144 nA I_Q Low Quiescent Current Buck DC/DC Converter for Energy Harvester

No. EA-414-200508

OVERVIEW

R1800K is a power-storing buck DC/DC converter for a photovoltaic and vibration energy harvester. A low operating quiescent current allows a harvester to be used under a low-illumination environment, and it is suitable for an equipment with low power supplied from a harvester.

KEY BENEFITS

- Providing a low operating quiescent current (I_Q 144 nA) and a high efficiency (approximately 90%@10 µA).
- A Control function that enables a maximum power optimizes a power supply from an energy harvester.

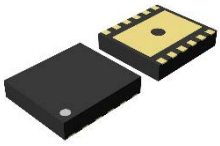
KEY SPECIFICATIONS

- Input Voltage Range: 2.0 V to 5.5 V
- Output Voltage Range: 2.0 V to 4.5 V
- Output Voltage Accuracy: ±3.0%
- Operating Quiescent Current:
  Typ.144 nA (Ta = 25°C, at no load)
- Starting Power: 720 nW
- Reverse Current Protection (V_{IN} ≥ 2.0 V)
- Accuracy of Maximum Power Voltage: 200 mV

APPLICATIONS

- Energy harvesting module of a photovoltaic and vibration energy harvester

PACKAGE



DFN(PL)2730-12

2.7 mm x 3.0 mm x 0.6 mm

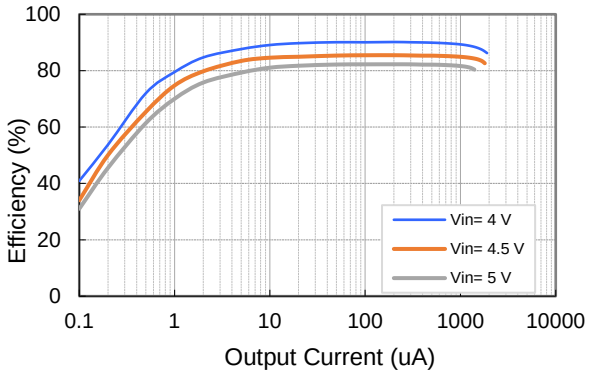
SELECTION GUIDE

Product Name	Package	Quantity per Reel
R1800KxxxA-TR	DFN(PL)2730-12	5,000 pcs

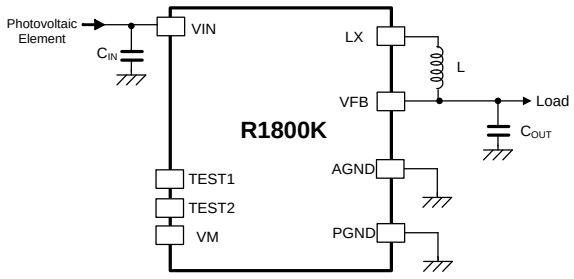
xxx: Select the ideal combination of the set output voltage (V_{SET}) and the set maximum power voltage (V_{MPSET}) from the code number starting from 002.

