PRIMARY SIDE CONTROL IC FOR OFF-LINE BATTERY CHARGERS   AP3706

General Description

The AP3706 is a high performance AC/DC power supply controller for battery charger and adapter applications. The device uses Pulse Frequency Modulation (PFM) method to build discontinuous conduction mode (DCM) flyback power supplies.

The AP3706 provides constant voltage, constant current (CV/CC) regulation without requiring an opto-coupler and secondary control circuitry. It also eliminates the need of loop compensation circuitry while maintaining stability.

The AP3706 achieves excellent regulation and high power efficiency, the no-load power consumption is less than 200mW at 265VAC input.

The AP3706 is available in SOIC-8 and DIP-8 packages.

Features

- Primary Side Control for Rectangular Constant Current and Constant Voltage Output
- Eliminates Opto-Coupler and Secondary CV/CC Control Circuitry
- Eliminates Control Loop Compensation Circuitry
- Flyback Topology in DCM Operation
- Random Frequency Modulation to Reduce System EMI
- Valley Turn on of External Power NPN Transistor
- Built-in Soft Start
- Open Circuit Protection
- Over Voltage Protection
- Short Circuit Protection

Applications

- Adapters/Chargers for Cell/Cordless Phones, PDAs, MP3 and Other Portable Apparatus
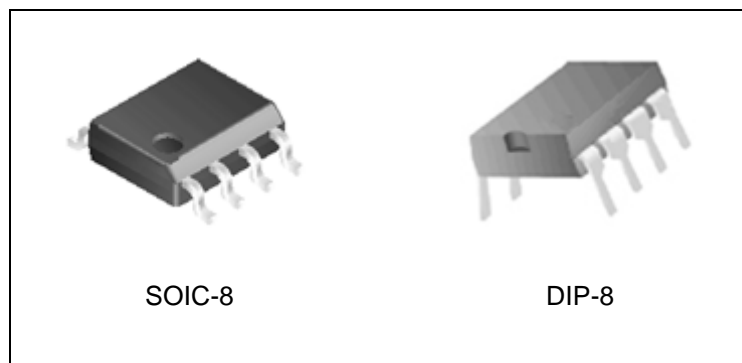- Standby and Auxiliary Power Supplies

SOIC-8   DIP-8

Figure 1. Package Types of AP3706

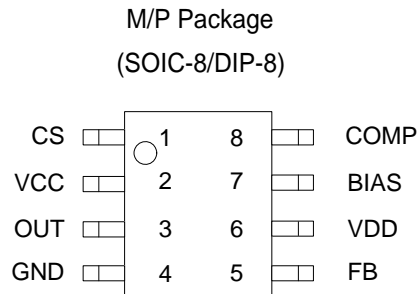**PRIMARY SIDE CONTROL IC FOR OFF-LINE BATTERY CHARGERS   AP3706**

Pin Configuration

M/P Package

(SOIC-8/DIP-8)

```
CS    ⊏⊐  1   8  ⊏⊐   COMP
VCC   ⊏⊐  2   7  ⊏⊐   BIAS
OUT   ⊏⊐  3   6  ⊏⊐   VDD
GND   ⊏⊐  4   5  ⊏⊐   FB
```

Figure 2. Pin Configurations of AP3706 (Top View)

Pin Description

Pin Number	Pin Name	Function
1	CS	The primary current sense
2	VCC	Supply voltage
3	OUT	This pin drives the base of external power NPN switch
4	GND	Ground
5	FB	The voltage feedback from the auxiliary winding
6	VDD	The 5V output of the internal voltage regulator
7	BIAS	This pin sets the bias current inside AP3706 with an external resistor to GND
8	COMP	This pin connects a bypass capacitor for CC function

