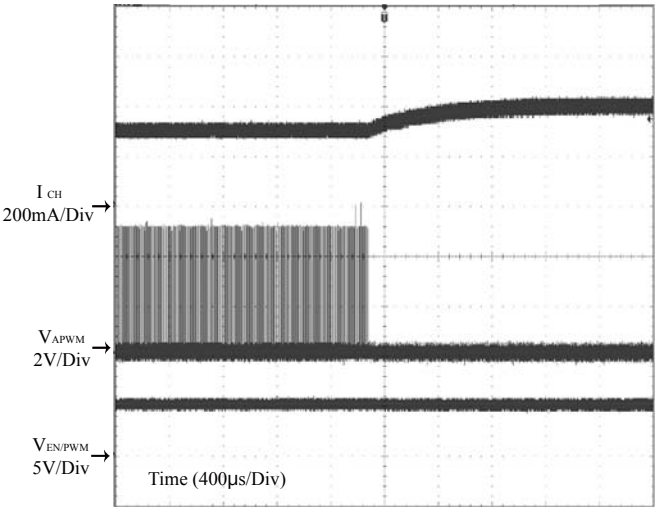


Figure 31 A 25% Duty Cycle Signal Removed From The APWM Pin

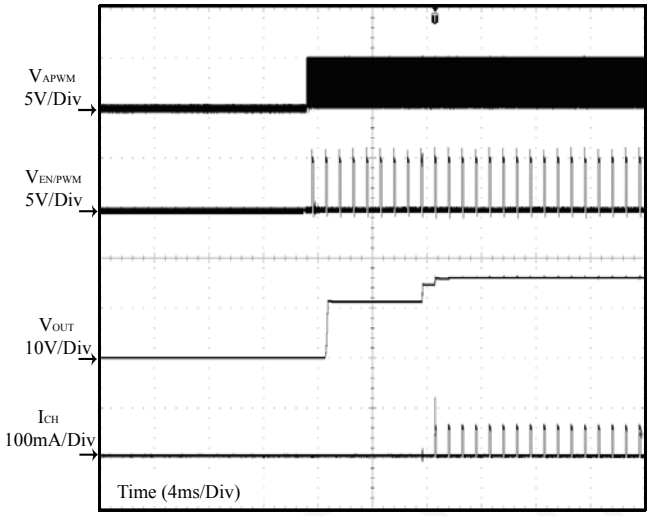


Figure 32 Power-Up With Both Dimming

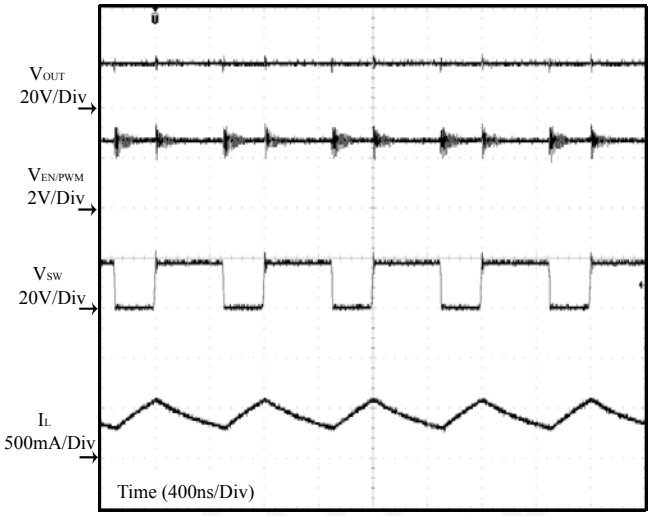


Figure 33 Normal Operation

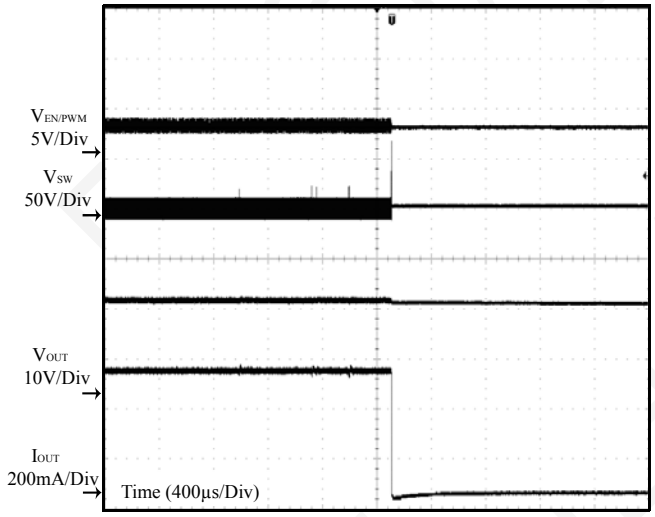


Figure 34 OVP Protection When The IC Is Enabled During An Open Diode Condition

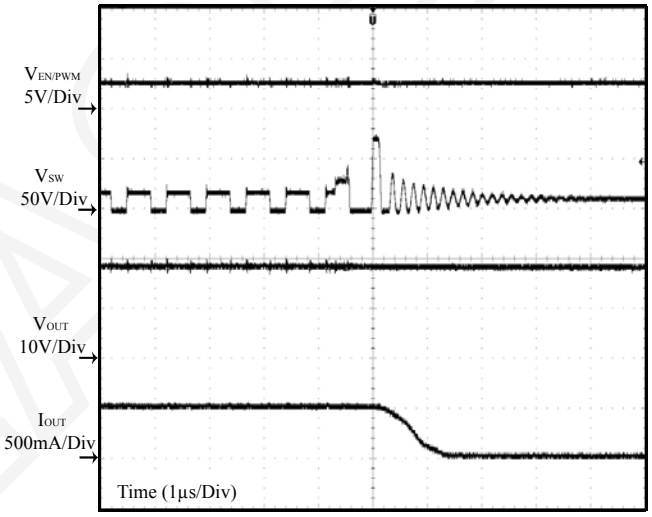


Figure 35 Open Schottky Diode During Normal Operation

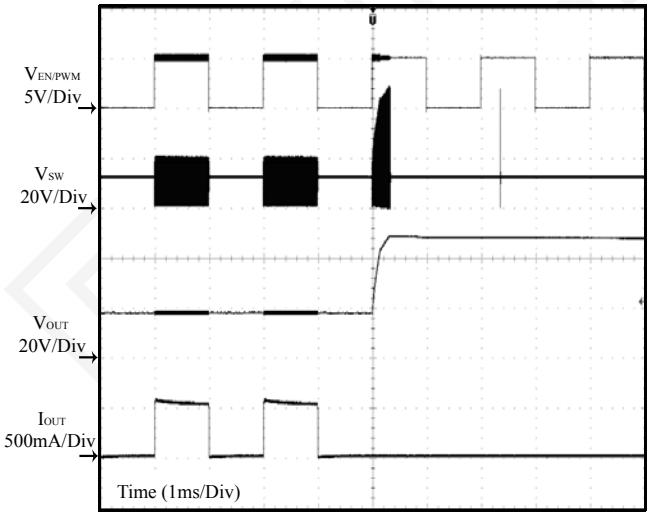


Figure 36 OVP Protection With Output Disconnect

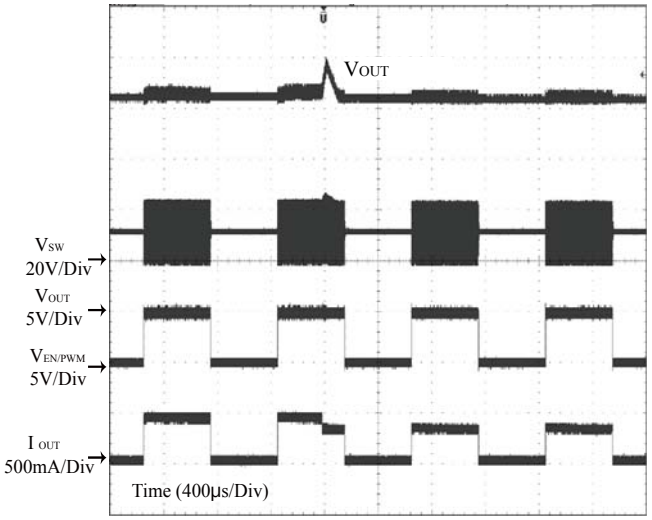


Figure 37 OVP Protection With Open LED String

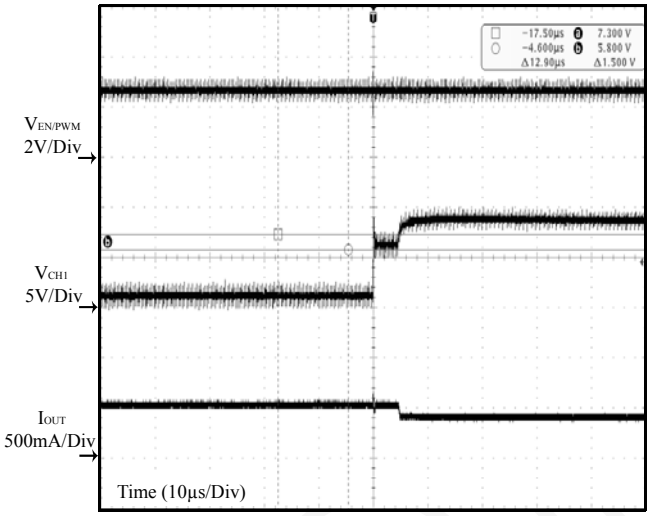