TYPICAL CHARACTERISTICS

Efficiency vs. Output Current V_{SET} = 3.3 V



TYPICAL APPLICATION



L = 22 µH, C_{IN} = 10 µF, C_{OUT} = 47 µF

SELECTION GUIDE

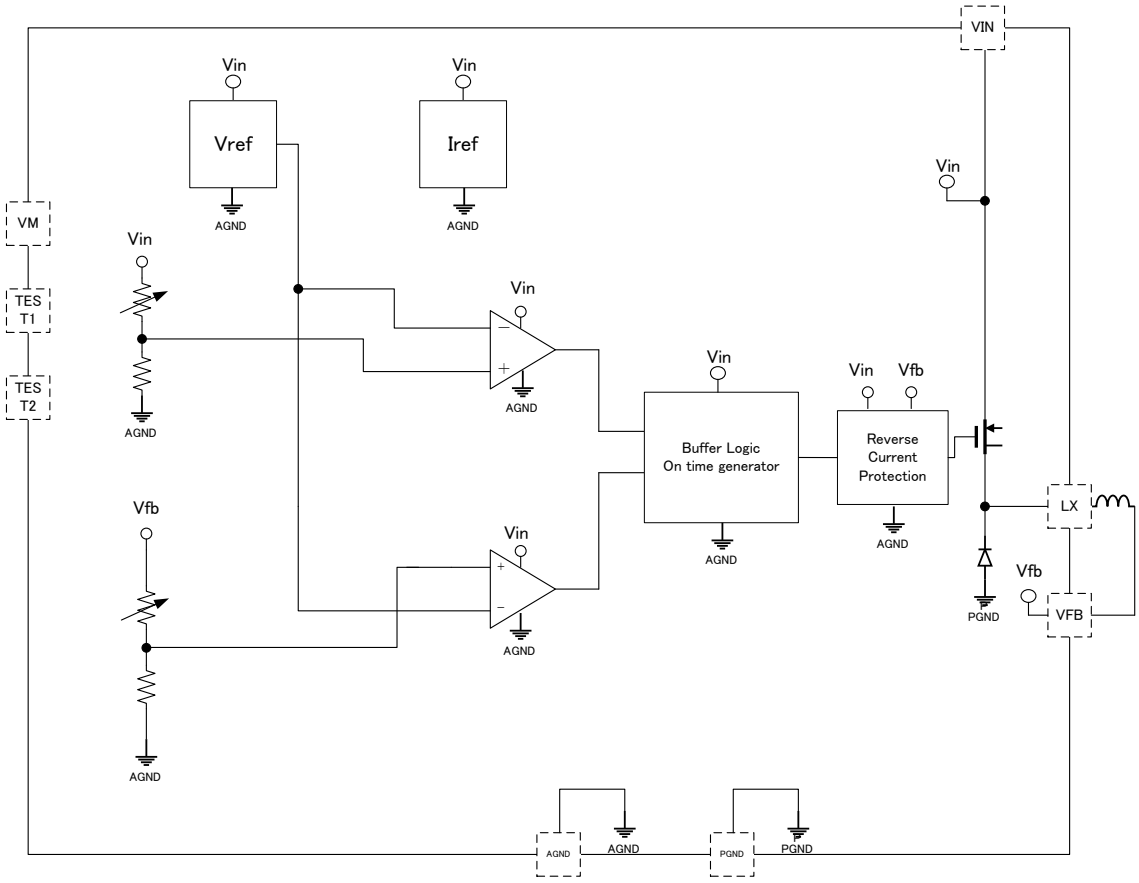
The set output voltage and set maximum power voltage are user-selectable options.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1800KxxxA-TR	DFN(PL)2730-12	5,000 pcs	Yes	Yes

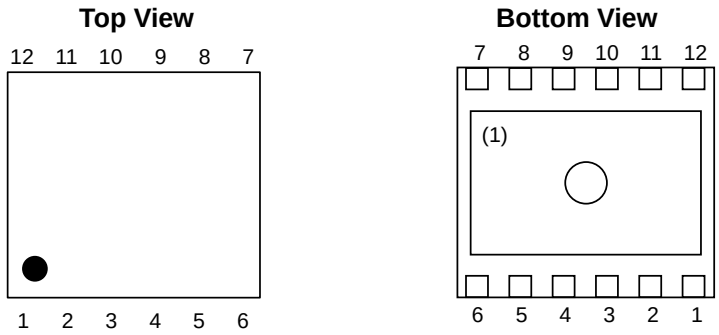
xxx: Select the ideal combination of the set output voltage (V_{SET}) and
the set maximum power voltage (V_{MPSET}) from the code number starting from 002.
Output voltage: 2.0 V to 4.5 V in 0.1 V step
Maximum power voltage: 2.0 V to 5.3 V in 0.1 V step

BLOCK DIAGRAM



R1800K Block Diagram

PIN DESCRIPTION



DFN(PL)2730-12 Pin Configuration

DFN(PL)2730-12 Pin Description

Pin No.	Symbol	Description
1	AGND	AGND Pin
2	TEST1	Pin for Testing (Must not be connected)
3	TEST2	Pin for Testing (Must not be connected)
4	VM	Pin for Testing (Must not be connected)
5	NC	No Connection (Must not be connected)
6	NC	No Connection (Must not be connected)
7	VFB	Feedback Pin
8	PGND	PGND Pin
9, 10	LX	DC/DC Switching Pin
11, 12	VIN	Pin for Connecting Photovoltaic Element

(1) The tab on the bottom of the package enhances thermal performance and is electrically connected to GND (substrate level). It is recommended that the tab be connected to the ground plane on the board, or otherwise be left floating.

