

## General Description

The AP3700E is a green-mode pulse width modulation (PWM) controller. It is specially designed for low power applications such as off-line battery chargers, where the needs for low standby power, space saving and low cost are all required. In a battery charger rated 5V/0.8A, the maximum standby power is only 0.18Watt.

In normal operation, the AP3700E switches on and off at a fixed switching frequency of 60 kHz. With a current limit capability of 460mA, the AP3700E can directly drive the emitter of high voltage NPN transistor. When output power falls below a given level, the IC enters skip cycle mode to reduce power consumption.

The AP3700E also features under-voltage lockout, over-current and short circuit protections.

The AP3700E is available in TO-92 package.

## Features

- Current Mode Control with Skip Cycle Capability
- Lower Operating Current: 0.45mA
- Fixed Switching Frequency: 60 kHz
- Frequency Dithering for Low EMI:  $\pm 2.5$ kHz
- Under-Voltage Lockout Protection
- Over-Current Protection
- Internal Short Circuit Protection
- Higher Output Voltage at OUT Terminal
- Low Total Cost Solution

## Applications

- Battery Chargers
- Off-Line Power Supplies

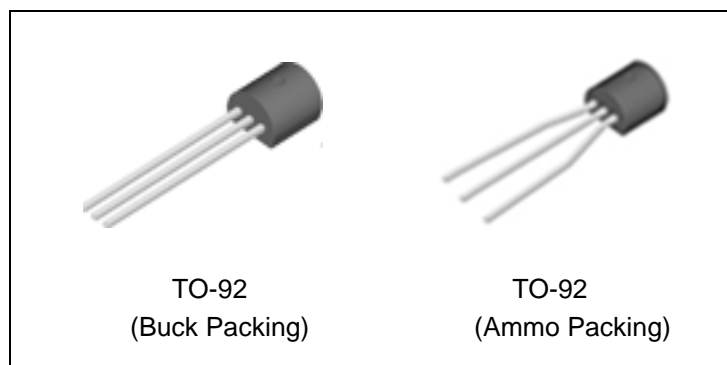


Figure 1. Package Types of AP3700E

**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER      AP3700E**

**Pin Configuration**

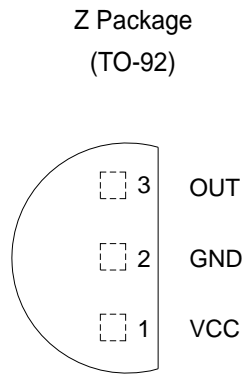


Figure 2. Pin Configuration of AP3700E (Top View)

**Pin Description**

| Pin Number | Pin Name | Function   |
|------------|----------|--|
| 1          | VCC      | The power supply of the IC, and is generally connected to opto-coupler's emitter   |
| 2          | GND      | Supply ground  |
| 3          | OUT      | The output pin, connected to the emitter of NPN transistor or the source of MOSFET |

