DC/DC Boost Converter for APD Bias with Current Mirror

GENERAL DESCRIPTION

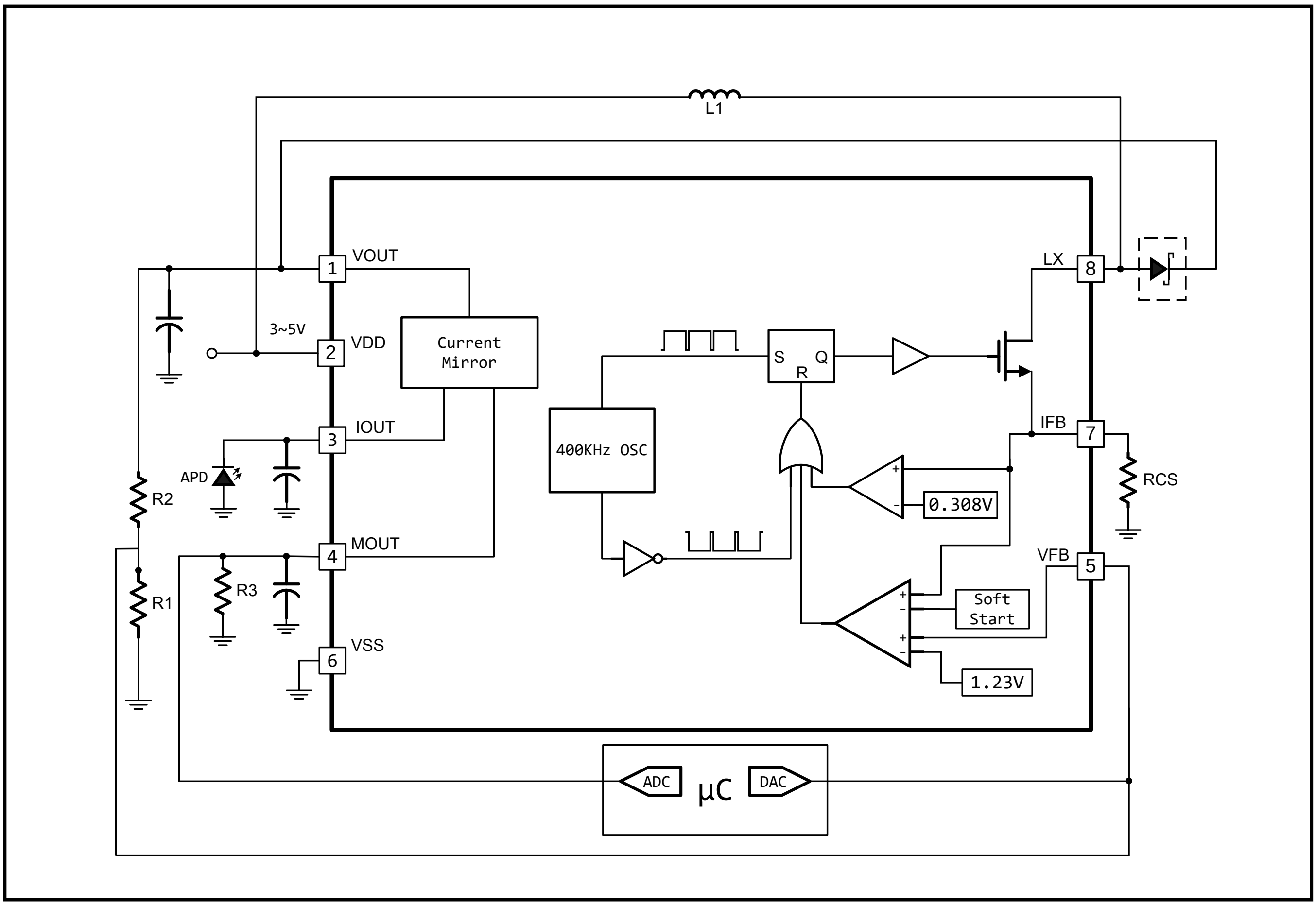
IS31PM7212 is a low pin count DC/DC boost converter for APD (Avalanche Photo Diode) bias in fiber optics application. A high reverse bias voltage (10V to 76V) is typically required for obtaining good optical conversion efficiency. IS31PM7212 can generate output voltages up to 76V and provides current monitoring up to 4mA (up to 300mW). There is also a current mirror of APD for RSSI monitor purpose.

