# HIGH EFFICIENCY 1x/2x CHARGE PUMP FOR WHITE LED APPLICATIONS

## Description

The DIODES™ AL3158 is a low noise, constant frequency charge pump DC/DC converter that uses a dual mode load switch (1x), and (2x) conversion for white LED applications. The AL3158 is capable of driving three groups of three LED channels at 20mA from a 2.7V to 5.5V input. The current sinks may be operated using three simple PWM dimming inputs individually or in parallel for driving higher-current LEDs. Low external part counts (one 1µF flying capacitor and two 2.2µF capacitors at $V_{IN}$ and $V_{OUT}$) make this part ideally suited for small, battery-powered applications.

AL3158 PWM dimming inputs are used to enable, disable device and dimming LED current with a fixed default current settings at 20mA or other factory programming options available.

Each output of the AL3158 is equipped with built-in protection for $V_{OUT}$ short circuit and auto-disable for LED short conditions. Built-in soft-start circuitry prevents excessive inrush current during start-up and mode switching. A low-current shutdown feature disconnects the load from $V_{IN}$ to reduce quiescent current less than 1µA.

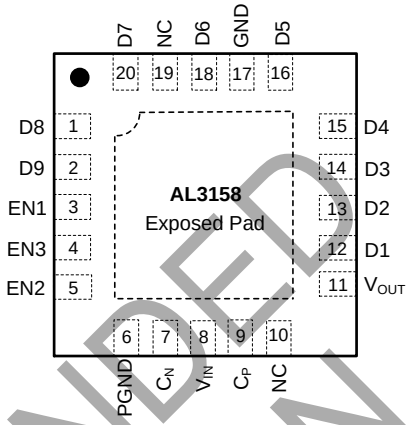
The AL3158 is available in a lead-free, space-saving, thermally enhanced 20-pin 3 x 3mm QFN3030-20 package.

## Features

- $V_{IN}$ Range: 2.7V to 5.5V
- Up to 93% Max Power Efficiency
- 1% Current Matching Accuracy Between Channels
- Three Simple PWM Dimming for RGB or WLED
- Low Transition Threshold Voltage Typical 150mV
- Dual-Mode 1x and 2x Charge Pump
- Drives up to 3 + 3 + 3 Channels of LEDs
- 1.2MHz Constant Switching Frequency
- $V_{OUT}$ Short Circuit and Thermal Protections
- Soft Start for Reducing Inrush Current
- Under Voltage Lockout Protection
- $I_Q$ < 1µA in Shutdown
- Thermally-Enhanced QFN3030-20 Package: Available in “Green” Molding Compound (No Br, Sb)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. “Green” Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

## Pin Assignments

(Top View)




QFN3030-20

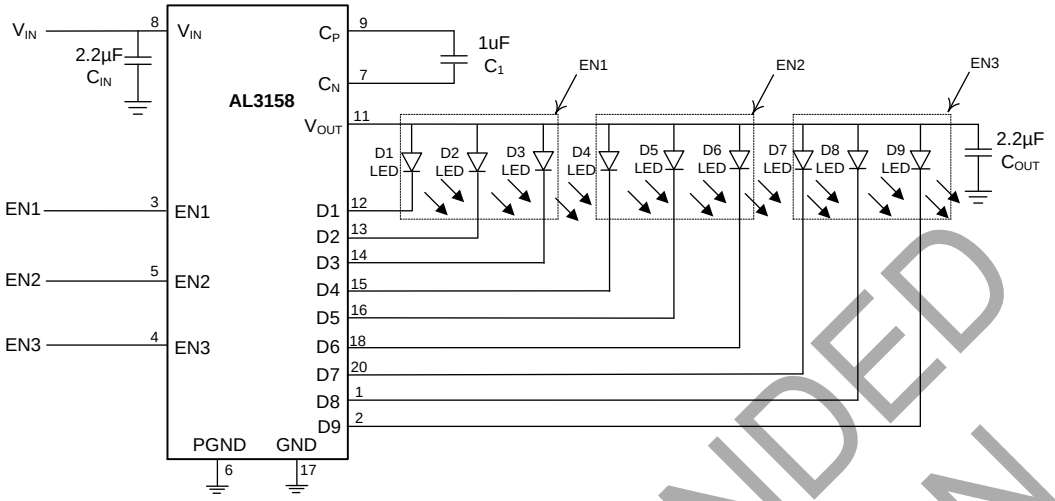
## Applications

- Mobile phone white LED backlighting and indicators
- PDA white LED backlighting
- Battery-operated phone main and sub screen white LED backlighting



Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated’s definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green” products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

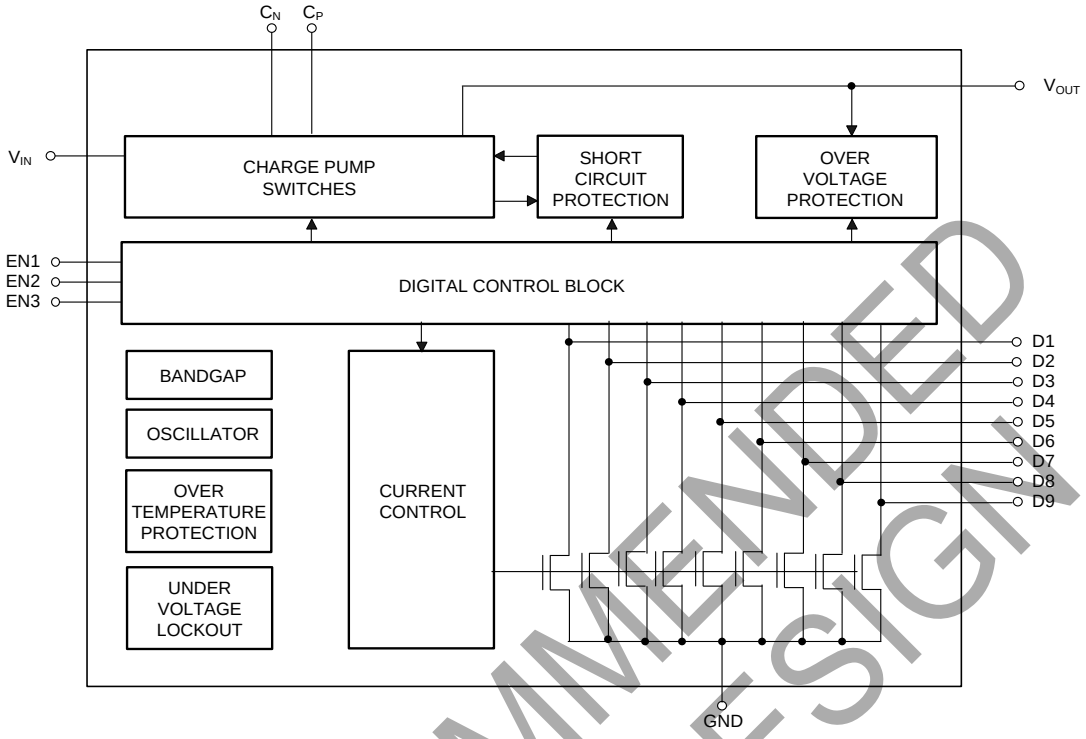
## Typical Application Circuit




## Pin Descriptions

| Pin Name | Pin Number | Description |
|---|---|---|
| D8 | 1 | Current Sink Input #8. Connected to $V_{OUT}$ when unused. |
| D9 | 2 | Current Sink Input #9. Connected to $V_{OUT}$ when unused. |
| EN1 | 3 | Enable Pin 1 |
| EN3 | 4 | Enable Pin 3 |
| EN2 | 5 | Enable Pin 2 |
| PGND | 6 | Charge Pump Switch Ground |
| $C_N$ | 7 | Negative Terminal of Flying Capacitor |
| $V_{IN}$ | 8 | Input Power Supply. Requires 2.2µF capacitor between this pin and ground. |
| $C_P$ | 9 | Positive Terminal of Flying Capacitor |
| NC | 10, 19 | No-Connect |
| $V_{OUT}$ | 11 | Charge Pump Output to Drive Load Circuit. Requires 2.2µF capacitor between this pin and ground. |
| D1 | 12 | Current Sink Input #1. Connected to $V_{OUT}$ when unused. |
| D2 | 13 | Current Sink Input #2. Connected to $V_{OUT}$ when unused. |
| D3 | 14 | Current Sink Input #3. Connected to $V_{OUT}$ when unused. |
| D4 | 15 | Current Sink Input #4. Connected to $V_{OUT}$ when unused. |
| D5 | 16 | Current Sink Input #5. Connected to $V_{OUT}$ when unused. |
| GND | 17 | Ground |
| D6 | 18 | Current Sink Input #6. Connected to $V_{OUT}$ when unused. |
| D7 | 20 | Current Sink Input #7. Connected to $V_{OUT}$ when unused. |
| Exposed Pad | EP Pad | Exposed Pad (bottom). Connected to GND directly underneath the package. |