Figure 38 Disabling Of An LED String

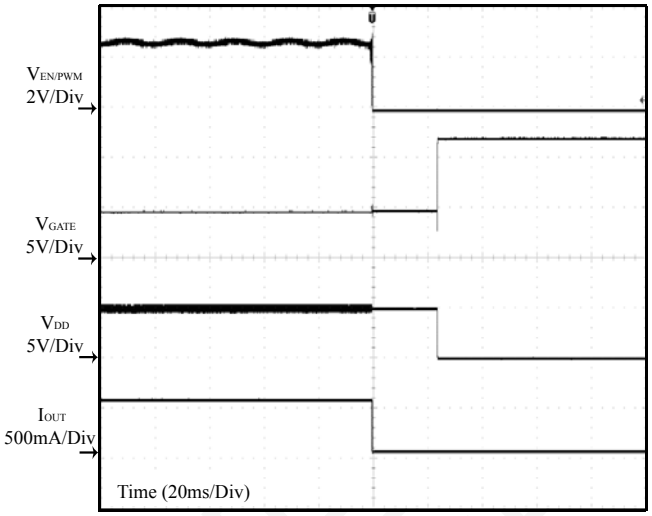


Figure 39 EN/PWM Disable

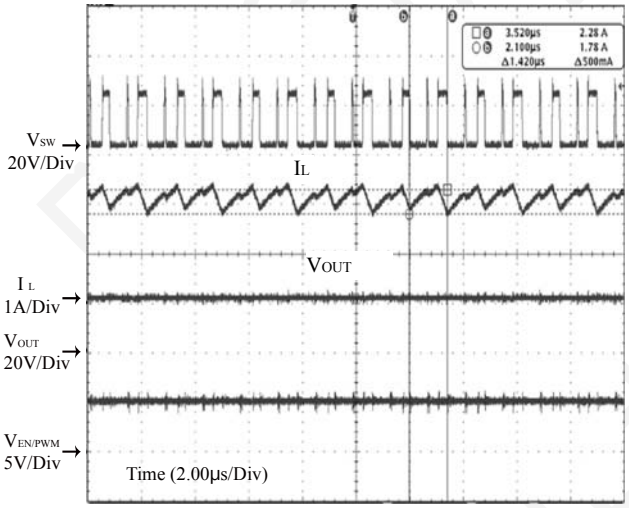


Figure 40 Cycle-By-Cycle Current Limiting

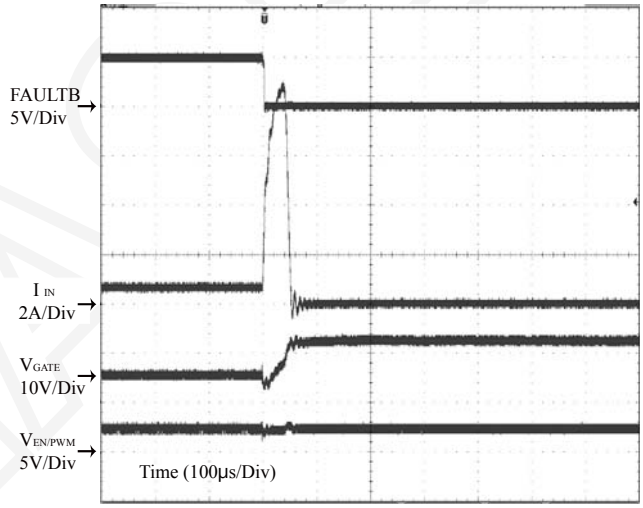


Figure 41 2X Mode, Secondary Over Current Fault Condition

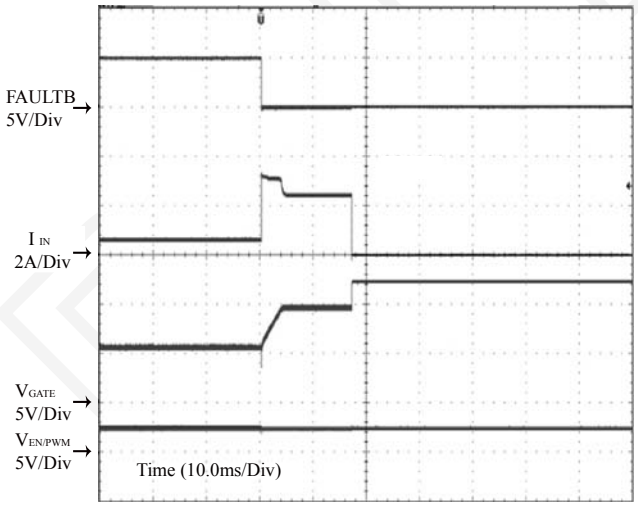


Figure 42 1X Current Limit Under A Fault Condition

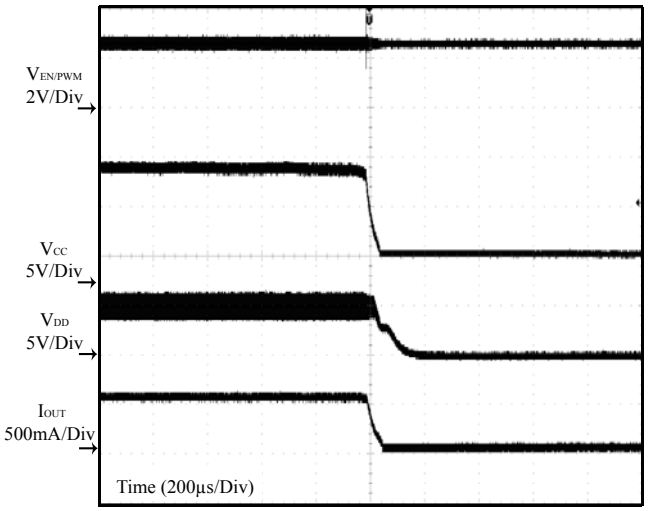
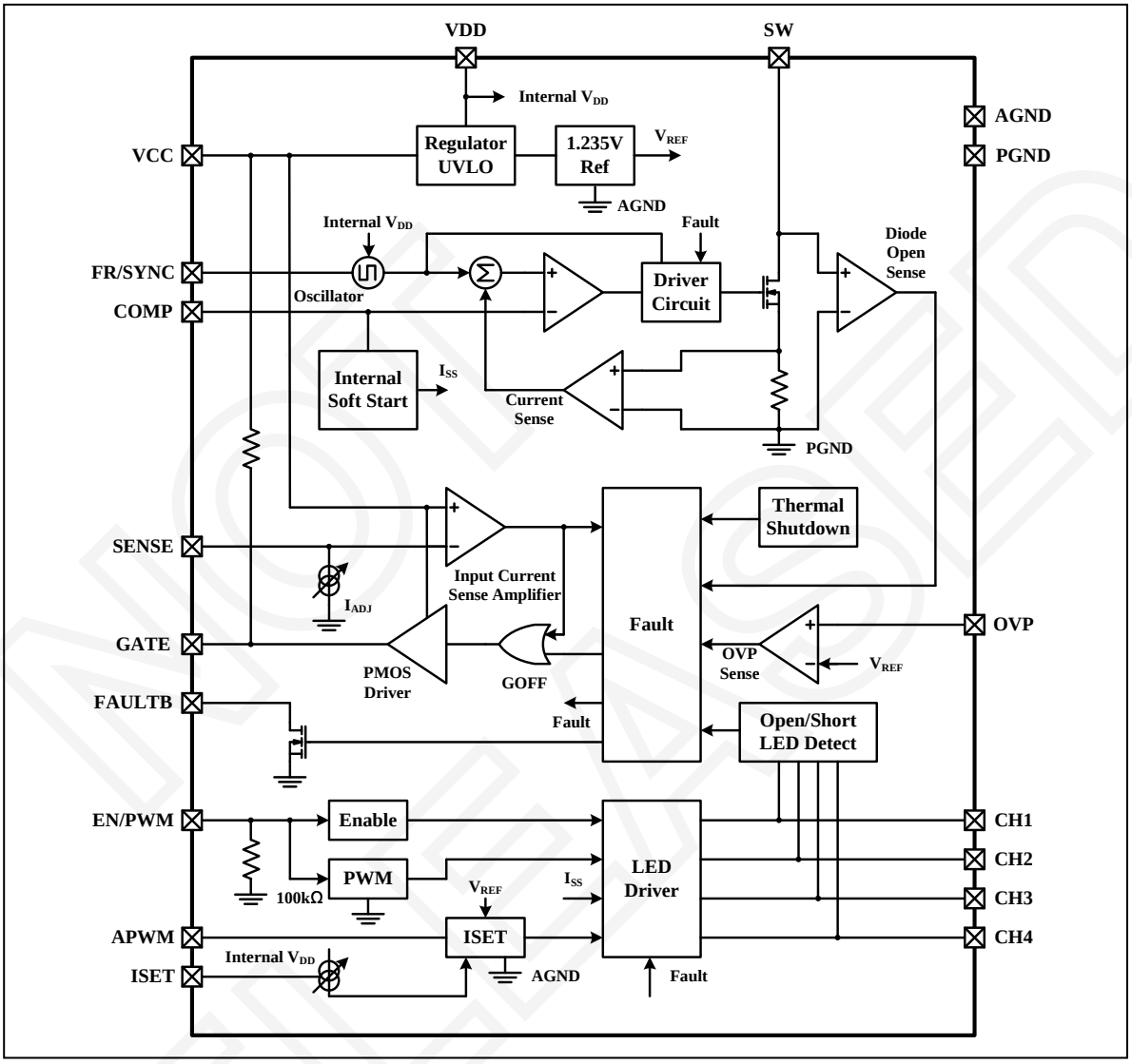


Figure 43 Power Down

FUNCTIONAL BLOCK DIAGRAM



APPLICATION INFORMATION

The IS32BL3556 is a highly integrated current-mode boost HBLED driver with integrated switching FET and four LED current sinks. It is designed to drive four LED strings of up to 12 white LEDs in series, with current up to 120mA per string. An adaptive headroom control feature automatically adjusts the output boost stage to the minimum voltage (V_{OUT}) required to power the LED strings (V_{STRx}). This is expressed by the following Equation (1):

$$V_{OUT} = Max(V_{STR1},...,V_{STR4}) + V_{CH} \quad (1)$$

Where V_{STRx} is the voltage drop across LED strings 1 through 4, and V_{CH} is the headroom (regulation) voltage of the LED current sinks (typically 0.72V at the maximum LED current). The dynamic headroom control will adjust the VOUT to equal the sum of the highest LED string voltage plus the IS32BL3556 operating headroom voltage.

