



# THE DATASHEET OF AP3125HBKTR-G1

**AP3125HA/HB**
**GREEN MODE PWM CONTROLLER**

## Description

The AP3125HA/HB is a current mode PWM controller which is optimized for high performance, low standby power and cost effective offline flyback converters.

The PWM switching frequency at normal operation is internally fixed (about 100kHz). In middle load, the IC will enter green mode to improve system efficiency with the help of frequency foldback. A minimum switching frequency (about 20kHz) is set to avoid the audible noise. In no load or light load, the IC will enter the burst mode to minimize standby power. Furthermore, the frequency dithering function is built-in to reduce EMI emission.

Internal slope compensation allows more stable Peak-Current Mode control over wide range of input voltage and load conditions. Internal line compensation ensures constant output power limit over entire universal line voltage range.

Comprehensive protection features are included, such as cycle-by-cycle current limit (OCP), VCC Over Voltage Protection (VOVP), internal OTP, Over Load Protection (OLP) and pins' fault protection.

AP3125HA features external OTP/OVP by using a minimal number of external components with CTRL pin. AP3125HB features built-in Brownout (BNO) and Line Over Voltage Protection (LOVP).

## Features

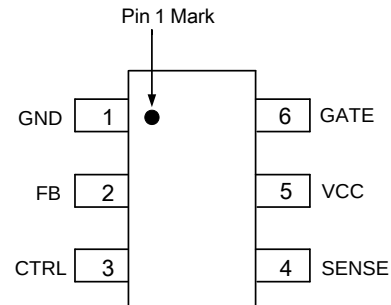
- Very Low Start-up Current
- Current Mode Control
- Non-audible-noise Green-mode Control
- Internal Slope Compensation
- Soft Start During Startup Process
- Frequency Fold Back for High Average Efficiency
- Secondary Winding Short Protection with FOCP
- Soft Switching for Reducing EMI
- VCC Maintain Mode
- Brownout Protection (BNO, AP3125HB)
- Line Over Voltage Protection (LOVP, AP3125HB)
- Useful Pin Fault Protection:
  - SENSE Pin Floating
  - CTRL Pin Short to Ground (AP3125HA)
  - FB/Opto-coupler Open/Short
- Comprehensive System Protection Feature:
  - VCC Over Voltage Protection (VOVP)
  - Over Load Protection (OLP)
- External OTP/OVP with CTRL Pin Protection (AP3125HA)
- Mini Size Package of SOT26
- Pin to Pin Compatible with AP3125A/V/R/L/B
- **Totally Lead-free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Notes:

1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) 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.

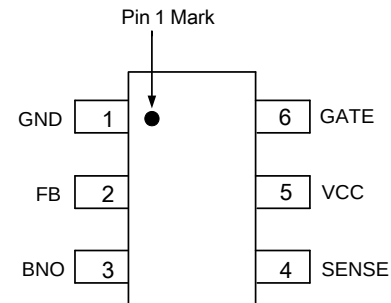
## Pin Assignments

(Top View)



**SOT26 (For AP3125HA)**

(Top View)

