600 nA I_Q Low Quiescent Current Boost DC/DC Converter for Energy Harvester

No.EA-423-250303

OVERVIEW

R1810x is a boost DC/DC converter for electrical power storage devices, especially dedicated for 1 cell photovoltaic energy harvester since the start-up voltage is Typ.0.35V.
This product can start up with only 9uW, and applicable for charging 1 cell photovoltaic element. A system which is working under low-illuminance environment can be composed with the R1810x.

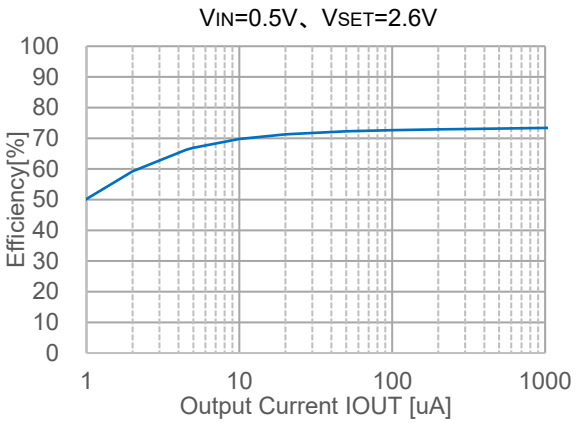
KEY BENEFITS

- Providing a low quiescent current (I_{Q_VOUT} =Typ.600 nA), and high efficiency (66%@ I_{OUT}=5 μA)
- Start up with low input energy, 9 μW (low illuminance) is possible.
- Maximum power point control function is built-in.

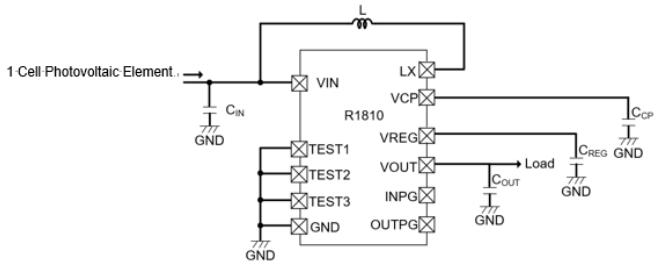
KEY SPECIFICATIONS

- Start-up voltage: Typ. 0.35V
  Max. 0.50V (0°C ≤ Ta ≤ 65°C),
  Max. 0.55V (-40°C ≤ Ta ≤ 85°C)
- Input Voltage Range: 0.2 V to 2.1 V (V_{SET}=2.7V)
- Output Voltage Range: 2.3 V to 4.5 V
- Output Voltage Accuracy: ±5.0%
- Low current consumption:
  Typ.600 nA (Ta = 25°C, at no load)
- Start-up power: 9 μW (V_{MPSET} = 0.5V / V_{SET} = 2.6V)
- Maximum Power Point Control Voltage Setting:
  from 0.2V to 2.1V , in 50 mV increments
- Input Power Good Function
- Output Power Good Function

EFFICIENCY CURVE



TYPICAL APPLICATION



L = 22 μH, C_{IN} = 22 μF, C_{CP} = 22 nF, C_{REG} = 4.7 μF
C_{OUT} = 4.7 μF

SELECTION GUIDE

Product name	Package	Quantity per Reel
R1810Zxxx$-E2-T	WLCSP-15-P1	5,000 pcs
R1810Lxxx$-E2	DFN2735-14	5,000 pcs

xxx: Select the combination Code number of the set output voltage (V_{SET}) and the set maximum power voltage (V_{MPSET}) ex. 001
Refer to the Product-specific Electrical Characteristics for detail information.

$: Set output power good low (PGL) (Refer to selection guide.)

PACKAGES

WLCSP-15-P1
2.88 x 1.68 x 0.4 (mm)

DFN2735-14
3.5 x 2.7 x 0.6 (mm)

APPLICATION

- Energy harvesting modules such as 1 cell photovoltaic element /thermoelectric power generation.

SELECTION GUIDE

The set output voltage, the set maximum power point control voltage, and the output power good setting are user-selectable options.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1810Zxxx$-E2-T	WLCSP-15-P1	5,000 pcs	Yes	Yes
R1810Lxxx$-E2	DFN2735-14	5,000 pcs	Yes	Yes

xxx: Select the combination of the set output voltage (V_{SET}) and the set maximum power point control voltage (V_{MPSET}) by the code number. Ex. 001

Output voltage: from 2.3 V to 4.5 V in 0.1 V increments

Maximum power point control voltage: from 0.2 V to 2.1 V in 0.05 V increments

Refer to the Product-specific Electrical Characteristics for detail information.

* Contact our sales representatives for other codes.

It is recommended to set as $V_{SET} \geq V_{MPSET} + 1.0$ V.

$: Set output power good low (PGL) [(1)]

A ; Vset x 80%

B ; Vset x 70%

C ; Vset x 60%

D ; Vset x 50%

The accuracy of the OUTPG detection voltage depends on the output set voltage.