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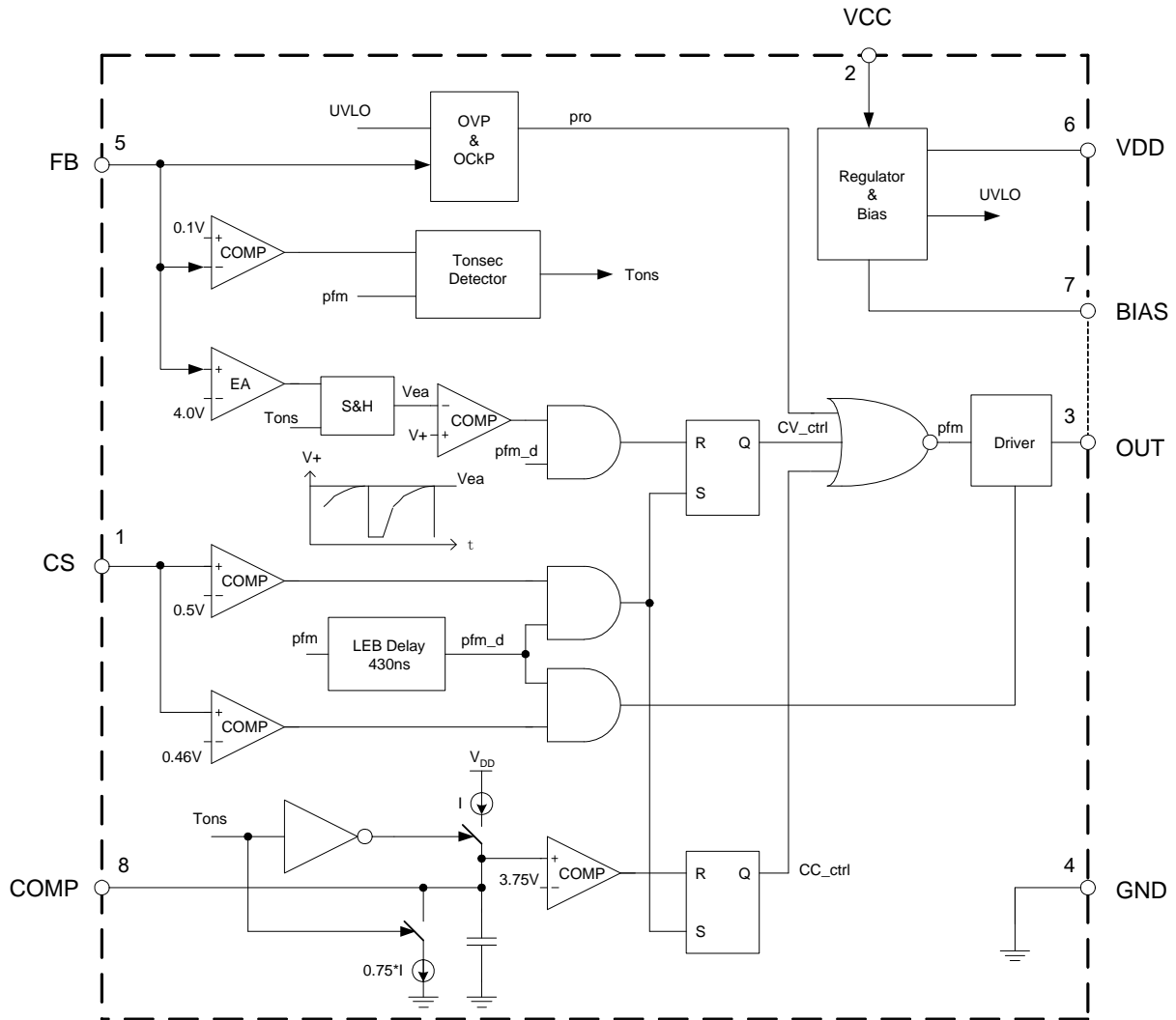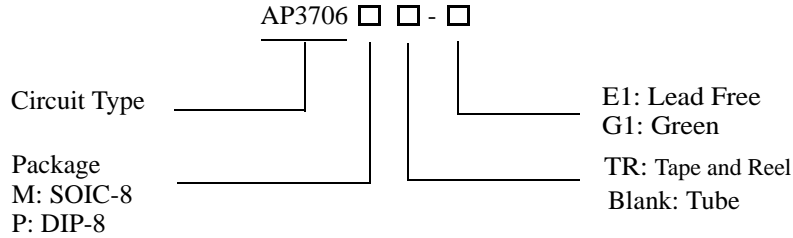
Functional Block Diagram

Figure 3. Functional Block Diagram of AP3706

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PRIMARY SIDE CONTROL IC FOR OFF-LINE BATTERY CHARGERS   AP3706

Ordering Information

AP3706 ☐ ☐ - ☐

Circuit Type

Package
M: SOIC-8
P: DIP-8

E1: Lead Free
G1: Green

TR: Tape and Reel
Blank: Tube

Package	Temperature Range	Part Number		Marking ID		Packing Type
		Lead Free	Green	Lead Free	Green	
SOIC-8	-40 to 85°C	AP3706M-E1	AP3706M-G1	3706M-E1	3706M-G1	Tube
		AP3706MTR-E1	AP3706MTR-G1	3706M-E1	3706M-G1	Tape & Reel
DIP-8		AP3706P-E1	AP3706P-G1	AP3706P-E1	AP3706P-G1	Tube

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 VCC	-0.3 to 30	V
Voltage at CS, BIAS, OUT, VDD, COMP to GND	-0.3 to 7	V
FB input (Pin 5)	-40 to 10	V
Output Current at OUT	Internally limited	A
Power Dissipation at T_A=25°C	0.657	W
Operating Junction Temperature	150	°C
Storage Temperature	-65 to 150	°C
Lead Temperature (Soldering, 10s)	300	°C
Thermal Resistance Junction-to-Ambient	190	°C/W
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.