INITIAL POWER UP SEQUENCE

The power-up sequence is shown in Figure 16. The IS32BL3556 integrates a UVLO/Regulator function which monitors the supply voltage level at the VCC input pin. The IS32BL3556 will power-up only when the supply voltage is above the internal UVLO threshold level of 4.35V (max) and the EN/PWM pin is pulled high. During the power up sequence, the IS32BL3556 will first enable the disconnect switch to apply power to the LED strings. Then before the LEDs are enabled, the IS32BL3556 check if any CHx pins are shorted to ground and/or are not used as shown in Figure 44.

The LED status detection process is initiated when the disconnect switch GATE voltage equals V_{CC} – 4.5V. Then once any of the CHx pin voltage rises above 120mV, a delay of between 3000 and 4000 clock cycles must pass before pin status detection is enabled. Therefore the LED detection period will vary depending on the switching frequency, as shown in the following table:

Switching Frequency (MHz)	Detection Time (ms)
2	1.5 ~ 2.0
1	3 ~ 4
0.800	3.75 ~ 5.0
0.600	5.0 ~ 6.7

The CHx pin voltage thresholds used in detecting short/open LED conditions are as follows:

CHx	LED Pin Status	Action
<35mV	Short to ground	Power-up is halted
<220mV	Not used	LED removed from operation
>220mV	LED pin in use	None

As shown in Figure 44, any unused CHx pins should be connected with a 1.54kΩ resistor to ground. The CHx pin with a pull-down resistor will be ignored and will not be used for adaptive headroom control in Equation (1).

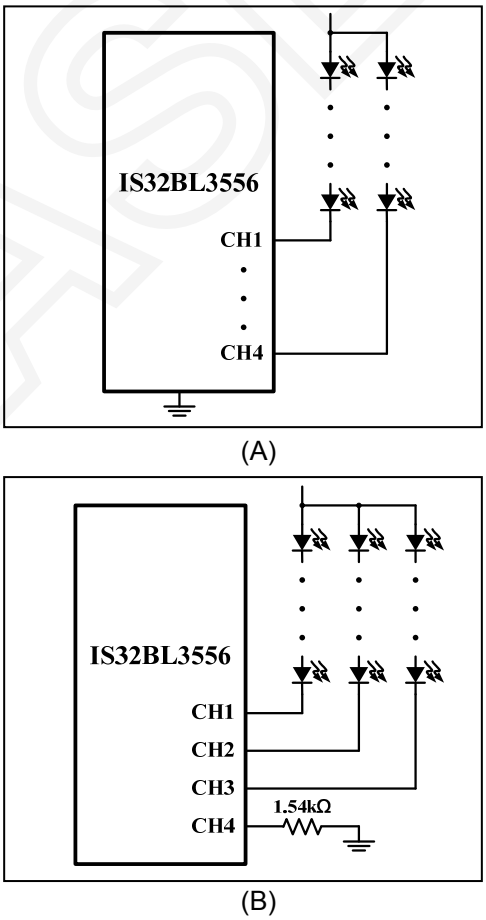


Figure 44 Channel Select Setup: (A) Using All Four Channels And (B) Using Only CH1, CH2, And CH3.

If any CHx short to ground (V_{CHx}<35mV) is detected, the IS32BL3556 will not soft start until the short condition is removed. This protects the LED strings from an uncontrolled amount of current at power up due to shorted CHx pins.

SOFT START

When in soft start mode, the CHx pins will initially sink the soft start current (I_{CH_SS}). As the CHx pin voltage rises above 220mV, the IS32BL3556 will set the boost switch current limit to the I_{SW_LIM1} level and proceed to increase the LED current to the level set by the Iset resistor value. This is shown in Figure 17, the test condition is SW frequency = 1.54MHz, C_Z=0.47μF, C_{OUT} = 10μF. Under this condition, the soft start time is approximate 10ms.

ENABLING FUNCTION

The IS32BL3556 will turn on when a logic high (>t_{PWM_ON}) on EN/PWM pin and the VCC voltage rises above 4.35V to clear the UVLO (V_{UVLO_R}) threshold.

A logic low on the EN/PWM pin will completely shut down the IS32BL3556. It will not power-up if the FR/SYNC pin is pulled low.

SWITCHING FREQUENCY SELECTION

A resistor connected to the FR/SYNC pin is used to set the boost regulator's switching frequency from 200kHz to 2.3MHz. Figure 20 shows the typical switching frequencies, in MHz, for resistor values, in kΩ.

$$R_{FSET} = 15 / f_{SW}$$

The FR/SYNC pin is clamped to a maximum switching frequency of 3.5MHz if a fault occurs during operation. It will shut down when the FR/SYNC pin is shorted to GND.

SYNCHRONIZE

The FR/SYNC pin can be used as a synchronization input, allowing the IS32BL3556 to operate with an external clock in the range of 600kHz to 2.2MHz as long as it satisfies the 150ns requirements of t_{SY_ON} and t_{SY_OFF}. When an external synchronization clock is applied to the FR/SYNC pin, the internal oscillator is over-driven so that each switching cycle begins at the rising edge of external clock. The IS32BL3556 will not be enabled if the FR/SYNC pin is held low during power-up. Only when the FR/SYNC pin is tri-stated to allow the pin to rise, to about 1V, or when a synchronization clock is detected, will the IS32BL3556 try to power-up.

Figure 45 shows the timing for a synchronization clock into the IS32BL3556 at 2.2MHz. Thus any pulse with a duty cycle of 33% to 66% at 2.2MHz can be used to synchronize the IC.

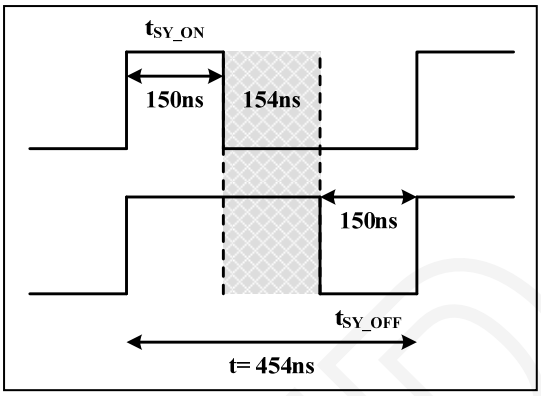


Figure 45 SYNC Pulse On And Off Time Requirements

The SYNC pulse duty cycle ranges for selected switching frequencies are:

SYNC Pulse Frequency(MHz)	Duty Cycle Range (%)
2.2	33 ~ 66
2	30 ~ 70
1	15 ~ 85
0.800	12 ~ 88
0.600	9 ~ 91

If the clock is lost, the IC will revert to the preset switching frequency set by the RFSET resistor. The IC will stop switching during this period for a maximum period of about 7μs to allow the sync detection circuitry to switch over to the resistor preset switching frequency. Figure 18 shows the synchronized normal operation of the external sync signal and switching frequency. Figure 21 shows the switching frequency locking to the external sync signal. LED current does vary during the frequency changeover.