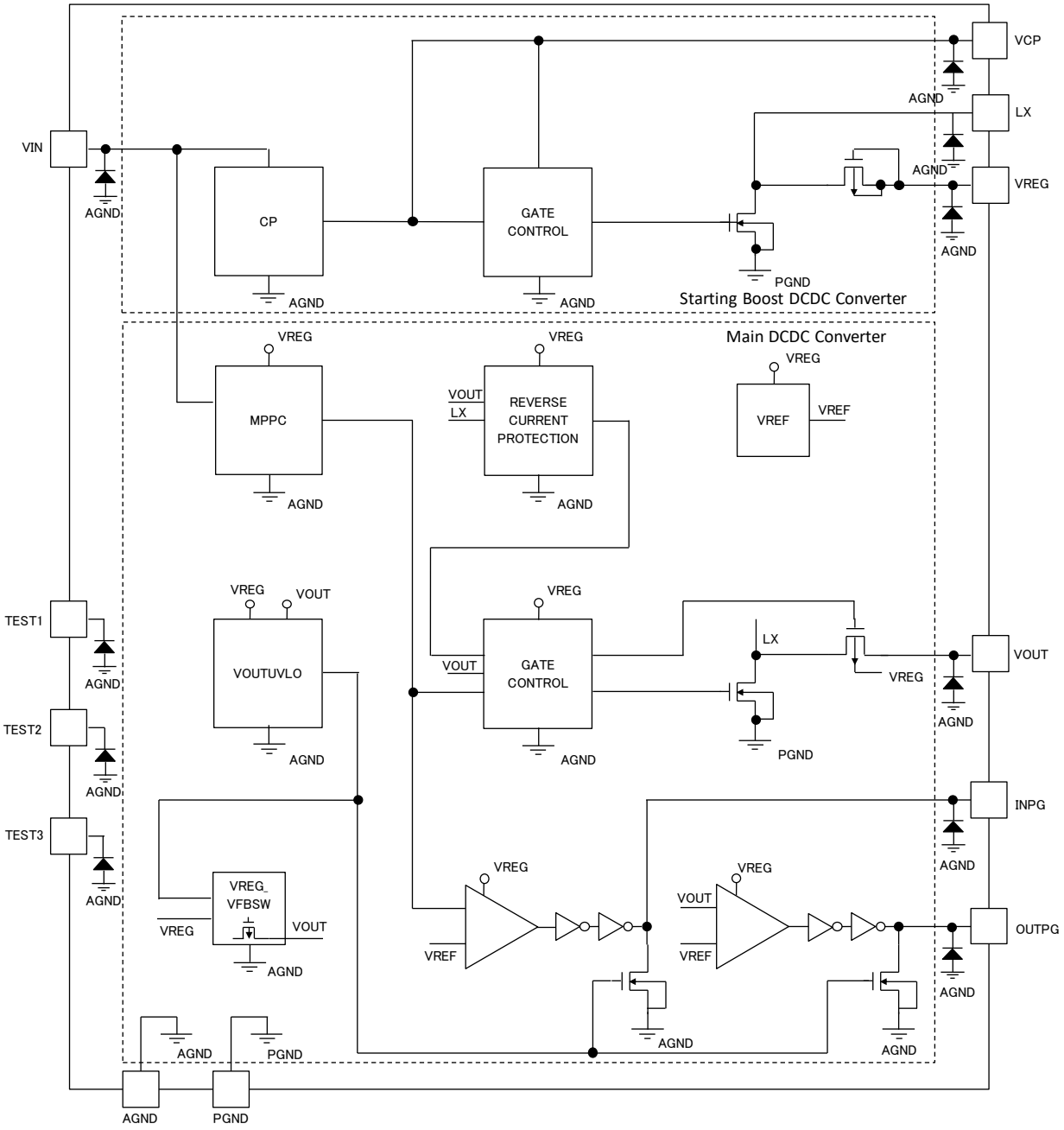
Output power good low OUTPG detection accuracy

		Set Output Voltage Vset [V]																						
		2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5
$	A	-	-	-	5.0%							4.0%												
	B	-	-	-	-	-	-	-	-	5.0%		4.0%												
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0%									
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0%		

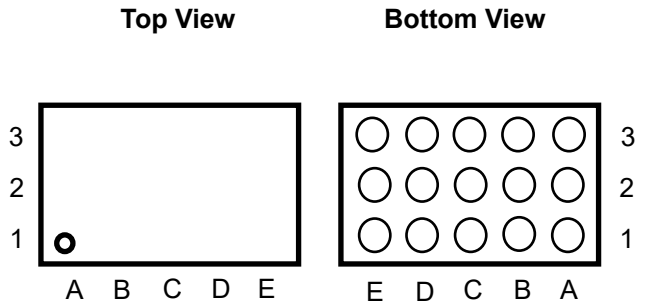
"—"; The OUTPG function cannot be used. please set the OUTPG pin to open.

[(1)] OUTPG outputs "Low" when the output is below the threshold of PGL according to the table above.

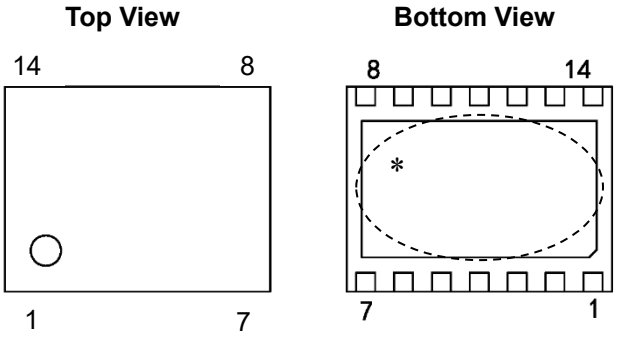
BLOCK DIAGRAM



PIN DESCRIPTIONS



R1810Z (WLCSP-15-P1) Pin Configuration



R1810L (DFN2735-14) Pin Configuration

* The tab on the bottom of the package enhances thermal performance and is electrically connected to GND (substrate level). The backside tab should be connected to the ground plane on the board.

R1810Z 、R1810L Pin Description

Symbol	Description	I/O	Pin No.	
			R1810Z	R1810L
VIN	Power Supply Input Pin. Apply input voltage between VIN pin and GND. Connect the input capacitor between the VIN pin and GND.	I	C3	5
VOUT	Output voltage pin of step-up DC / DC converter. Connect the output load between VOUT pin and GND. Connect the output capacitor between VOUT pin and GND.	O	D1,E1	8
INPG	Power good output pin for power input voltage (V_{IN}). "High" level of the output voltage for CMOS output is the output voltage (V_{OUT}) of the step-up DC / DC converter. Outputs "High" when V_{IN} exceeds V_{MPSET} and V_{OUT} exceeds $V_{OUTUVLOR}$※1. Please left open when not in use.	O	A1	13
VREG	Output pin of step-up DC / DC converter (internal power supply) for startup. Supply voltage to the main DC / DC converter circuit that produces VOUT at startup. Please connect a capacitor between VREG pin and GND for voltage stabilization.	O	C1	11
LX	The drain of the internal MOSFET. Connect an inductor between VIN pin and LX pin.	O	D2,D3	6
VCP	Output pin of the startup internal step-up charge pump (internal power source). Supply voltage to the start-up DC / DC converter circuit that generates the VREG voltage at startup. Please connect a capacitor between the VCP pin and GND for voltage stabilization.	O	B1	12
OUTPG	Power good output pin for V_{OUT}. "High" level of the output voltage for CMOS output is V_{OUT}. Outputs "High" when V_{OUT} is V_{OUTPGH}※1 or higher, and outputs "Low" when V_{OUT} is V_{OUTPGL}※1 or lower. Please left open when not in use.	O	A2	14
TEST 1,2,3	Test pins for the IC. Be sure to connect to AGND.	—	C2,B2,A3	9,4,1
AGND	Analog ground of the internal circuit. Please connect to the PGND and GND.	—	B3	2
PGND	Power ground of the internal circuit. Please connect to the AGND and GND.	—	E2,E3	7
NC	No connection. It is recommended to make it open to prevent short circuit with adjacent pins during mounting.	—	—	3,10

※1：Refer to electrical characteristics.