The boost converter operates under DCM mode current mode control and internal compensations, thus making control loop stable under a wide range of boost voltage and load variations. The intrinsic switching frequency of IS31PM7212 is 400KHz and allows using external inductor from 2uH to 10uH. Minimum number of external components are required for the DC/DC.

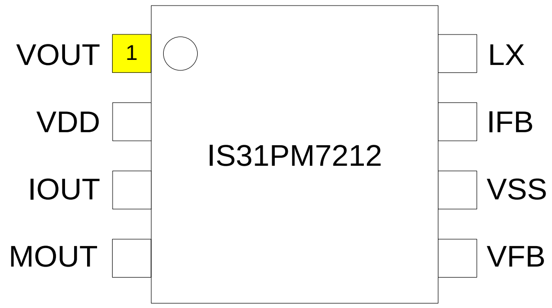
FEATURES

- Fully Internal Compensation, no External Frequency Compensation Network required.
- Constant PWM Frequency Provides Easy Switching Noise Filtering.
- Wide Output Voltage Range from 10V to 76V
- 300mW Boost Converter Output Power
- Fixed APD Current Limit at 6mA.
- Programmable Peak Inductor Current Limit
- Internal Soft-Start.
- With External Shut-Down Function
- Small form factor packages – MSOP-8 and DFN-8.

BLOCK DIAGRAM



PIN CONFIGURATION

Package	Pin Configuration (Top View)
MSOP-8 / DFN-8	

PIN DESCRIPTION

PIN #	PIN NAME	TYPE	PIN FUNCTION DESCRIPTION
1	VOUT	A	High Voltage Output Pin. (10V - 76V)
			Current flows into this pin through the embedded or external Schottky diode.
			VOUT pin provides high bias voltage and supply current for avalanche photodiode operation. At least 0.1uF capacitor is necessary to be connected to minimize the output ripple.
2	VDD	P	Supply Voltage Input (3V – 5.5V)
			VDD supplies power to the controller of PWM.
3	IOUT	A	Current Output Pin
			Connect this pin to APD Cathode to provide APD current.
4	MOUT	A	Current Monitor Output Pin.
			This pin mirrors the current source of IOUT (to APD). By connecting a specified resistor to ground and measuring its voltage, one can calculate the equivalent current of MOUT, thus derive APD current from IOUT.
5	VFB	A	Voltage Feedback Pin.
			This pin should be connected to the output voltage dividing resistors. Due to the feedback control behavior of IS31PM7212, the voltage of VFB will be close to 1.23V.
			External Shut Down Function: Pull this pin higher than 2V will shut down the IC. It will restart soft start procedure to boost the output again if v(VFB) keeps lower than 1.6V.
6	VSS	G	Ground Pin
			Minimize the trace length to reduce ground bounce.
7	IFB	A	Current Feedback Pin whose Voltage Denotes the Inductor Current.
			Connect this pin with a 0.5 ~ 1 ohm resistor to ground, the inductor current magnitude will then be converted to voltage signal of pin IFB. By limiting this voltage under 0.308V, we can limit the peak inductance current to $0.308/R_{IFB}$ (A) thus limit the output current of VOUT pin.
8	LX	A	Switch Pin that Used to Magnetize the Inductor.
			Please minimize the trace length on this pin to reduce EMI.
-	EP	G	Exposed Pad. Connect to a large copper plane at the VSS potential to improve thermal dissipation.

Note: “P” denotes power supply pins
“G” denotes ground pins. All VSS pins are internally shorted resistively.
“A” denotes an analog I/O pin.

ORDERING INFORMATION

Operating temperature -40°C to 85°C

Order Part No.	Package	QTY/Reel
IS31PM7212-SLS2-TR	MSOP-8, Lead-free	2500/Reel
IS31PM7212-DLS2-TR	DFN-8, Lead-free	2500/Reel

OPERATION

IS31PM7212 is a constant frequency, current mode, boost converter. Boost converter utilizes indirect magnetize, demagnetize cycle to transfer the energy from input voltage to output load. Please refer to Fig. 1 block diagram: when switch S1 turns on, the inductor L1 is magnetized and the energy stored as the magnetic flux of the inductor. When switch S1 turns off, the inductor is demagnetized and the energy that stored in on-period is released and transferred to the output load.