Keeping the FR/SYNC pin lower than 0.4V for greater than 7μs will effectively shut down the IS32BL3556 and open the P-FET disconnect switch. If the FR/SYNC pin is held low during power-up, the IC will not power-up. Normal operation is resumed when the FR/SYNC pin is released and rises above 1V which starts the soft-start sequence. The IC can be placed into a low-power mode by keeping the EN pin low for 32,750 clock cycles.

SETTING LED CURRENT

The I_{SET} pin is used to set the I_{LED} channel current from 10mA up to a maximum of 120mA. To adjust the I_{LED} current, the resistor, R_{ISET}, is selected according to the following Formula (2):

$$R_{ISET} = (1.000 \times 1000) / I_{LED} \qquad (2)$$

Where I_{LED} is in Amps and R_{ISET} is in Ω. This sets the maximum channel current, referred to as the peak current.

Sample standard R_{ISET} values with the corresponding I_{LED} current are as follows:

Standard Closest Resistor, R_{ISET} (kΩ)	LED Current, I_{LED} (mA)
8.3	120
10.0	100
25.1	40
33.4	30

PWM DIMMING

A PWM signal in the range of 200Hz ~ 1kHz applied to the EN/PWM pin will adjust the average LED current for all enabled channels. The PWM duty cycle sets the average LED current by turning on and off the current sinks. During the "high level" period of the PWM signal, the current sinks are turned ON at peak current level. During the "low level" period the current sinks are turned OFF and only critical internal circuits are kept active resulting in minimal power consumption. Figures 22 to 25 provide examples of PWM switching behavior.

PWM signal to LED current delay is less than 1µs typically, which allows greater accuracy at low PWM dimming duty cycles, as shown in Figure 26.

APWM PIN

As shown in Figure 46, the APWM pin is used to trim the LED peak current set by the R_{ISET} resistor. The duty cycle of this 20kHz to 1MHz digital signal will adjust the internally I_{SET} current. The duty cycle of this signal is inversely proportional to the percentage of current that is delivered to the LEDs (Shown in Figure 27). There is a several millisecond propagation delay between applying an APWM signal and the change in LED current peak current. This effect is shown in Figures 29, 30, and 31.

The APWM pin should be connected to ground if it is not used.

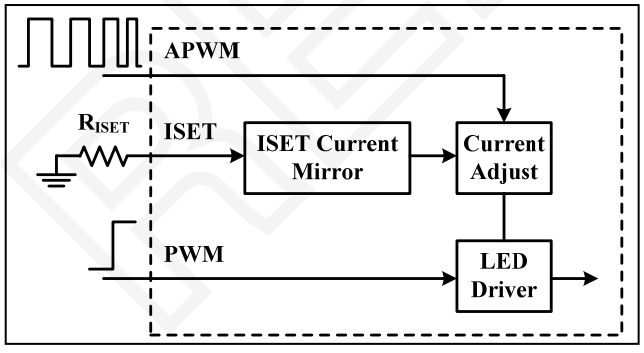


Figure 46 Simplified Block Diagram Of The APWM And ISET Circuit

When using the APWM input to trim the LED current, the R_{ISET} should selected for an LED current at least 5% higher than the desired peak current. The LED current is then trimmed down to the desired value. The trim down percentage corresponds to the APWM duty cycle. Therefore duty cycles between 30% and 60% will result in LED current trim from 30% and 60%. (Shown in Figure 28, I_{CH}=100mA, %ErrLED<2).

For example, a peak LED current of 80mA (set by R_{ISET}) would deliver 60mA of current per LED sink if an APWM signal is applied with a duty cycle of 25% (Figures 30 and 31).

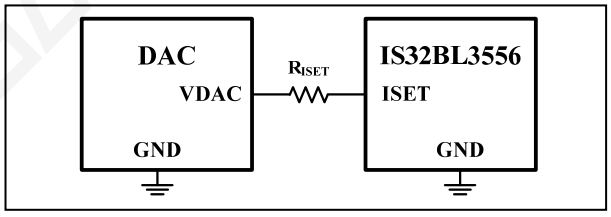
Although the order in which APWM and the PWM signal are enabled does not matter.

The APWM signal should be enable before the PWM signal when actively adjusting the IS32BL3556 to output a lower current. This is to prevent the light intensity from changing during power up of the IC. Figure 32 shows the sequence of applying APWM before the PWM signal during power-up to prevent inadvertent light intensity changes. The peak current output with no APWM or PWM dimming is 120mA per channel.

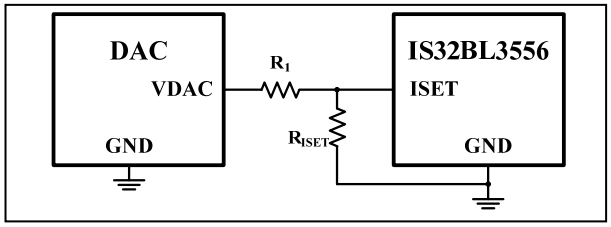
For the best APWM dimming accuracy it is recommended to use frequency ranges between 50 and 500kHz.

ANALOG DIMMING

The LED current can also be dimmed by using an external DAC or another voltage source applied either directly to the ground side of the RISET resistor or through an external resistor to the ISET pin (Figure 47). For this type of dimming the I_{SET} range 20µA ~ 120µA will set the dimming limits.



(A)



(B)

Figure 47 Simplified Diagrams Of Voltage Control Of I_{LED}: Typical Applications Using A DAC To Control I_{LED} Using A Single Resistor (Upper), And Dual Resistors (Lower).

• For Figure 47A, the I_{SET} current is calculated by the following Formula (3). The LED can only be decreased from the peak current set by R_{ISET}.

$$I_{SET} = \frac{V_{SET} - V_{DAC}}{R_{ISET}} \qquad (3)$$

Where V_{SET} is the I_{SET} pin voltage (1V Typ.) and V_{DAC} is the DAC output voltage. The LED current is maximum

value when the DAC voltage is 0V. Select R_{ISET} resistor so the I_{SET} current is in the range of 20μA ~ 120μA to maintain stability of the internal gain amplifier.

• For the dual-resistor configuration (Figure 47B), the I_{SET} current is calculated by the following Formula (4). The LED current can be increased or decreased.

$$I_{SET} = \frac{V_{SET}}{R_{ISET}} - \frac{V_{DAC} - V_{SET}}{R_1} \qquad (4)$$

For this resistor circuit the LED current can be increased or decreased.by adjusting the DAC voltage higher or lower. The LED current can be made higher or lower than the current set by the R_{ISET} resistor:

▫ V_{DAC}= 1.000V; R_{ISET} controls current output

▫ V_{DAC}> 1.000V; the LED current is reduced

▫ V_{DAC}< 1.000V; the LED current is increased

LED SHORT DETECT

The IS32BL3556 integrates an LED short-circuit protection circuit. If the voltage at any of the two channel pins exceeds a threshold of approximately V_{CH_S} during normal operation, the corresponding string is turned off and is latched off (Figure 38). This is to prevent the IC from dissipating too much power by having a large voltage present on a CHx pin.

