

Boost Type LED Driver with 12-Channel Current Source
AP3612

General Description

The AP3612 is a high efficiency boost controller with 12-string current sources for driving WLED backlight. It operates over a wide input voltage range from 4.5V to 33V.

The current of 12 strings are simply programmed from 20mA to 75mA with an external resistor. The current matching between each string is 1.5% (Typ). Its operating frequency can be adjusted from 0.1MHz to 1MHz.

The AP3612 features Cycle-by-cycle Current Limit, Soft Start, Under Voltage Lock Out (UVLO) protection, programmable OVP, Over Temperature Protection (OTP), open/short LED protection, V_{OUT} short protection and Schottky diode short-circuit protection.

The AP3612 is available in HSOP-28 and SOIC-24 packages.

Features

- Input Voltage Range: 4.5V to 33V
- Drives up to 12 Strings in Parallel, 75mA per String
- Programmable WLED Current from 20mA to 75mA
- Adjustable Operating Frequency: 100kHz to 1MHz
- String-to-string Current Matching Accuracy: 1.5%
- Built-in OCP, OTP, UVLO
- External PWM Dimming
- Open/Short LED Protection
- Programmable Soft Start
- Programmable OVP
- Schottky Diode/Inductor Short-circuit Protection
- V_{OUT} Short/Schottky Diode Open Protection

Applications

- LCD Monitor
- LCD Display Module
- LCD TV

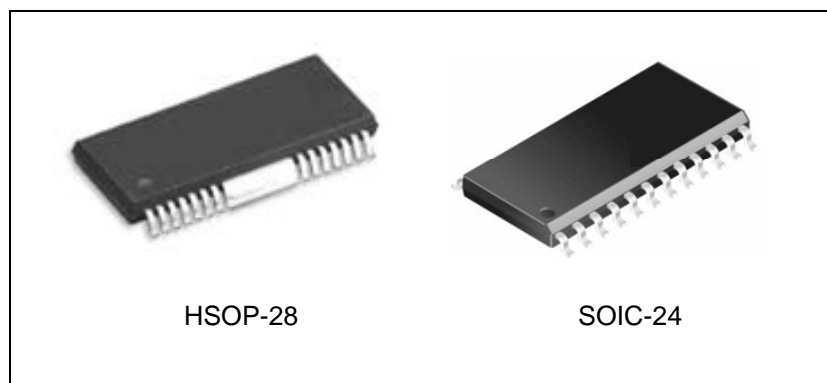


Figure 1. Package Types of AP3612

Pin Configuration

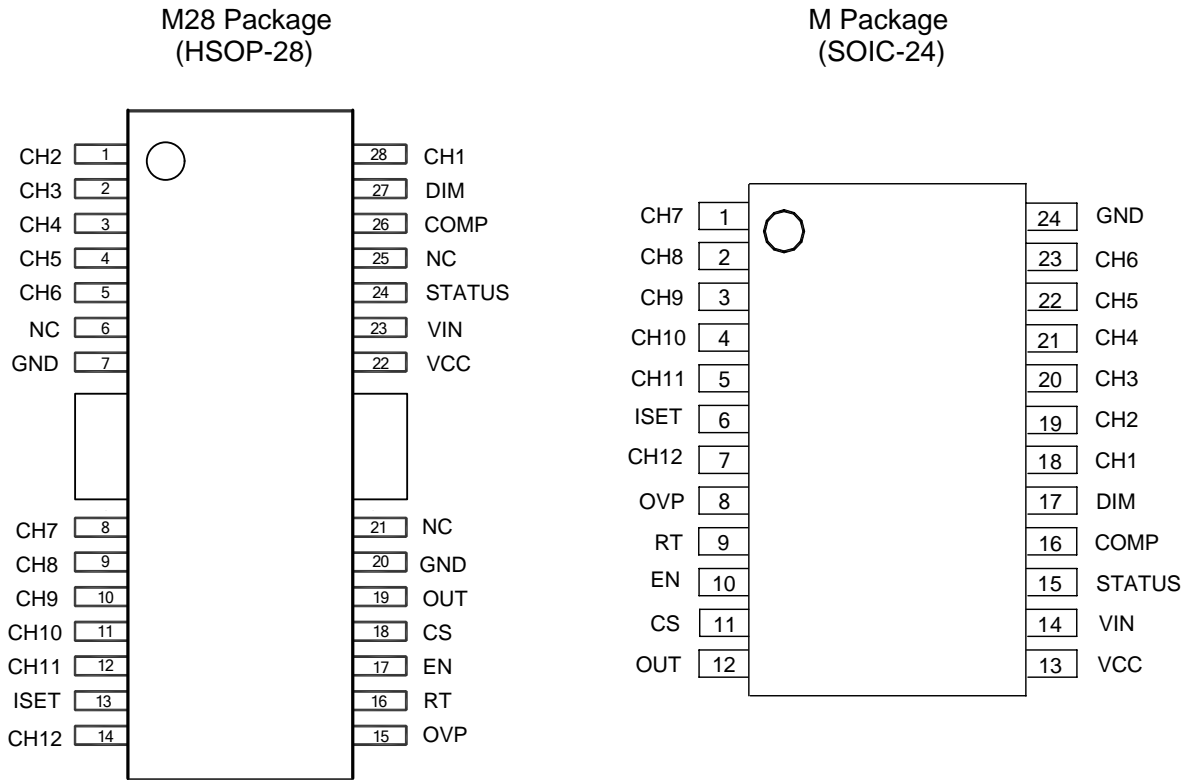


Figure 2. Pin Configuration of AP3612 (Top View)