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Electrical Characteristics

(V_{CC}=15V, T_A=25°C, unless otherwise specified.)

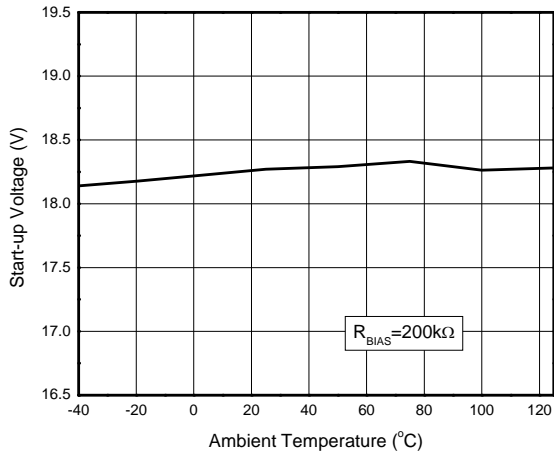| Parameter		Symbol	Conditions	Min	Typ	Max	Unit
UVLO SECTION							
Start-up Threshold		$V_{TH (ST)}$		17	18.5	20	V
Minimal Operating Voltage		$V_{OPR}(min)$	After turn on	6.5	7.3	8.1	V
REFERENCE VOLTAGE SECTION							
BIAS Pin Voltage		V_{BIAS}	R_{BIAS}=200kΩ, Before turn on	1.170	1.205	1.240	V
VDD Pin Voltage		VDD		4.75	5.0	5.25	V
STANDBY CURRENT SECTION							
Start-up Current		I_{ST}	V_{CC} = $V_{TH (ST)}$-0.5V, R_{BIAS}=200kΩ, Before turn on		70	80	μA
Operating Current		$I_{CC(OPR)}$	R_{BIAS}=200kΩ		680	900	μA
DRIVE OUTPUT SECTION							
OUT Maximum Current	Sink	I_{OUT}	R_{BIAS}=200kΩ	50			mA
	Source			25	30		
CURRENT SENSE SECTION							
Current Sense Threshold		V_{CS}		490	510	530	mV
Pre-Current Sense		$V_{CS(PRE)}$		440	460	480	mV
Leading Edge Blanking					430		ns
FEEDBACK INPUT SECTION							
Feedback Pin Input Leakage Current		I_{FB}	V_{FB}=4V	10.0	12.5	15.0	μA
Feedback Threshold		V_{FB}		3.90	4.00	4.10	V
Enable Turn-on Voltage		$V_{FB(EN)}$		-0.9	-0.7	-0.5	V
COMP THRESHOLD VOLTAGE SECTION							
Turn-on Threshold Voltage		V_{COMP}		3.42	3.60	3.78	V
PROTECTION SECTION							
Over Voltage Protection		$V_{FB(OVP)}$		7	8	9	V

Typical Performance Characteristics
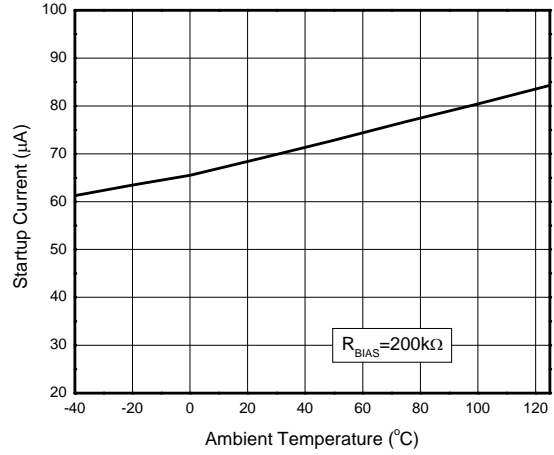
Figure 4. Start-up Voltage vs. Ambient Temperature

