PRIMARY SIDE REGULATED SWITCHING MODE POWER SUPPLY CONTROLLER

Description

The AP3783 is a high performance AC/DC power supply controller for battery charger and adapter applications. The controller regulates the output voltage and current in the primary side by piece-wise Pulse Frequency Modulation (p-PFM) in discontinuous conduction mode (DCM).

The AP3783 provides accurate constant voltage (CV), constant current (CC) and outstanding dynamic performance without requiring an opto-coupler. It also eliminates the need of loop compensation circuitry while maintaining stability.

The AP3783 provides valley turn-on function, operating frequency Jitter function (about 5.5% frequency change every 256μs) from light to full load range and 3-segment drive current to improve the power supply EMI performance. The AP3783 also has built-in fixed cable voltage drop compensation (4%, 7% and 12% of nominal system output voltage to meet various cables with different length and gauge) and adjustable line voltage compensation.

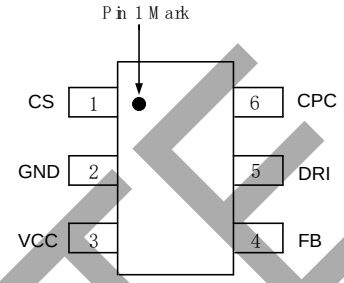
The AP3783 is packaged in SOT26.

Applications

- Adapters/Chargers
- LED Lighting
- Standby and Auxiliary Power Supplies

Pin Assignments

(Top View)



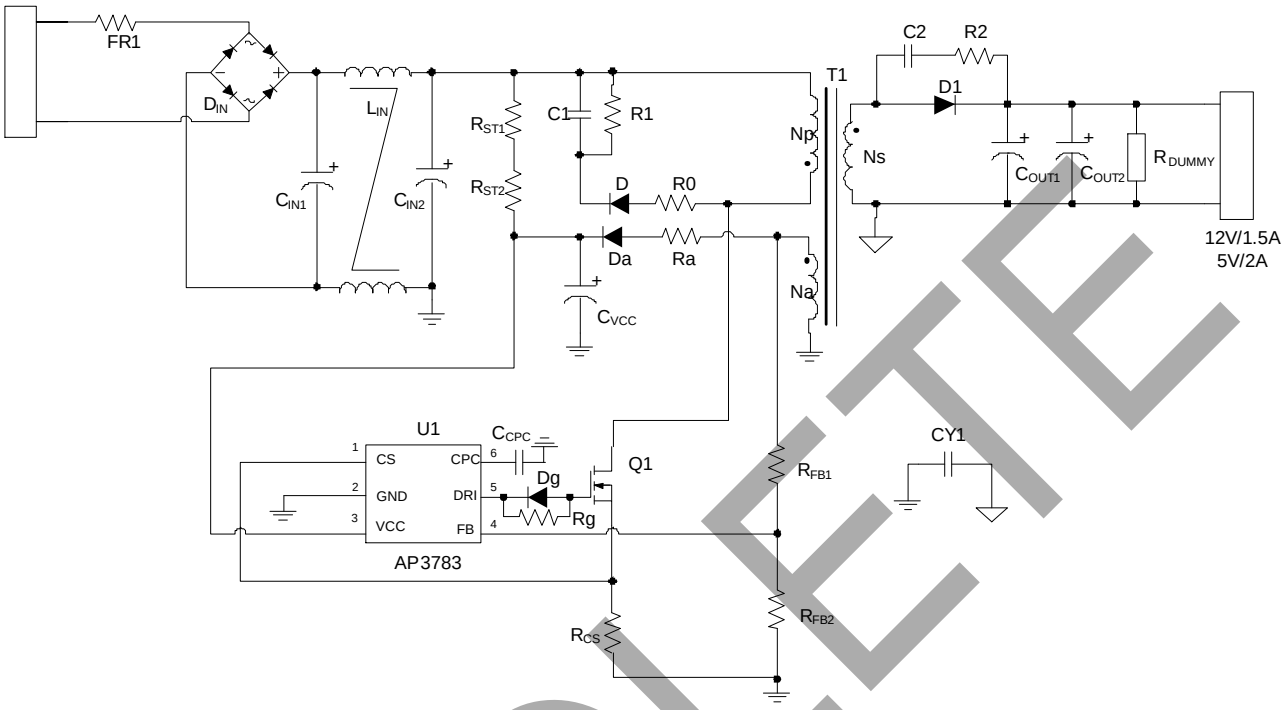
SOT26

Features

- Less than 75mW Standby Power Consumption
- Meet Efficiency Requirement of COC Trier2
- Valley Turn-on to Reduce Switching Loss and Improve EMI
- Piece-Wise Frequency Reduction to Enhance Conversion Efficiency and Suppress Audio Noise
- Over Voltage Protection (OVP)
- Over Temperature Protection (OTP)
- Short Circuit Protection (SCP) with Hiccup
- 3-Segment Drive Current for Radiative EMI Suppression
- Operating Frequency Jitter Function for Conductive EMI Suppression
- Drive MOSFET for 5W to 30W Battery Charger/Adapter Applications
- SOT26 SMD Package Comply with Level 3 of IPC/JEDEC J-STD-033A
- **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-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

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.