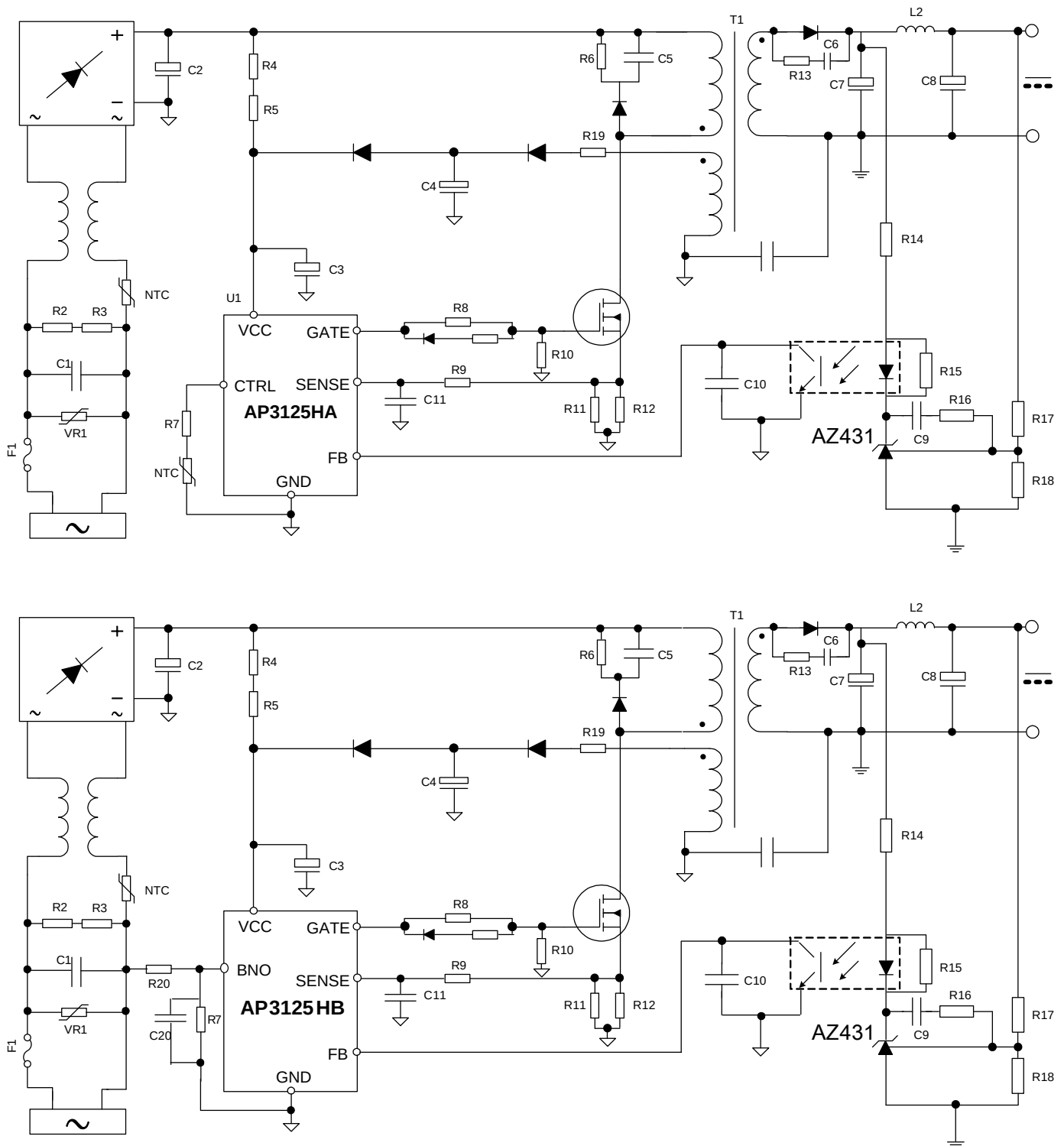


**SOT26 (For AP3125HB)**

## Applications

- Switching AC-DC Adapter/Charger
- ATX/BTX Auxiliary Power
- Set-top Box (STB) Power Supply
- Open Frame Switching Power Supply