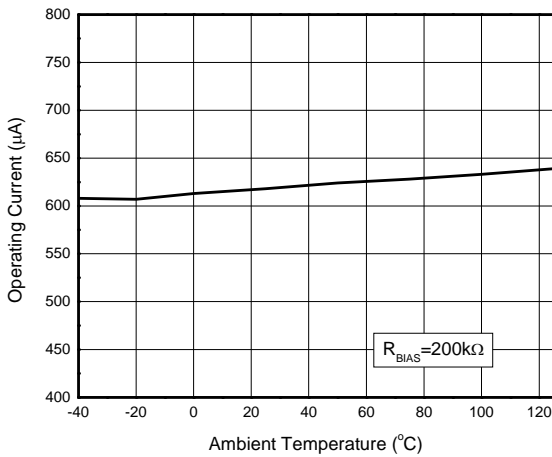Figure 5. Start-up Current vs. Ambient Temperature
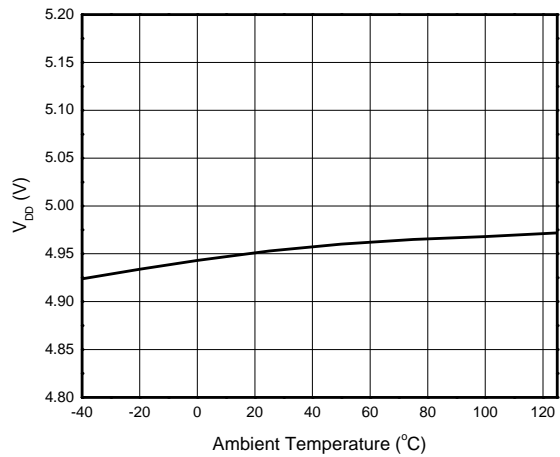
Figure 6. Operating Current vs. Ambient Temperature

Figure 7. V_{DD} vs. Ambient Temperature

PRIMARY SIDE CONTROL IC FOR OFF-LINE BATTERY CHARGERS   AP3706

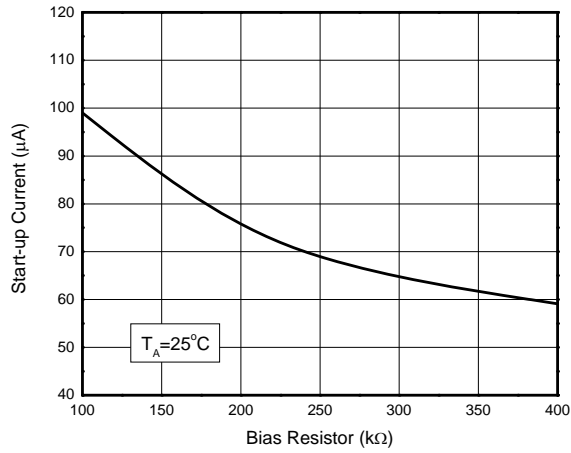## Typical Performance Characteristics (Continued)
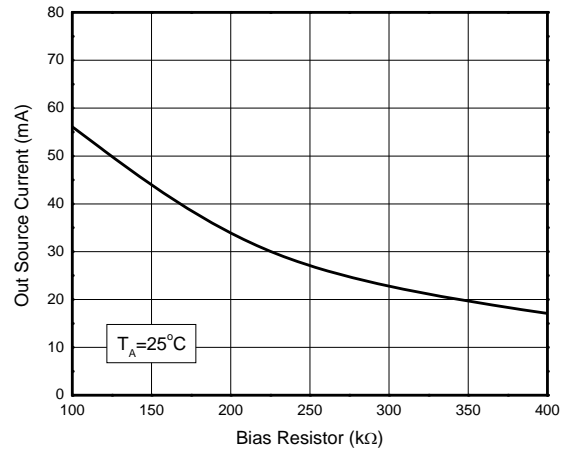