**Boost Type LED Driver with 12-Channel Current Source****AP3612****Pin Description**

| Pin Number | | Pin Name | Function |
|----------------------------------|---|-------------|---|
| HSOP-28 | SOIC-24 | | |
| 28,1,2,3,4,5, 8,9,10,11,12,14 | 18,19,20,21, 22,23, 1, 2, 3, 4, 5, 7 | CH1 to CH12 | LED current sink. Leave the pin open directly if not used |
| 6, 21,25 | | NC | No connection |
| 7, 20 | 24 | GND | Ground pin |
| 13 | 6 | ISET | LED current setting pin. The corresponding maximum current of all strings is set through connecting a resistor from this pin to GND |
| 15 | 8 | OVP | Over voltage protection pin. When the OVP pin voltage exceeds 2.0V, the OVP is triggered and the power switch is turned off. When the OVP pin voltage drops below hysteresis voltage, the OVP is released and the power switch will resume normal operation |
| 16 | 9 | RT | Frequency control pin |
| 17 | 10 | EN | ON/OFF control pin. Forcing this pin above 2.4V enables the IC while below 0.5V shuts down the IC. When the IC is in shutdown mode, all functions are disabled to decrease the supply current below 3 μ A |
| 18 | 11 | CS | Power switch current sense input |
| 19 | 12 | OUT | Boost converter power switch gate output. This pin output high voltage ($5V/V_{IN}-0.5V$) to drive the external N-MOSFET |
| 22 | 13 | VCC | 5V linear regulator output pin. This pin should be bypassed to GND (recommend to connect with GND pin) with a ceramic capacitor |
| 23 | 14 | VIN | Supply input pin. A capacitor (typical 10 μ F) should be connected between the VIN and GND to keep the DC input voltage constant |
| 24 | 15 | STATUS | LED operation status output |
| 26 | 16 | COMP | Soft-start and control loop compensation |
| 27 | 17 | DIM | PWM dimming control pin. Adding a PWM signal to this pin to control LED dimming. If not used, connect it to the high level |

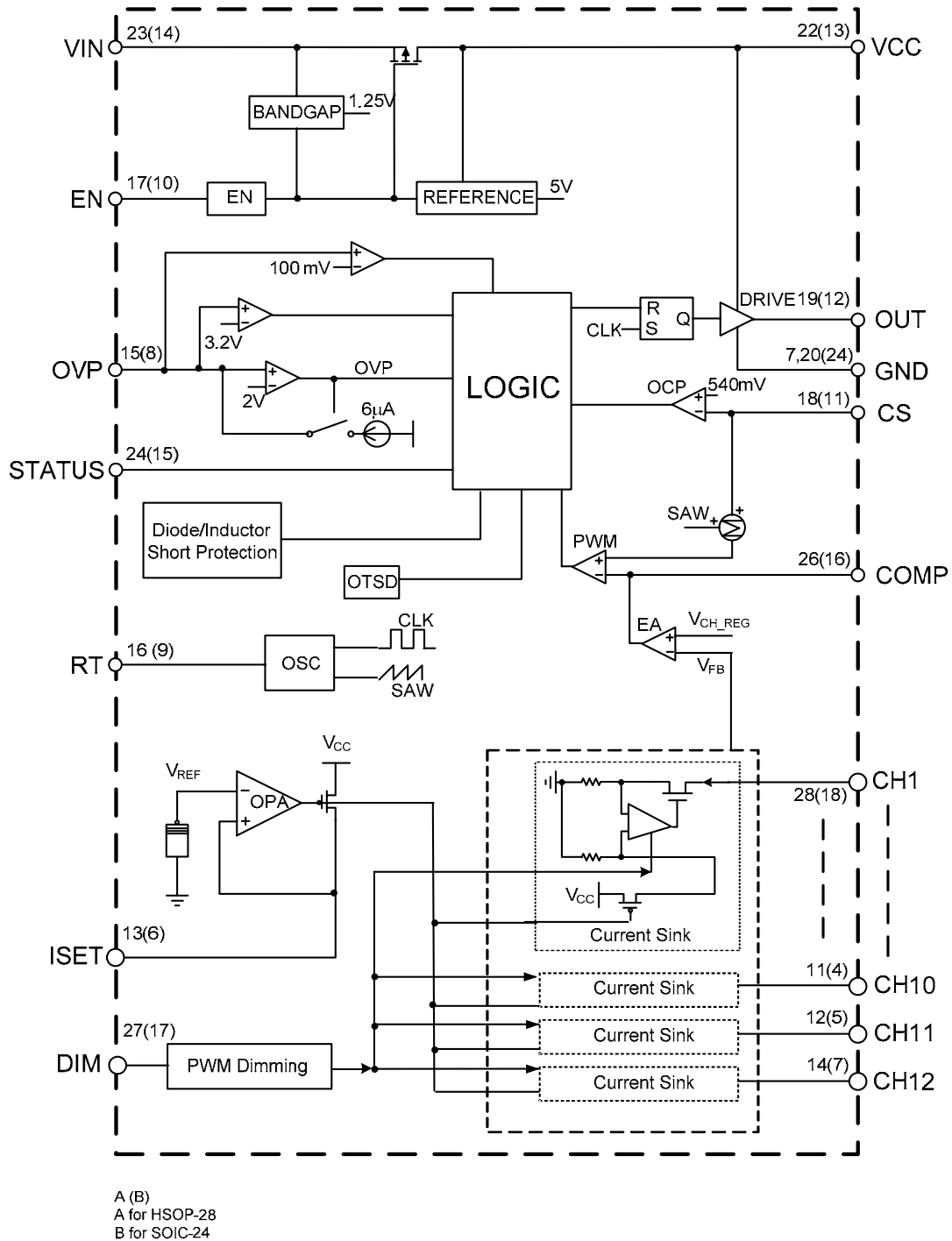
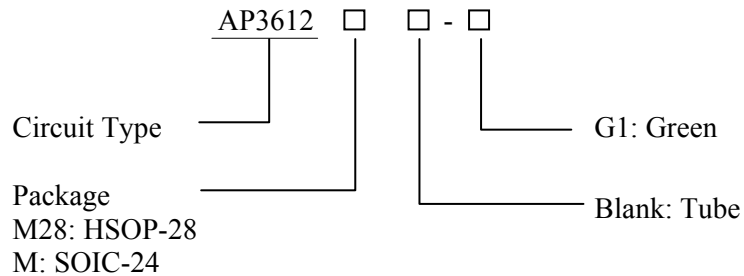
Functional Block Diagram


Figure 3. Functional Block Diagram of AP3612

**Boost Type LED Driver with 12-Channel Current Source****AP3612****Ordering Information**

| Package | Temperature Range | Part Number | Marking ID | Packing Type |
|---------|-------------------|--------------|--------------|--------------|
| HSOP-28 | -40 to 85°C | AP3612M28-G1 | AP3612M28-G1 | Tube |
| SOIC-24 | | AP3612M-G1 | AP3612M-G1 | Tube |

BCD Semiconductor's Pb-free products, as designated with "G1" suffix in the part number, are RoHS compliant and green.