Further speaking, IS31PM7212 is a peak current controlled boost converter. It means that at each operation cycle, the maximum current of inductor is regulated by control loop. Shown in Fig. 1, the internal oscillator initially sets the flip-flop at each clock cycle and turns on S1 to make the inductor current increased that makes energy stored. Resistor RCS is connected between the switch and ground to sense the inductor current. The voltage of pin IFB (denotes as V(IFB)) will contributes to the add-subtract amplifier and let the amplifier assert high to turn off the switch if V(IFB) reaches some level of voltage.

Voltage feedback contributes to the add/subtract error amplifier too. The higher the voltage of pin VFB (denotes as V(VFB)) goes, the easier the amplifier output to assert high to turn off the switch. By adequately adjusting the weighting of the each input signals of the error amplifier, we can let the loop both be controlled by feedback voltage feedback current signal.

In addition to providing high reverse bias voltage for avalanche photodiode (APD), IS31PM7212 monitors its bias current too. The current of IOUT pin is mirrored 1:0.2 to MOUT pin. By connecting a resistor to ground and calculating the voltage difference of this resistor, we can derive the current of MOUT and thus the current of APD. This current message is often used for adjusting the APD bias voltage, by injecting or retrieving additional current from VFB pin.

DESIGN PROCEDURE

Set Output Voltage

IS31PM7212 will automatically adjust the output voltage to make V_{FB} equals V_{REF}. Therefore, the output voltage is set by the voltage of V_{REF} and the value of R_1, R_2. If we set the target output voltage as V_{OUT} and choose R_1 around the value of 5K ohm, then derive the value of R2 by following formulas

$$R_2 = R_1 \cdot \left[\frac{V_{OUT}}{V_{REF}} - 1\right]$$

to get desire output voltage.

Estimate the Maximum Limit of Inductor Value

If the output load is heavy, inductor has to take longer magnetization time (equals the on time of switch S1) to store the energy before it charges the output load during off-time. And if the inductor value is bigger, the required on-time will be even longer. Since IS31PM7212 is a fixed frequency converter, there is a maximum on-time limitation. If the required on-time exceed this limit, the switch will be turned off even though the peak inductor current are not sufficient to provide enough V_{OUT}. In this case, the output voltage will be lower than design target. For this reason, the inductance value can't be selected too big. The upper bound of the inductor value at worst case can be approximated by:

$$L_{MAX\_WC} = \frac{0.35 \times V_{IN\_MIN}^2 \times T_{SW}}{\left(V_{OUT} - V_{IN\_MIN}\right) \times I_{OUT\_MAX}}$$

Where T_{SW} is the switching period in μS, V_{OUT} is the output voltage in volts, V_{IN_MIM} is the minimum input voltage in volts, I_{OUT_MAX} is the maximum output current in amps, L is the inductor value in μH.

Check the Peak Inductor Current and Set Its Limit

After derived the upper bound of the inductor value, we should choose a inductor value and check its corresponding peak inductor current of the system. Generally, half of L_{MAX_WC} is a good start. Peak inductor current has to be designed not to make the IC or devices over-stressed. Because IS31PM7212 operates in the discontinuous conduction mode (DCM), the peak inductor current is a function of load current, inductor value and the switching frequency. The formula is:

$$I_{L\_PEAK\_MAX} = \sqrt{\frac{2 \times T_{SW} \times \left(V_{OUT} - V_{IN\_MIM}\right) \times I_{OUT\_MAX}}{L}}$$

Where T_{SW} is the switching period in μS, V_{OUT} is the output voltage in volts, V_{IN_MIM} is the minimum input voltage in volts, I_{OUT_MAX} is the maximum output current in amps, L is the inductor value in μH. The recommend value of $I_{L\_PEAK\_MAX}$ should be smaller than Switch Current Limit (ISW_LIM listed in DC Electrical Characteristics). If the calculated value is more then the Switch Current Limit, designer may change the inductor bigger to get a smaller inductor peak current. ($\propto \frac{1}{\sqrt{L}}$).

Determine the Value of Current Sense Resistor, R_{CS}

After the maximum peak inductor current, $I_{L\_PEAK\_MAX}$ determined, we can set the inductor current limit as

20% or 50% higher than $I_{L\_PEAK\_MAX}$. By setting current sense resistor with the value

$$R_{CS} = \frac{0.308}{I_{L\_LIM}} \quad \text{(in ohm)}$$

we can protect the system from being destroyed by any un-expected switch current more than I_{L_LIM}.