## Functional Block Diagram






## Absolute Maximum Ratings (Note 4)

| Symbol | Description | Rating | Unit |
|---|---|---|---|
| ESD HBM | Human Body Model ESD Protection | 2 | kV |
| ESD MM | Machine Model ESD Protection | 200 | V |
| $V_{IN}$ | Input Voltage | -0.3 to 6 | V |
| $V_{EN1,2,3}$ | EN1, EN2, EN3 to GND Voltage | -0.3 to $V_{IN}$ +0.3 | V |
| $I_{OUT}$ | Maximum DC Output Current | 270 | mA |
| $T_J$ | Operating Junction Temperature | +150 | °C |
| $T_{LEAD}$ | Maximum Soldering Temperature (at leads, 10 sec) | +300 | °C |

Note: 4. Stresses greater than those listed under *Absolute Maximum Ratings* can 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 can affect device reliability.

## Recommended Operating Conditions

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $V_{IN}$ | Input Voltage | 2.7 | 5.5 | V |
| $T_A$ | Operating Ambient Temperature | -40 | +85 | °C |

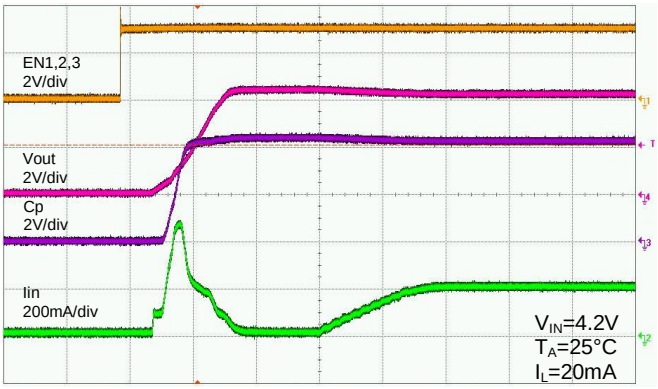
## Electrical Characteristics ($T_A$ = +25°C, $V_{IN}$ = 3.6V, $C_{IN}$ = $C_{OUT}$ = 2.2µF, $C_1$ = 1µF, unless otherwise noted.)

| Symbol | Parameter | Test Conditions | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| $I_Q$ | Quiescent Current | 1x Mode, 3.0 ≤ $V_{IN}$ ≤ 5.5, Active No Load Current | — | 0.3 | 0.6 | mA |
| | | 2x Mode, 3.0 ≤ $V_{IN}$ ≤ 5.5, Active No Load Current | — | 2 | 5 | |
| $I_{SHDN}$ | Shutdown Current | EN1, EN2, EN3 = 0 | — | — | 1 | µA |
| $I_{DX}$ | $I_{SINK}$ Current Accuracy (Note 5) | — | 19 | 20 | 21 | mA |
| $I_{D\text{-}Match}$ | Current Matching Between Any Two Current Sink Inputs (Note 6) | $V_F$: D1:D9 = 3.6V | — | 1 | 2 | % |
| $R_{OUT}$ | Open Loop $V_{OUT}$ Resistance | 1x Mode | — | 0.5 | — | Ω |
| | | 2x Mode | — | 4.5 | — | |
| $V_{TH}$ | 1x to 2x Transition Threshold at Any $I_{SINK}$ Pin | $I_{DX}$ = 20mA | — | 150 | — | mV |
| $V_{HS}$ | Mode Transition Hysteresis | — | — | 250 | — | mV |
| $t_{SS}$ | Soft-Start Time | — | — | 100 | — | µs |
| $f_{SW}$ | Switching Frequency | — | — | 1.2 | — | MHz |
| $V_{EN1, 2, 3 (L)}$ | EN1, 2, 3 Threshold Low | $V_{IN}$ = 2.7V | — | — | 0.4 | V |
| $V_{EN1, 2, 3 (H)}$ | EN1, 2, 3 Threshold High | $V_{IN}$ = 5.5V | 1.4 | — | — | V |
| $t_{EN1, 2, 3}$ | EN1, 2, 3 Off Timeout | — | — | — | 20 | ms |
| UVLO | $V_{IN}$ Under-Voltage Lockout | — | 1.8 | 2 | 2.2 | V |
| $I_{EN1, 2, 3}$ | EN1, 2, 3 Input Leakage | — | -1 | — | 1 | µA |
| $T_{SHDN}$ | Thermal Shutdown Protection | — | — | +160 | — | °C |
| $T_{HYS}$ | Thermal Shutdown Hysteresis | — | — | +10 | — | °C |
| $\theta_{JA}$ | Thermal Resistance Junction-to-Ambient | QFN3030-20 (Note 7) | — | 52 | — | °C/W |