Figure 8. Start-up Current vs. Bias Resistor

Figure 9. OUT Source Current vs. Bias Resistor

PRIMARY SIDE CONTROL IC FOR OFF-LINE BATTERY CHARGERS   AP3706

Operation Description
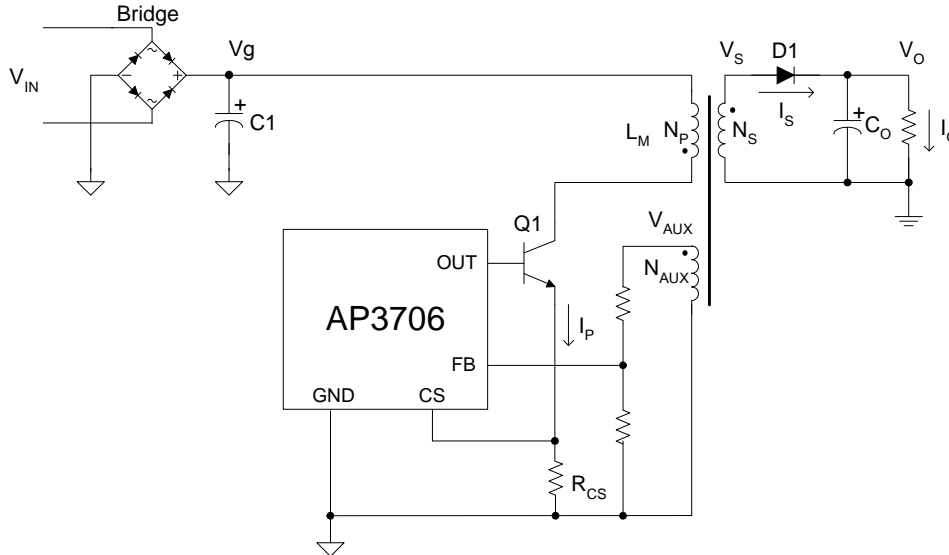
Figure 10. Simplified Flyback Converter Controlled by AP3706

Figure 10 illustrates a simplified flyback converter controlled by AP3706.

Constant Primary Peak Current

The primary current ip(t) is sensed by a current sense resistor R_{CS} as shown in Figure 10.

The current rises up linearly at a rate of:

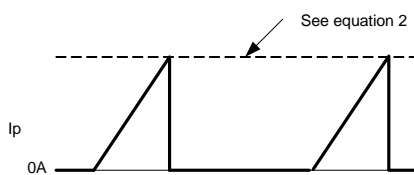$$\frac{dip(t)}{dt} = \frac{vg(t)}{L_M} \qquad \text{................(1)}$$

Figure 11. Primary Current Waveform

As illustrated in Figure 11, when the current ip(t) rises up to Ipk, the switch Q1 turns off. The constant peak current is given by:

$$Ipk = \frac{Vcs}{Rcs} \qquad \text{................(2)}$$

The energy stored in the magnetizing inductance LM each cycle is therefore:

$$Eg = \frac{1}{2} \times L_M \cdot Ipk^2 \qquad \text{................(3)}$$

So the power transferring from the input to the output is given by:

$$P = \frac{1}{2} \times L_M \times Ipk^2 \times f_{SW} \qquad \text{................(4)}$$

Where the fsw is the switching frequency. When the peak current Ipk is constant, the output power depends on the switching frequency fsw.

Constant Voltage Operation

The AP3706 captures the auxiliary winding feedback voltage at FB pin and operates in constant-voltage (CV) mode to regulate the output voltage. Assuming the secondary winding is master, the auxiliary winding is slave during the D1 on-time. The auxiliary voltage is given by:

$$V_{AUX} = \frac{N_{AUX}}{N_S} \times (Vo + Vd) \qquad \text{................(5)}$$

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Operation Description (Continued)

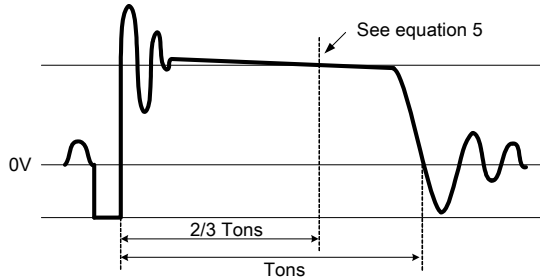Where the Vd is the diode forward drop voltage.

Figure 12. Auxiliary Voltage Waveform

The output voltage is different from the secondary voltage in a diode forward drop voltage. The diode drop voltage depends on the current. If the secondary voltage is always detected at a constant secondary current, the difference between the output voltage and the secondary voltage will be a fixed Vd. The voltage detection point is at two-thirds of the D1 on-time. The CV loop control function of AP3706 then generates a D1 off-time to regulate the output voltage.

Constant Current Operation

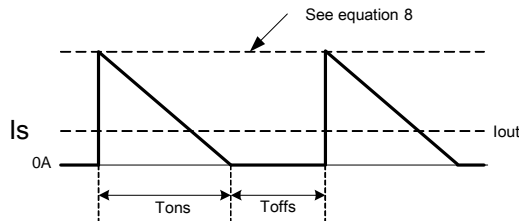The AP3706 is designed to work in constant-current (CC) mode. Figure 13 shows the secondary current waveforms.