Absolute Maximum Ratings (Note 1)

| Parameter | Symbol | Value | Unit |
|---|--------------|---------------|------|
| Input Voltage | V_{IN} | -0.3 to 42 | V |
| CH1 to CH12 Voltage | V_{CH} | -0.3 to 65 | V |
| EN Pin Voltage | V_{EN} | -0.3 to 7 | V |
| VCC Pin Voltage | V_{CC} | -0.3 to 7 | V |
| CS Pin Voltage | V_{CS} | -0.3 to 7 | V |
| COMP Pin Voltage | V_{COMP} | -0.3 to 7 | V |
| ISET Pin Voltage | V_{ISET} | -0.3 to 7 | V |
| OUT Pin Voltage | V_{OUT} | -0.3 to 7 | V |
| OVP Pin Voltage | V_{OVP} | -0.3 to 7 | V |
| RT Pin Voltage | V_{RT} | -0.3 to 7 | V |
| STATUS Pin Voltage | V_{STATUS} | -0.3 to 7 | V |
| DIM Pin Voltage | V_{DIM} | -0.3 to 7 | V |
| GND Pin Voltage | V_{GND} | -0.3 to 0.3 | V |
| Thermal Resistance (Junction to Ambient, Free Air, No Heatsink) | HSOP-28 | θ_{JA} | °C/W |
| | SOIC-24 | | |
| | | | 100 |

**Boost Type LED Driver with 12-Channel Current Source****AP3612****Absolute Maximum Ratings (Note 1) (Continued)**

| Parameter | Symbol | Value | Unit |
|--|------------|------------|------|
| Operating Junction Temperature | T_J | 150 | °C |
| Storage Temperature | T_{STG} | -65 to 150 | °C |
| Lead Temperature (Soldering, 10sec) | T_{LEAD} | 260 | °C |
| ESD (Machine Model) | | 200 | V |
| ESD (Human Body Model) | | 2000 | V |

Note 1: Stresses greater than 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 conditions beyond those indicated under “Recommended Operating Conditions” is not implied. Exposure to “Absolute Maximum Ratings” for extended periods may affect device reliability.

Note 2: Negative CS 100ns Transient maximum rating voltage reach to -0.4V.

Recommended Operating Conditions

| Parameter | Symbol | Min | Max | Unit |
|-------------------------------------|-----------|-----|-----|------|
| Input Voltage | V_{IN} | 4.5 | 33 | V |
| Operating Frequency | f_O | 0.1 | 1 | MHz |
| LED Channel Voltage | V_{CHX} | | 60 | V |
| LED Channel Current | I_{CHX} | 20 | 75 | mA |
| PWM Dimming Frequency | f_{PWM} | 0.1 | 20 | kHz |
| Operating Ambient Temperature Range | T_A | -40 | 85 | °C |



Boost Type LED Driver with 12-Channel Current Source

AP3612

Electrical Characteristics

$V_{IN}=24V$, $V_{EN}=5V$, Typical $T_A=25^{\circ}C$, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|--|----------------|--------------------------------|-----|--------------|-----|---------|
| INPUT SUPPLY | | | | | | |
| Input Voltage | V_{IN} | | 4.5 | | 33 | V |
| Quiescent Current | I_Q | No Switching | | 3 | 5 | mA |
| Shutdown Supply Current | I_{SHTD} | $V_{EN}=V_{DD}=0V$ | | 0.1 | 3 | μA |
| UVLO | V_{UVLO} | V_{IN} Rising | 3.6 | 3.8 | 4.0 | V |
| UVLO Hysteresis | V_{HYS} | | | 200 | | mV |
| VCC SECTION | | | | | | |
| VCC Voltage | V_{CC} | $V_{IN} \geq 5.5V$ | | 5 | | V |
| | | $V_{IN} < 5.5V$, Load=10mA | | $V_{IN}-0.1$ | | V |
| OUT Pin Rising Time (Note 3) | t_{RISING} | 1nF Load | | 30 | 50 | ns |
| OUT Pin Falling Time (Note 3) | $t_{FALLING}$ | 1nF Load | | 30 | 50 | ns |
| Load Regulation (Note 3) | | Load=0 to 30mA | | 5 | | mV/mA |
| Line Regulation (Note 3) | | $V_{IN}=5.5$ to 24V | | 0.3 | | mV/V |
| HIGH FREQUENCY OSCILLATOR | | | | | | |
| Switch Frequency (Target: 10% Variation) | f_{OSC} | $R_T=100k\Omega$ | 440 | 520 | 600 | kHz |
| Switch Frequency Range | | | 0.1 | | 1 | MHz |
| Maximum Duty Cycle | D_{MAX} | $f=500kHz$ | 88 | 90 | | % |
| Minimum On-time (Note 3) | $t_{ON-TIME}$ | $f=500kHz$ | | 200 | | ns |
| ENABLE LOGIC AND DIMMING LOGIC | | | | | | |
| EN High Voltage | V_{EN_H} | | 2.4 | | | V |
| EN Low Voltage | V_{EN_L} | | | | 0.5 | V |
| PWM Logic for External Dimming | V_{DIM_H} | | 2.5 | | | V |
| | V_{DIM_L} | | | | 0.3 | V |
| PWM Dimming Minimum Pulse Width (Note 3) | t_{PWM_MIN} | | | $3/f_{osc}$ | | μs |