Notes:
5. Determined by the average current levels of all active channels.
6. Determined by the maximum sink current (MAX), the minimum sink current (MIN), and the average sink current (AVG). Two matching numbers are calculated as (MAX-AVG)/AVG and (AVG-MIN)/AVG. The largest number of the two (worst case) is considered as the matching data.
7. Device mounted on FR-4 substrate, 2" x 2", 2oz copper, double-sided PC board, with minimum recommended pad on top layer and 4 vias to bottom layer.

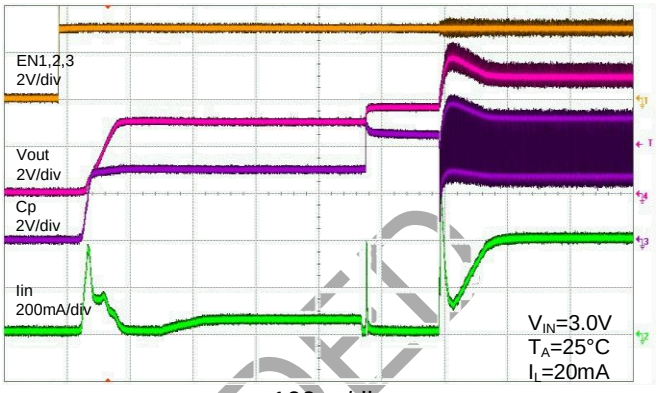