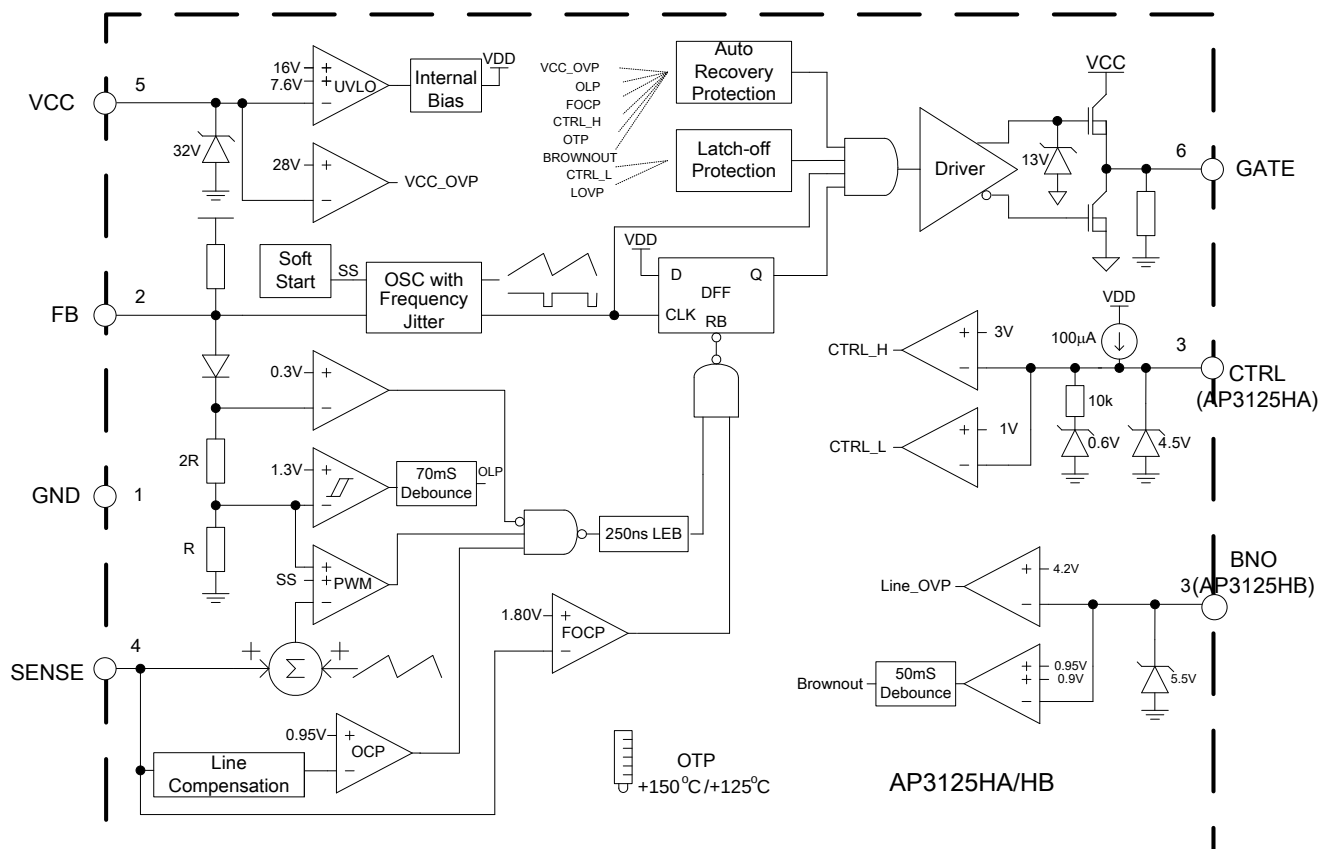
# Typical Applications Circuit



## Pin Descriptions

| Pin Number |          | Pin Name | Function                                                                                                                                                                                               |
|------------|----------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AP3125HA   | AP3125HB |          |                                                                                                                                                                                                        |
| 1          | 1        | GND      | Signal ground. Current return for driver and control circuits                                                                                                                                          |
| 2          | 2        | FB       | Feedback. Directly connected to the opto-coupler                                                                                                                                                       |
| 3          | –        | CTRL     | Latch trigger if this pin voltage drops below a threshold or over another threshold, leave CTRL pin open if this function is not needed. Connecting a NTC thermistor to GND can achieve OTP protection |
| –          | 3        | BNO      | Brownout protection pin, connect a resistor divider to set the brownout level                                                                                                                          |
| 4          | 4        | SENSE    | Current Sense                                                                                                                                                                                          |
| 5          | 5        | VCC      | Supply voltage of driver and control circuits                                                                                                                                                          |
| 6          | 6        | GATE     | Gate driver output                                                                                                                                                                                     |

## Functional Block Diagram



## Absolute Maximum Ratings (Note 4)

| Symbol                        | Parameter                                                | Rating      | Unit |
|-------------------------------|----------------------------------------------------------|-------------|------|
| $V_{CC}$                      | Power Supply Voltage                                     | 30          | V    |
| $I_O$                         | Gate Output Current                                      | 350         | mA   |
| $V_{FB}, V_{SENSE}, V_{CTRL}$ | Input Voltage to FB, SENSE, CTRL                         | -0.3 to 7   | V    |
| $\theta_{JA}$                 | Thermal Resistance (Junction to Ambient)                 | 250         | °C/W |
| $P_D$                         | Power Dissipation at $T_A < +25\text{ }^{\circ}\text{C}$ | 500         | mW   |
| $T_J$                         | Operating Junction Temperature                           | -40 to +150 | °C   |
| $T_{STG}$                     | Storage Temperature Range                                | +150        | °C   |
| –                             | ESD (Human Body Model)                                   | 3000        | V    |
| –                             | ESD (Machine Model)                                      | 300         | V    |

Note 4: 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.

## Recommended Operating Conditions

| Symbol   | Parameter      | Min | Max | Unit |
|----------|----------------|-----|-----|------|
| $V_{CC}$ | Supply Voltage | 10  | 25  | V    |