**Boost Type LED Driver with 12-Channel Current Source****AP3612****Electrical Characteristics (Continued)** $V_{IN}=24V$, $V_{EN}=5V$, Typical $T_A=25^\circ C$, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|-----------------|--------------------------------|-----|------|-----|------------|
| POWER SWITCH DRIVE | | | | | | |
| Current Limit Threshold Voltage | V_{LIMIT} | | 480 | 540 | 600 | mV |
| D/L Short Threshold Voltage (Note 3) | V_{LIMIT2} | | 720 | 800 | 880 | mV |
| Current Sense LEB Time (Note 3) | t_{LEB} | | 80 | 100 | 150 | ns |
| COMPENSATION AND SOFT START (COMP PIN) | | | | | | |
| Error Amplifier Trans-conductance | G_{EA} | | | 2300 | | $\mu A/V$ |
| Sourcing Current | I_{O_H} | $V_{COMP}=0.5V$ | 80 | 120 | 160 | μA |
| Sinking Current | I_{O_L} | $V_{COMP}=2V$ | 80 | 120 | 160 | μA |
| OVER VOLTAGE PROTECTION | | | | | | |
| OVP Threshold Voltage | V_{OVP} | V_{OUT} Rising | 1.9 | 2.0 | 2.1 | V |
| OVP Hysteresis | V_{OVP_HYS} | | | 250 | | mV |
| Shutdown Under Abnormal Condition | V_{OVP-SH} | | 3.0 | 3.2 | 3.4 | V |
| CURRENT SOURCE | | | | | | |
| LED Current Matching between Each String (Note 4) | I_{CH_MATCH} | $I_{CH}=60mA$ | | 1.5 | 4 | % |
| Regulation Current per Channel | I_{CH} | $R_{ISET}=6.667k\Omega$ | 55 | 60 | 65 | mA |
| Minimum LED Regulation Voltage | V_{LED_REG} | $I_{CHX}=60mA$ | | 400 | | mV |
| CH1 to CH12 Leakage Current | I_{LED_LEAK} | $V_{EN}=0V$, $V_{LED}=37V$ | | 0.1 | 1 | μA |
| LED Short Protection Threshold | V_{LED-S} | | 6.6 | 7.3 | 8.0 | V |
| OVER TEMPERATURE PROTECTION | | | | | | |
| Thermal Shutdown Temperature (Note 3) | T_{OTSD} | | | 160 | | $^\circ C$ |
| Thermal Shutdown Recovery (Note 3) | T_{HYS} | | | 140 | | $^\circ C$ |

Note 3: Guaranteed by design.

$$\text{Note 4: } I_{ST_MATCH} = \frac{I_{MAX} - I_{MIN}}{2 \times I_{AVG}} \times 100\%$$



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Typical Performance Characteristics

$V_{IN}=24V$, $V_{EN}=V_{DD}=5V$, 13 LEDs in series, 12 strings in parallel, 60mA/string, $T_A=25^\circ C$, unless otherwise specified.

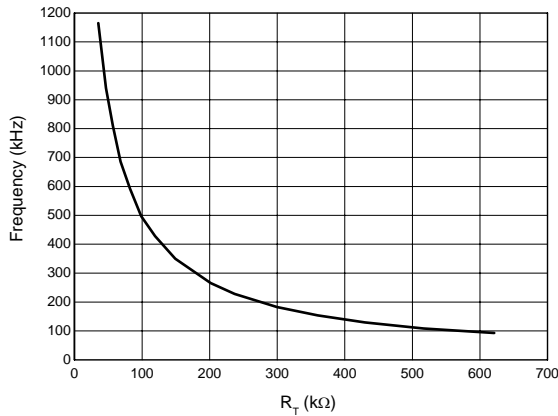


Figure 4. Frequency vs. R_T

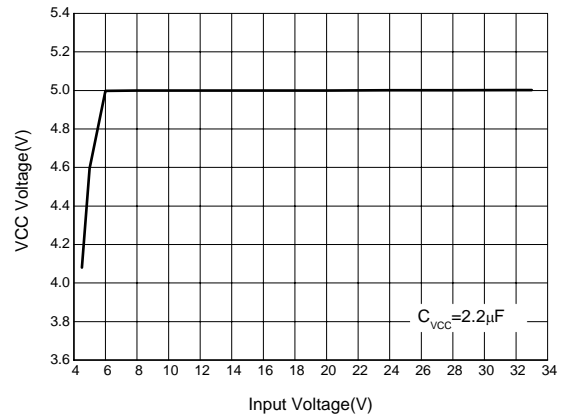


Figure 5. VCC Voltage vs. Input Voltage

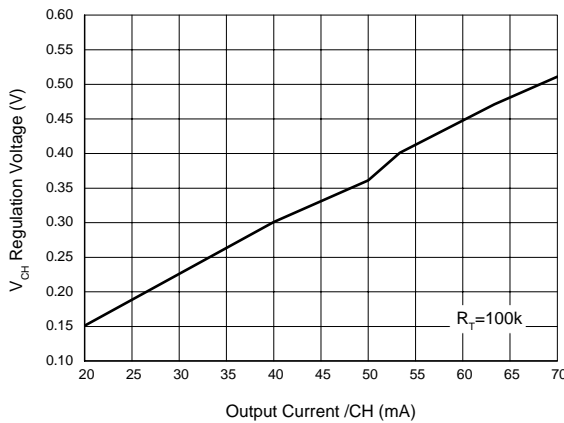


Figure 6. V_{CH} Regulation Voltage vs. Output Current

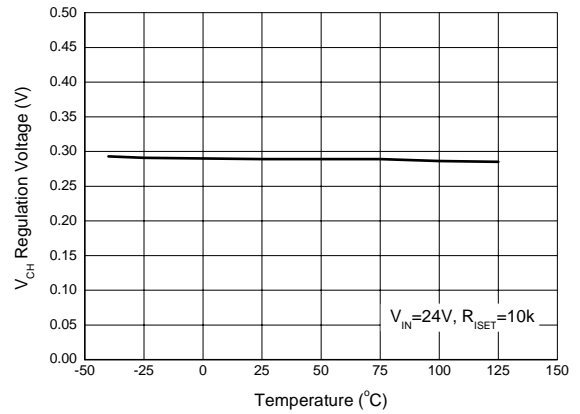


Figure 7. V_{LED} Regulation Voltage vs. Temperature

Typical Performance Characteristics (Continued)

$V_{IN}=24V$, $V_{EN}=V_{DD}=5V$, 13 LEDs in series, 12 strings in parallel, 60mA/string, $T_A=25^\circ C$, unless otherwise specified.