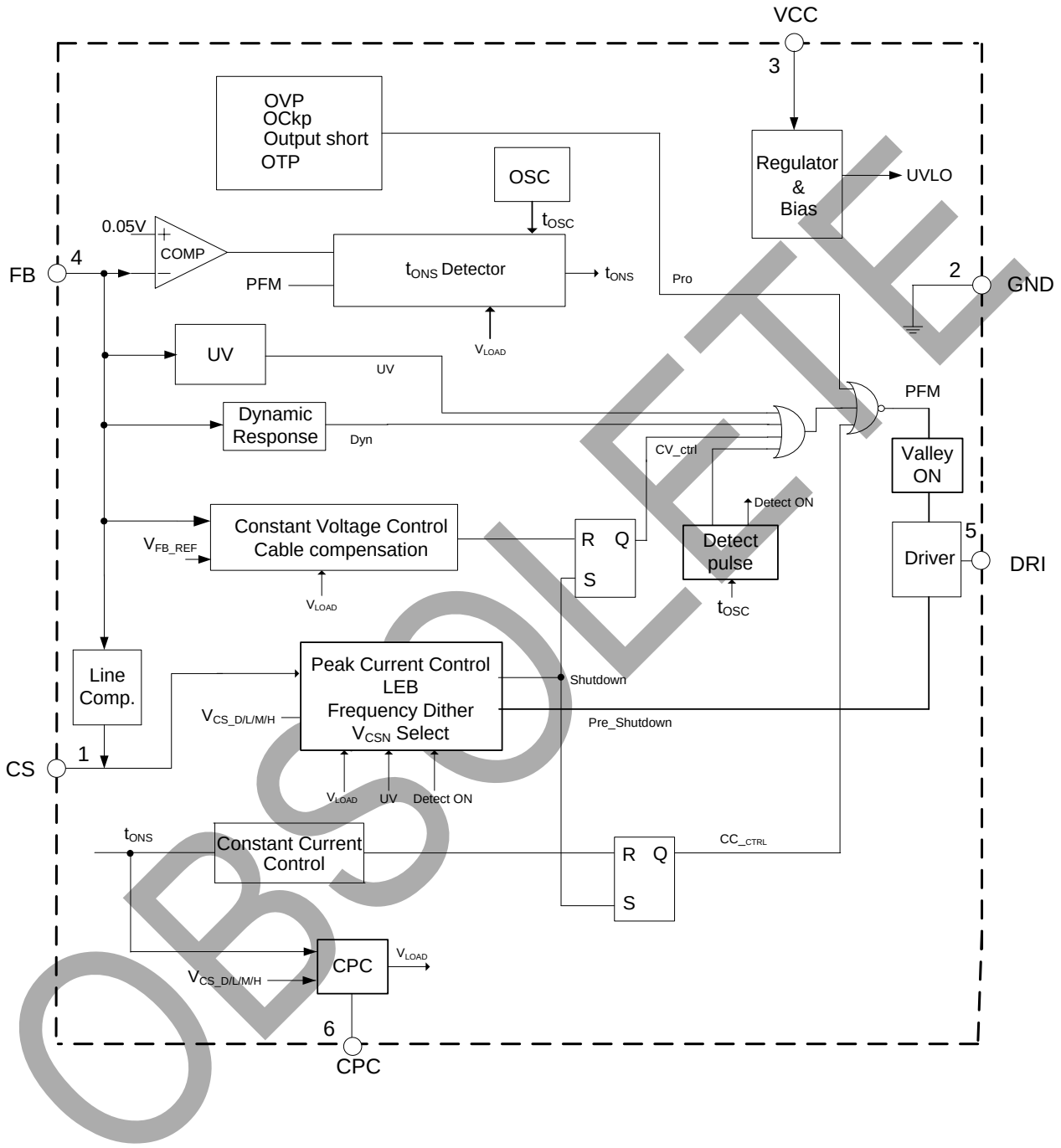
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	CS	The CS is the current sense pin of the IC. The IC will turn off the power MOSFET according to the voltage on the CS pin
2	GND	The ground of the controller
3	VCC	The VCC pin supplies the power for the IC. In order to get the correct operation of the IC, a capacitor with low ESR should be placed as close as possible to the VCC pin
4	FB	The CV and CC regulation are realized based on the voltage sampling of this pin
5	DRI	Output pin to drive external MOSFET
6	CPC	A capacitor about 50nF should be connected to this pin. The voltage of CPC pin is linear to load of the system and it is used for the functions of cable voltage drop compensation and audio noise suppression

Functional Block Diagram



Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Supply Voltage	-0.3 to 35	V
V_{CS}, V_{CPC}	Voltage on CS, CPC Pin	-0.3 to 7	V
V_{FB}	FB Input Voltage	-0.4 to 10	V
I_{SOURCE}	Source Current from OUT Pin	Internally Limited	A
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10 sec)	+300	°C
θ_{JA}	Thermal Resistance (Junction to Ambient)	200	°C/W
ESD	ESD (Human Body Model)	6000	V
	ESD (Charged Device Model)	400	V

Notes: 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.

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

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
STARTUP AND UVLO SECTION						
V_{TH_ST}	Startup Threshold	–	13	15.5	18	V
$V_{OPR(MIN)}$	Minimal Operating Voltage	–	6	6.8	7.6	V
STANDBY CURRENT SECTION						
I_{ST}	Startup Current	V_{CC} = V_{TH_ST} - 1V before startup	0	0.2	0.6	μA
I_{CC_OPR}	Operating Current	Static current @ no load	300	450	600	
DRIVING OUTPUT SECTION						
V_{GATE}	Gate Voltage	–	12	13	14	V
I_{SOURCE_L}	Low Driver Source Current	–	17.5	20	22.5	mA
I_{SOURCE_H}	High Driver Source Current	–	100	110	120	mA
V_{TH}	High/Low Driver Source Current Threshold Voltage	–	6	6.5	7	V
R_{SINK}	Sink Resistance	–	5.5	6.5	7.5	Ω

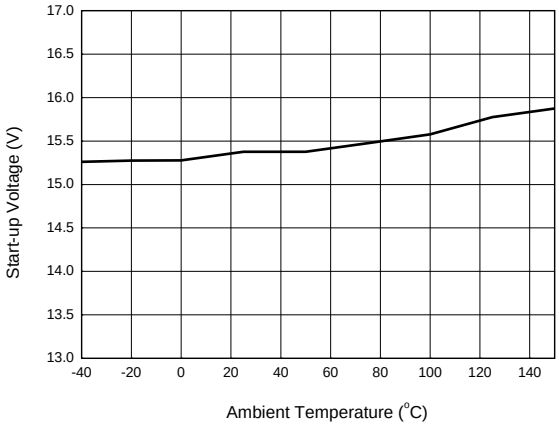
Electrical Characteristics (Cont.) (@V_{CC} = 15V, T_A = +25°C, unless otherwise specified.)