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings (GND = 0 V)

Symbol	Parameter	Rating	Unit
V_{IN}	Input Pin Voltage	−0.3 to 2.3	V
V_{LX}	LX Pin Voltage	−0.3 to 6.5	V
V_{OUT}	Output Pin Voltage	−0.3 to 6.5	V
V_{REG}	Output Voltage of Boost DC to DC Converter for Start-up	−0.3 to 6.5	V
V_{CP}	Output Pin Voltage of Charge Pump Circuit	−0.3 to 6.5	V
$V_{TEST1\ to\ 3}$	Pin Voltage for Testing	−0.3 to 6.5	V
V_{INPG}	INPG Pin Voltage	−0.3 to 6.5	V
I_{INPG}	INPG Pin Current	10	mA
V_{OUTPG}	OUTPG Pin Voltage	-0.3 to 6.5	V
I_{OUTPG}	OUTPG Pin Current	10	mA
P_D	Power Dissipation	Refer to the Power Dissipation in the supplementary item	
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 are not assured.

RECOMMENDED OPERATING CONDITIONS

Recommended Operating Conditions

Symbol	Parameter	Rating	Unit
V_{IN}	Input Voltage[1]	0.35 to 2.1	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. The semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

[1] The lower limit of the input voltage depends on the set output voltage. Please refer to Page.22 for details.

ELECTRICAL CHARACTERISTICS

The specifications surrounded by [ ] are guaranteed by design at −40°C ≤ Ta ≤ 85°C, not mass production tested.

R1810x Electrical Characteristics (Ta = 25°C)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{Q_VOUT}	VOUT Pin Quiescent Current	V_{IN} = 0.5V, V_{OUT} = 4.5 V, at no switching		600	3000	nA
I_{Q_VIN}	VIN Pin Quiescent Current	V_{IN} = 0.5 V, V_{OUT} = 4.5 V, at no switching		400		nA
V_{OUT}	Output Pin Voltage	$V_{IN} > V_{MP}$	[V_{SET} ×0.95]		[V_{SET} ×1.05]	V
V_{MP}	Accuracy of Maximum Power Point Control Voltage	$V_{OUT} = V_{SET}$、V_{MPSET} ≥0.5V	[-5]		[5]	%
		$V_{OUT} = V_{SET}$、V_{MPSET} <0.5V	[-50]		[50]	mV
V_{OUTPGH}	OUTPG “High” Threshold Voltage	xxxA: 2.6V ≤ V_{SET} xxxB: 3.1V ≤ V_{SET} xxxC: 3.6V ≤ V_{SET} xxxD: 4.3V ≤ V_{SET}	[V_{SET} × 0.87]	V_{SET} × 0.90	[V_{SET} × 0.93]	V
V_{OUTPGL}	OUTPG “Low” Threshold Voltage	xxxA: 2.6V ≤ V_{SET} < 3.3V xxxB: 3.1V ≤ V_{SET} < 3.3V	[V_{SET} × (PGL -0.05)]	V_{SET} × PGL	[V_{SET} × (PGL +0.05)]	V
		xxxA: 3.3V ≤ V_{SET} xxxB: 3.3V ≤ V_{SET} xxxC: 3.6V ≤ V_{SET} xxxD: 4.3V ≤ V_{SET}	[V_{SET} × (PGL -0.04)]	V_{SET} × PGL	[V_{SET} × (PGL +0.04)]	V
V_{INPGH}	INPG “High” Threshold Voltage		[V_{MPSET} × 1.05]			V
V_{INPGL}	INPG “Low” Threshold Voltage				[V_{MPSET} × 0.95]	V
$V_{OUTUVLOR}$	$V_{OUTUVLO}$ Release Voltage				[2.11]	V
$V_{OUTUVLOF}$	$V_{OUTUVLO}$ Detection Voltage		[1.55]			V
V_{OUTPGH}	OUTPG "High" Output Voltage	I_{OUTPG}=-1μA	[V_{SET} ×0.9]			V
V_{INPGH}	INPG "High" Output Voltage	I_{INPG}=-1μA	[V_{SET} ×0.9]			V
V_{OUTPGL}	OUTPG ”Low” Output Voltage	I_{OUTPG}=1μA			[0.1]	V
V_{INPGL}	INPG "Low" Output Voltage	I_{INPG}=1μA			[0.1]	V

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.