Check the On-Time and Inductance Value

The on time of switch can be calculated by I_{L_PEAK}:

$$t_{ON} = \frac{I_{L\_PEAK} \times L}{V_{IN}}$$

or directly from formula

$$t_{ON} = \frac{\sqrt{2 \times T_{SW} \times L \times I_{OUT} \times (V_{OUT} - V_{IN})}}{V_{IN}}$$

More specifically,

$$t_{ON\_MIN} = \frac{\sqrt{2 \times T_{SW} \times L \times I_{OUT\_MIN} \times (V_{OUT} - V_{IN\_MAX})}}{V_{IN\_MAX}}$$

, when loading is light (don't forget to count on the current flowing through the voltage divider resistors) and V_{IN} is high. and

$$t_{ON\_MAX} = \frac{\sqrt{2 \times T_{SW} \times L \times I_{OUT\_MAX} \times (V_{OUT} - V_{IN\_MIN})}}{V_{IN\_MIN}}$$

, when loading is heavy and V_{IN} is low. It is recommended that the t_{ON_MIN} should not be smaller than 150nS, and t_{ON_MAX} no bigger than 90% of the switching period, T_{SW}. When t_{ON_MIN} is too small, one can increase it by increasing the inductance value or adding dummy load on the output. If t_{ON_MAX} is too big, designers should decrease the inductance value. In general, bigger inductance value can get better load regulation performance due to the higher gain; but it is of little influence on output voltage ripple when system operates in DCM.

Select Output Capacitor

Low ESR capacitors should be used to minimize the output voltage ripple. Use X7R type of ceramic capacitor to retain the capacitance over wider range of temperature. Typically, a capacitor more then 0.1uF is sufficient. The more the capacitance value the smaller the output voltage ripple. If the output ripple is in the shape of saw tooth, its magnitude can be described as:

$$V_{OUT\_PK2PK} = \frac{1}{C_{OUT}} \times I_{OUT} \times T_{SW}$$

If tantalum or electrolytic capacitors are used to achieve high capacitance values, please add a smaller ceramic capacitor in parallel to bypass the high frequency noise components of the diode current.

Example

If user wants to have a 3~5 volts input voltage boost to 70 volts, with 0 ~ 5mA loading:

STEP1: set R1 = 5K (ohm)

STEP2: calculate R2, as

$$R_2 = 5K \cdot \left[\frac{70V}{1.23V} - 1\right] = 279.6K$$

STEP3: calculate the upper bound of inductor value

$$L_{MAX\_WC} = \frac{0.35 \times 3^2 \times 2.5\mu S}{(70 - 3) \times 5mA} = 23.5\mu H$$

STEP4: Choose around half of L_{MAX_WC}, $10\mu H$ as the initial design value of inductor.

STEP5: Calculate corresponding $I_{L\_PEAK\_MAX}$

$$I_{L\_PEAK\_MAX} = \sqrt{\frac{2 \times 2.5\mu S \times (70 - 3) \times 5mA}{10\mu H}} = 409mA$$

smaller than the limit of Switch Current Limit.

STEP6: Determine the value of R_{CS} as

$$R_{CS} = \frac{0.308V}{0.409A \times (100\% + 20\%)} = 0.628\,\text{ohm},$$

here we use 20% as the tolerance.

STEP7: Calculate corresponding t_{ON_MIN}

Since the user's minimum loading is 0, the actual minimum loading is the leakage current in resistors of voltage dividers.

$$I_{OUT} = \frac{70V}{(5K + 279.6K)} = 246\mu A$$

then

$$t_{ON\_MIN} = \frac{\sqrt{2 \times 2.5\mu S \times 10\mu H \times 246\mu A \times (70\text{-}5)}}{5} = 179\,nS,$$

which is bigger than 150nS.

STEP8: Calculate t_{ON_MAX}

$$t_{ON\_MAX} = \frac{\sqrt{2 \times 2.5\mu S \times 10\mu H \times 5mA \times (70\text{-}5)}}{3} = 1364\,nS$$

, smaller then 90% of $T_{SW.}$ (=2500nS.)

Therefore, L = 10 μH is an acceptable choice of inductor. If users want to use smaller inductor value, the dummy load can be considered to overcome the issue of t_{ON_MIN} too small.

STEP9: Set C_{OUT} = 0.1 μF, the calculate V_{OUT_PK2PK}

$$V_{OUT\_PK2PK} = \frac{1}{0.1\mu F} \times 5mA \times 2.5\mu S = 125\,mV$$

Increase C_{OUT} if you want the voltage ripple further reduced. Remind the designer again, the inductor value cause very little effect on output voltage ripple.