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
OPERATING FREQUENCY SECTION						
$f_{S(MAX)}$	The Maximum Operating Frequency	$I_{O(MAX)}$ (Note 5)	–	–	60	kHz
$t_{OFF(MAX)}$	Maximum Off Time		691	768	845	μs
t_{SAMPLE_H}	Sample Time	57% to 100% $I_{O(MAX)}$	5.2	5.8	6.4	μs
t_{SAMPLE_M}		34% to 57% $I_{O(MAX)}$ (Note 6)	4.3	4.8	5.3	μs
t_{SAMPLE_L}		5.5% to 34% $I_{O(MAX)}$ (Note 6)	2.7	3	3.3	μs
t_{SAMPLE_D}		0% to 5.5% $I_{O(MAX)}$ (Note 6)	1.5	1.7	1.9	μs
FREQUENCY JITTER SECTION						
$\Delta V_{CS}/V_{CS}$	V_{CS} Modulation	5.5% load to 100% $I_{O(MAX)}$	4.5	5	5.5	%
f_{MOD}	V_{CS} Modulation Frequency	5.5% load to 100% $I_{O(MAX)}$	3.6	4	4.4	kHz
CURRENT SENSE SECTION						
V_{CS_H}	Peak Current Sense Threshold Voltage	57% to 100% $I_{O(MAX)}$	828	900	972	mV
V_{CS_M}	As Above	34% to 57% $I_{O(MAX)}$ (Note 6)	690	750	810	mV
V_{CS_L}	As Above	5.5% to 34% $I_{O(MAX)}$ (Note 6)	414	450	486	mV
V_{CS_D}	As Above	0% to 5.5% $I_{O(MAX)}$ (Note 6)	230	250	270	mV
R_{LINE}	Built-in Line Compensation Resistor	(Note 7)	245	260	275	Ω
t_{LEB}	Leading Edge Blanking	V_{CS} (Note 6)	495	550	605	ns
CONSTANT VOLTAGE SECTION						
V_{FB}	Feedback Voltage	Closed loop test of V_{OUT}	3.95	4.01	4.07	V
R_{FB}	FB Pin Input Resistance	V_{FB}=4V	560	700	840	kΩ
V_{CABLE} /V_{OUT}%	Cable Compensation Ratio	AP3783A	6	7	8	%
		AP3783B	3	4	5	%
		AP3783C	10	12	14	%
CONSTANT CURRENT SECTION						
t_{ONS}/t_{SW}	Secondary Winding Conduction Duty	V_{FB} = 3.5V	0.47	0.5	0.53	–
VALLEY-ON SECTION						
t_{VAL-ON}	Valid Off Time of Valley-on	From the end of t_{ONS}	14.4	16	17.6	μs
DYNAMIC SECTION						
V_{UV_H}	Under Voltage of FB Pin for V_{CS_H}	–	3.61	3.68	3.75	V
PROTECTION FUNCTION SECTION						
$V_{FB(OVP)}$	Over Voltage Protection at FB Pin	–	7.1	7.5	7.9	V
$V_{CC(OVP)}$	Over Voltage Protection at VCC Pin	–	28	30	32	V
$t_{ONP(MAX)}$	Maximum Turn-on Time	–	13.5	16	25	μs
$V_{FB(SCP)}$	Short Circuit Protection	V_{FB} @ Hiccup	2.45	2.6	2.75	V
t_{SCP}	Maximum Time under $V_{FB(SCP)}$	–	115	128	141	ms
T_{OTP}	Shutdown Temperature	–	+144	+160	+176	°C
T_{HYS}	Temperature Hysteresis	–	+36	+40	+44	°C

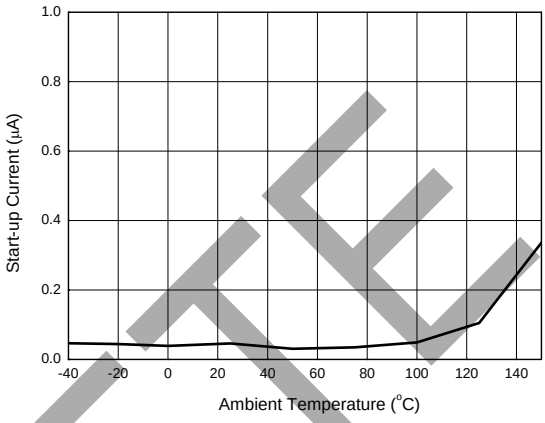
Notes: 5. The output constant-current design value, generally set to 110% to 120% of full load.
6. Guaranteed by Design.
7. Line compensation voltage on CS reference: $\Delta V_{CS\_REF} = 0.438 \times \frac{R_{LINE}}{R_{FB1} + R_{LINE}} \times V_{AUX}$

Performance Characteristics

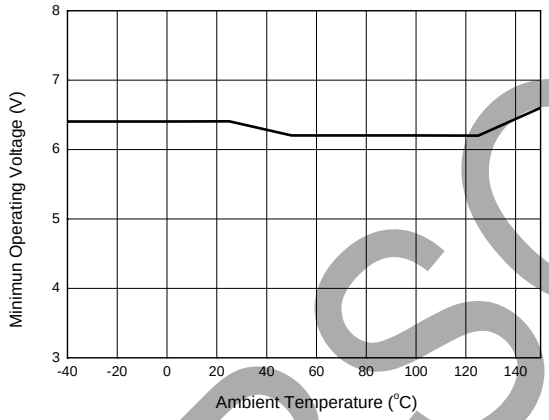
Start-up Voltage vs. Ambient Temperature



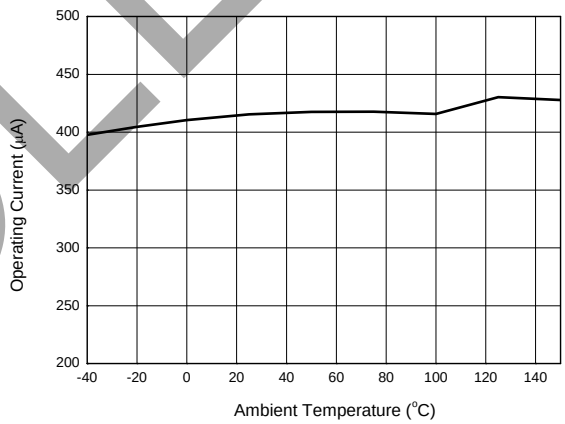
Start-up Current vs. Ambient Temperature



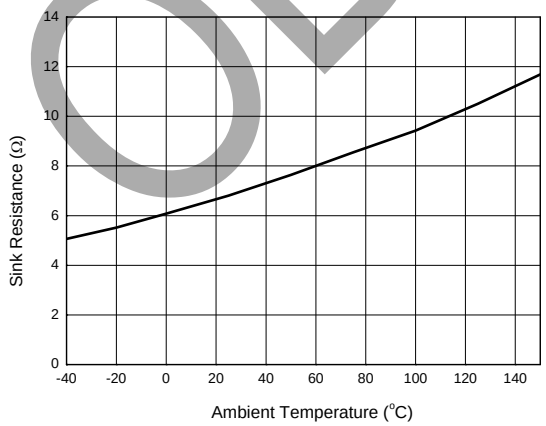
Minimal Operating Voltage vs. Ambient Temperature