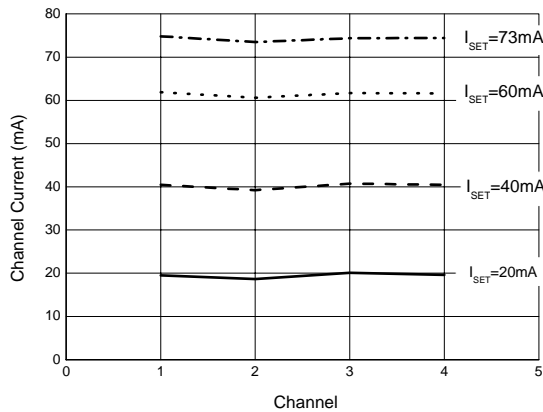


Figure 8. Channel Current vs. Channel

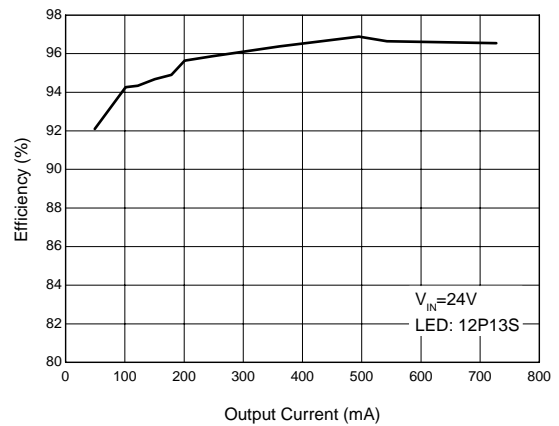
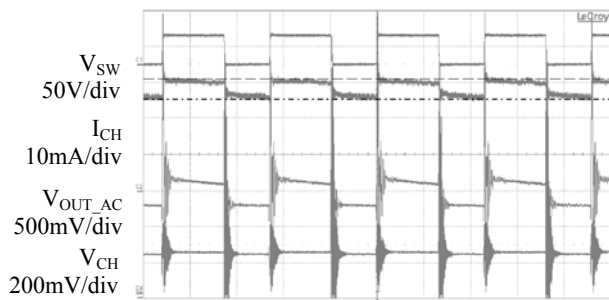
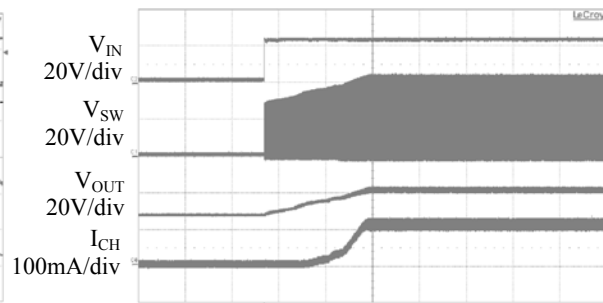


Figure 9. Efficiency vs. Output Current



Time 1µs/div

Figure 10. Steady State



Time 20ms/div

Figure 11. System Startup

Typical Performance Characteristics (Continued)

$V_{IN}=24V$, $V_{EN}=V_{DD}=5V$, 13 LEDs in series, 12 strings in parallel, 60mA/string, $T_A=25^\circ C$, unless otherwise specified.