Figure 13. Secondary Current Waveform

In CC operation, the CC loop control function of AP3706 will keep a fixed proportion between D1 on-time Tons and D1 off-time Toffs by discharging or charging the capacitance connected in COMP pin. The fixed proportion is

$$\frac{Tons}{Toffs} = \frac{4}{3} \qquad ....(6)$$

The relationship between the output constant-current and secondary peak current Ipks is given by:

$$Iout = \frac{1}{2} \times Ipks \times \frac{Tons}{Tons + Toffs} \qquad ....(7)$$

At the instant of D1 turn-on, the primary current transfers to the secondary at an amplitude of:

$$Ipks = \frac{N_P}{N_S} \times Ipk \qquad ....(8)$$

Thus the output constant-current is given by:

$$Iout = \frac{1}{2} \times \frac{N_P}{N_S} \times Ipk \times \frac{Tons}{Tons + Toffs} = \frac{2}{7} \times \frac{N_P}{N_S} \times Ipk$$

$$................(9)$$

Leading Edge Blanking

When the power switch is turned on, a turn-on spike will occur on the sense-resistor. To avoid false-termination of the switching pulse, a 430ns leading-edge blanking is built in. During this blanking period, the current sense comparator is disabled and the gate driver can not be switched off.

CCM Protection

The AP3706 is designed to operate in discontinuous conduction mode (DCM) in both CV and CC modes. To avoid operating in continuous conduction mode (CCM), the AP3706 detects the falling edge of the FB input voltage on each cycle. If a 0.1V falling edge of FB is not detected, the AP3706 will stop switching.

OVP & OCkP

The AP3706 includes output over-voltage protection (OVP) and open circuit protection (OCkP) circuitry as shown in Figure 14. If the voltage at FB pin exceeds 8V, 100% above the normal detection voltage, or the -0.7V falling edge of the FB input can not be monitored, the AP3706 will immediately shut off and enters hiccup mode. The AP3706 sends out a fault detection pulse every 8ms in hiccup mode until the fault has been removed.

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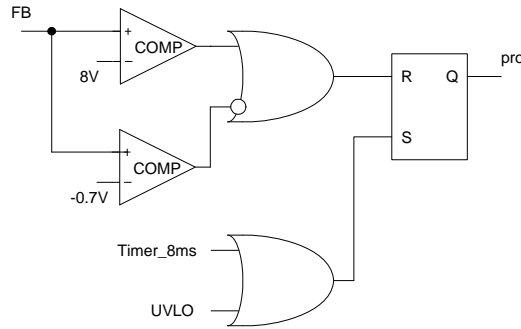
Operation Description (Continued)