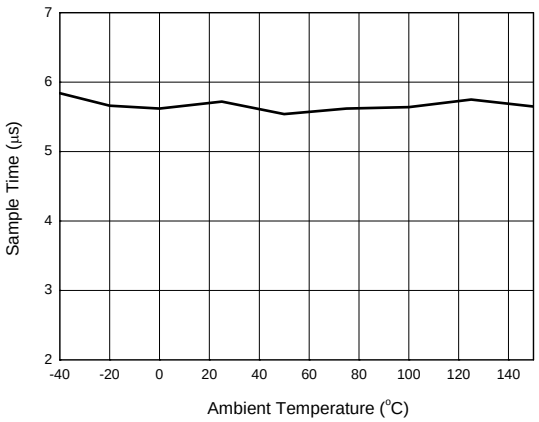
Operating Current vs. Ambient Temperature



Sink Resistance vs. Ambient Temperature

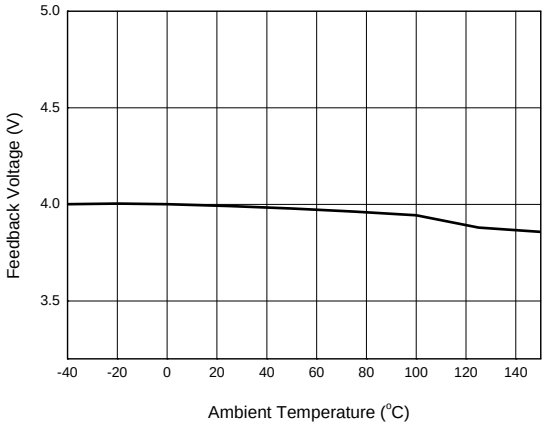


Sample Time vs. Ambient Temperature

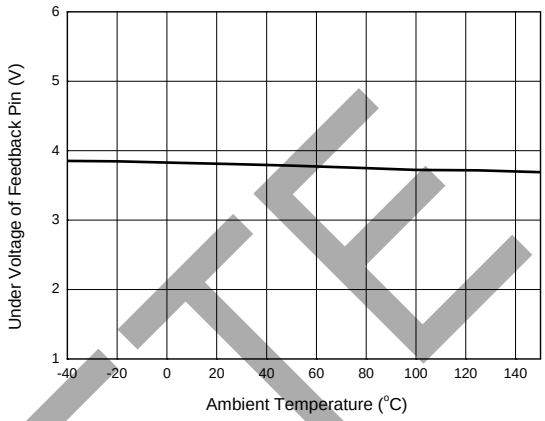


Performance Characteristics (Cont.)

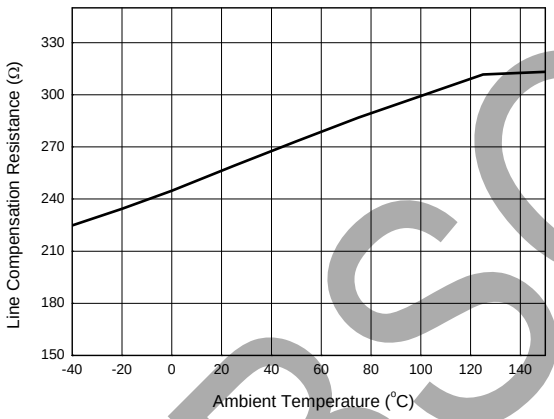
Feedback Voltage vs. Ambient Temperature



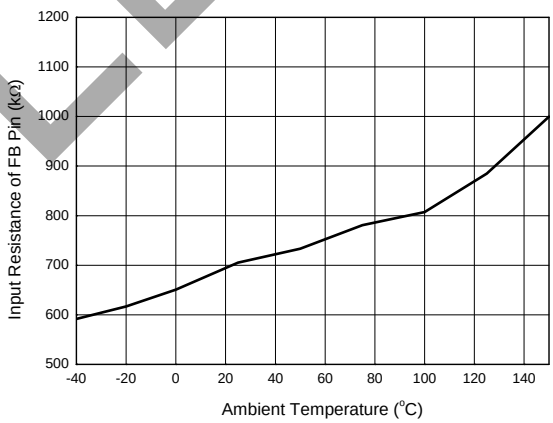
Under Voltage of FB Pin vs. Ambient Temperature