**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER AP3700E**

**Functional Block Diagram**

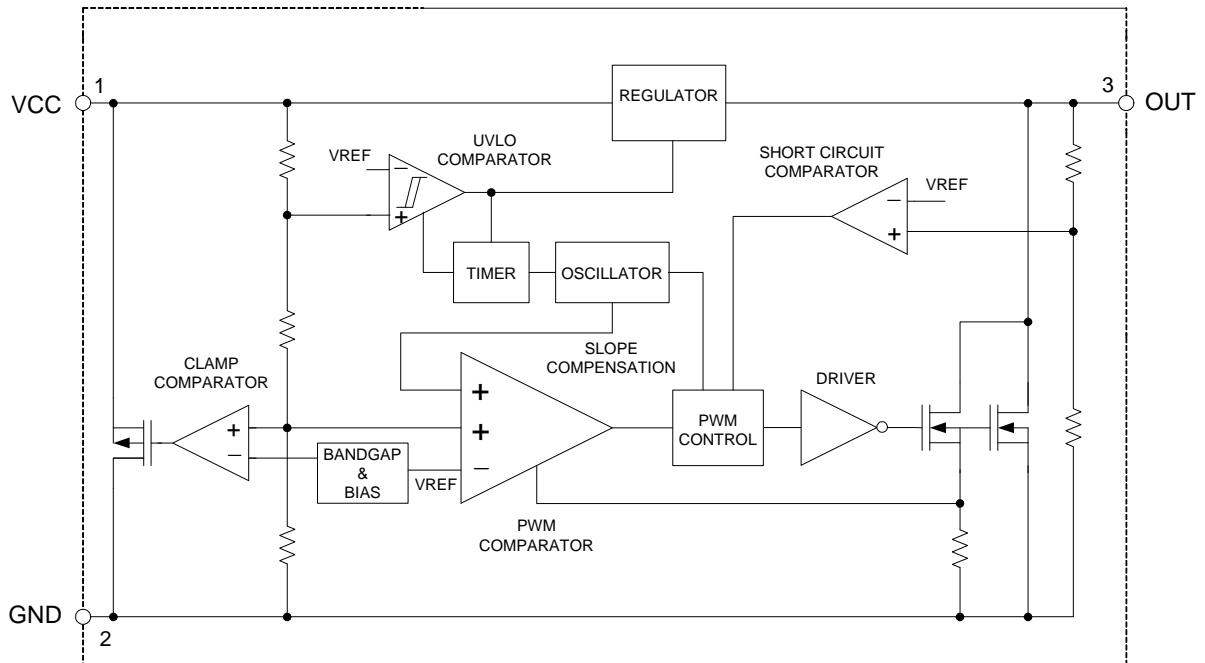
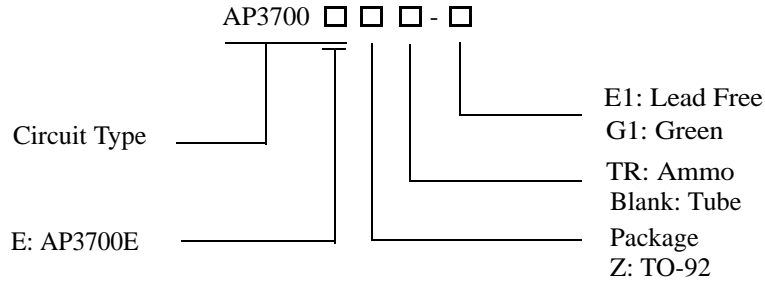


Figure 3. Functional Block Diagram of AP3700E



**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER AP3700E**

**Ordering Information**



| Package | Switching Frequency | Temperature Range | Part Number   |               | Marking ID |           | Packing Type |
|---------|---------------------|-------------------|---------------|---------------|------------|-----------|--------------|
|         |                     |                   | Lead Free     | Green         | Lead Free  | Green     |              |
| TO-92   | 60kHz               | -40 to 85°C       | AP3700EZ-E1   | AP3700EZ-G1   | 3700EZ-E1  | 3700EZ-G1 | Bulk         |
|         |                     |                   | AP3700EZTR-E1 | AP3700EZTR-G1 | 3700EZ-E1  | 3700EZ-G1 | Ammo         |

BCD Semiconductor's Pb-free products, as designated with "E1" suffix in the part number, are RoHS compliant. Products with "G1" suffix are available in green packages.

**Absolute Maximum Ratings (Note 1)**

| Parameter                         | Value              | Unit |
|-----------------------------------|--------------------|------|
| Supply Voltage                    | -0.3 to 6.0        | V    |
| Voltage at OUT (Note 2)           | -0.3 to 40         | V    |
| Output Current at OUT             | Internally limited | A    |
| Power Dissipation                 | 0.6                | W    |
| Operating Junction Temperature    | 150                | °C   |
| Storage Temperature               | -65 to 150         | °C   |
| Lead Temperature (Soldering, 10s) | 300                | °C   |
| ESD (Machine Model)               | 200                | 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: The Breakdown Voltage. The actual operating voltage can not be greater than the value listed here.