## Typical Performance Characteristics

**Turn-On to 1x Mode**



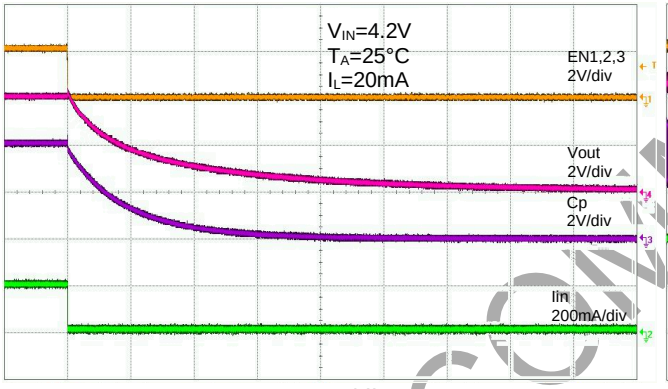

50µs/div

**Turn-On to 2x Mode**



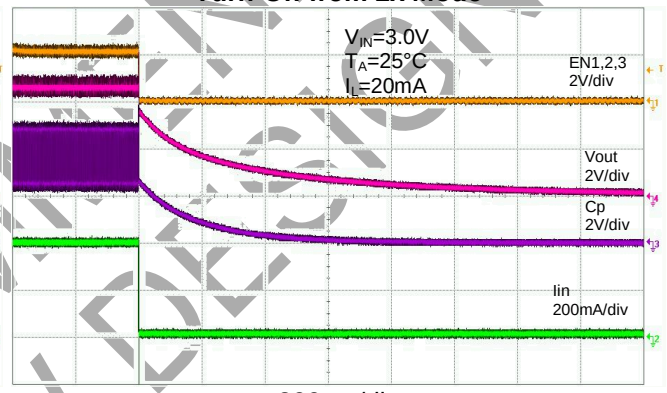

100µs/div

**Turn-Off from 1x Mode**



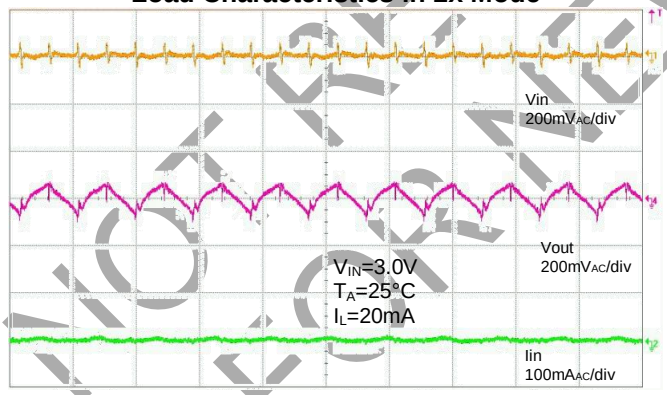

200ms/div

**Turn-Off from 2x Mode**



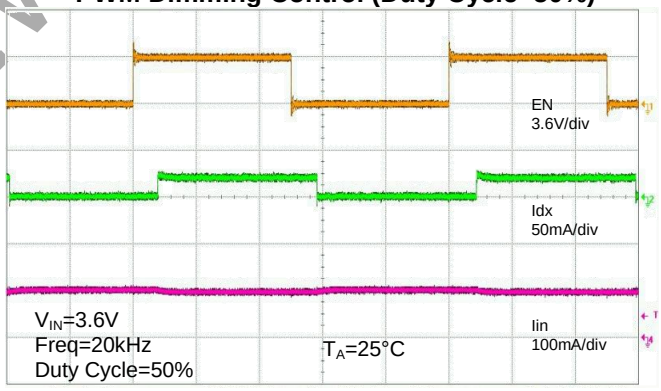

200ms/div

**Load Characteristics in 2x Mode**



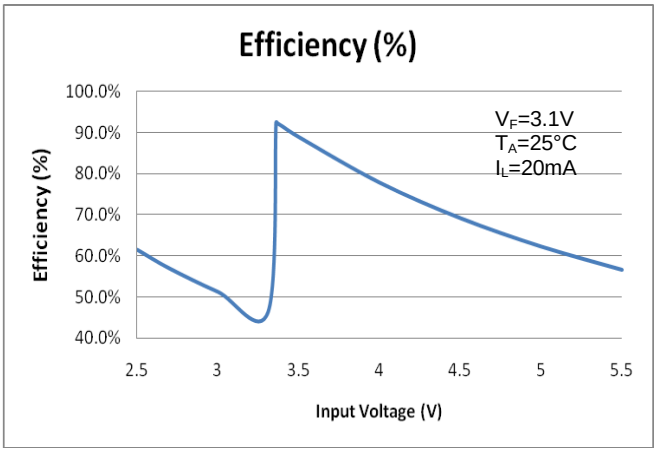

1µs/div

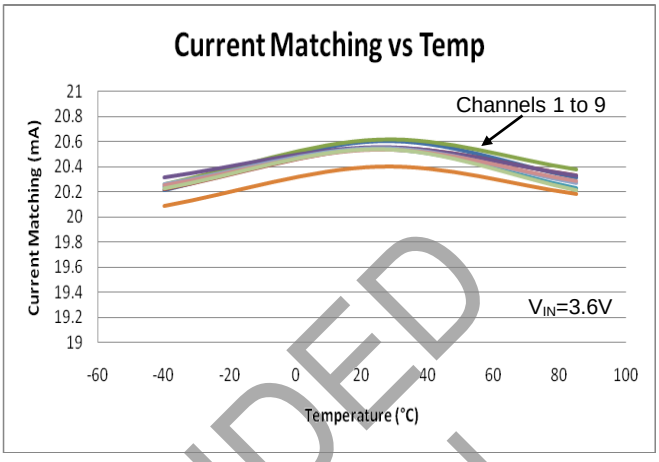
**PWM Dimming Control (Duty Cycle=50%)**