To prevent false tripping of an LED short event, the IS32BL3556 rechecks the disabled LED string every time the PWM signal goes high. This enables self-correction for an intermittent LED pin short.

OVERVOLTAGE PROTECTION

The IS32BL3556 integrates an OVP circuit and open Schottky diode protection to prevent system damage should the output voltage become excessive. The OVP protection default level is 8.1V and can be increased to 53V by connecting a resistor R_{OVP} from the OVP pin to VOUT. When the current into the OVP pin exceeds 199μA (typical), the OVP comparator goes low and stops the switching.

The following Equation (5) can be used to determine the resistance for setting the OVP level:

$$R_{OVP} = \frac{V_{OVP\_OUT} - V_{OVP1}}{I_{OVPS}} \qquad (5)$$

Where: V_{OVP_OUT} is the target overvoltage level, R_{OVP} is the value of the external resistor, in Ω, V_{OVP1} is the pin OVP threshold found in the Electrical Characteristics Table, and I_{OVPS} is the sense current into the OVP pin.

The two most common reasons for an OVP condition are: a disconnected output, and an open LED string. Examples of these are provided in Figures 36 and 37.

Figure 36 shows when the output of the IS32BL3556 is disconnected from the load during normal operation. The output voltage V_{OUT} immediately increases to the OVP voltage level which then stops the switching to prevent damage to the IC. Switching will resume once V_{OUT} discharges to below the OVP threshold and will stop if V_{OUT} increases above the OVP threshold.

Figure 37 displays a typical OVP event caused by an open LED string. After the OVP condition is detected, the IS32BL3556 stops switching, the open LED string is disabled and V_{OUT} begins to drop. The switching will resume and the IS32BL3556 continues with normal operation.

IS32BL3556 also has secondary overvoltage protection for the internal switch (SW pin). In the event of an open schottky diode the voltage on the SW pin (VSW) may exceed 60V, which is above the device safe operating voltage rating. Under this condition the secondary overvoltage protection will disable the IS32BL3556 and remain in a latched off condition. To clear the latch and resume operation, the IS32BL3556 must be shut down by either lowering the supply voltage below the UVLO threshold or by driving the EN/PWM pin as shown in Figure 35.

If the IS32BL3556 is enabled with an open diode condition, it will go through all its initial LED detection procedure and then try to enable the switcher, at which time the open diode is detected the device shuts down as shown in Figure 34.

BOOST SWITCH OVERCURRENT PROTECTION

A minimum of 3.0A current limiting is used to protect boost switch. Various boost switches over current conditions are shown in Figures 33 through 40.

INPUT OVER CURRENT PROTECTION AND DISCONNECT SWITCH

The input isolation switch's main function is to protect the system from high current surge caused by a fault state. Figure 48 shows the support circuitry for the external PMOS disconnect switch. The switch is optional, if it is not implemented, the SENSE pin must be tied to VCC and the GATE pin must be left open.

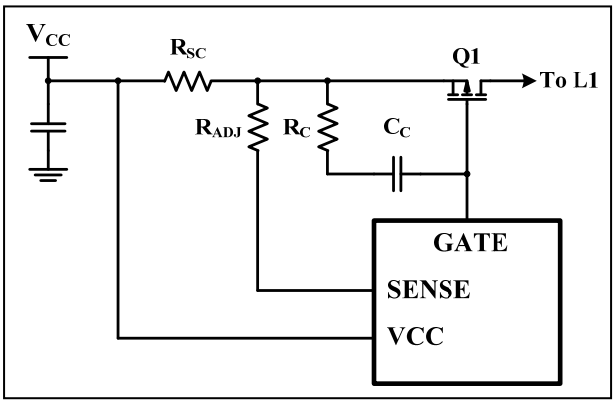


Figure 48 Typical Circuit Showing The Implementation Of The Input Disconnect Feature.

The external PMOS disconnect switch should meet the following parameters:

• Drain-source breakdown voltage (V_{DS_BD}) > -40V

• Gate threshold voltage (fully conducting at V_{GS} = -4V, and cut off at -1V)

• R_{DS_ON}: On-resistance rated at V_{GS} = -4.5V and derated for higher temperatures

The input disconnect switch has two operating modes:

• **1X Mode** When the input current is above 1x and below 2x the current limit value (I_{SW_LIM1}) , the disconnect switch enters a constant- current linear mode for a maximum duration of 8,192 cycles or 5.4ms at 1.5MHz. During this time, the fault flag is set and the input is current limited to a value close to the 1X current trip point level (Figure 42). If the fault condition is removed before expiration of the timer, the fault flag is removed and normal operation resumes.

The IS32BL3556 can be manually placed in sleep or shut down mode. To enter sleep mode the EN/PWM pin is held low for a period of 32,750 clock cycles. To enter shut down mode, the FR/SYNC pin is held low for >7µs. In shut down mode, the IC stops switching, the input disconnect switch is opened, and the CHx pins stop sinking current.

To keep the disconnect switch stable while the disconnect switch is in 1X mode, use a 22nF capacitor for C_C and a 20Ω resistor for R_C.

• **2X Mode** If the input current is >2X the preset current limit threshold, the IS32BL3556 will automatically shut down in less than 3µs (Figure 41) to prevent catastrophic failure. The fault flag is set and the device is latched in the OFF state until power cycle. This feature is meant to prevent catastrophic failure in the system due to inductor short to ground, switch pin short to ground, or output short to ground.

SETTING THE CURRENT SENSE RESISTOR

With an R_{ADJ} value of 0Ω, the typical threshold for the current sense pin is 104mV. The R_{ADJ} resistor is used to set the V_{ADJ} voltage. The typical 1X trip point should be set at about 3A, which coincides with the cycle-by-cycle current limit minimum threshold.

For example, for a 3A of input current, and a calculated maximum value of the sense resistor, R_{SC} = 0.033Ω. The R_{SC} chosen is 0.03Ω, a standard.

Also:

$$R_{ADJ} = \frac{V_{SENSE} - V_{ADJ}}{I_{ADJ}} \qquad (6)$$

The trip point voltage is calculated as:

V_{ADJ} = 3.0A × 0.03Ω = 0.090V

R_{ADJ} = (0.104 – 0.09V)/(20.3µA) = 731Ω

INPUT UVLO

The IS32BL3556 will be enabled when V_{CC} and V_{SENSE} rise above the V_{UVLO_R} threshold. It will be disabled when V_{CC} falls below the V_{UVLO_F} threshold for more than 50µs. This small delay is used to avoid shutting down because of momentary glitches in the input power supply. It will shut down if V_{CC} falls below 4.35V, (see Figure 43).