**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER AP3700E****Electrical Characteristics**(V<sub>CC</sub>=4.5V, T<sub>J</sub>=25°C, unless otherwise specified.)

| Parameter                      | Symbol                | Conditions                               | Min | Typ  | Max  | Unit |
|--------------------------------|-----------------------|--|-----|------|------|------|
| <b>UVLO SECTION</b>            |                       |  |     |      |      |      |
| Start-up Voltage               | V <sub>TH(ST)</sub>   |  | 5.5 | 5.75 | 5.95 | V    |
| Minimal Operating Voltage      | V <sub>OPR(min)</sub> |  | 3.6 | 3.8  | 4.0  | V    |
| <b>STANDBY CURRENT SECTION</b> |                       |  |     |      |      |      |
| Start-up Current (Note 3)      | I <sub>ST</sub>       | V <sub>CC</sub> =4.5V                    |     | 0.22 | 0.45 | mA   |
| Operating Current              | I <sub>CC(OPR)</sub>  |  |     | 0.45 | 0.7  |      |
| V <sub>CC</sub> Zener Voltage  | V <sub>Z</sub>        | I <sub>CC</sub> =10mA                    | 6   | 6.3  |      | V    |
| Dynamic Impedance              | R <sub>VCC</sub>      | V <sub>CC</sub> =3.8 to 4.8V             |     | 18   |      | kΩ   |
| <b>INTERNAL OSCILLATOR</b>     |                       |  |     |      |      |      |
| Switching Frequency            | f <sub>SW</sub>       |  | 50  | 60   | 75   | kHz  |
| Frequency dithering            |                       |  | ±2  | ±2.5 | ±3   | kHz  |
| Temperature Stability          |                       | -40 to 85°C                              |     | 5    | 10   | %    |
| <b>DRIVE OUTPUT SECTION</b>    |                       |  |     |      |      |      |
| OUT Turn-on Voltage            | V <sub>OUT(ON)</sub>  |  |     | 9.5  | 12   | V    |
| OUT Turn-off Voltage           | V <sub>OUT(OFF)</sub> |  | 5   | 5.5  | 6.5  | V    |
| Rise Time                      | T <sub>R</sub>        | C <sub>L</sub> =1nF, 15Ω pull-up         |     | 60   |      | ns   |
| Fall Time                      | T <sub>F</sub>        | C <sub>L</sub> =1nF, 15Ω pull-up         |     | 30   |      |      |
| Maximum Duty Cycle             | D <sub>MAX</sub>      | V <sub>OPR(min)</sub> + 0.2V             | 67  | 75   | 84   | %    |
| Minimum Duty Cycle             |                       |  |     | 3    |      |      |
| Driver OUT On-Resistance       | R <sub>OUT</sub>      | I <sub>OUT</sub> =0.06A                  |     | 3    |      | Ω    |
| Switch Off Current (OUT)       |                       | Driver off, V <sub>OUT</sub> =10V        |     | 20   | 40   | μA   |
| Effective Current Limit        | I <sub>LIM</sub>      | V <sub>CC</sub> = V <sub>OPR</sub> +0.1V | 460 |      |      | mA   |
| OUT Current Coefficient        | G <sub>A</sub>        |  |     | -0.3 |      | A/V  |

Note 3: AP3700E is an emitter drive controller, the PWM controller will start up only when the voltage on the OUT pin rises up to its threshold value.