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

R1810xxxxA **Product-specific Electrical Characteristics**

Product Name	Output Voltage [V]			Maximum Power Point Control Voltage [V]			OUTPG"High" Detection Voltage [V]		
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.
R1810x003A	2.470	2.6	2.730	0.475	0.5	0.525	2.262	2.34	2.418
R1810x005A	4.275	4.5	4.725	0.475	0.5	0.525	3.915	4.05	4.185
R1810x006A	4.275	4.5	4.725	1.140	1.2	1.260	3.915	4.05	4.185
R1810x007A	4.275	4.5	4.725	1.995	2.1	2.205	3.915	4.05	4.185
R1810x013A	2.565	2.7	2.835	1.425	1.5	1.575	2.349	2.43	2.511
R1810x015A	2.565	2.7	2.835	0.250	0.3	0.350	2.349	2.43	2.511
R1810x016A	2.185	2.3	2.415	0.475	0.5	0.525	-	-	-
R1810x017A	3.135	3.3	3.465	0.475	0.5	0.525	2.871	2.97	3.069
R1810x018A	3.135	3.3	3.465	1.995	2.1	2.205	2.871	2.97	3.069
R1810x019A	3.420	3.6	3.780	0.475	0.5	0.525	3.132	3.24	3.348
R1810x022A	2.565	2.7	2.835	0.475	0.5	0.525	2.349	2.43	2.511
R1810x023A	2.470	2.6	2.730	0.523	0.55	0.577	2.262	2.34	2.418
R1810x024A	2.565	2.7	2.835	0.523	0.55	0.577	2.349	2.43	2.511
R1810x025A	2.470	2.6	2.730	0.570	0.6	0.630	2.262	2.34	2.418
R1810x026A	2.565	2.7	2.835	0.570	0.6	0.630	2.349	2.43	2.511
R1810x027A	2.470	2.6	2.730	0.855	0.9	0.945	2.262	2.34	2.418
R1810x028A	2.565	2.7	2.835	0.855	0.9	0.945	2.349	2.43	2.511
R1810x029A	2.470	2.6	2.730	0.950	1.0	1.050	2.262	2.34	2.418
R1810x030A	2.565	2.7	2.835	0.950	1.0	1.050	2.349	2.43	2.511
R1810x031A	2.470	2.6	2.730	1.045	1.1	1.155	2.262	2.34	2.418
R1810x032A	2.565	2.7	2.835	1.045	1.1	1.155	2.349	2.43	2.511
R1810x033A	2.565	2.7	2.835	0.665	0.7	0.735	2.349	2.43	2.511
R1810x034A	2.565	2.7	2.835	0.760	0.8	0.840	2.349	2.43	2.511
R1810Z035A	2.850	3.0	3.150	0.713	0.75	0.787	2.610	2.70	2.790

If VSET < 2.6V, the OUTPG function cannot be used.

Product Name	OUTPG"Low" Detection Voltage [V]			INPG"High" Detection Voltage [V]	INPG"Low" Detection Voltage [V]
	Min.	Typ.	Max.	Min.	Max.
R1810x003A	1.950	2.080	2.210	0.525	0.475
R1810x005A	3.420	3.600	3.780	0.525	0.475
R1810x006A	3.420	3.600	3.780	1.260	1.140
R1810x007A	3.420	3.600	3.780	2.205	1.995
R1810x013A	2.025	2.160	2.295	1.575	1.425
R1810x015A	2.025	2.160	2.295	0.315	0.285
R1810x016A	-	-	-	0.525	0.475
R1810x017A	2.508	2.640	2.772	0.525	0.475
R1810x018A	2.508	2.640	2.772	2.205	1.995
R1810x019A	2.736	2.880	3.024	0.525	0.475
R1810x022A	2.025	2.160	2.295	0.525	0.475
R1810x023A	1.950	2.080	2.210	0.578	0.523
R1810x024A	2.025	2.160	2.295	0.578	0.523
R1810x025A	1.950	2.080	2.210	0.630	0.570
R1810x026A	2.025	2.160	2.295	0.630	0.570
R1810x027A	1.950	2.080	2.210	0.945	0.855
R1810x028A	2.025	2.160	2.295	0.945	0.855
R1810x029A	1.950	2.080	2.210	1.050	0.950
R1810x030A	2.025	2.160	2.295	1.050	0.950
R1810x031A	1.950	2.080	2.210	1.155	1.045
R1810x032A	2.025	2.160	2.295	1.155	1.045
R1810x033A	2.025	2.160	2.295	0.735	0.665
R1810x034A	2.025	2.160	2.295	0.840	0.760
R1810Z035A	2.250	2.400	2.550	0.787	0.713

If VSET < 2.6V, the OUTPG function cannot be used.

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

R1810xxxxB **Product-specific Electrical Characteristics**

Product Name	Output Voltage [V]			Maximum Power Point Control Voltage [V]			OUTPG"High" Detection Voltage [V]		
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.
R1810x003B	2.470	2.6	2.730	0.475	0.5	0.525	-	-	-
R1810x005B	4.275	4.5	4.725	0.475	0.5	0.525	3.915	4.05	4.185
R1810x006B	4.275	4.5	4.725	1.140	1.2	1.260	3.915	4.05	4.185
R1810x007B	4.275	4.5	4.725	1.995	2.1	2.205	3.915	4.05	4.185
R1810x013B	2.565	2.7	2.835	1.425	1.5	1.575	-	-	-
R1810x017B	3.135	3.3	3.465	0.475	0.5	0.525	2.871	2.97	3.069
R1810x018B	3.135	3.3	3.465	1.995	2.1	2.205	2.871	2.97	3.069
R1810x019B	3.420	3.6	3.780	0.475	0.5	0.525	3.132	3.24	3.348
R1810x022B	2.565	2.7	2.835	0.475	0.5	0.525	-	-	-
R1810x023B	2.470	2.6	2.730	0.523	0.55	0.577	-	-	-
R1810x024B	2.565	2.7	2.835	0.523	0.55	0.577	-	-	-
R1810x025B	2.470	2.6	2.730	0.570	0.6	0.630	-	-	-
R1810x026B	2.565	2.7	2.835	0.570	0.6	0.630	-	-	-
R1810x027B	2.470	2.6	2.730	0.855	0.9	0.945	-	-	-
R1810x028B	2.565	2.7	2.835	0.855	0.9	0.945	-	-	-
R1810x029B	2.470	2.6	2.730	0.950	1.0	1.050	-	-	-
R1810x030B	2.565	2.7	2.835	0.950	1.0	1.050	-	-	-
R1810x031B	2.470	2.6	2.730	1.045	1.1	1.155	-	-	-
R1810x032B	2.565	2.7	2.835	1.045	1.1	1.155	-	-	-
R1810x033B	2.565	2.7	2.835	0.665	0.7	0.735	-	-	-
R1810x034B	2.565	2.7	2.835	0.760	0.8	0.840	-	-	-

If VSET < 3.1V, the OUTPG function cannot be used.