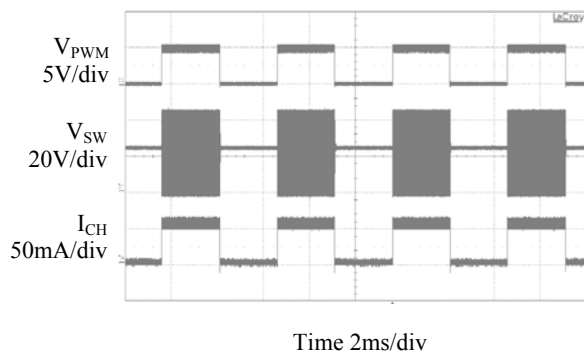


Figure 12. PWM Dimming

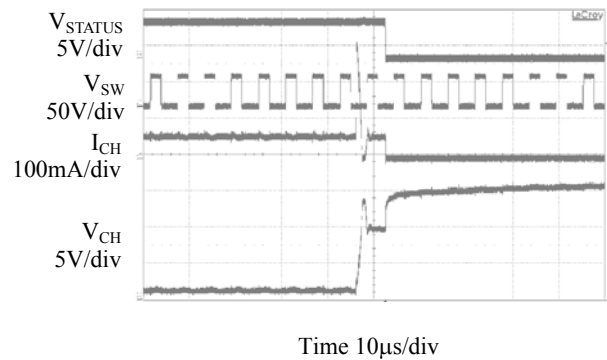


Figure 13. LED Short Protection

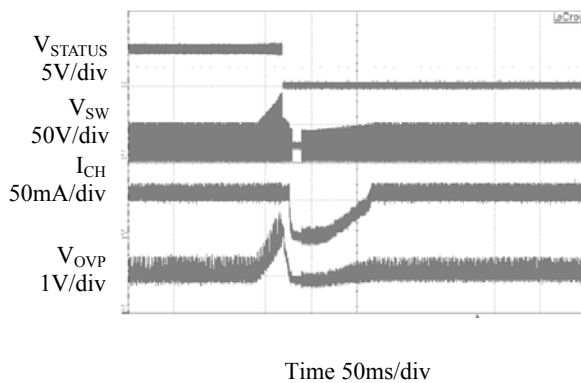


Figure 14. LED Open Protection

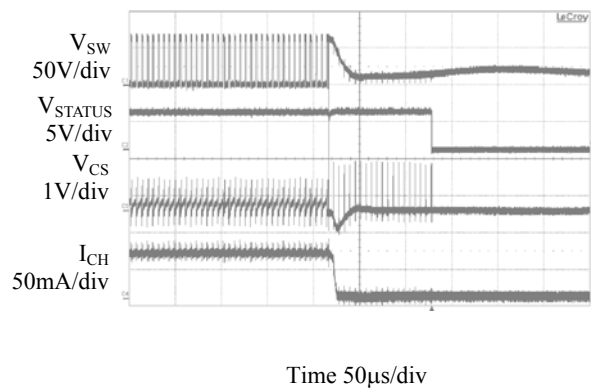


Figure 15. Schottky/Inductor Short Protection

Typical Performance Characteristics (Continued)

$V_{IN}=24V$, $V_{EN}=V_{DD}=5V$, 13 LEDs in series, 12 strings in parallel, 60mA/string, $T_A=25^\circ C$, unless otherwise specified.

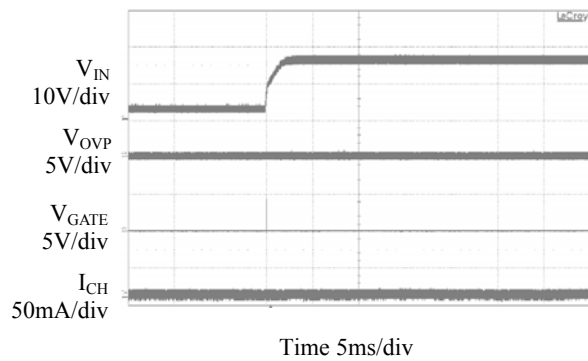
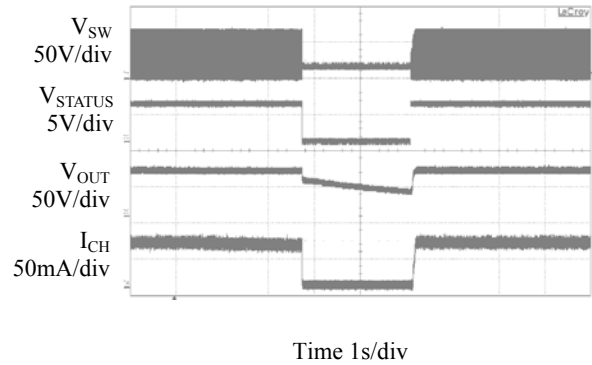

 Figure 16. V_{OUT} Short/Diode Open Protection


Figure 17. Over Temperature Protection



Application Information

1. Enable

The AP3612 is enabled when the voltage to EN is greater than approximately 2.4V, disabled when lower than 0.5V.

2. Frequency Selection

An external resistor R_T , placed between RT pin and GND, can be used to set the operating frequency. The operating frequency ranges from 100kHz to 1MHz. The high frequency operation optimizes the regulator for the smallest-sized component application, while low frequency operation can help to reduce switch loss. The approximate operating frequency can be expressed as below:

$$f_{osc} [MHz] = \frac{52}{R_{RT} [K\Omega]}$$

3. LED Current Setting

The maximum LED current per channel can be adjusted up to 75mA via ISET pin. When $\geq 75mA$ current is needed in application, two or more channels can be paralleled to provide larger drive current. Connect a resistor R_{ISET} between ISET pin and GND to set the reference current I_{SET} . The LED current can be expressed as below:

$$I_{LED} [mA] = \frac{400}{R_{ISET} [K\Omega]}$$

4. Dimming Control

Applying a PWM signal to DIM pin to adjust the LED current, that means, the LED current of all enabled channels can be adjusted at the same time and the LED brightness can be adjusted from $1\% \times I_{CHX_MAX}$ to $100\% \times I_{CHX_MAX}$. During the “high level” period of PWM signal, the LED is turned on and 100% of the current flows through LED, while during the “low level” period of the PWM signal, the LED is turned off and almost no current flows through the LED, thus changing the average current through LED and finally adjusting LED brightness. The external PWM signal frequency applied to PWM pin is allowed to be 100Hz or higher.

5. Status Output

After IC is enabled, STATUS will output logic low if any of the following conditions exists:

- 1) Any String is Open
- 2) LED Short Circuit Protection
- 3) Shut Down Under Abnormal Condition
- 4) Over Temperature Protection
- 5) Schottky Diode Short Protection
- 6) Over Voltage Protection
- 7) V_{OUT} Short/Open Schottky Diode Protection

6. Over Voltage Protection

The AP3612 integrates an OVP circuit. The OVP pin is connected to the center tap of voltage-divider (R_{OV1} and R_{OV2}) that placed between high voltage output and GND. If the voltage on OVP pin exceeds 2.0V, which may results from open loop or excessive output voltage, all the functions of AP3612 will be disabled with output voltage falling. The OVP hysteresis is 250mV. The formula of OVP can be expressed as below:

$$V_{OVP} = \frac{(R_{OV1} + R_{OV2}) \times 2.0V}{R_{OV2}}$$

7. Over Current Protection

The AP3612 integrates an OCP circuit. The CS pin is connected to the voltage-sensor (R_{CS}) that placed between the Drain of MOS and GND. If the voltage on CS pin exceeds 0.54V, it is turned off immediately and will not turn on until the next cycle begins.

8. LED Short-circuit Protection

The AP3612 integrates an LED Short-circuit protection circuit. If the voltage at any of the CH1-CH12 pins exceeds a threshold of approximately 7.3V during normal operation, the corresponding string is turned off and is latched off. Toggle V_{IN} and/or EN to reset the latch. LED short detecting logic priority is lower than open LED and OVP logic. The LED short detecting is triggered when $0.1V < V_{LED_MIN}$ under dimming on mode, disabled when LED open occurs until output voltage resumes to the regulated voltage.