OTHER APPLICATION INFOMATION

Use FB pin to Shutdown IC

Users can use FB pin to shut down IC. By pulling FB pin higher than 2V and endure more than 1 ms endurance, IS31PM7212 will be shut down: the switch S1 will be closed and the operating current of most blocks will be turned off to minimize the shutdown current. To release the shutdown condition, users have to let the FB pin go down below 1.6V. After that, system will restart the soft start procedure to boost the output voltage up again.

Current Limit of APD Bias Current

In addition to using R_{CS} to set the maximum peak current, IS31PM7212 also provides a constant 5 mA current limit function on APD bias current. When a low impedance loading connected to APD pin and the current limit function is triggered, APD bias current will become a constant current source of the current limit value. Thus, the bias voltage of APD will be dropped off and the avalanche photo diode may not work properly.

ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings

SYMBOL	PARAMETER	RATING	UNIT	NOTE
VDD	Supply Voltage	5.5	V	
MAXJT	Maximum Junction Temperature	150	℃	
TSTG	Storage Temperature	-65 – 150	℃	

Recommended Operating Condition

SYMBOL	PARAMETER	RATING	UNIT	NOTE
LX	Voltage Difference of LX to GND	-0.3 – 76	V	
VOUT	Voltage Difference of VOUT to GND	-0.3 – 76	V	
IOUT	Voltage Difference of IOUT to GND	-0.3 – 76	V	
MOUT	Voltage Difference of MOUT to GND	-0.3 – 76	V	
VDD	Voltage Difference of VDD to GND	3 – 5	V	
VFB	Voltage Difference of VFB to GND	-0.3 – VDD	V	
IFB	Voltage Difference of IFB to GND	0 – 0.4	V	
TA	Ambient Operating Temperature	-40 – 85	℃	

DC Electrical Characteristics

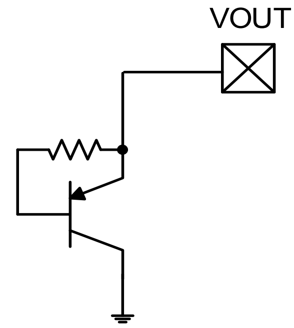
(VDD=3.3V, GND=0V, LX=IOUT=MOUT=unconnected, MOUT=0V TA=-40C to 85C)

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT	NOTE
VDD Related						
V_{DD}	Supply Voltage Range	2.8	-	5.5	V	
I_{DD}	VFB=1.4V, no switching	-	1	1.2	mA	
V_{UVLO}	Under Voltage Lockout Threshold	2.475	2.6	2.775	V	
V_{UVLO_HYS}	Under Voltage Lockout Hysteresis	-	200	-	mV	
I_{VOUT_SHDN}	VOUT current when VFB > 2V	-	-	200	uA	
Boost Converter						
VOUT	Output-Voltage Adjustment Range	V_{DD}+5V	-	76	V	
F_{SW}	Switching Frequency		400		KHz	VDD=5V
D_{CLK}	Maximum Duty Cycle	88	90	92	%	VDD=2.8V
V_{FB}	Reference Voltage to Compare VFB	1.2054	1.23	1.2546	V	
I_{FB_IN}	VFB Input Current	-	-	500	nA	
VISW_LIM	Voltage of Switch Current Limit	-	0.3	-	V	VISW_LIM/RCS= Switch Current Limit
AISW_LIM	Absolute Switch Current Limit	-	1000	-	mA	Current Exceed AISW_LIM may suffer reliability issue.
TSWLIM	Current Limit Response Time	-	100	500	ns	Guaranteed by design
SLNR	Line Regulation	-	0.2	-	%	3V≦VDD≦5V, ILOAD=4.5mA
SLDR	Load Regulation	-	1	-	%	VDD=5V 0mA≦ILOAD≦4.5mA
T_{SF}	Soft Start Time	-	2.5	-	ms	
R_{ON}	On Resistance of Internal Switch	-	1	2	Ω	ILX=0.1A, VIN=3V
LOGIC						
VFBSHDN	VFB Shutdown Voltage	2	-	-	V	