Line Compensation Resistance vs. Ambient Temperature



Input Resistance of FB Pin vs. Ambient Temperature



Operation Principle Description

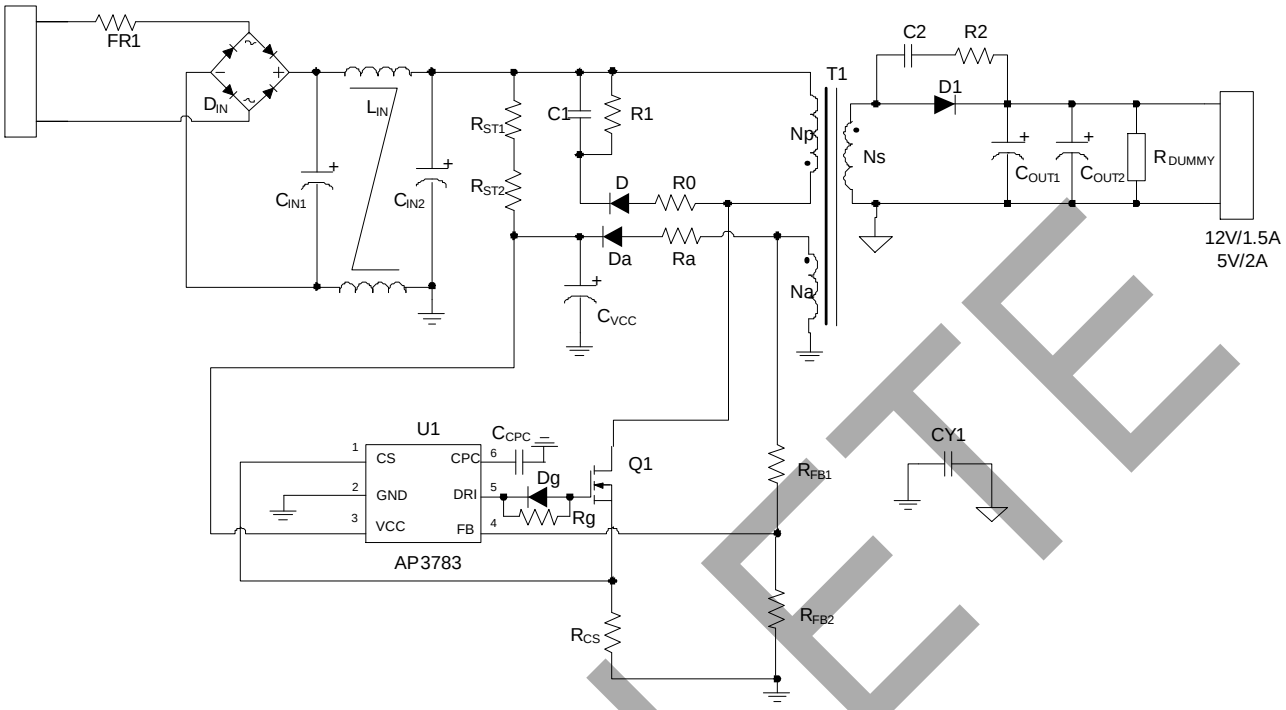


Figure 1. Typical Application Circuit of AP3783

Figure 1 is the typical application circuit of AP3783, which is a conventional Flyback converter with a 3-winding transformer---primary winding (N_P), secondary winding (N_S) and auxiliary winding (N_{AUX}). The auxiliary winding is used for providing VCC supply voltage for IC and sensing the output voltage feedback signal to FB pin.

Figure 2 shows the typical waveforms which demonstrate the basic operating principle of AP3783 application. And the parameters are defined as following.

I_P---The primary side current

I_S ---The secondary side current

I_{PK}---Peak value of primary side current

I_{PKS}---Peak value of secondary side current

V_{SEC}---The transient voltage at secondary winding

V_S---The stable voltage at secondary winding when rectification diode is in conducting status, which equals the sum of output voltage V_{OUT} and the forward voltage drop of diode

V_{AUX}---The transient voltage at auxiliary winding

V_A--- The stable voltage at auxiliary winding when rectification diode is in conducting status, which equals the sum of voltage VCC and the forward voltage drop of auxiliary diode

t_{SW} ---The period of switching frequency

t_{ONP} ---The conduction time when primary side switch is “ON”

t_{ONS} ---The conduction time when secondary side diode is “ON”

t_{OFF} ---The dead time when neither primary side switch nor secondary side diode is “ON”

t_{OFFS} --- The time when secondary side diode is “OFF”

Operation Principle Description (Cont.)

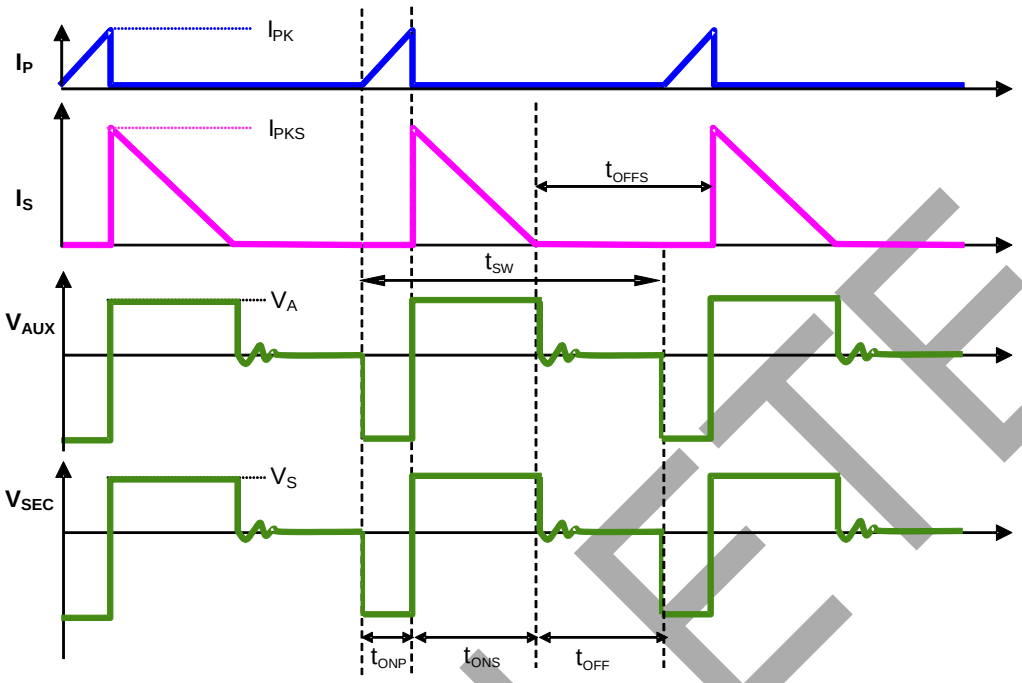


Figure 2. The Operation Waveform of Flyback PSR System

For primary-side regulation, the primary current ip(t) is sensed by a current sense resistor R_{CS} (as shown in Figure 1).The current rises up linearly at a rate of:

$$\frac{dip(t)}{dt} = \frac{V_{IN}(t)}{L_M} \quad (1)$$

As illustrated in Figure 2, when the current ip(t) rises up to I_{PK}, the switch Q1 turns off. The constant peak current is given by:

$$I_{PK} = \frac{V_{CS}}{R_{CS}} \quad (2)$$

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

$$Eg = \frac{1}{2} \times L_M \cdot I_{PK}^{\ 2} \quad (3)$$

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

$$P = \frac{1}{2} \times L_M \times I_{PK}^{\ 2} \times f_{SW} \quad (4)$$

Where, the f_{SW} is the switching frequency. When the peak current I_{PK} is constant, the output power depends on the switching frequency f_{SW}.

Constant Voltage Operation

As to constant-voltage (CV) operation mode, the AP3783 detects the auxiliary winding voltage at FB pin to regulate the output voltage. The auxiliary winding voltage is coupled with secondary side winding voltage, so the auxiliary winding voltage at D1 conduction time is:

$$V_{AUX} = \frac{N_{AUX}}{N_S} \times (V_O + V_D) \quad (5)$$

Where the V_D is the diode forward voltage drop.

Operation Principle Description (Cont.)

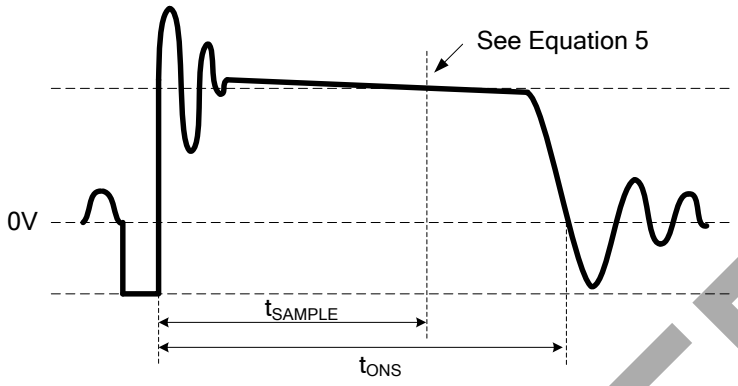


Figure 3. Auxiliary Voltage Waveform

The voltage detection point is at a constant delay time of the D1 on-time. The constant delay time is changed with the different primary peak current. The CV loop control function of AP3783 then generates a D1 off-time to regulate the output voltage.