Application Information (Continued)

9. LED Open-circuit Protection

The AP3612 integrates an LED Open-circuit Protection circuit. When any LED string is open, V_{OUT} will boost up until the voltage at OVP pin reaches an approximate 2.0V threshold. The IC will automatically ignore the open string whose corresponding pin voltage is less than 100mV and the remaining string will continue operation. If all the strings are open and the voltage at OVP reaches a threshold of 2.0V, the MOSFET drive GATE will turn off and IC will shut down and latch.

10. V_{OUT} Short/Open Schottky Diode Protection

The AP3612 monitors the OVP pin, if the OVP pin voltage is less than 0.1V, MOSFET drive output will turn off. This protects the converter if the output Schottky diode is open or V_{OUT} is shorted to ground.

11. Under Voltage Lockout

The AP3612 provides an under voltage lockout circuit to prevent it from undefined status when startup. The UVLO circuit shuts down the device when V_{CC} drops below 3.6V. The UVLO circuit has 200mV hysteresis, which means the device starts up again when V_{CC} rise to 3.8V.

12. Over Temperature Protection

The AP3612 features Over Temperature Protection, if the junction temperature exceeds approximately 160°C, the IC will shut down until the junction temperature is less than approximately 140°C. When the IC is released from over temperature shutdown, it will start a soft-start process.

13. Schottky Diode/Inductor Short Circuit Protection

The AP3612 features Schottky diode/inductor short-circuit protection circuit. When CS pin voltage exceeds 0.8V for greater than 16 switching clocks, the IC will be latched. The voltage of CS is monitored after a short delay of LEB.

14. Shut Down under Abnormal Condition

The AP3612 features shutdown under abnormal condition protection circuit. When OVP pin voltage exceeds 3.2V, the IC will latch. Toggle EN to restart the IC. This feature can be used for any other protection to shut down the IC.

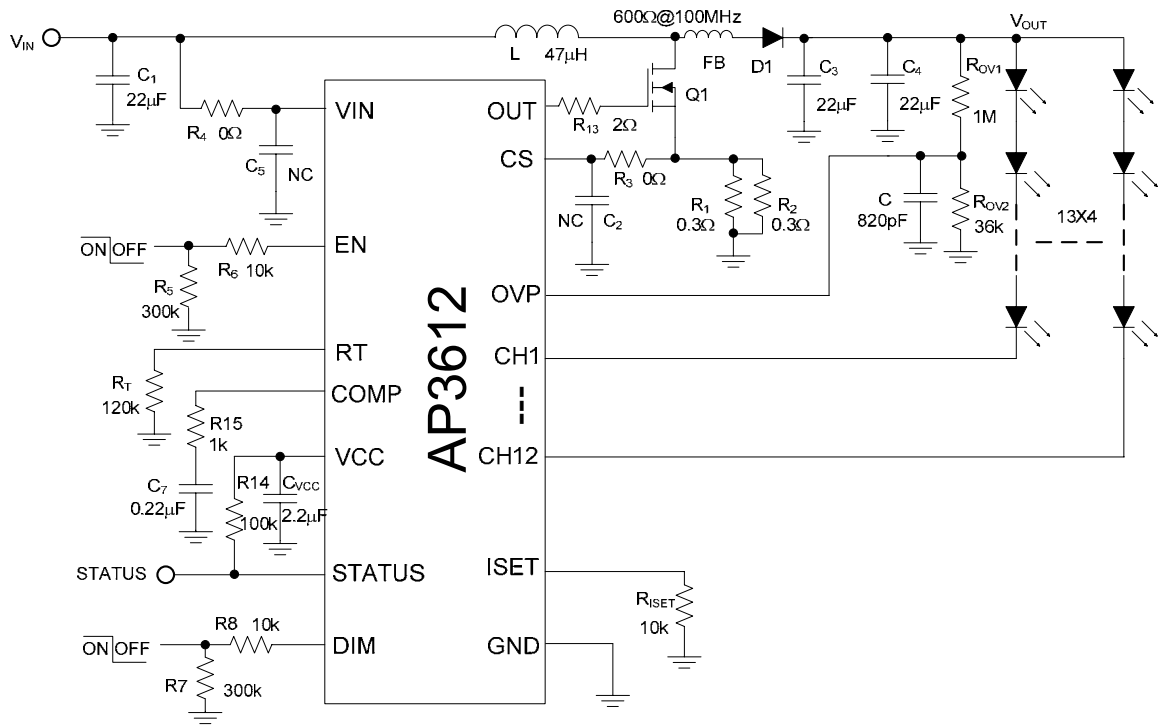
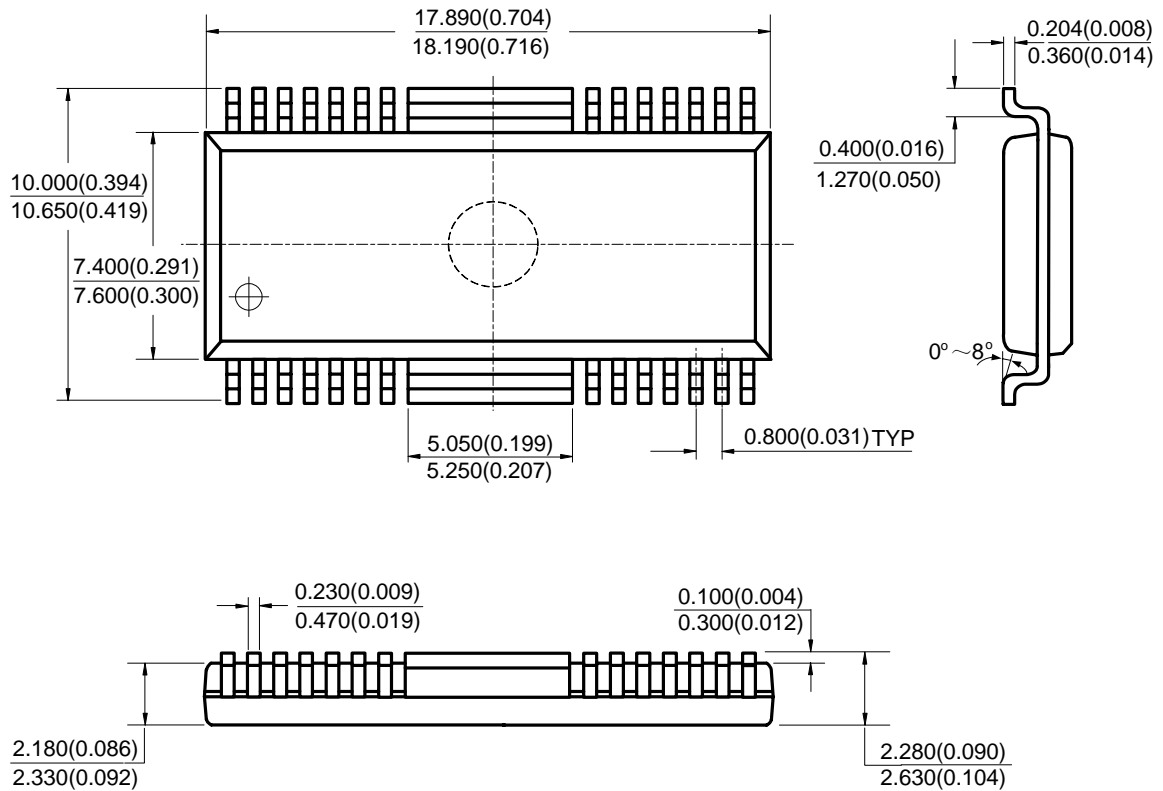
Typical Application