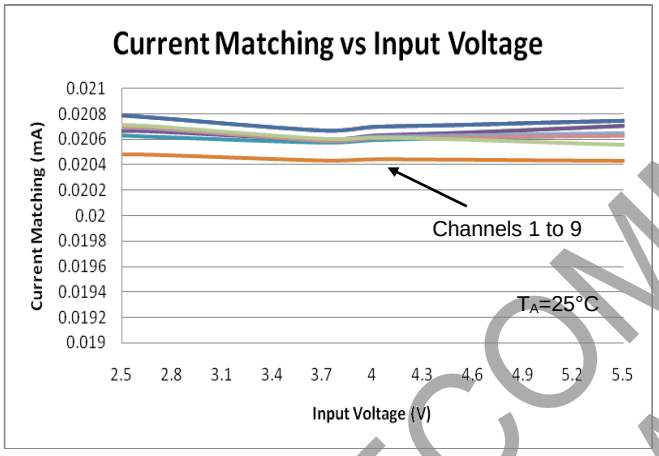


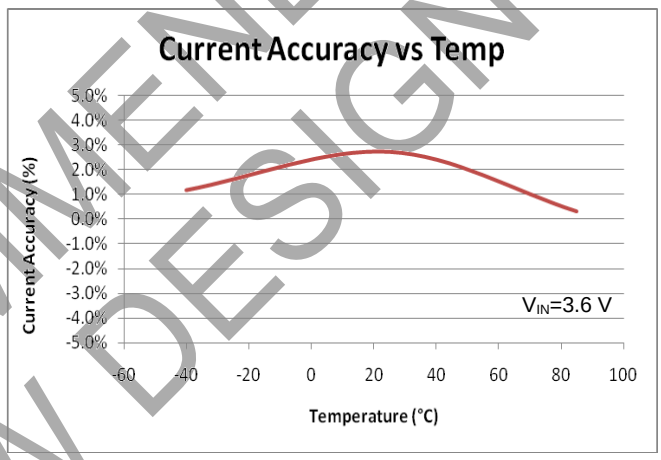

10µs/div

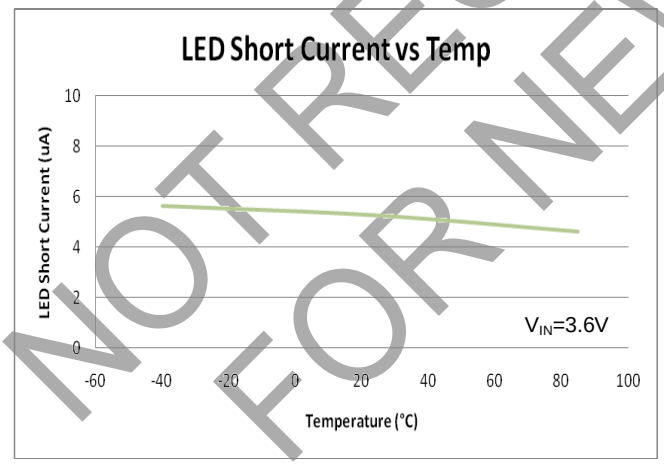
## Typical Performance Characteristics (continued)

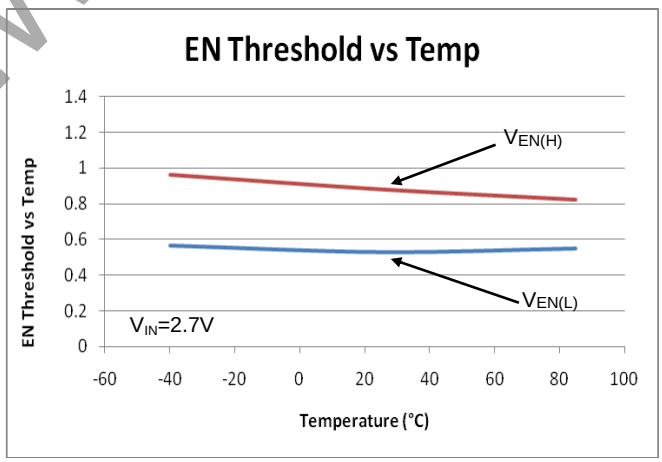


## Functional Description

The AL3158 is a dual-mode high efficiency charge pump (1x and 2x) device, driving three groups of three LED channels at 30mA maximum each, intended for white LED backlight applications. An internal comparator circuit compares the voltage at each constant current sink input against a reference voltage. To ensure maximum power efficiency, the most appropriate switching mode (1x and 2x) is automatically selected.