**Electrical Characteristics** (@T<sub>A</sub> = +25°C, V<sub>CC</sub> = 16V, unless otherwise specified.)

| Symbol                                   | Parameter                                           | Conditions                                 | Min  | Typ   | Max   | Unit |
|------------------------------------------|-----------------------------------------------------|--------------------------------------------|------|-------|-------|------|
| <b>Supply Voltage (VCC Pin)</b>          |                                                     |                                            |      |       |       |      |
| I <sub>STARTUP</sub>                     | Startup Current                                     | —                                          | —    | 1     | 10    | μA   |
| I <sub>CC</sub>                          | Operating Supply Current                            | V <sub>FB</sub> =0V, C <sub>L</sub> =1nF   | 0.5  | 0.7   | 1     | mA   |
|                                          |                                                     | V <sub>FB</sub> =3V, C <sub>L</sub> =0nF   | 0.6  | 1.2   | 2.0   |      |
| —                                        | UVLO <sub>(on)</sub>                                | —                                          | 14.5 | 15.8  | 16.5  | V    |
| —                                        | V <sub>CC</sub> Maintain                            | —                                          | 8.6  | 9.1   | 9.6   | V    |
| —                                        | UVLO <sub>(off)</sub>                               | —                                          | 7.1  | 7.6   | 8.1   | V    |
| —                                        | V <sub>CC</sub> OVP                                 | —                                          | 27   | 28.5  | 30    | V    |
| —                                        | V <sub>CC</sub> Clamp                               | I <sub>CC</sub> =5mA                       | 31   | 34    | —     | V    |
| <b>PWM Section/Oscillator Section</b>    |                                                     |                                            |      |       |       |      |
| —                                        | Maximum Duty Cycle                                  | —                                          | 70   | 75    | 80    | %    |
| —                                        | Oscillation Frequency                               | —                                          | 92   | 100   | 108   | kHz  |
| —                                        | Green Mode Frequency                                | —                                          | 20   | —     | 30    | kHz  |
| —                                        | Frequency Temperature Stability                     | -20°C to +125°C (Note 5)                   | —    | —     | 5     | %    |
| —                                        | Frequency Voltage Stability                         | V <sub>CC</sub> =12V to 30V                | —    | —     | 3     | %    |
| —                                        | Frequency Dithering                                 | —                                          | ±4   | ±6    | ±8    | %    |
| <b>Current Sense Section (SENSE Pin)</b> |                                                     |                                            |      |       |       |      |
| V <sub>CS</sub>                          | Maximum SENSE Voltage                               | V <sub>FB</sub> =4.5V                      | 0.9  | 0.95  | 1     | V    |
| —                                        | FOCP Voltage                                        | —                                          | 1.5  | 1.7   | 1.9   | V    |
| —                                        | LEB Time of SENSE                                   | —                                          | 150  | 250   | 350   | ns   |
| —                                        | Delay to Output (Note 5)                            | —                                          | —    | 100   | —     | ns   |
| —                                        | Soft-start Time                                     | —                                          | 3    | 5     | 8     | ms   |
| <b>Feedback Input Section (FB Pin)</b>   |                                                     |                                            |      |       |       |      |
| —                                        | The Ratio of Input Voltage to Current Sense Voltage | —                                          | 2.5  | 3     | 3.5   | V/V  |
| —                                        | Input Impedance                                     | —                                          | 12   | 15    | 18    | kΩ   |
| —                                        | Source Current                                      | V <sub>FB</sub> =0V                        | -0.2 | -0.27 | -0.34 | mA   |
| —                                        | Green Mode Threshold                                | —                                          | —    | 2.3   | —     | V    |
| —                                        | Input Voltage for Zero Duty                         | —                                          | 1.3  | 1.55  | 1.8   | V    |
| <b>Output Section (GATE Pin)</b>         |                                                     |                                            |      |       |       |      |
| —                                        | Output Low Level                                    | I <sub>O</sub> =20mA, V <sub>CC</sub> =12V | —    | —     | 1     | V    |
| —                                        | Output High Level                                   | I <sub>O</sub> =20mA, V <sub>CC</sub> =12V | 8    | —     | —     | V    |
| —                                        | Output Clamping Voltage                             | —                                          | 11   | 13    | 15    | V    |
| —                                        | Rising Time (Note 5)                                | C <sub>L</sub> =1nF, V <sub>CC</sub> =13V  | —    | 150   | 250   | ns   |
| —                                        | Falling Time (Note 5)                               | C <sub>L</sub> =1nF, V <sub>CC</sub> =13V  | —    | 50    | 100   | ns   |

# Electrical Characteristics (Cont.) (@T<sub>A</sub> = +25°C, V<sub>CC</sub> = 16V, unless otherwise specified.)

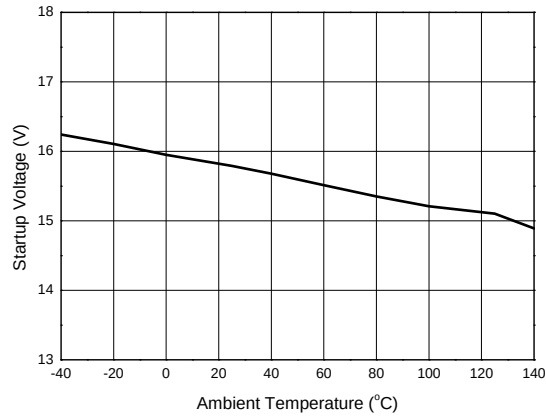
| Symbol                                             | Parameter                         | Conditions              | Min   | Typ   | Max   | Unit   |
|----------------------------------------------------|-----------------------------------|-------------------------|-------|-------|-------|--------|
| <b>Protection Section (CTRL Pin, For AP3125HA)</b> |                                   |                         |       |       |       |        |
| –                                                  | Source Current                    | –                       | 93    | 100   | 107   | μA     |
| –                                                  | Internal Reference Voltage        | –                       | –     | 1.9   | –     | V      |
| –                                                  | Low Threshold Trigger for Latch   | –                       | 0.97  | 1.01  | 1.04  | V      |
| –                                                  | High Threshold Trigger for Latch  | –                       | 2.85  | 3     | 3.15  | V      |
| –                                                  | Pull-up Current (Note 6)          | –                       | –     | –     | 2     | mA     |
| <b>Brownout Section (BNO Pin, For AP3125HB)</b>    |                                   |                         |       |       |       |        |
| –                                                  | Brown-in Voltage                  | –                       | 0.935 | 0.955 | 0.975 | V      |
| –                                                  | Brownout Voltage                  | –                       | 0.875 | 0.895 | 0.915 | V      |
| –                                                  | Clamping Voltage                  | I <sub>CLAMP</sub> =1mA | –     | 5.5   | –     | V      |
| –                                                  | Line OVP                          | –                       | 4.1   | 4.2   | 4.3   | V      |
| <b>Delay Time Section</b>                          |                                   |                         |       |       |       |        |
| –                                                  | Delay of Short Circuit Protection | –                       | –     | 70    | –     | ms     |
| –                                                  | Delay of Hiccup Protection        | VCC OVP                 | –     | 5     | –     | Cycles |
| <b>Internal OTP Section</b>                        |                                   |                         |       |       |       |        |
| –                                                  | OTP Enter                         | –                       | –     | +150  | –     | °C     |
| –                                                  | OTP Exit                          | –                       | –     | +125  | –     | °C     |

Notes: 5. Guaranteed by design.