Constant Current Operation

The AP3783 can work in constant-current (CC) mode. Figure 2 shows the secondary current waveforms.

In CC operation mode, the CC control loop of AP3783 will keep a fixed proportion between D1 on-time t_{ONS} and D1 off-time t_{OFFS}. The fixed proportion is

$$\frac{t_{ONS}}{t_{OFFS}} = \frac{4}{4} \quad (6)$$

The relationship between the output current and secondary peak current I_{PKS} is given by:

$$I_{OUT} = \frac{1}{2} \times I_{PKS} \times \frac{t_{ONS}}{t_{ONS} + t_{OFFS}} \quad (7)$$

As to tight coupled primary and secondary winding, the secondary peak current is

$$I_{PKS} = \frac{N_P}{N_S} \times I_{PK} \quad (8)$$

Thus the output constant-current is given by:

$$I_{OUT} = \frac{1}{2} \times \frac{N_P}{N_S} \times I_{PK} \times \frac{t_{ONS}}{t_{ONS} + t_{OFFS}} = \frac{2}{8} \times \frac{N_P}{N_S} \times I_{PK} \quad (9)$$

Therefore, AP3783 can realize CC mode operation by constant primary peak current and fixed diode conduction duty cycle.

Multiple Segment Constant Peak Current

As to the original PFM PSR system, the switching frequency decreases with output current decreasing, which will encounter audible noise issue since switching frequency decreases to audio frequency range, about less than 20kHz.

In order to avoid audible noise issue, AP3783 uses 4-segment constant primary peak current control method. At constant voltage mode, the current sense threshold voltage is multiple segments with different loading, as shown in Figure 4, which are V_{CS_H} for high load, V_{CS_M} for medium load, V_{CS_L} for light load and V_{CS_D} for ultra light load. At constant current mode, the peak current is still V_{CS_H}.

Operation Principle Description (Cont.)

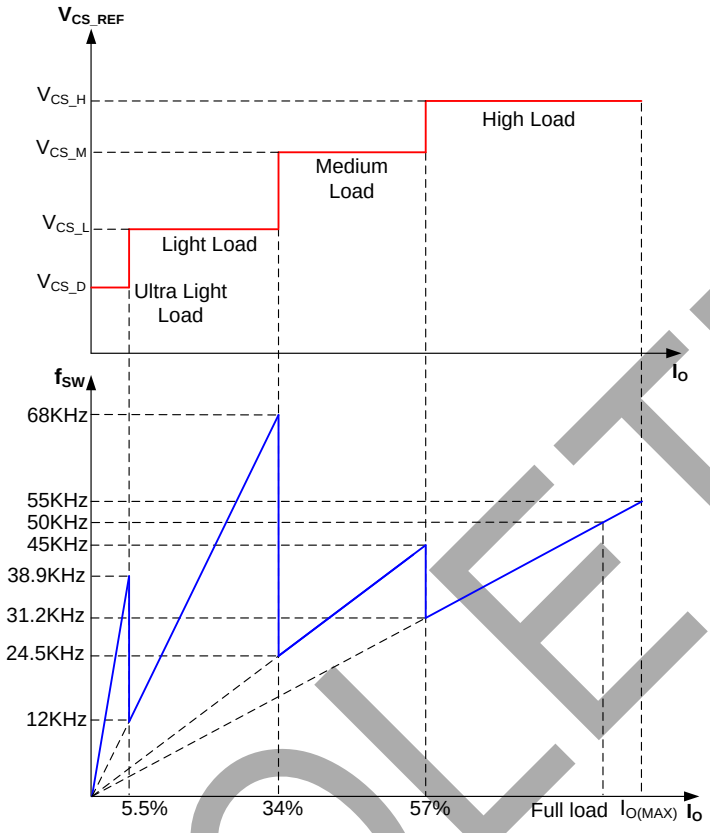


Figure 4. Multiple Segment Peak Current at CV Mode

It can be seen from Figure 4, with multiple segment peak current control, AP3783 power system can achieve good audible noise performance.

3-Segment Drive Current for Radiative EMI Suppression

When the power switch is turned on, a turn-on spike will occur, that worsens the radiative EMI. It is an effective way to decrease drive current before gate voltage gets to miller platform. The AP3783 uses 3-segment drive current for radiative EMI suppression, as shown in Figure 5. When gate voltage gets to 6V, the AP3783 drive current switches from low current (typical: 20mA) to high current (typical: 110mA). When the gate voltage gets to 10V, the drive current will decrease gradually to 0mA until the gate voltage goes up to the clamp voltage (13V).

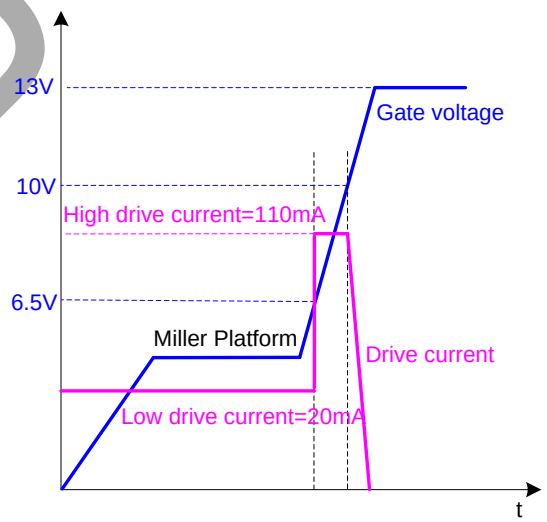


Figure 5. Drive Current and Gate Voltage

Operation Principle Description (Cont.)

Leading Edge Blanking (LEB) Time

When the power switch is turned on, a turn-on spike will occur on the sense-resistor. To avoid false turn off switch, a leading-edge blanking is built in. During this blanking time, the current sense comparator is disabled and the external power switch cannot be turned off. Furthermore, due to multiple segment peak current design, the required maximum on time t_{ONP} changes with different load conditions. Therefore the LEB time parameter also changes with different load conditions.