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings (GND = 0 V)

Symbol	Parameter	Rating	Unit
V_{IN}	VIN Pin Voltage	−0.3 to 6.5	V
V_{LX}	LX Pin Voltage	−0.3 to V_{IN} + 0.3	V
V_{VFB}	VFB Pin Voltage	−0.3 to 6.5	V
P_D	Power Dissipation [1] [DFN(PL)2730-12, JEDEC STD. 51-7 Test Land Pattern]	1850	mW
Tj	Junction Temperature Range	−40 to 85	°C
Tstg	Storage Temperature Range	−55 to 125	°C

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause permanent damage and may degrade the lifetime and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

RECOMMENDED OPERATING CONDITIONS

Recommended Operating Conditions

Symbol	Parameter	Rating	Unit
V_{IN}	Input Voltage	2.0 to 5.5	V
Ta	Operating Temperature Range	−40 to 85	°C

RECOMMENDED OPERATING CONDITIONS

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

[1] Refer to *POWER DISSIPATION* for detailed information.

ELECTRICAL CHARACTERISTICS

The specifications surrounded by [ ] are guaranteed by design engineering at −40°C ≤ Ta ≤ 85°C.

R1800K Electrical Characteristics (Ta = 25°C)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{OUT}	Output Voltage	$V_{IN} \geq V_{SET}$ + 0.5 V, at no load	x 0.97		x 1.03	V
I_Q	Operating Quiescent Current	V_{IN} = 5.0 V, V_{SET} = 3.0 V, device not switching		144	300	nA
P_{ST}	Minimum Starting Power	Ta = 25°C, V_{IN} = 4 V, V_{SET} = 3.3 V, when constant current is applied		720		nW
V_{MP}	Accuracy of Maximum Power Voltage				200	mV
I_{REV}	Reverse Current	$V_{IN} \geq$ 2.0 V, V_{FB} = 4.5 V (When VIN drops from 2.5 V or more) Charging current to C_{IN} and C_{OUT} are not included(1)		10	100	nA

All test items listed under Electrical Characteristics are done under the pulse load condition (Tj ≈ Ta = 25°C).
Test circuit is operated with “Open Loop Control” (GND = 0 V), unless otherwise specified.

(1) Reverse current protection operates at $V_{IN} \geq$ 2 V. It does not function with the voltage under 2 V. Set as $V_{MPSET} > V_{SET}$ + 0.5 V. Due to having a hysteresis in the reverse current protection, a state may be detected as a reverse current even if $V_{IN} = V_{OUT}$.

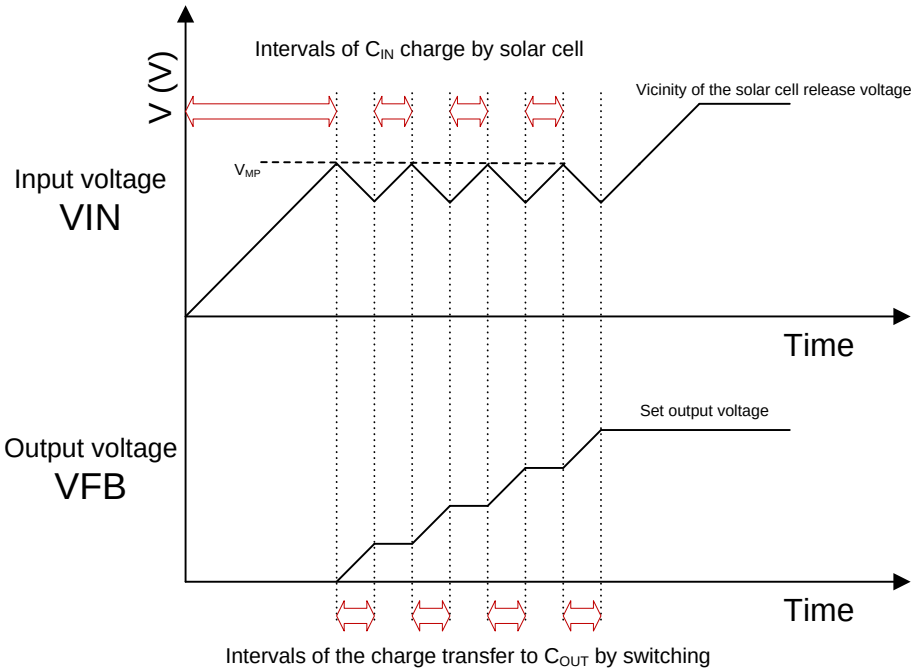
The specifications surrounded by [ ] are guaranteed by design engineering at −40°C ≤ Ta ≤ 85°C.