**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER AP3700E**

**Typical Performance Characteristics**

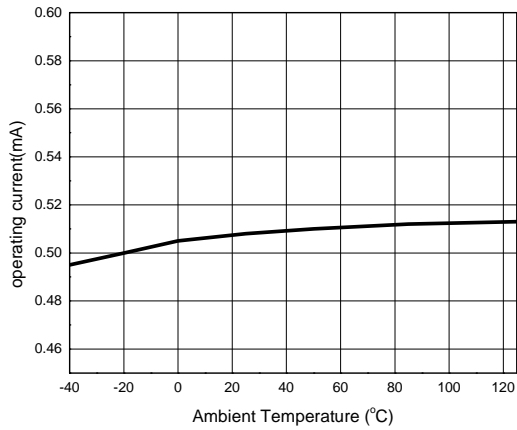


Figure 4. Operating Current vs. Ambient Temperature

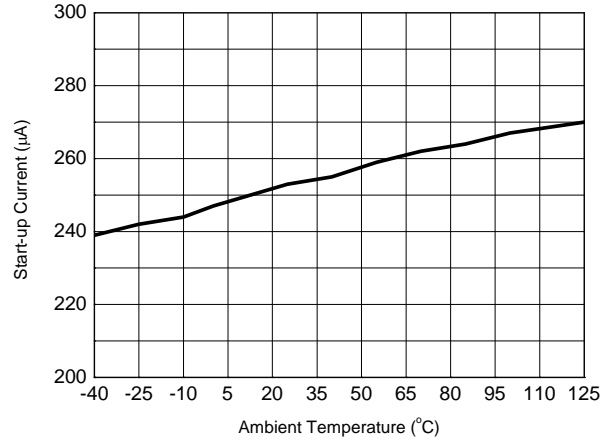


Figure 5. Start-up Current vs. Ambient Temperature

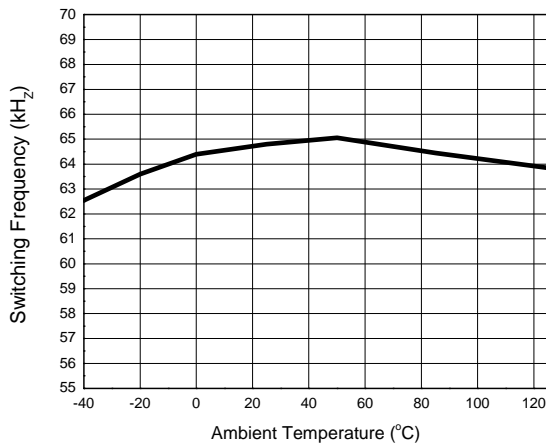


Figure 6. Switching Frequency vs. Ambient Temperature

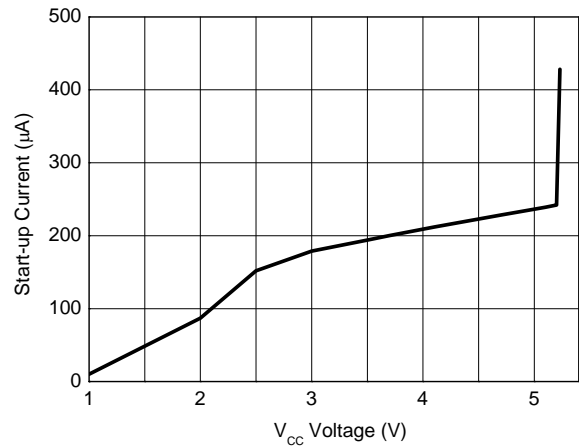


Figure 7. Start-up Current vs. V<sub>CC</sub> Voltage



**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER AP3700E**

**Typical Performance Characteristics (Continued)**

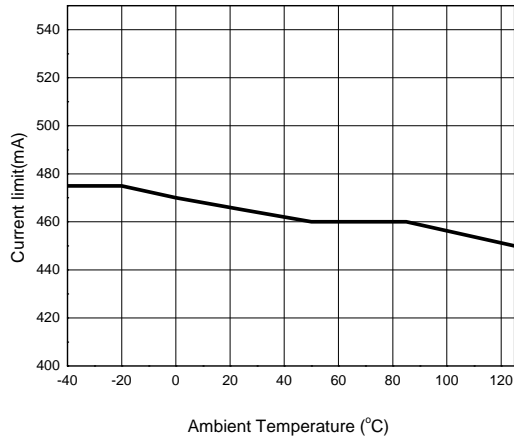


Figure 8. Current Limit vs. Ambient Temperature

## Function Description

### 1. Startup Circuit

Figure 3 is the functional block diagram of AP3700E, and there are 3 external pins: the VCC pin, the OUT pin and GND pin. In typical application shown by Figure 10, the VCC pin is used for both bias supply and feedback control. The OUT pin directly drives external NPN transistor or MOSFET, and also provides initial bias power for UVLO comparator. When the IC works in PWM mode, the auxiliary winding will supply the  $V_{CC}$  enough operating current.

Figure 9 shows the start-up sequence of the  $V_{CC}$  and the  $V_{OUT}$ .

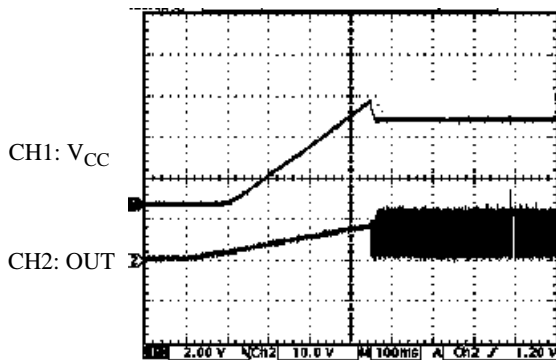


Figure 9. Start-up Sequence of  $V_{CC}$  and  $V_{OUT}$

### 2. $V_{CC}$ /Feedback Control

An opto-coupler and secondary constant voltage/current controller consists of voltage feedback network. When load is heavy, the voltage on VCC will be lower to enlarge duty cycle; on the contrary, if load drops, the voltage on VCC will rise to reduce duty cycle.