Product Name	OUTPG"Low" Detection Voltage [V]			INPG"High" Detection Voltage [V]	INPG"Low" Detection Voltage [V]
	Min.	Typ.	Max.	Min.	Max.
R1810x003B	-	-	-	0.525	0.475
R1810x005B	2.970	3.150	3.330	0.525	0.475
R1810x006B	2.970	3.150	3.330	1.260	1.140
R1810x007B	2.970	3.150	3.330	2.205	1.995
R1810x013B	-	-	-	1.575	1.425
R1810x017B	2.178	2.310	2.442	0.525	0.475
R1810x018B	2.178	2.310	2.442	2.205	1.995
R1810x019B	2.376	2.520	2.664	0.525	0.475
R1810x022B	-	-	-	0.525	0.475
R1810x023B	-	-	-	0.578	0.523
R1810x024B	-	-	-	0.578	0.523
R1810x025B	-	-	-	0.630	0.570
R1810x026B	-	-	-	0.630	0.570
R1810x027B	-	-	-	0.945	0.855
R1810x028B	-	-	-	0.945	0.855
R1810x029B	-	-	-	1.050	0.950
R1810x030B	-	-	-	1.050	0.950
R1810x031B	-	-	-	1.155	1.045
R1810x032B	-	-	-	1.155	1.045
R1810x033B	-	-	-	0.735	0.665
R1810x034B	-	-	-	0.840	0.760

If VSET < 3.1V, the OUTPG function cannot be used.

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

R1810xxxxC **Product-specific Electrical Characteristics**

Product Name	Output Voltage [V]			Maximum Power Point Control Voltage [V]			OUTPG"High" Detection Voltage [V]		
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.
R1810x005C	[4.275]	4.5	[4.725]	[0.475]	0.5	[0.525]	[3.915]	4.05	[4.185]
R1810x006C	[4.275]	4.5	[4.725]	[1.140]	1.2	[1.260]	[3.915]	4.05	[4.185]
R1810x007C	[4.275]	4.5	[4.725]	[1.995]	2.1	[2.205]	[3.915]	4.05	[4.185]
R1810x017C	[3.135]	3.3	[3.465]	[0.475]	0.5	[0.525]	-	-	-
R1810x018C	[3.135]	3.3	[3.465]	[1.995]	2.1	[2.205]	-	-	-
R1810x019C	[3.420]	3.6	[3.780]	[0.475]	0.5	[0.525]	[3.132]	3.24	[3.348]

Product Name	OUTPG"Low" Detection Voltage [V]			INPG"High" Detection Voltage [V]	INPG"Low" Detection Voltage [V]
	Min.	Typ.	Max.	Min.	Max.
R1810x005C	[2.520]	2.700	[2.880]	[0.525]	[0.475]
R1810x006C	[2.520]	2.700	[2.880]	[1.260]	[1.140]
R1810x007C	[2.520]	2.700	[2.880]	[2.205]	[1.995]
R1810x017C	-	-	-	[0.525]	[0.475]
R1810x018C	-	-	-	[2.205]	[1.995]
R1810x019C	[2.016]	2.160	[2.304]	[0.525]	[0.475]

If VSET < 3.6V, the OUTPG function cannot be used.

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

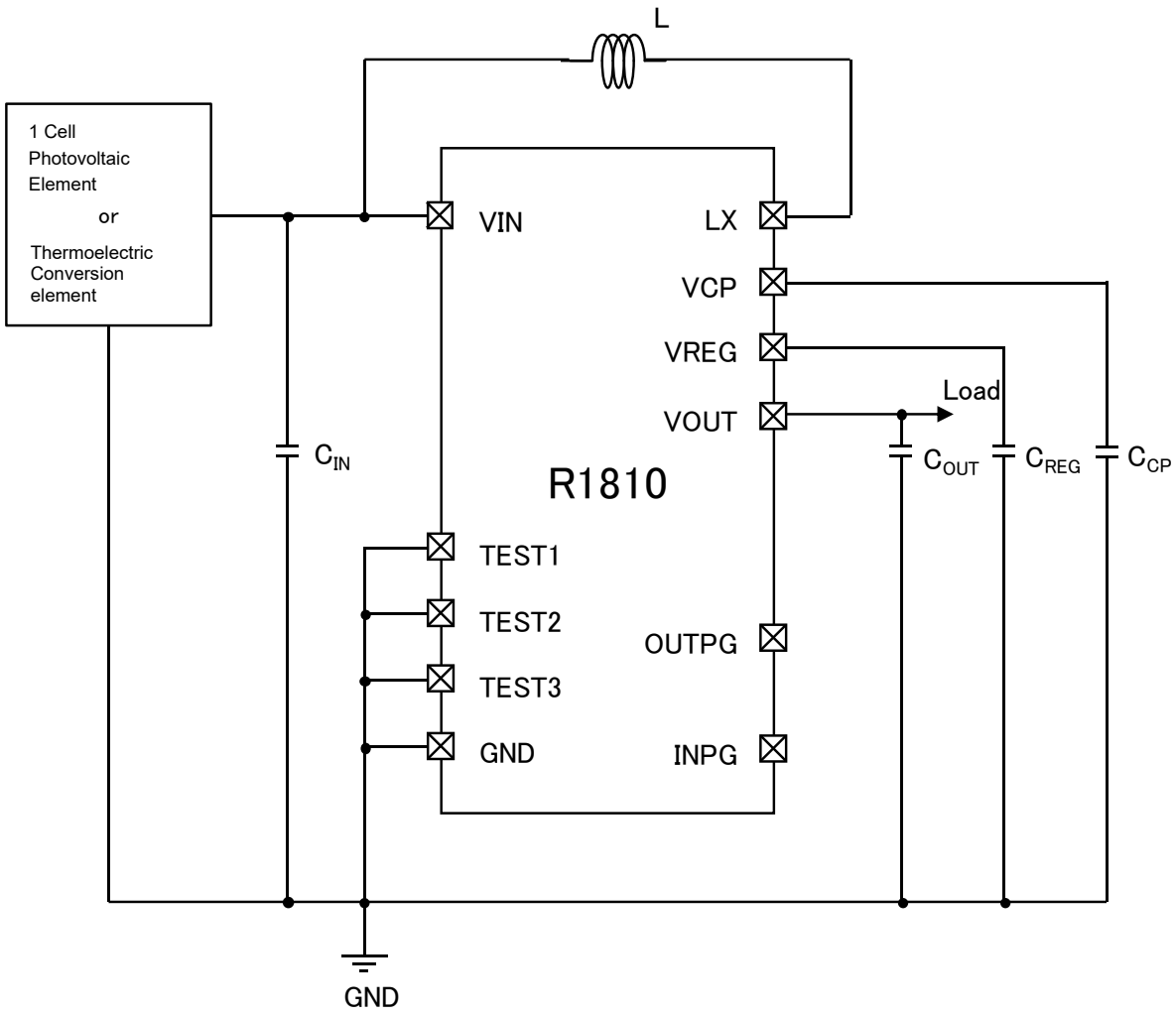
R1810xxxxD **Product-specific Electrical Characteristics**