Product-specific Electrical Characteristics

Product Name	V_{OUT} [V]			V_{MP} [V]	
	Min.	Typ.	Max.	Typ.	Max.
R1800K002A	1.940	2.0	2.060	2.5	2.7
R1800K003A	1.940	2.0	2.060	3.8	4.0
R1800K004A	1.940	2.0	2.060	4.0	4.2
R1800K005A	1.940	2.0	2.060	4.5	4.7
R1800K006A	1.940	2.0	2.060	5.0	5.2
R1800K008A	3.201	3.3	3.399	3.8	4.0
R1800K009A	3.201	3.3	3.399	4.0	4.2
R1800K010A	3.201	3.3	3.399	4.5	4.7
R1800K011A	3.201	3.3	3.399	5.0	5.2
R1800K014A	4.365	4.5	4.635	5.0	5.2
R1800K016A	3.783	3.9	4.017	4.4	4.6
R1800K019A	2.910	3.0	3.090	4.4	4.6
R1800K020A	2.910	3.0	3.090	4.2	4.4
R1800K021A	2.619	2.7	2.781	3.9	4.1
R1800K022A	2.619	2.7	2.781	4.4	4.6
R1800K023A	2.619	2.7	2.781	5.0	5.2

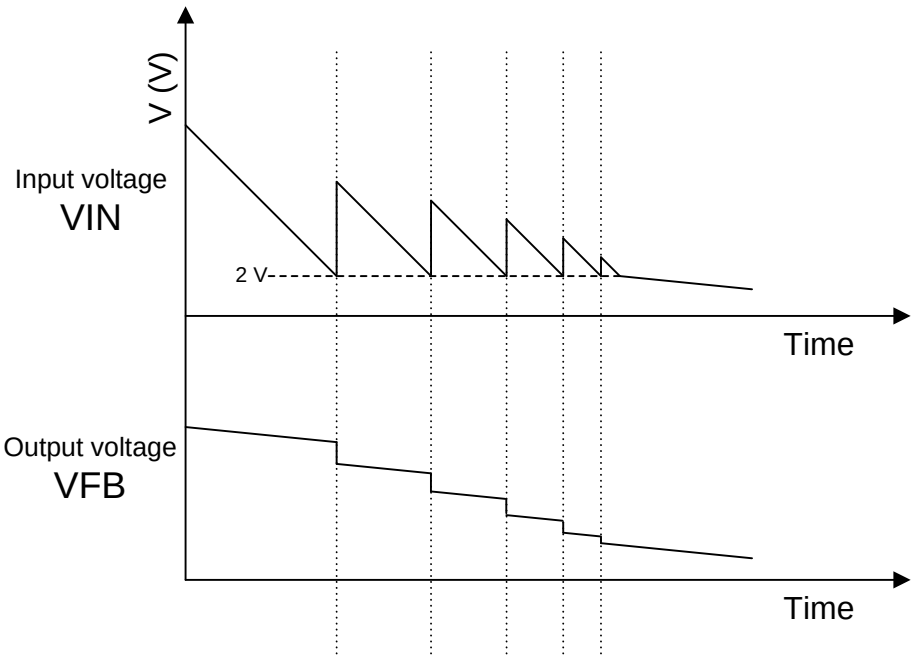
THEORY OF OPERATION

MAXIMUM POWER CONTROL



R1800K transfers power to a secondary side at the maximum power voltage (V_{MP}), which is the operating point of the maximum amount of power generation of a solar cell. After R1800K receives power from the solar cell, the input voltage increases and when it reaches the V_{MP}, a switching starts and the R1800K transfers power to the secondary side. When a power transfer amount exceeds the supplied power from the solar cell, the input voltage decreases by the switching. At a certain point, the switching stops and a state changes to a charging mode. When the input voltage reaches the V_{MP} again, the R1800K transfers power to the secondary side. By repeating this operation enables transferring power to the secondary side while maintaining the operating point of the maximum amount of power generation of the solar cell.