The AL3158 requires only three external components: one 1µF ceramic flying capacitor ($C_1$) for the charge pump, one 2.2µF ceramic input capacitor ($C_{IN}$), and one 2.2µF ceramic charge pump output capacitor ($C_{OUT}$).

Each output channel of the AL3158 can drive three groups of three individual LED channels with a maximum current of fixed manufacture setting (20mA or 30mA) per channel. These can be paralleled to give a total output current of 270mA.

| EN <3:1> | LED ON/OFF CONTROL |
|---|---|
| XX0 | LED1 to LED3 OFF |
| XX1 | LED1 to LED3 ON |
| X0X | LED4 to LED6 OFF |
| X1x | LED4 to LED6 ON |
| 0XX | LED7 to LED9 OFF |
| 1xX | LED7 to LED9 ON |

**Disabled Current Sinks**

Unused current channels must be disabled by connecting the sinks to $V_{OUT}$ with only a small sense current flowing through the disabled channel.

**Soft-Start**

Soft-start is incorporated to prevent excessive inrush current during power-up, mode switching, and transitioning out of stand-by mode.

**Short-Circuit Protection**

Short-circuit protection function is incorporated to prevent excessive load current when either flying cap terminals or output pin electrically tied to a very lower voltage or ground.

**Over-Voltage Protection**

Over-voltage protection function is incorporated to limit the output voltage under a safe value to avoid on-chip device breakdown.

**Under-Voltage Lockout**

Under-voltage lockout feature disables the device when the input voltage drops below UVLO threshold.

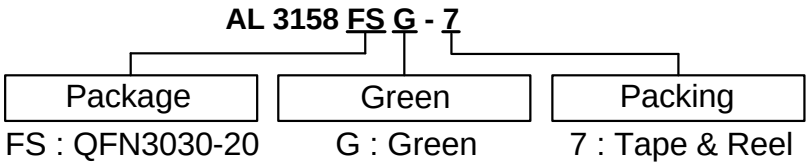
**Thermal Auto Shutdown**

When the die temperature exceeds the thermal limit, the device will be disabled and enter stand-by mode. The operation resumes whenever the die cools off sufficiently.

**PWM Dimming Control**

The AL3158 provides simple PWM dimming control through ENx pins, and the current is adjusted by the duty cycle of the signal applied on ENx pin. The recommended PWM frequency is from 200Hz to 50kHz depending on applications.

## Ordering Information



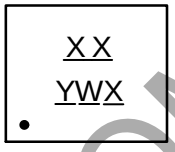

| Part Number | Part Number Suffix | Package Code | Package (Note 8) | Packing | |
|---|---|---|---|---|---|
| | | | | Qty. | Carrier |
| AL3158FSG-7 | -7 | FS | QFN3030-20 | 3000 | 7” Tape & Reel |

Note: 8. Pad layout as shown on Diodes Incorporated’s suggested pad layout, which can be found on our website at http://www.diodes.com/package-outlines.html.