Product Name	Output Voltage [V]			Maximum Power Point Control Voltage [V]			OUTPG"High" Detection Voltage [V]		
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.
R1810x005D	[4.275]	4.5	[4.725]	[0.475]	0.5	[0.525]	[3.915]	4.05	[4.185]
R1810x006D	[4.275]	4.5	[4.725]	[1.140]	1.2	[1.260]	[3.915]	4.05	[4.185]
R1810x007D	[4.275]	4.5	[4.725]	[1.995]	2.1	[2.205]	[3.915]	4.05	[4.185]
R1810x019D	[3.420]	3.6	[3.780]	[0.475]	0.5	[0.525]	-	-	-

Product Name	OUTPG"Low" Detection Voltage [V]			INPG"High" Detection Voltage [V]	INPG"Low" Detection Voltage [V]
	Min.	Typ.	Max.	Min.	Max.
R1810x005D	[2.070]	2.250	[2.430]	[0.525]	[0.475]
R1810x006D	[2.070]	2.250	[2.430]	[1.260]	[1.140]
R1810x007D	[2.070]	2.250	[2.430]	[2.205]	[1.995]
R1810x019D	-	-	-	[0.525]	[0.475]

If VSET < 4.3V, the OUTPG function cannot be used.

TYPICAL APPLICATION CIRCUIT



R1810x Typical Application Circuit

Recommended External Components

Symbol	Descriptions
C_{IN}	Ceramic Capacitor, 22 µF or more
C_{CP}	Ceramic Capacitor, 0.022µF or more
C_{REG}	Ceramic Capacitor, 4.7 µF or more
C_{OUT}	Ceramic Capacitor, 4.7 µF or more
	Large-capacity Electrical Storage Device
L	Inductor, 22 µH

TECHNICAL NOTES

The performance of the IC largely depends on the external components and circuitry layout. Especially, design the circuit carefully not to exceed each rating (voltage, current, power) for each component and the IC and consider the best layout pattern.

Use a ceramic capacitor with low ESR (equivalent series resistance). We recommend 22uF as C_{IN} which is set between V_{IN} and GND.

We recommend 4.7uF ceramic capacitor or 10uF or more ceramic capacitor with large capacity of electrical storage device as C_{OUT}. The capacitors should cover the operating temperature range, and effective capacitance should be more than our recommendation capacity with 0 bias. Note that insulation resistance should not be too small. If insulation resistance is small, the leakage current may increase. Such a system cannot be recommended. (Refer to Page.24, 31)

We recommend an inductor with equal or more current rating (400mA or more), ESR, DC superimposition characteristics as our recommendation part. If ESR is large, or bad DC superimposition characteristics may lead to the bad efficiency. If the current rating is too small, the inductor may be broken down.

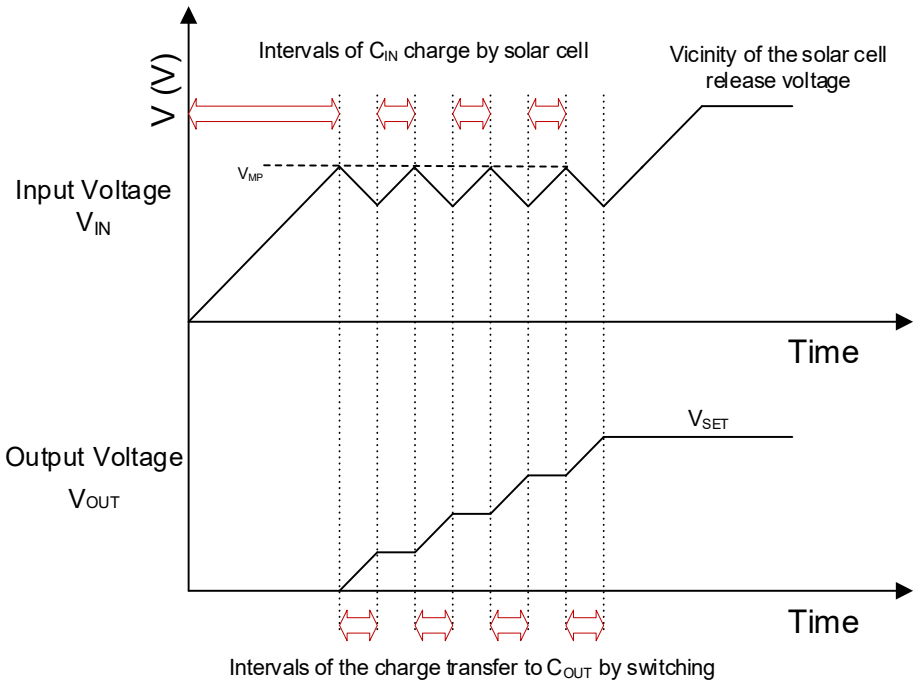
If other than GND level is connected to the TEST1,2,3 pins, by the shoot current of logic circuits inside the IC, consumption current may increase. Make sure to connect these pins to the ground level.

OPERATION

Boost DC/DC Converters For Energy Harvesting

Generally, boost DC/DC converters are used to make a suitable voltage for MCU and logic circuits by boost the input voltage. The R1810s is not a general boost DC to DC converter, but it is dedicated for energy harvesting, in other words, the power generated by a photovoltaic element is converted and accumulated to an electrical storage device with high efficiency. By intermittent operation by the power from the electrical storage device, the system can operate continuously without using a primary battery or power supply. The R1810x has the function of the maximum power point control to generate power at the best suitable voltage point. To realize single cell photovoltaic element base, the start-up voltage is 0.5V and once after start-up, even if the input voltage goes down to 0.2V, keeping on the operation is possible. Furthermore, start-up and charging to an electrical storage device with only 9uW input power, the system which operates under the low illuminance condition, can be built.