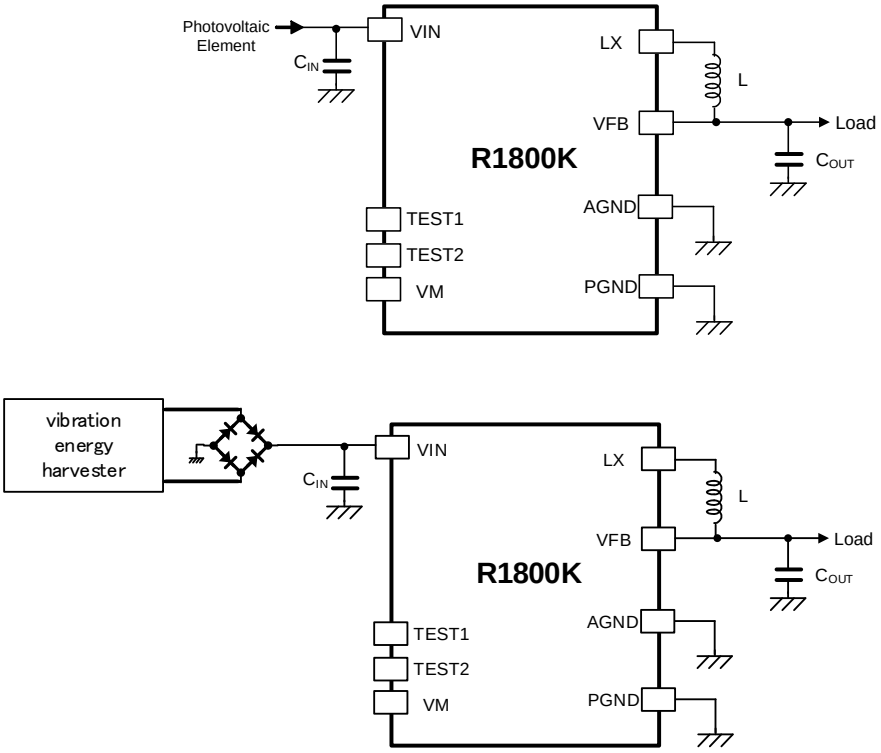
REVERSE CURRENT DETECTION



R1800K has a reverse current protection to maintain an electric charge of the output side when the light is cut off. When the light is cut off after a normal operation and a power supply from the solar cell is discontinued, the charge of supply current of a circuit connected respectively to the input and output sides is drawn. When the input voltage drops below the output voltage, the reverse current protection operates (at the backflow) and prevents the charge drawn from the output side. As shown in the figure above, this protection operates at 2 V or higher. When the input voltage drops below 2 V, the charge of the output side flows back to the input side. The drawn charge increases for a moment, but the R1800K returns to the reverse current protection state. The average amount of charge drawn from the output side is extremely minute.

APPLICATION INFORMATION

Typical Application Circuit



R1800K Typical Application Circuit

Recommended External Components

Symbol	Descriptions	Parts Name
C_{IN}	Ceramic Capacitor 10 µF or higher	C1608X5R1E106M080AC
C_{OUT}	Ceramic Capacitor 47 µF or higher	C3216X6S1A476M160AC
	Large-capacity Electrical Storage Device	Refer below table
L	Inductor 22 µH	VLS201612CX-220M-1

Recommended Large-capacity Electrical Storage Devices

Manufacturer	Series	Parts Name	Capacity	Type	Supplement
TDK	CeraCharge™	BCT1812M101AG	100µAh	All-solid-state Li-ion	CeraCharge™ is a trademark of TDK
NICHICON	SLB series	SLB03070LR35	350µAh	Li-ion	
NGK	EnerCera®	ET1210C-R ET2016C-R ET271704P-H	5mAh 25mAh 5mAh	Li-ion	EnerCera® is a trademark of NGK
Murata	CT series	CT04120	3mAh	Li-ion	