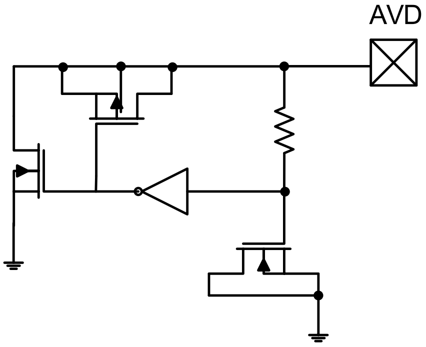
VFBSHDN_TIME	VFB Shutdown Threshold Durance Time	-	0.6	-	ms	
VFBSDRL	VFB Shutdown Release Voltage	-	-	1.6	V	
Current Output and Current Monitor						
V_{OUT}	IOUT Pin Voltage Range	V_{DD}+5V		VOUT-4.8	V	
IMOUT_OVER_IOUT	100nA ≦ IOUT ≦ 1uA	0.16	0.2	0.24		±20%
	1uA ≦ IOUT ≦ 4mA	0.18	0.2	0.22		±10%
IOUT_DROP	IOUT Voltage Drop (V(VOUT)-V(IOUT))	-	2.7	3.5	V	IOUT=2mA
ILIM_APD	APD Input Current Limit		6		mA	
MOUT_VRANGE	MOUT Voltage Range	-	-	VDD-3.5	V	IOUT=2mA
Thermal Protection						
	Thermal Shutdown		+150		℃	Rising Temperature
	Thermal Shutdown Hysteresis		15		℃	