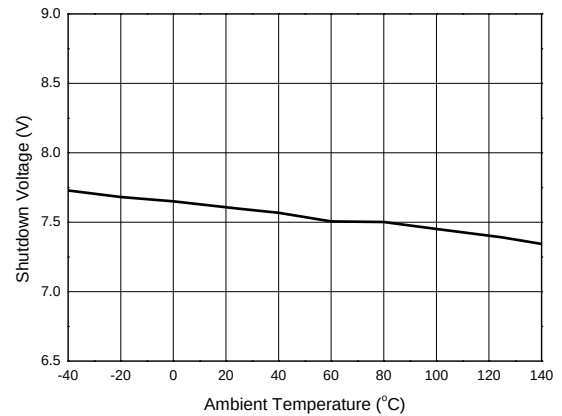
6. The sourcing current of CTRL pin must be limited below 5mA. Otherwise it may cause permanent damage to the device.

## Performance Characteristics

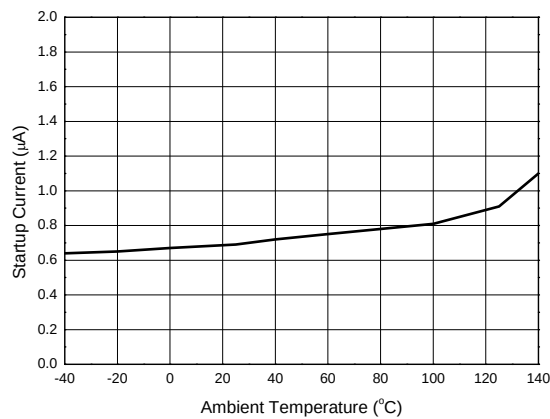
Startup Voltage vs. Ambient Temperature



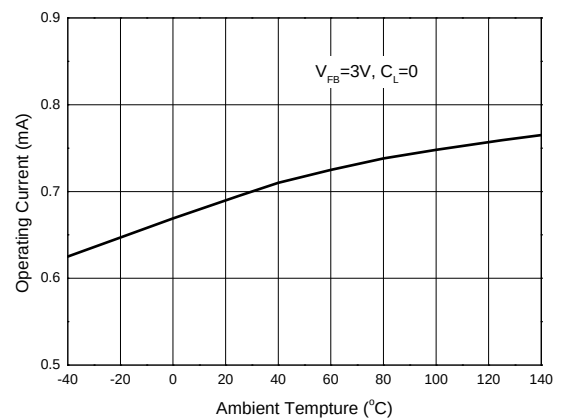
Shutdown Voltage vs. Ambient Temperature



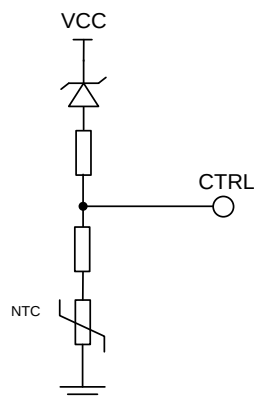
Startup Current vs. Ambient Temperature



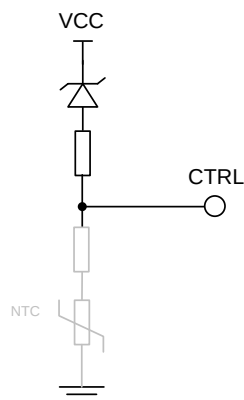
Operating Current vs. Ambient Temperature



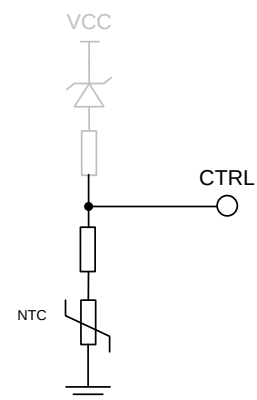
## CTRL Utilization for Latch



OVP and OTP

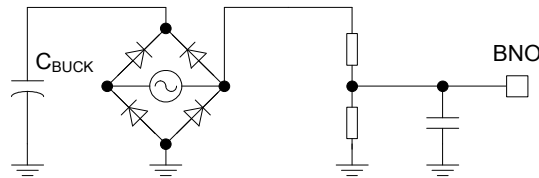


OVP



OTP

## BNO Utilization for Brownout



## Operation Description

The AP3125HA/HB is specifically designed for off-line AC-DC power supply used in LCD monitor, notebook adapter and battery charger applications. It offers a cost effective solution with a versatile protection function.

### Start-up Current and UVLO

The start-up current of AP3125HA/HB is optimized to realize ultra low current (1μA typical) so that VCC capacitor can be charged more quickly. The direct benefit of low start-up current is the availability of using large start-up resistor, which minimizes the resistor power loss for high voltage AC input.

An UVLO comparator is included in AP3125HA/HB to detect the voltage on VCC pin. It ensures that AP3125HA/HB can draw adequate energy from hold-up capacitor during power-on. The turn-on threshold is 16V and the turn-off threshold is 7.6V.