Adjustable Line Compensation and Fixed Cable Compensation

The AP3783 power system can adjust line compensation by changing the upper resistor at FB pin. The line compensation capability is increased by decreasing the resistance of the upper FB resistor.

Cable compensation is fixed in AP3783.

Valley Turn-on

When the off time (t_{OFF}) is lower than 16μs, AP3783 power system can work with valley turn-on. It can reduce MOSFET switching on power losses which is resulted from the equivalent output capacitance. At the same time, because of valley turn-on the switching frequency has the random jitter feature, which will be benefited for conductive EMI performance. And valley turn-on can also reduce the power switch turn-on spike current and then result in the better radiative EMI performance.

Frequency Jitter

Even though the valley turn on function can lead the random frequency jitter feature, an active frequency jitter function is added to AP3783 to ensure the frequency jitter performance in the whole loading condition. By adjusting the V_{CS_REF} with deviation of 5.0% every 256μs cycle, the active frequency jitter can be realized.

Short Circuit Protection (SCP)

Short Circuit Protection (SCP) detection principle is similar to the normal output voltage feedback detection by sensing FB pin voltage. When the detected FB pin voltage is below $V_{FB(SCP)}$ for a duration of about 128ms, the SCP is triggered. Then the AP3783 enters hiccup mode that the IC immediately shuts down and then restarts, so that the VCC voltage changes between V_{TH_ST} and UVLO threshold until $V_{FB(SCP)}$ condition is removed.

As to the normal system startup, the time duration of FB pin voltage below $V_{FB(SCP)}$ should be less than 18ms to avoid entering SCP mode. But for the output short condition or the output voltage below a certain level, the SCP mode will be triggered.

Figure 6 is the AP3783 normal start-up waveform that the voltage of FB pin is above $V_{FB(SCP)}$ during t_{SCP} after V_{CC} gets to the V_{TH_ST}, which doesn't enter the SCP mode. As shown in Figure 7, V_{OUT} is short and the voltage of FB pin is lower than $V_{FB(SCP)}$ during t_{SCP}, the AP3783 triggers the SCP and enters the hiccup mode.

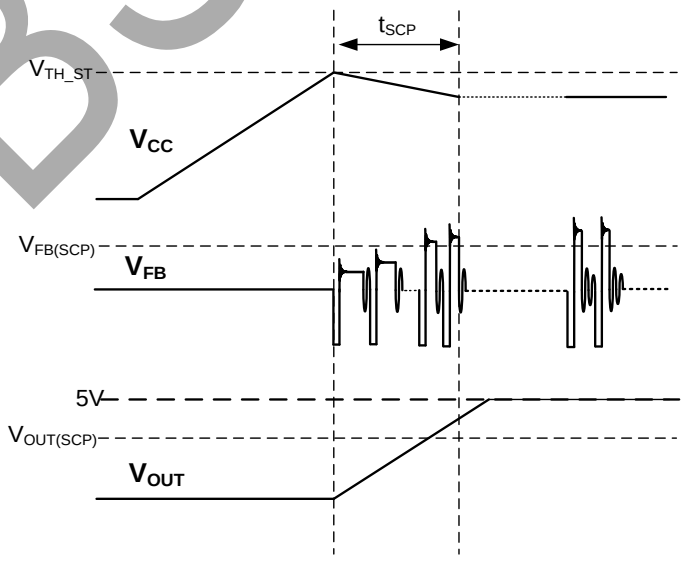


Figure 6. Normal Start-up

Operation Principle Description (Cont.)

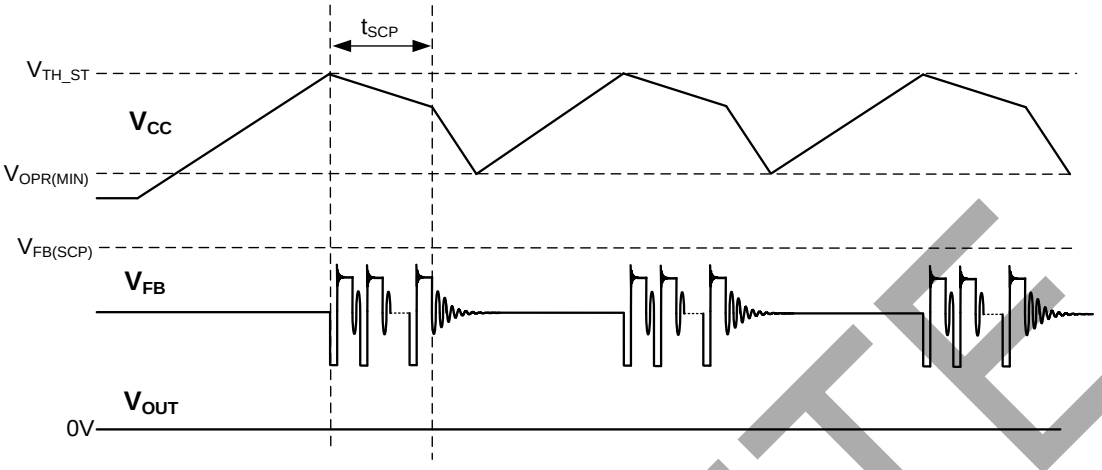


Figure 7. Short Circuit Protection (SCP) and Hiccup Mode

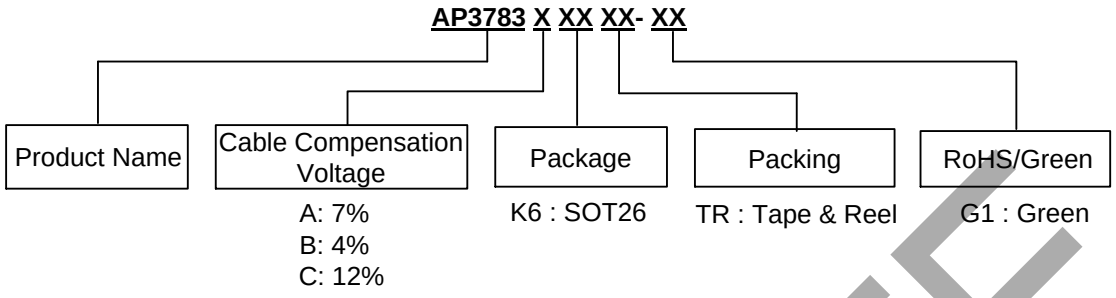
OVP

The AP3783 includes output over-voltage protection (OVP). If the voltage at FB pin exceeds $V_{FB(OVP)}$, the AP3783 immediately shuts down and keeps the internal circuitry enabled to discharge the VCC capacitor to the UVLO turn-off threshold. After that, the device returns to the start state and a start-up sequence ensues.