TECHNICAL NOTES

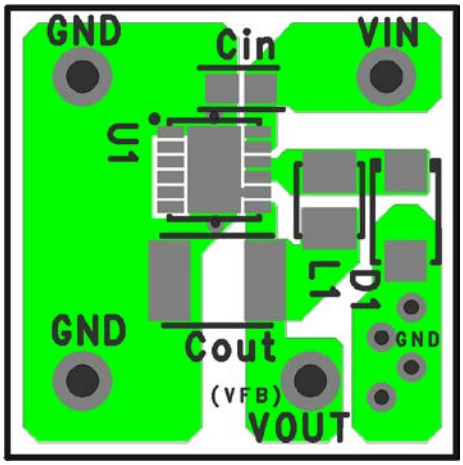
The performance of a power source circuit using this device is highly dependent on a peripheral circuit. A peripheral component or the device mounted on PCB should not exceed a rated voltage, a rated current or a rated power. When designing a peripheral circuit, please be fully aware of the following points.

- External components must be connected as close as possible to the IC and make wiring as short as possible. Especially, the capacitor connected in between V_{IN} pin and GND pin must be wiring the shortest.
- If their impedance is high, internal voltage of the IC may shift by the switching current, and the operating may be unstable. Make the power supply and GND lines sufficient.
- As for wirings of the power, the ground, the inductor, the LX and the VFB pins, due consideration must be given to large current occurred by switching.
- Using a ceramic capacitor with a lower equivalent series resistance (ESR) is recommended; a capacitor of 10µF or higher for C_{IN} between V_{IN} and GND pins, a capacitor of 47µF or higher for C_{OUT}. Using a mass-storage device for C_{OUT} also is recommended. Please choose capacitors depending on the bias characteristics, V_{IN} and V_{OUT}. (Refer to *Recommended External Components*)
- Please choose inductors which have low direct-current resistance, enough allowable current and low magnetic saturation. Current-limited circuit may operate with LX peak current before reaching expected load current in case of low allowable current and extremely low inductance value under load condition.
- Note that the current-limited circuit is self-heating and radiation environment sensitive.

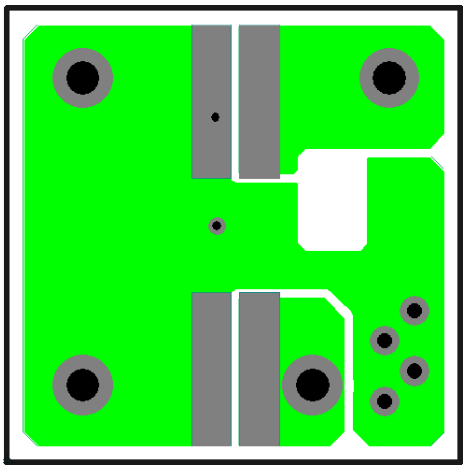
- **PCB Layout**

R1800KxxxA-TR (PKG:DFN(PL)2730-12)