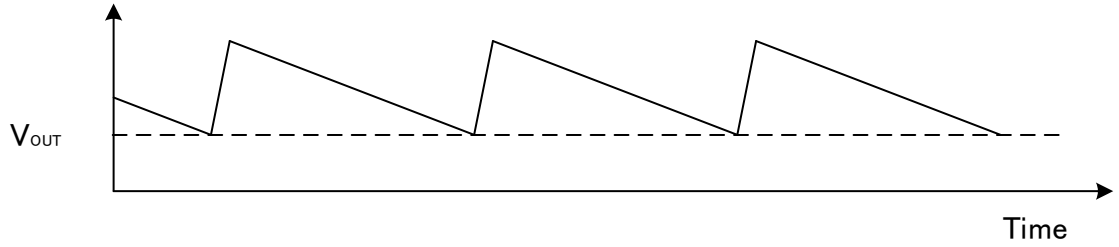
Maximum Power Point Control



The R1810x converts the power from the photovoltaic cell at the voltage (V_{MP}), which is the maximum power generation possible point, and transferred to the power to C_{OUT}.
In other words, when the input voltage of the R1810x increases by the power from a photovoltaic element, and when the voltage reaches maximum power voltage (V_{MP}), switching operation starts and the R1810x transfers power to the C_{OUT} side.
In case that the power transfer amount exceeds the supplied power from the photovoltaic element, the input voltage decreases by switching. Then, when the voltage of V_{IN} becomes lower than V_{MP}, the next switching stops and C_{IN} is charged by the photovoltaic element and the voltage of V_{IN} increases. When the input voltage reaches the V_{MP} again, the R1810x transfers power to C_{OUT} side. By repeating this operation enables transferring power to the C_{OUT} side with keeping the maximum power generation point of the photovoltaic element.

Supplemental Remarks: If the photovoltaic power supply is low while the secondary capacitor is charged with the photovoltaic cell, the input voltage (V_{IN}) will fall at every energy transfer point. The boost ratio can be big by connecting a bigger capacitance capacitor (C_{IN}), the efficiency at charging is also improved.

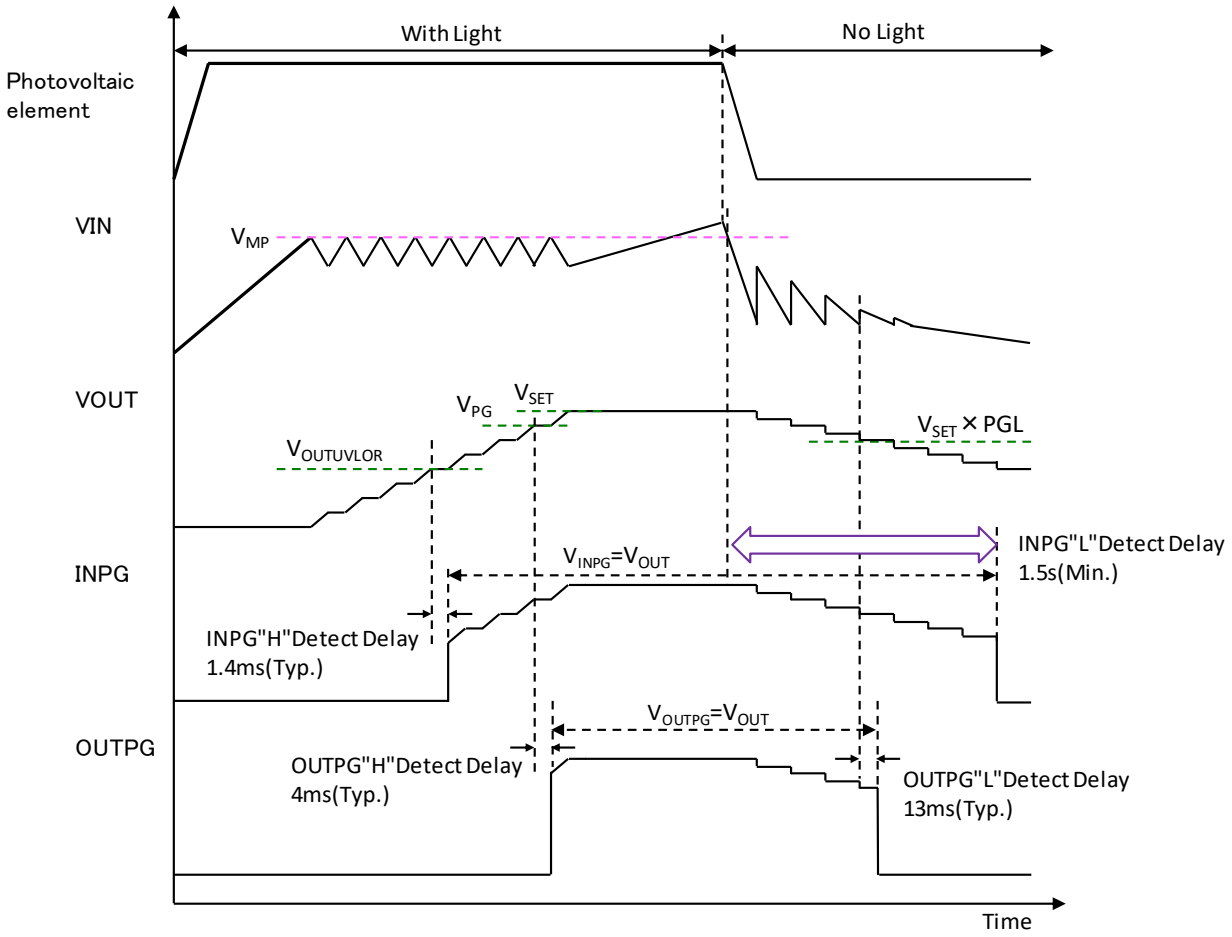
Operation While The Output Voltage Is At Stable Set Output Voltage.