### Current Sense Comparator and PWM Latch

The AP3125HA/HB operates as a current mode controller, the output switch conduction is initiated by every oscillator cycle and is terminated when the peak inductor current reaches the threshold level established by the FB pin. The inductor current signal is converted to a voltage signal by inserting a reference sense resistor  $R_S$ . The inductor current under normal operating conditions is controlled by the voltage at FB pin. The relation between peak inductor current ( $I_{PK}$ ) and  $V_{FB}$  is:

$$I_{PK} = (V_{FB} - 0.8) / 3R_S$$

Moreover, FOCP with 1.8V threshold is only about 100ns delay, which can avoid some catastrophic damages such as secondary rectifier short test. Few drive cycles can alleviate the destruction range and get better protection.

### Leading-edge Blanking

A narrow spike on the leading edge of the current waveform can usually be observed when the power MOSFET is turned on. A 250ns leading-edge blank is built-in to prevent the false-triggering caused by the turn-on spike. During this period, the current limit comparator is disabled and the gate driver can not be switched off.

At the time of turning off the MOSFET, a negative undershoot (maybe larger than -0.3V) can occur on the SENSE pin. So it is strongly recommended to add a small RC filter or at least connect a resistor "R" on this pin to protect the IC (Shown as Figure 1).

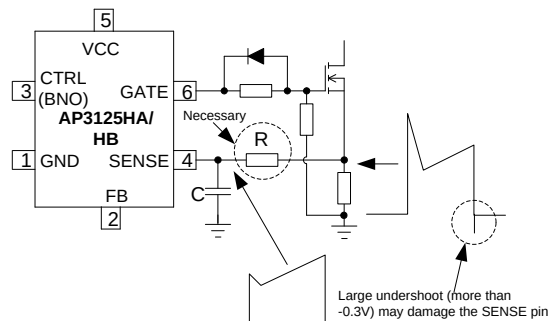


Figure 1

### Built-in Slope Compensation

It is well known that a continuous current mode SMPS may become unstable when the duty cycle exceeds 50%. The built-in slope compensation can improve the stability, so there is no need for design engineer to spend much time on that.

### FB Pin and Short Circuit Protection

This pin is normally connected to the opto-coupler and always paralleled with a capacitor for loop compensation. When the voltage at this pin is

## Operation Description (Cont.)

greater than 4.5V and lasts for about 70ms, the IC will enter the protection mode. For AP3125HA/HB, the system will enter hiccup mode to wait the  $V_{CC}$  decreasing to low UVLO level, then the IC will try to restart until the failure removed. And when this voltage is less than 1.55V, the IC will stop the drive pulse immediately. Therefore, this feature can be used for short circuit protection, which makes the system immune from damage. Normally, output short makes the  $V_{FB}$  value to the maximum because the opto-coupler is cut off.

### V<sub>CC</sub> Maintain Mode

During light load or step load,  $V_{FB}$  will drop and be lower than 1.55V, thus the PWM drive signal will be stopped, and there is no more new energy transferred due to no switching. Therefore, the IC supply voltage may reduce to the shutdown threshold voltage and system may enter the unexpected restart mode. To avoid this, the AP3125HA/HB hold a so-called  $V_{CC}$  maintain mode which can supply energy to  $V_{CC}$ .

When  $V_{CC}$  decreases to a setting threshold, the  $V_{CC}$  maintain comparator will output some drive signal to make the system switch and provide a proper energy to  $V_{CC}$  pin. The  $V_{CC}$  maintain function will cooperate with the PWM and burst mode loop which can make the output voltage variation be within the regulation. This mode is very useful for reducing startup resistor loss and achieving a better standby performance with a low value  $V_{CC}$  capacitor. The  $V_{CC}$  is not easy to touch the shutdown threshold during the startup process and step load. This will also simplify the system design. The minimum  $V_{CC}$  voltage is suggested to be designed a little higher than  $V_{CC}$  maintain threshold thus can achieve the best balance between the standby and step load performance.

### System Protection and Pin Fault Protection

The AP3125HA/HB provides versatile system and pin fault protections. The OCP comparator realizes the cycle-by-cycle current limiting (OCP). In universal input line voltage, the IC realizes the constant over load protection (OLP).  $V_{CC}$  over voltage protection can be applied as the primary OVP or opto-coupler broken protection. The AP3125HA/HB also has pin fault connection protection including floating and short connection. The floating pin protection includes the SENSE, FB, etc. The short pin protection includes the CTRL pin short protection. When these pins are floated or CTRL pin is shorted to ground, PWM switching will be disabled, thus protecting the power system.

### External OTP Protection Function

The CTRL pin of AP3125HA has two kinds of modes to trigger the latch protection: high level trigger (auto-recovery mode) and low level trigger (latch mode). The low threshold is 1V and high threshold voltage is 3V. Once the latch protection is triggered, the IC will disable the output signal, and the bulk capacitor provides the energy to IC through the startup resistor to ensure the IC disable the output. This mode will be not released until the AC input is shut off. So, the de-latch time is mainly depending on the HV startup bulk capacitor value. Therefore, if the system wants a short de-latch time, it is better for the startup resistor take power from the point before the rectifier bridge as illustrated in Figure 2.