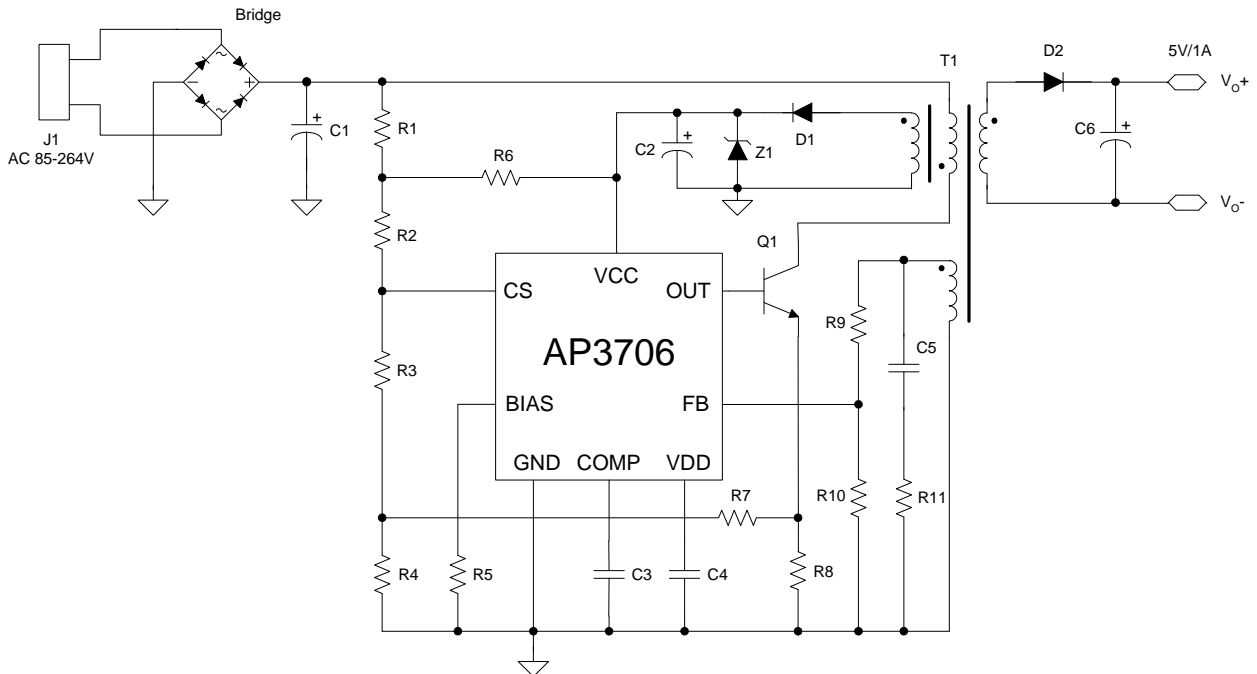Figure 14. OVP and OCkP Function Block

Typical Application

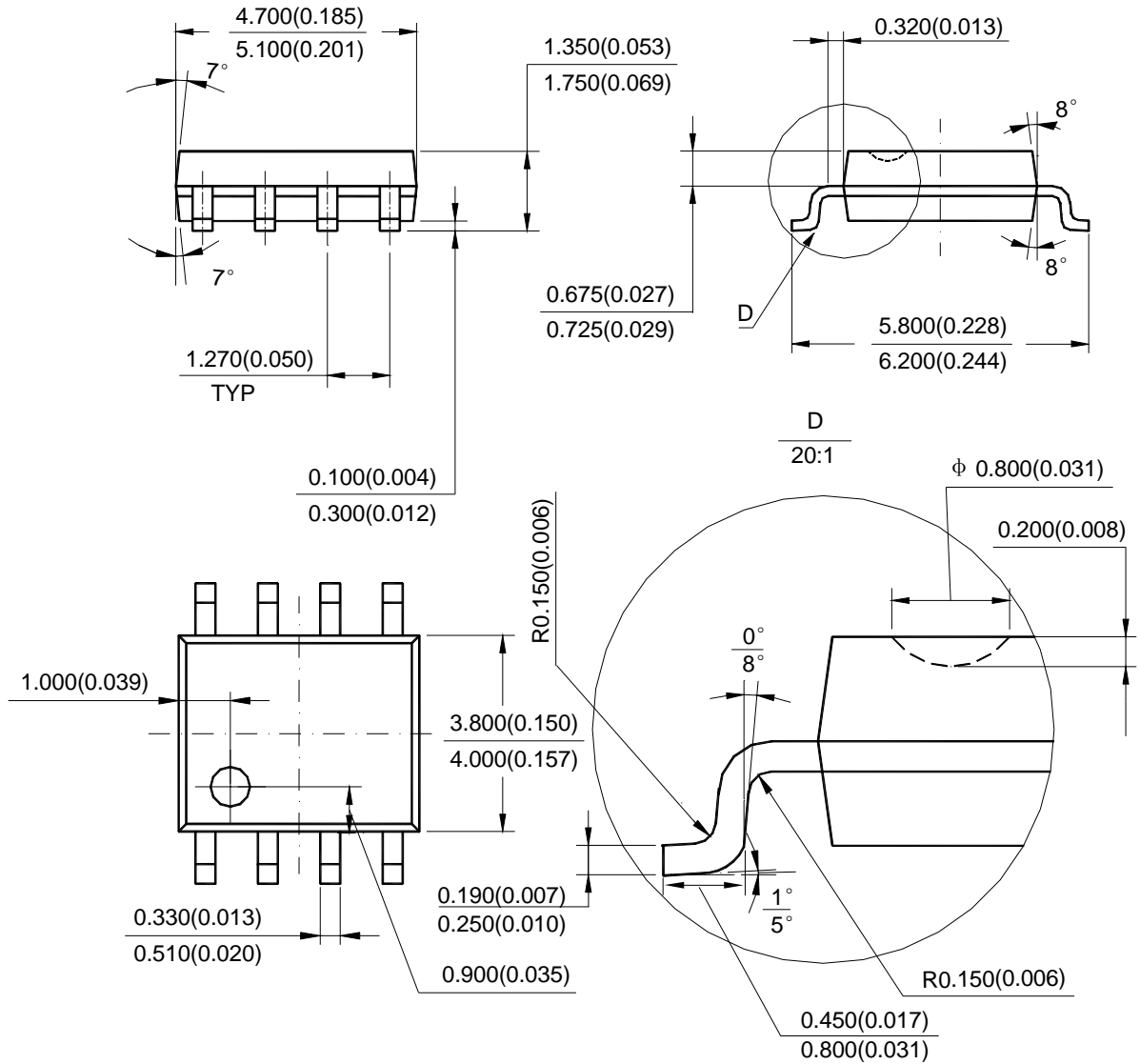Figure 15. 5V/1A Output for Battery Charger of Mobile Phone