I/O EQUIVALENT CIRCUITS

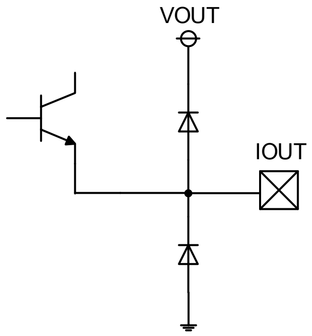
1. VOUT



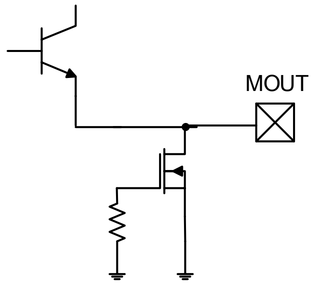
2. AVD



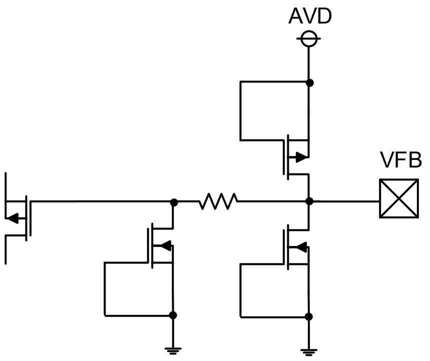
3. IOUT



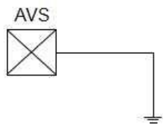
4. MOUT



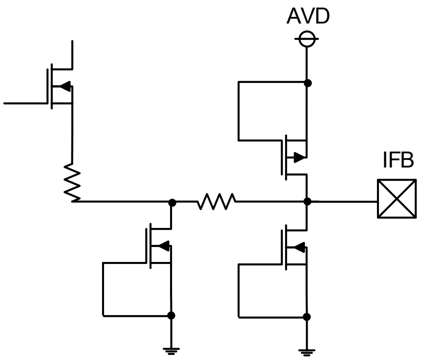
5. VFB



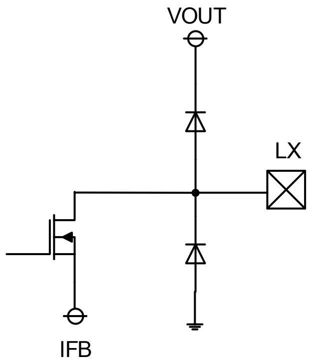
6. AVS



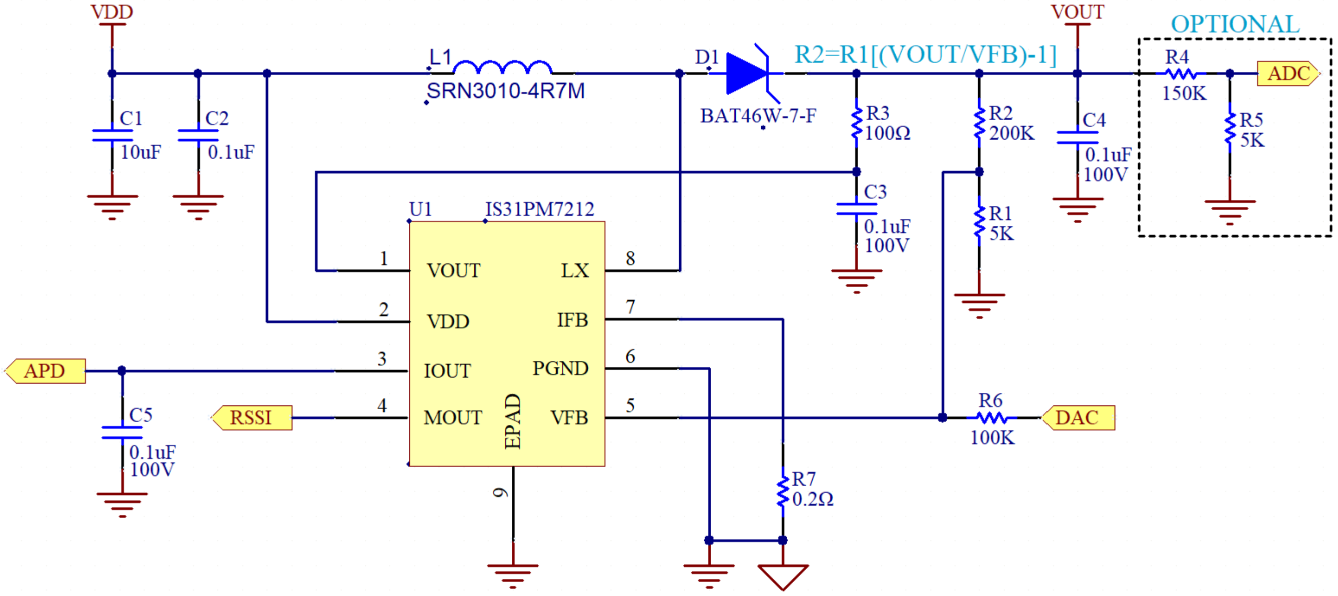
7. IFB



8. LX

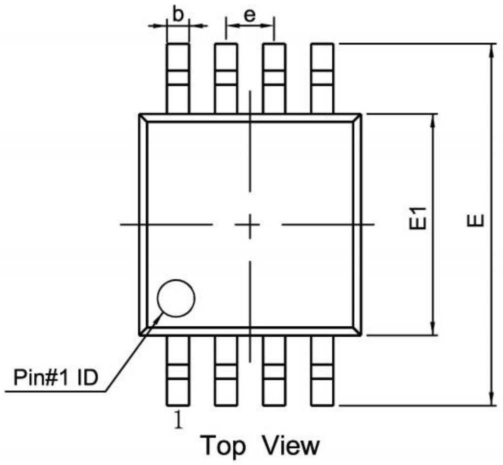


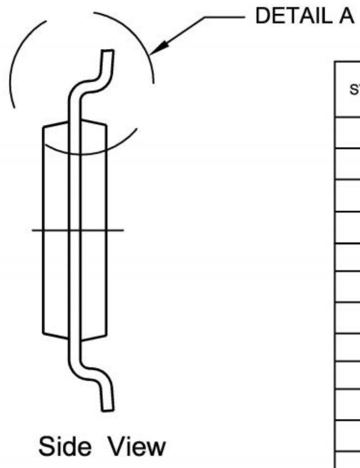
APPLICATION CIRCUITS



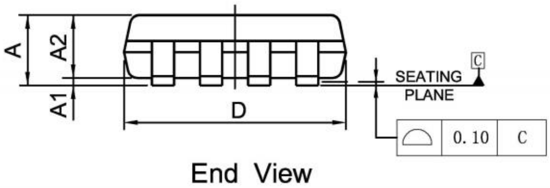
PACKAGE OUTLINE

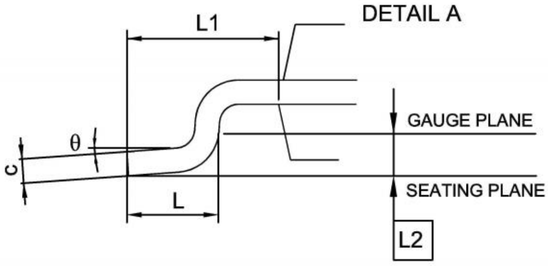
MSOP8 Outline

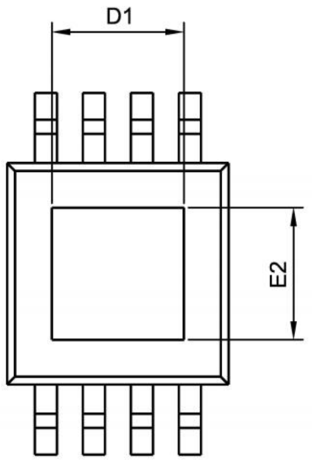




SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.10