OTP

If the junction temperature reaches the threshold of +160ºC, AP3783 shuts down immediately. Before VCC voltage decreases to UVLO, if the junction temperature decreases to +120ºC, AP3783 can recover to normal operation. If not, the power system enters restart Hiccup mode until the junction temperature decreases below +120ºC.

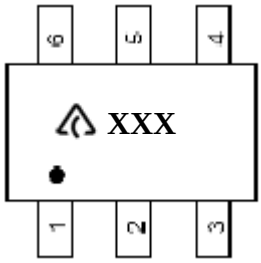
Ordering Information



Package	Temperature Range	Cable Compensation Voltage	Part Number	Marking ID	Packing
SOT26	-40 to +85°C	7%	AP3783AK6TR-G1	GBZ	3000/Tape & Reel
		4%	AP3783BK6TR-G1	GNZ	3000/Tape & Reel
		12%	AP3783CK6TR-G1	GPZ	3000/Tape & Reel

Marking Information

(Top View)

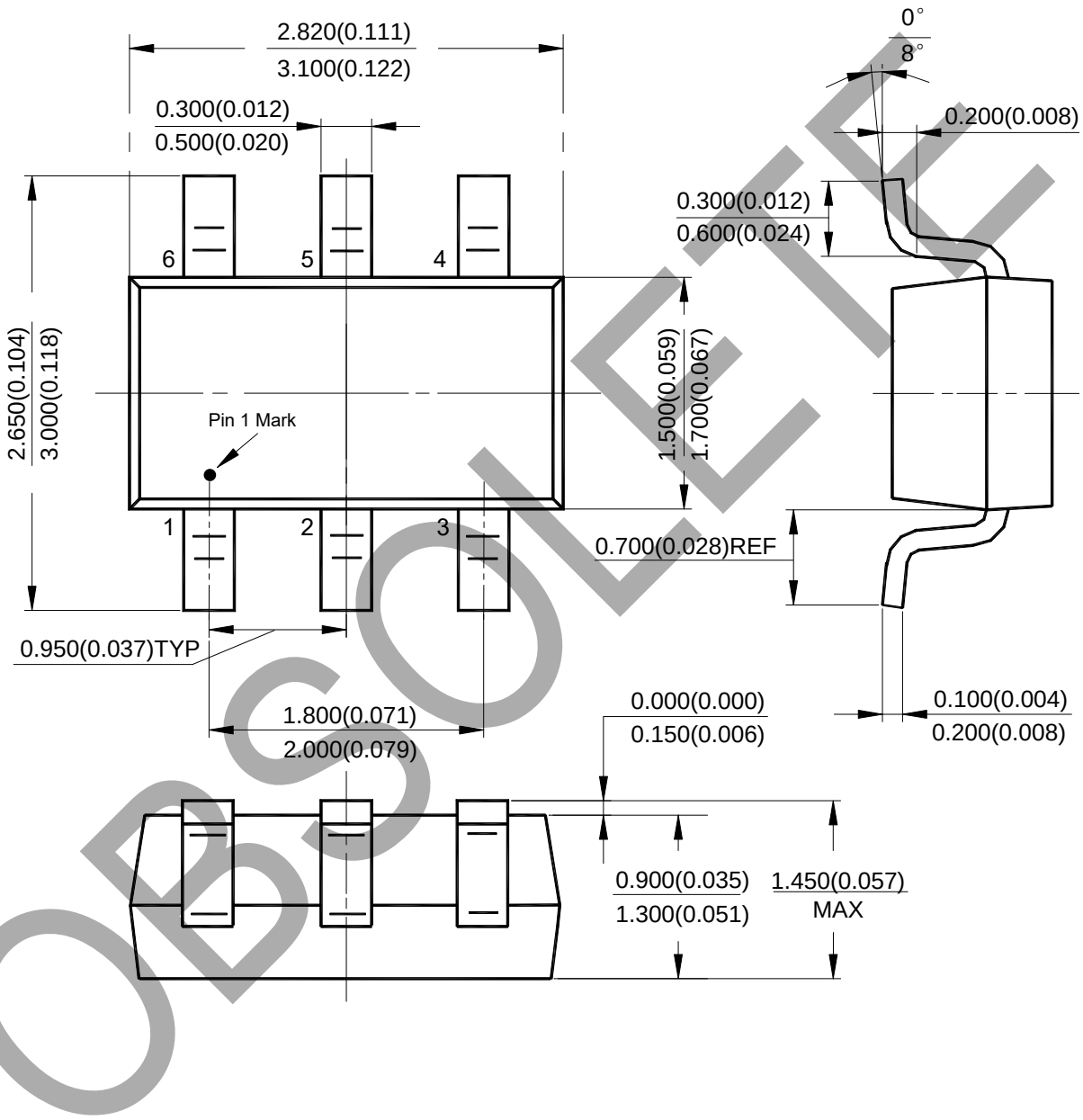


: Logo
XXX: Marking ID (See Ordering Information)

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

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

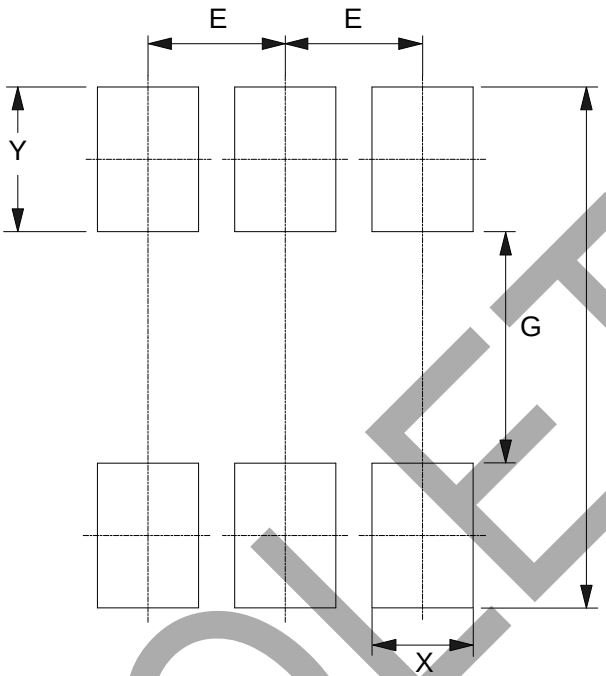
(1) Package Type: SOT26



Suggested Pad Layout

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

(1) Package Type: SOT26



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	E (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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