### Brownout Protection Function

To avoid potential high current stress at low line voltage, AP3125HB introduces reliable brownout protection. AC line voltage information is sampled through a voltage divider network, adjusting the divider ratio to achieve expected brownout protection voltage. A typical 0.1nF capacitor is strongly recommended to parallel with BNO pin to bypass any accidental spike in AC line for preventing false trigger. When the voltage across BNO pin is higher than 0.95V and  $V_{CC}$  reaches UVLO/ON, the GATE pin will output drive signals. If the BNO voltage falls below 0.9V and lasts for 50ms, the GATE pin will turn off and the system will enter hiccup mode until the line voltage rises over its brown-in voltage again.

### Internal OTP Protection Function

The AP3125HA/HB integrates an internal temperature sensor. It has a trigger window of entering OTP mode at +150°C and exiting at +125°C. The internal OTP protection mode is auto-recovery mode.

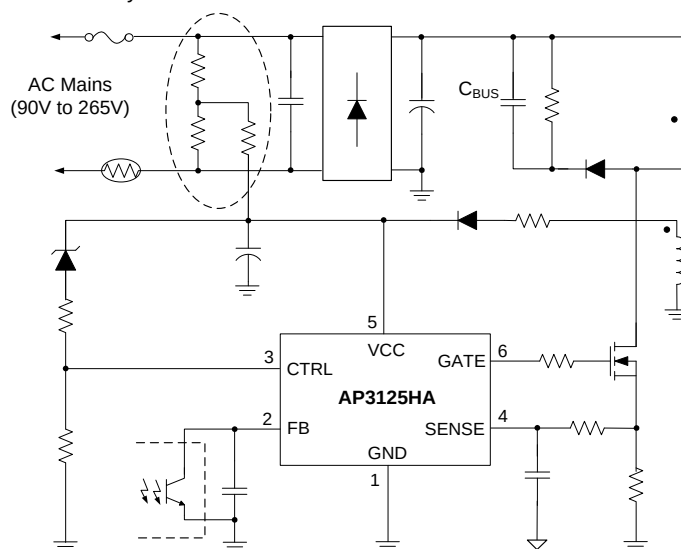
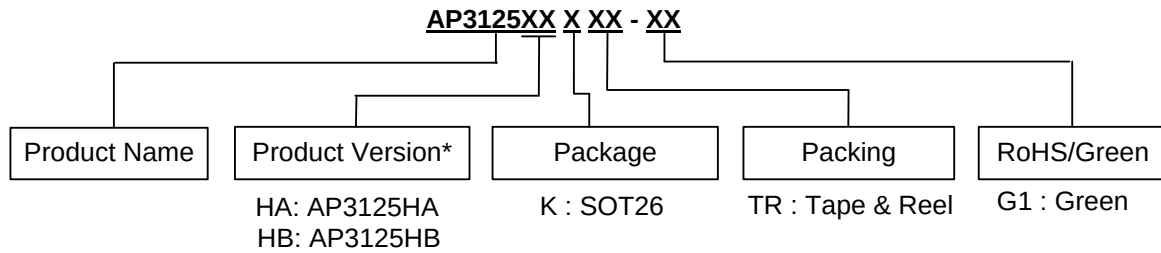


Figure 2

## Ordering Information



Diodes IC's Pb-free products with "G1" suffix in the part number, are RoHS compliant and green.

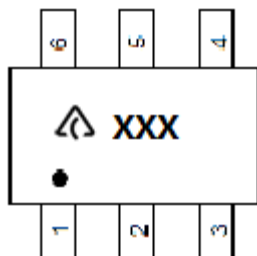
| Package | Part Number    | Marking ID | Packing          |
|---------|----------------|------------|------------------|
| SOT26   | AP3125HAKTR-G1 | GNP        | 3000/Tape & Reel |
|         | AP3125HBKTR-G1 | GNQ        | 3000/Tape & Reel |

## \*Product Version Classification (with Different Protection Functions)

| Product Version | Frequency | VOVP             | OLP & SOCP       | CTRL (Low) | CTRL (High)      | BNO              | LOVP  |
|-----------------|-----------|------------------|------------------|------------|------------------|------------------|-------|
| AP3125HA        | 100kHz    | Auto-Recoverable | Auto-Recoverable | Latch      | Auto-Recoverable | —                | —     |
| AP3125HB        | 100kHz    | Auto-Recoverable | Auto-Recoverable | —          | —                | Auto-Recoverable | Latch |