Top Layer



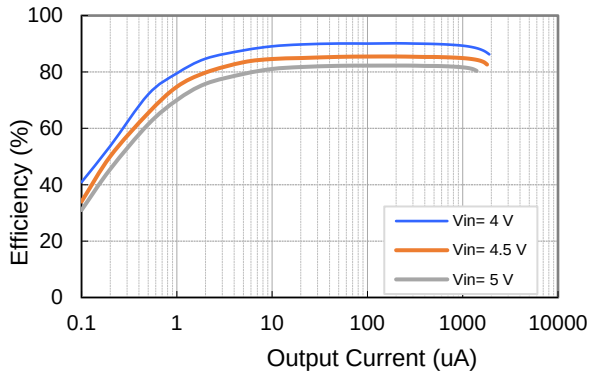
Bottom Layer



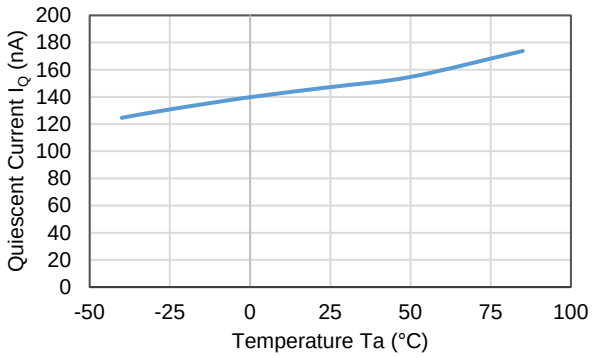
TYPICAL CHARACTERISTICS

Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

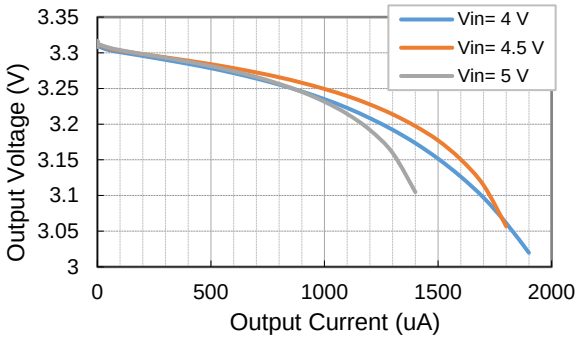
1) Efficiency vs. Output Current V_{SET} = 3.3 V

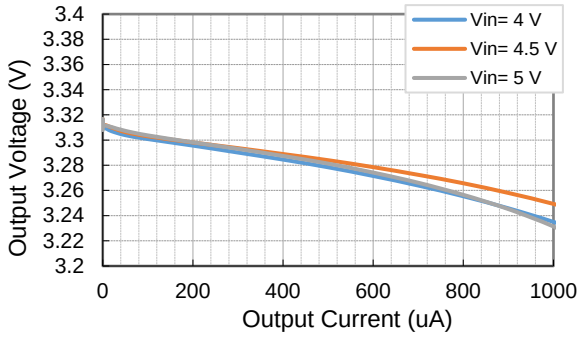


2) Quiescent Current vs. Temperature



3) Output Voltage vs. Output Current





Ver. A

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following measurement conditions are based on JEDEC STD. 51-7.

Measurement Conditions

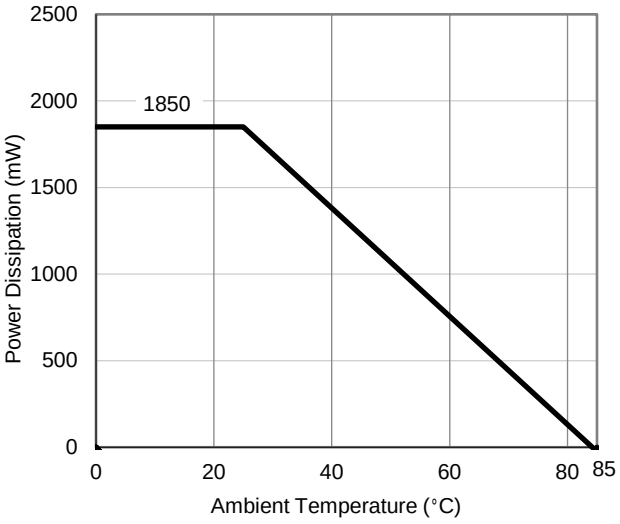
Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	Outer Layer (First Layer): Less than 95% of 50 mm Square Inner Layers (Second and Third Layers): Approx. 100% of 50 mm Square Outer Layer (Fourth Layer): Approx. 100% of 50 mm Square
Through-holes	ϕ 0.3 mm × 23 pcs

Measurement Result (Ta = 25°C, Tjmax = 85°C)

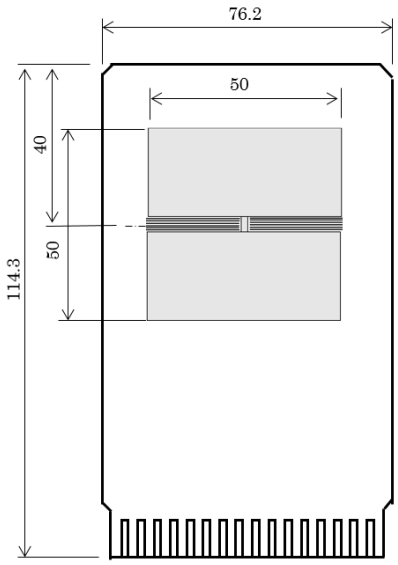
Item	Measurement Result
Power Dissipation	1850 mW
Thermal Resistance (θja)	θja = 32°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 8°C/W