## Marking Information

**QFN3030-20**

**(Top View)**



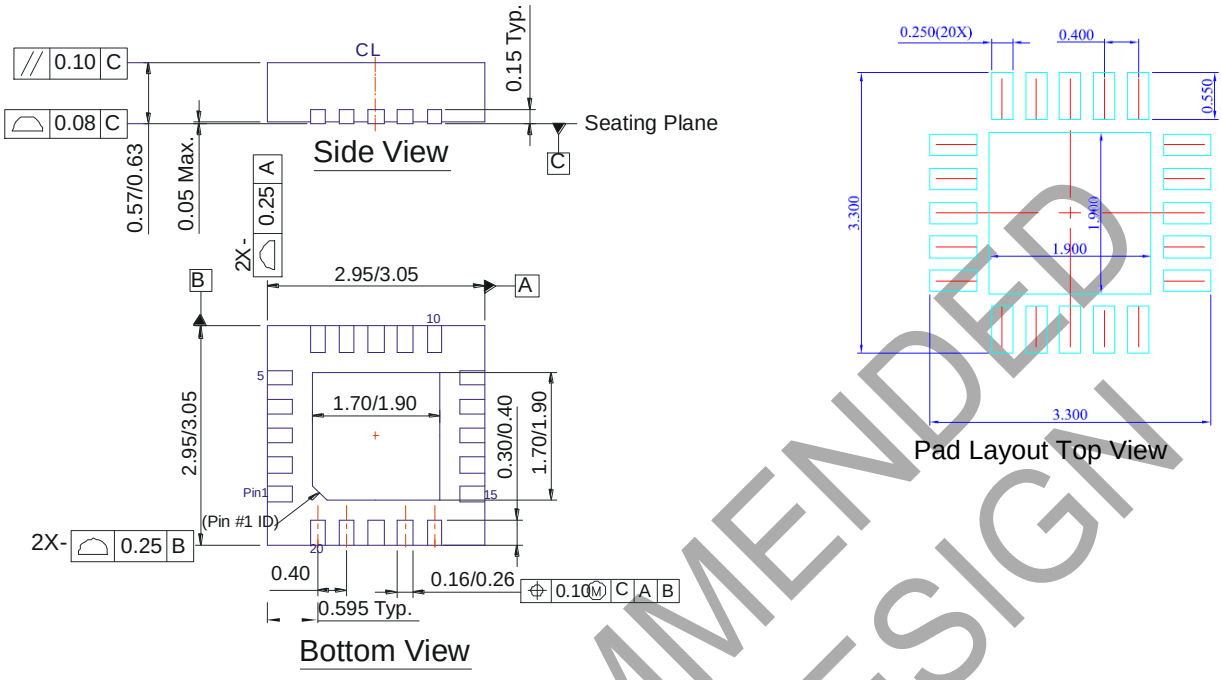

XX : B8 : AL3158
Y : Year : 0 to 9 (ex: 2 = 2022)
W : Week : A to Z : week 1 to 26;
a to z : week 27 to 52; z represents
week 52 and 53
X : A to Z : Green

| Part Number | Package | Identification Code |
|---|---|---|
| AL3158FSG-7 | QFN3030-20 | B8 |

## Package Outline Dimensions (All Dimensions in mm)

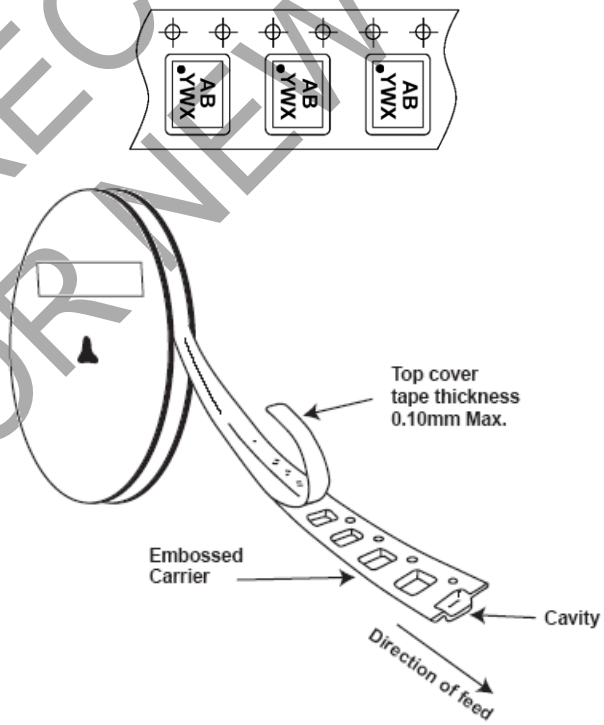
Please see http://www.diodes.com/package-outlines.html for the latest version.

**Package Type: QFN3030-20**






## Taping Orientation (Note 9)




Note: 9. The taping orientation of the other package type can be found on our website at https://www.diodes.com/assets/Packaging-Support-Docs/ap02007.pdf.

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