A1	0	—	0.15
A2	0.75	0.85	0.95
b	0.22	—	0.38
c	0.08	—	0.23
D	2.90	3.00	3.10
E	4.70	4.90	5.10
E1	2.90	3.00	3.10
L	0.40	0.60	0.80
L1	0.95 REF		
e	0.65 BSC		
L2	0.25 BSC		
θ	0°	—	8°
D1	1.42	—	1.78
E2	1.38	—	1.73



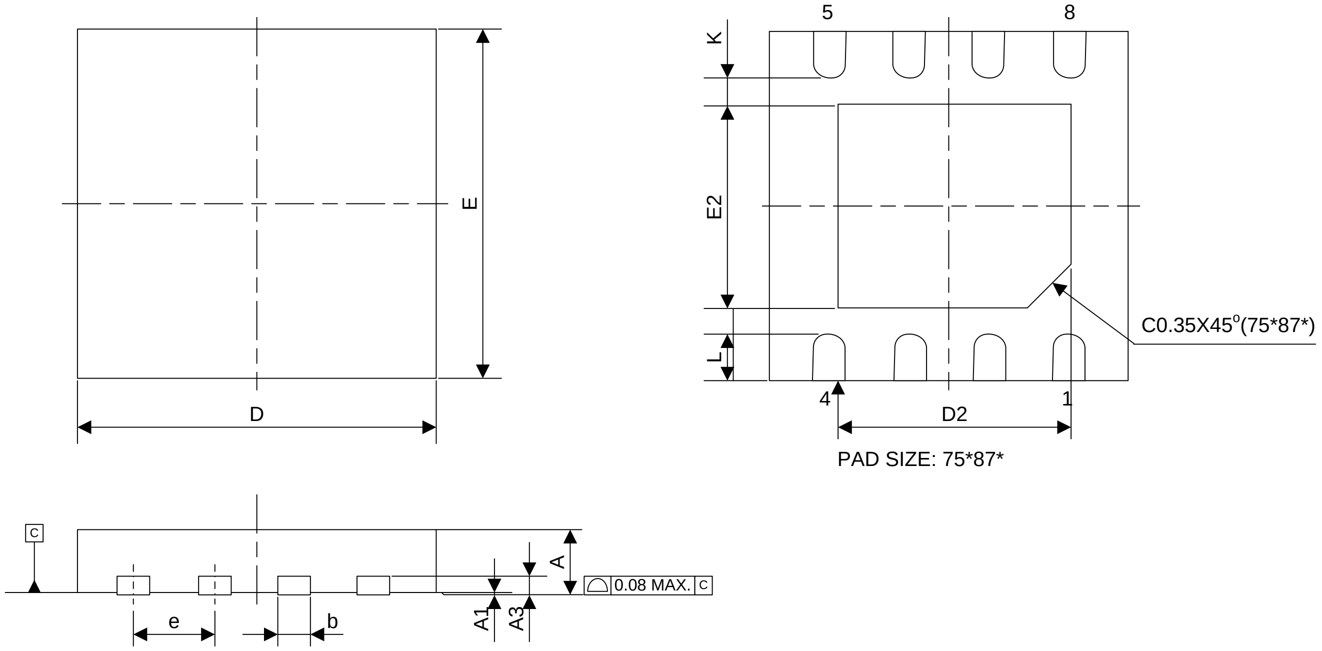




NOTE :

1. CONTROLLING DIMENSION : MM
2. REFERENCE DOCUMENT: JEDEC MO-187F

DFN3X3 Outline



	PACKAGE TYPE		
JEDEC OUTLINE	MO-229		
PKG CODE	WDFN(X308)		
SYMBOLS	MIN.	NOM.	MAX.
A	0.70	0.75	0.8
A1	0.00	0.02	0.05
A3	0.203 REF.		
D	3.00 BSC		
E	3.00 BSC		
e	0.65 BSC		
K	0.20	-	-

PAD SIZE	D2			E2			L			b		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
75*X87* MIL	1.95	2.00	2.05	1.60	1.65	1.70	0.35	0.40	0.45	0.25	0.30	0.35