Figure 18. Typical Application Circuit of AP3612

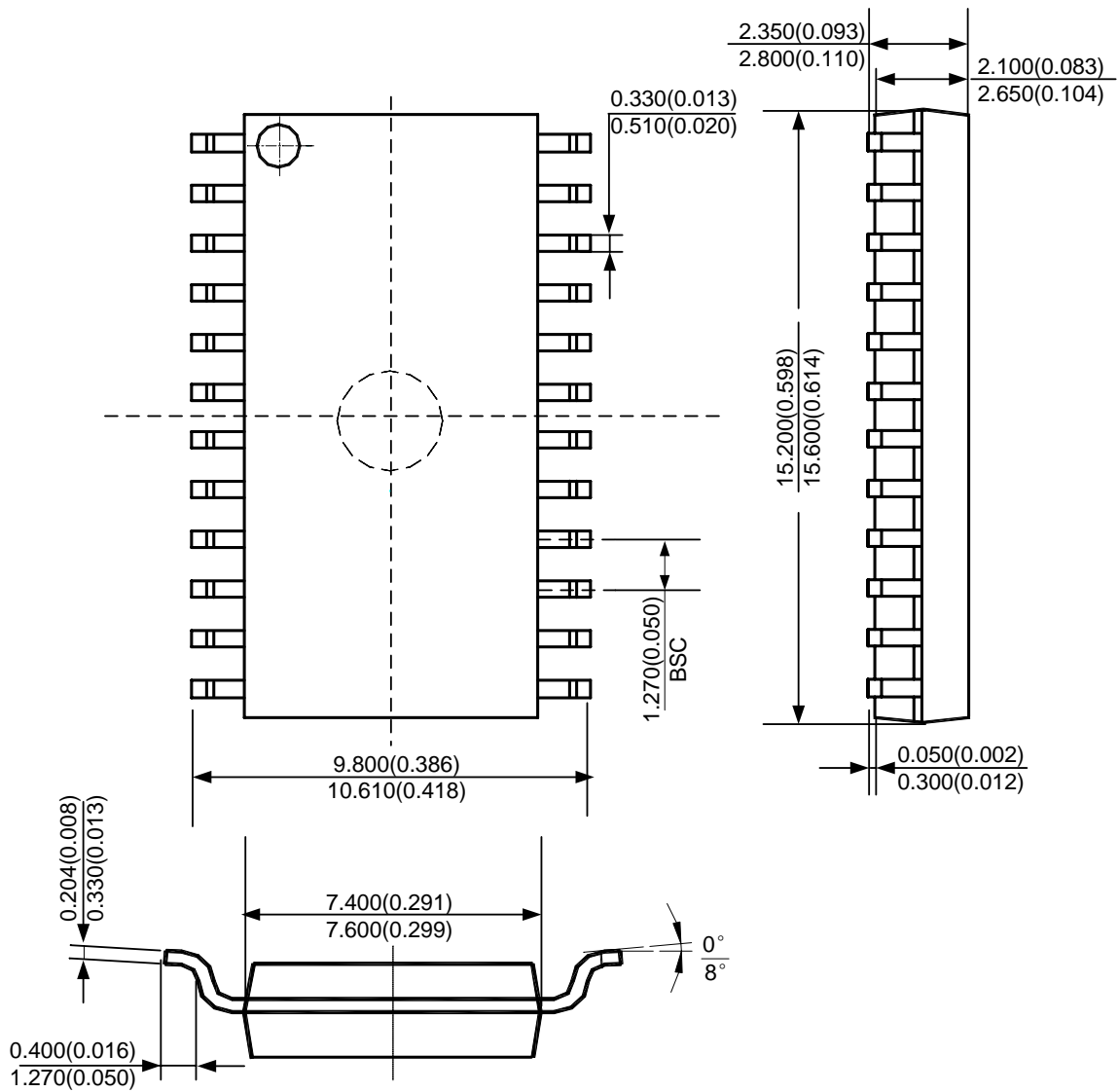
Mechanical Dimensions

HSOP-28

Unit: mm(inch)



Note: Eject hole, oriented hole and mold mark is optional.

Mechanical Dimensions (Continued)
SOIC-24
Unit: mm(inch)


Note: Eject hole, oriented hole and mold mark is optional.



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