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Mechanical Dimensions

SOIC-8   **Unit: mm(inch)**

PRIMARY SIDE CONTROL IC FOR OFF-LINE BATTERY CHARGERS   AP3706

Mechanical Dimensions (Continued)

DIP-8   **Unit: mm(inch)**

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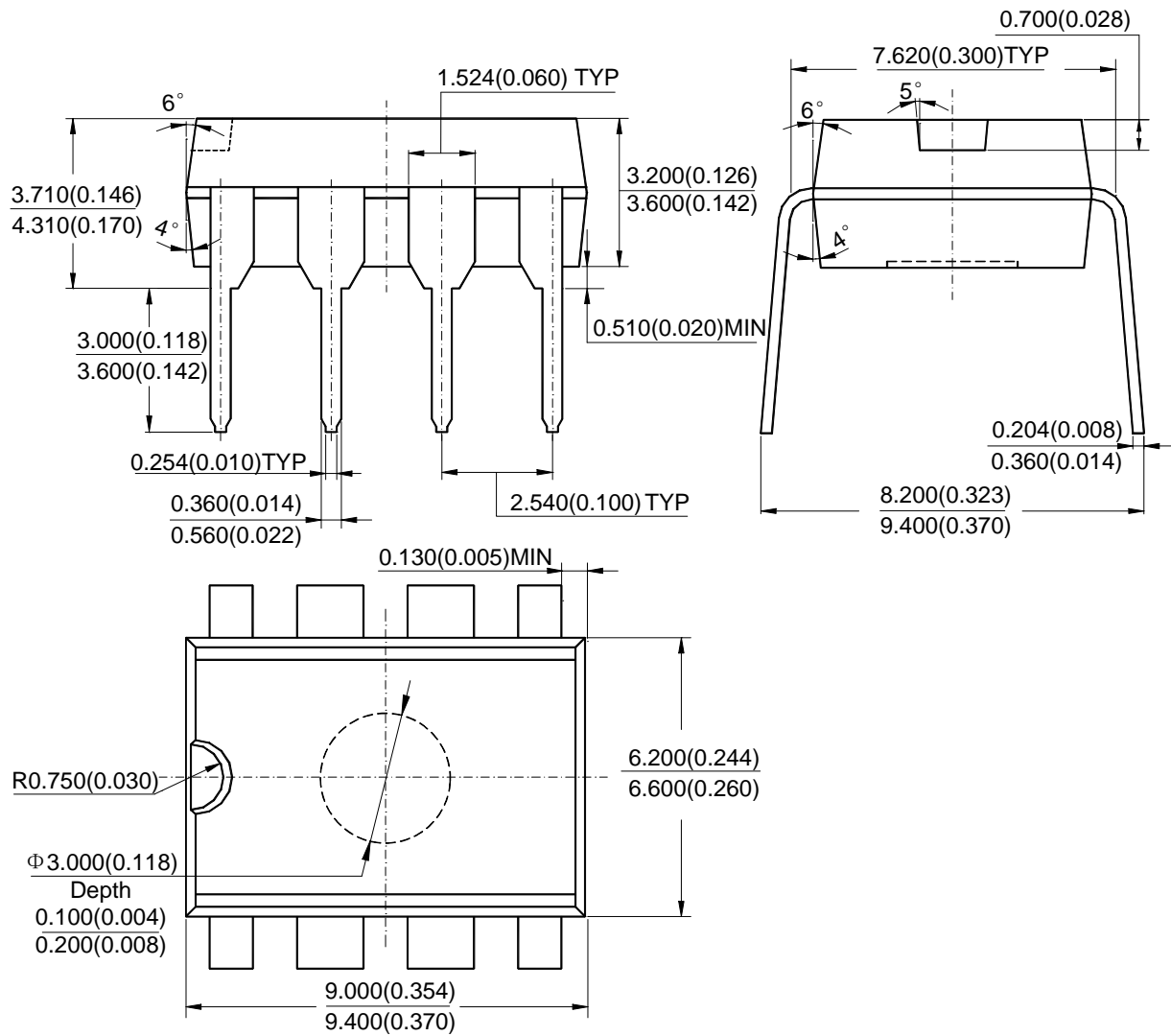
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