### 3. Frequency Dithering

Frequency dithering is performed by periodically spreading a single switching frequency into adjacent frequency band, so the peak energy is spread. This technique can improve EMI by reducing both quasi-peak and average EMI emissions.

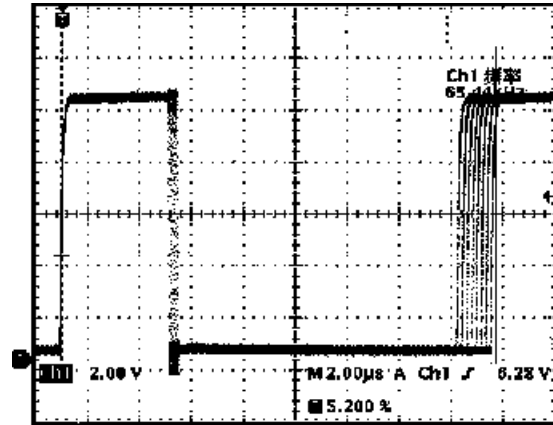


Figure 10. Frequency Dithering Influences the Switching Cycle

AP3700E has reference switching frequency of 60 kHz, and its frequency deviation is  $\pm 2.5$ kHz in period of 2ms. Figure 10 shows the frequency dithering influence to the waveform.

### 4. Current Limit Control

The AP3700E employs current mode control to improve transient response and voltage stability. In Figure 11, the external inductor current through the OUT pin is converted to a voltage by an internal resistor, and this voltage will participate to control duty cycle and peak inductor current.





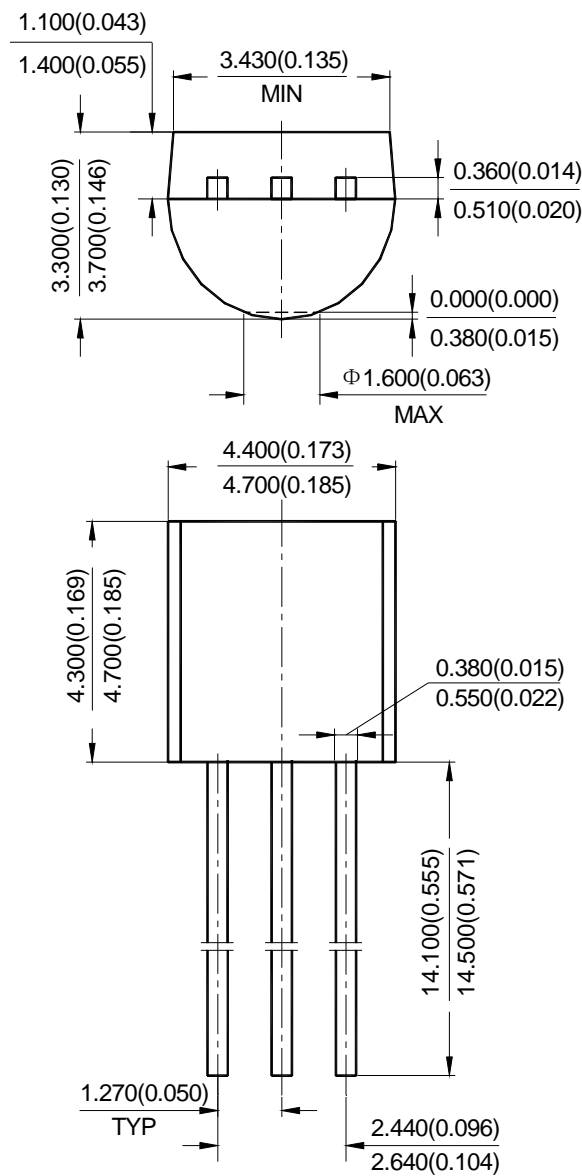


**LOW POWER PWM CONTROLLER FOR OFF-LINE BATTERY CHARGER AP3700E**

**Mechanical Dimensions**

**TO-92 (Bulk Packing)**

**Unit: mm(inch)**







## **BCD Semiconductor Manufacturing Limited**

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