VDD

The IS32BL3556 has an internal LDO to support internal circuits and provide a pull-up voltage (3.5V Typ.) for the FAULTB pin. The current is limited to <2mA and a capacitor C_{VDD} (>1µF) should be connected to the VDD pin.

SHUTDOWN

The IS32BL3556 enters a shutdown mode and clears all internal fault registers when the EN/PWM pin is pulled low for more than t_{PWM_OFF} (32,750 clock cycles). With a 1.5MHz clock frequency, it will take approximately 21ms to shut down (Figure 39). When the IS32BL3556 is shut down, all current sources are disabled. A high level on the EN/PWM will remove the shutdown condition. For a faster shutdown, the FR/SYNC pin can be pulled low.

FAULT PROTECTION DURING OPERATION

The IS32BL3556 constantly monitors the state of the system in order to determine whether there is any fault condition. The response to a triggered fault condition is summarized in the Fault Mode Table 1.

The device can detect these fault conditions:

- Open CH pin
- CH pin shorted to ground
- Shorted inductor
- VOUT short to ground
- SW pin shorted to ground
- ISET pin shorted to ground
- Input disconnect switch source shorted to ground

Some of these faults (VOUT short to ground) will not be protected if the input disconnect switch is not used. During power up, some of the protection features are disabled to prevent false fault triggering.

Table 1 Fault Mode

Fault Name	Type	Active	Flag	Description	Boost	Disconnect Switch	Sink Driver
Primary switch overcurrent protection (Cycle-by-cycle current limit)	Auto-restart	Always	No	This fault condition is triggered by the cycle-by-cycle current limit, $I_{SW(LIM)}$	Off for a single cycle	On	On
Input disconnect current limit	Latched	Always	Yes	The device is immediately shut off if the voltage across the input sense resistor is 2X the preset current value. The fault flag is set. If the input current limit is between 1X and 2X, the fault flag is set but the IC will continue to operate normally for $t_{GFAULT1}$ or until it is shut down. To re-enable the device the EN/PWM pin must be pulled low for 32,750 clock cycles.	Off	Off	Off
Secondary OVP	Latched	Always	Yes	Secondary overvoltage protection is used for open diode detection. When diode D1 opens, the SW pin voltage will increase until $V_{OVP(SEC)}$ is reached. This fault latches the IC. The input disconnect switch is disabled as well as the LED drivers, and the fault flag is set. To re-enable the part the EN/PWM pin must be pulled low for 32,750 clock cycles.	Off	Off	Off
LED pin short protection	Auto-restart	Startup	No	This fault prevents the device from starting-up if either of the CHx pins are shorted. The device stops soft-start from starting while either of the CHx pins are determined to be shorted. After the short is removed, soft-start is allowed to start.	Off	On	Off
LED pin open	Auto-restart	Normal Operation	No	When a CHx pin is open the device will determine which LED pin is open by increasing the output voltage until OVP is reached. Any LED string not in regulation will be turned off. The device will then go back to normal operation by reducing the output voltage to the appropriate voltage level.	On	On	Off for open pins. On for all others.
ISET short protection	Auto-restart	Always	No	This fault occurs when the ISET current goes above 150% of the maximum current. The boost will stop switching, the disconnect switch will turn off, and the IC will disable the LED sinks until the fault is removed. When the fault is removed the IC will try to regulate to the preset LED current.	Off	On	Off
FR/SYNC short protection	Auto-restart	Always	Yes	Fault occurs when the FR/SYNC current goes above 150% of maximum current, about 180µA. The boost will stop switching, the disconnect switch will turn off, and the IC will disable the LED sinks until the fault is removed. When the fault is removed the IC will try to restart with soft-start.	Off	Off	Off
Overvoltage protection	Auto-restart	Always	No	Fault occurs when OVP pin exceeds $V_{OVP(TH)}$ threshold. The IC will immediately stop switching to try to reduce the output voltage. If the output voltage decreases then the IC will restart switching to regulate the output voltage.	Stop during OVP event	On	On
LED short protection	Auto-restart	Always	No	Fault occurs when the LED pin voltage exceeds V_{LEDSC}. When the LED short protection is detected the LED string that is above the threshold will be removed from operation.	On	On	Off for shorted pins. On for all others.
Over temperature protection	Auto-restart	Always	No	Fault occurs when the die temperature exceeds the over temperature threshold, 165°C.	Off	Off	Off
VCC UVLO	Auto-restart	Always	No	Fault occurs when V_{CC} drops below V_{UVLO}, 3.9V maximum. This fault resets all latched faults.	Off	Off	Off

CLASSIFICATION REFLOW PROFILES

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature min (Tsmin) Temperature max (Tsmax) Time (Tsmin to Tsmax) (ts)	150°C 200°C 60-120 seconds
Average ramp-up rate (Tsmax to Tp)	3°C/second max.
Liquidous temperature (TL) Time at liquidous (tL)	217°C 60-150 seconds
Peak package body temperature (Tp)*	Max 260°C
Time (tp)** within 5°C of the specified classification temperature (Tc)	Max 30 seconds
Average ramp-down rate (Tp to Tsmax)	6°C/second max.
Time 25°C to peak temperature	8 minutes max.