θja: Junction-to-Ambient Thermal Resistance

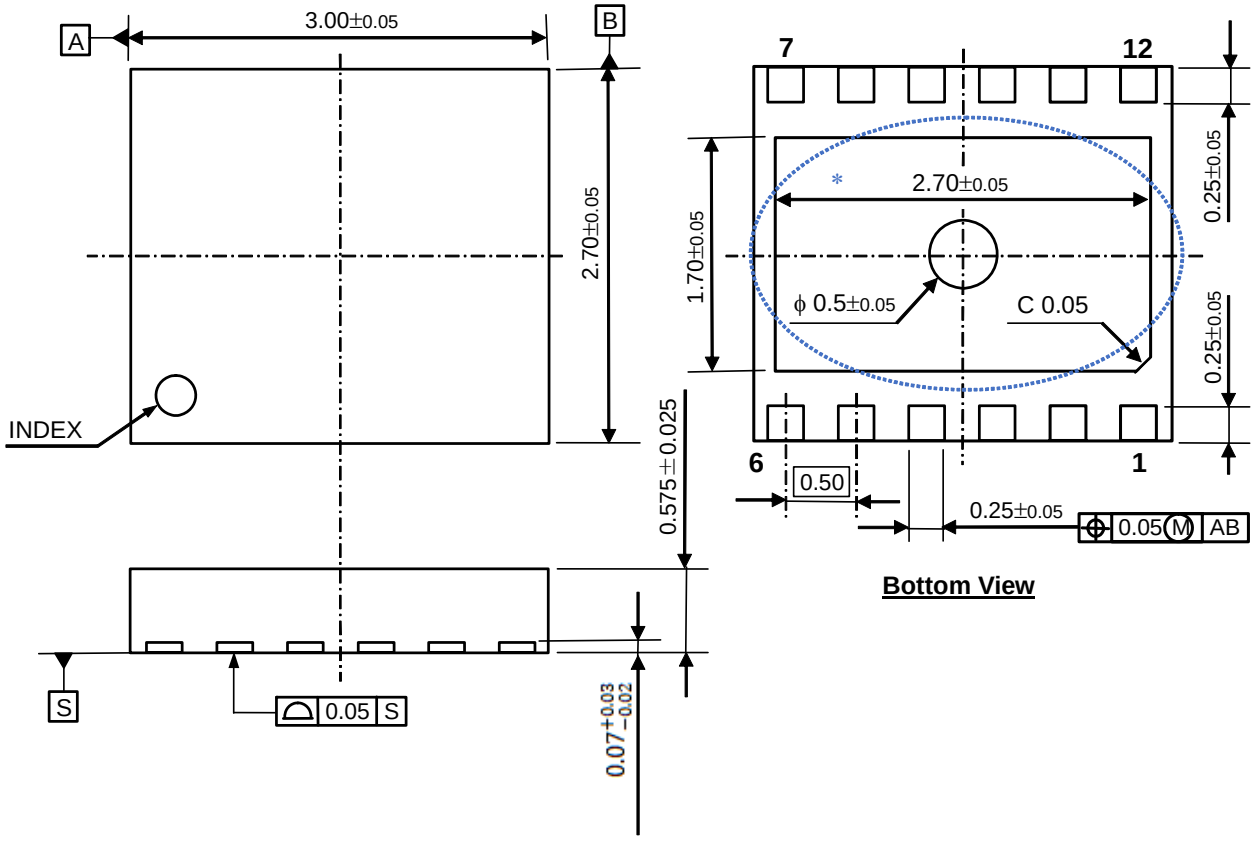
ψjt: Junction-to-Top Thermal Characterization Parameter



Power Dissipation vs. Ambient Temperature



Measurement Board Pattern



DFN(PL)2730-12 Package Dimensions (Unit: mm)

*The tab on the bottom of the package shown by blue circle is a substrate potential (GND). It is recommended that this tab be connected to the ground plane on the board but it is possible to leave the tab floating.

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