## Marking Information

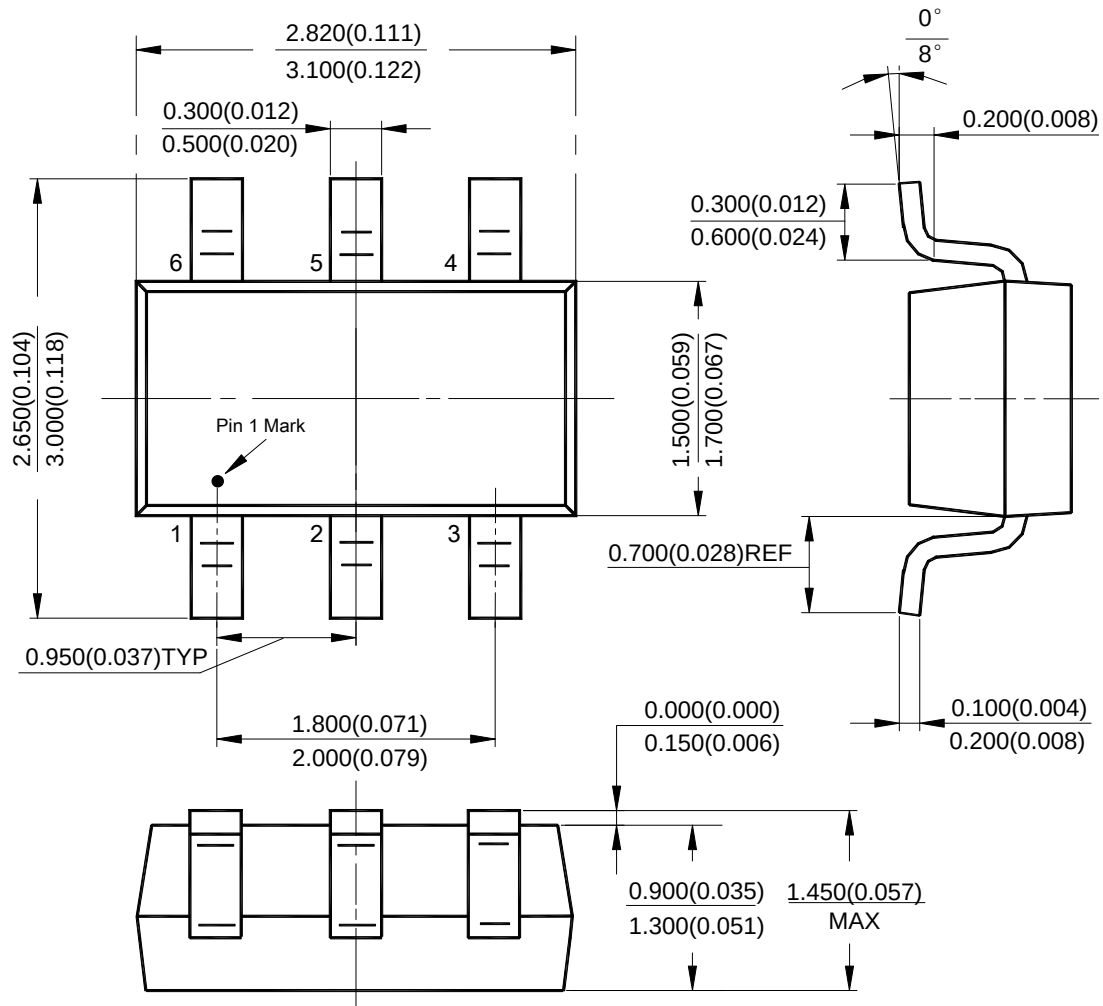
(Top View)



: Logo  
XXX: Marking ID (See Ordering Information)

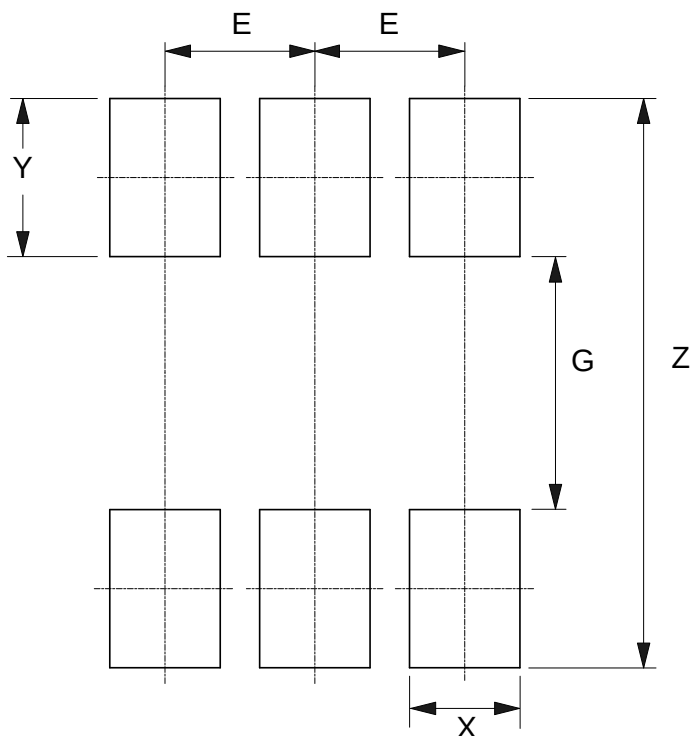
**Package Outline Dimensions** (All dimensions in mm(inch).)

(1) Package Type: SOT26



## Suggested Pad Layout

(1) Package Type: SOT26



| Dimensions | Z<br>(mm)/(inch) | G<br>(mm)/(inch) | X<br>(mm)/(inch) | Y<br>(mm)/(inch) | E<br>(mm)/(inch) |
|------------|------------------|------------------|------------------|------------------|------------------|
| Value      | 3.600/0.142      | 1.600/0.063      | 0.700/0.028      | 1.000/0.039      | 0.950/0.037      |

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