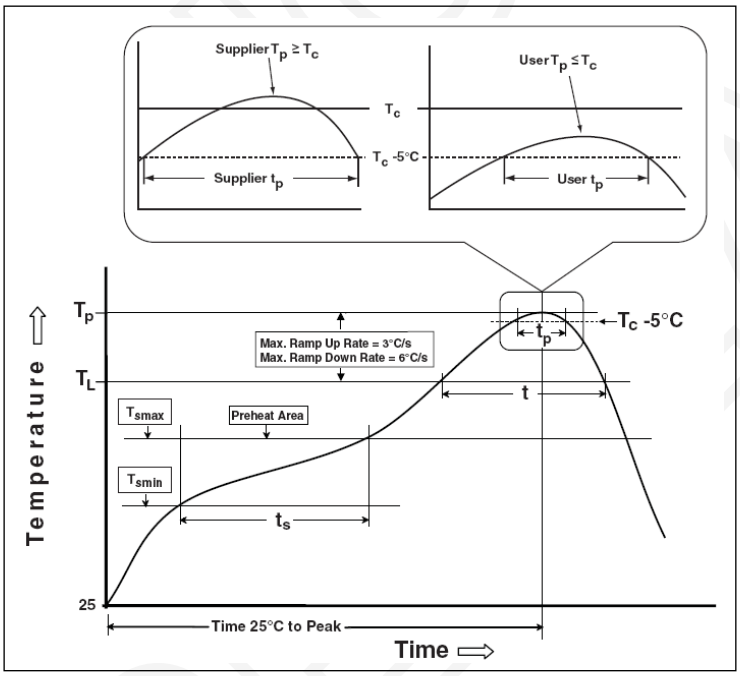
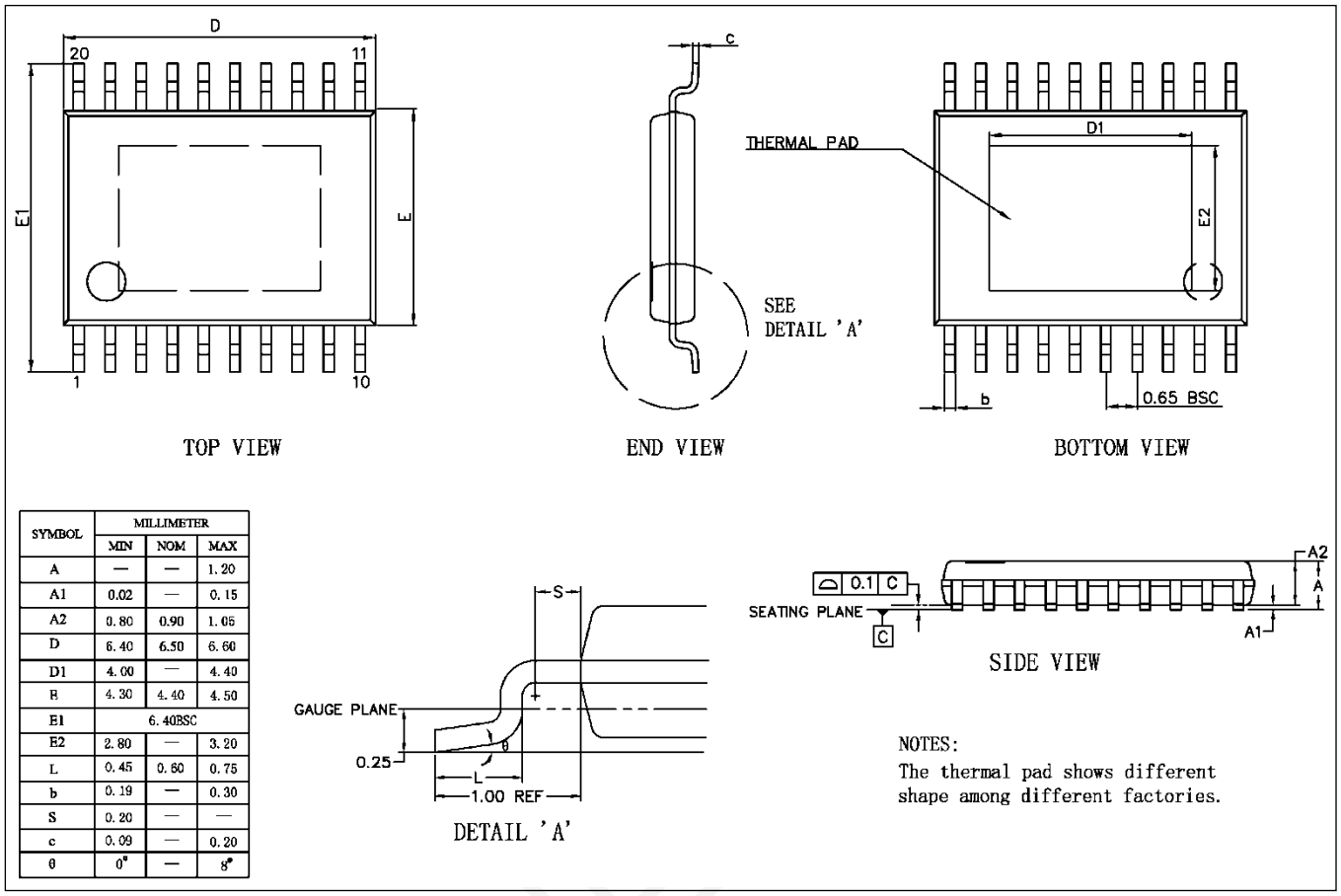


Figure 49 Classification Profile

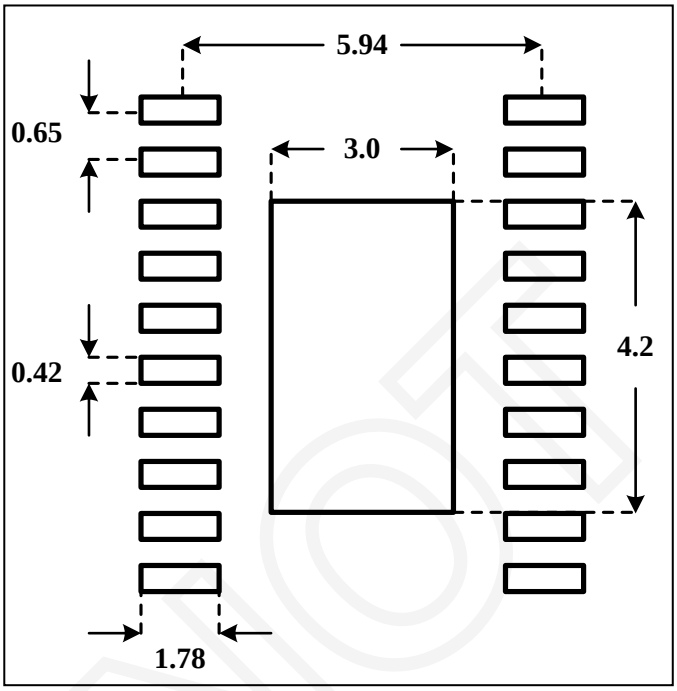
PACKAGE INFORMATION

eTSSOP-20



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.20
A1	0.02	—	0.15
A2	0.80	0.90	1.05
D	6.40	6.50	6.60
D1	4.00	—	4.40
E	4.30	4.40	4.50
E1	6.40BSC		
E2	2.80	—	3.20
L	0.45	0.60	0.75
b	0.19	—	0.30
S	0.20	—	—
c	0.09	—	0.20
θ	0°	—	8°

RECOMMENDED LAND PATTERN



Note:

1. Land pattern complies to IPC-7351.
2. All dimensions in MM.
3. This document (including dimensions, notes & specs) is a recommendation based on typical circuit board manufacturing parameters. Since land pattern design depends on many factors unknown (eg. user's board manufacturing specs), user must determine suitability for use.

REVISION HISTORY

Revision	Detail Information	Date
0A	Initial release	2016.08.18
0B	1. Add temperature chart 2. Add efficient chart 3. Update Figure 20, 26, 27, 28	2016.09.23
0C	1. Update t_{PWM_ON} and t_{PWM_OFF} value 2. Update Figure 45	2016.12.12
0D	Add soft star test condition	2017.02.06