Output Voltage Waveform at stable set output voltage point

When the output voltage reaches to set output voltage, the operation of the R1810x is as follows:
When the output voltage becomes higher than the set output voltage, even if V_{IN} voltage is higher than V_{MP} voltage, the switching stops. When the output voltage becomes equal to set V_{OUT} voltage by a load, the switching resumes. By repeating this operation, the output voltage is maintained as the set output voltage.

Power Good (PG) Function



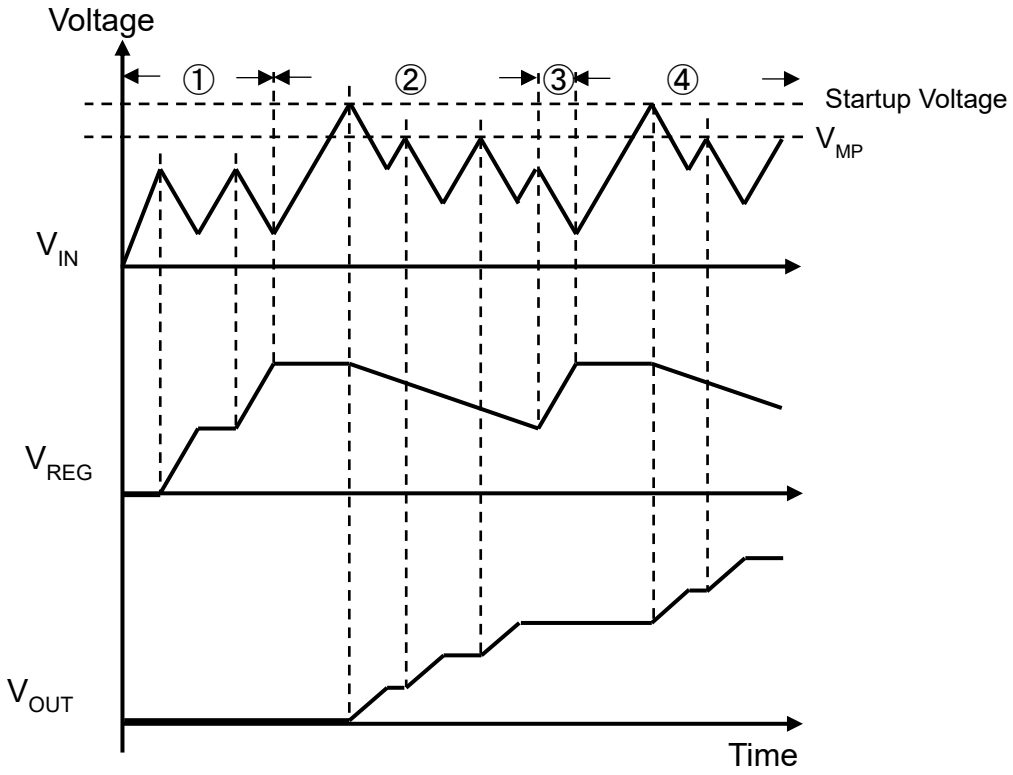
When V_{OUT} exceeds V_{OUT} released voltage, $V_{OUTUVLOR}$, the INPG pin becomes “High” (= V_{OUT} level). Otherwise, the INPG pin holds “Low”. There are two cases the INPG pin becomes from “High” to “Low”. One is when V_{OUT} falls below the $V_{OUTUVLO}$ detector threshold, $V_{OUTUVLOF}$, and the other is in the case that the switching stops for a certain time (Min. 1.5 sec.) (Refer to the chart above.). The halt of switching means V_{IN} voltage level is less than V_{MP} voltage, and the internal circuit recognizes the shading. If you do not use the INPG function, set the INPG pin to "Open".

Typ. 4ms from when the switching starts and the voltage of V_{OUT} exceeds 90% of V_{SET}, the OUTPG pin becomes “High”. Depending on the PG pin voltage, the condition of the output can be judged, and sequence control is possible. While the OUTPG is ”High”, the output is same as set voltage. When the output becomes lower than the (PGL) of V_{SET}, the OUTPG pin becomes “Low”. This preset value (PGL) can be selected from 50% and 80% with 10% increment depending on V_{SET}. Refer to the “*SELECTION GUIDE*” about PGL setting.

OUTPG function operates with using the V_{OUT} voltage as the power supply, therefore regardless of the supply of V_{IN} voltage, the operation is possible. For example, supposed that a system substantially operates a few times a day, and a large capacitance electrical storage device is connected with C_{OUT}, even if V_{IN} voltage becomes too low, as long as V_{OUT} voltage is beyond the $V_{OUTUVLO}$ released voltage ($V_{OUTUVLOR}$), OUTPG can maintain “High”. However, if you use the OUTPG function, please note that the VSET value varies in between 50% and 80% of the PGL value to ensure the minimum operating voltage of the OUTPG function. If you do not use the PG function, Set the OUTPG pin to “Open”.

Cold Start Function

When the start-up voltage or more voltage is input, initially the boost DC/DC converter for start-up operates. The internal power supply (V_{REG}) for main DC/DC converter's operation is generated by the built-in start-up boost DC/DC converter. When the main converter starts the operation and output voltage rises high enough, the internal power supply is generated from the output of the main DC/DC converter, then the boost DC/DC converter for startup stops the operation.

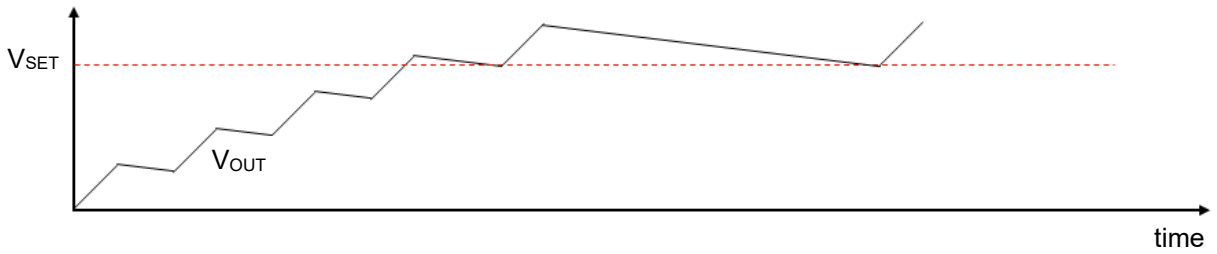


① Boost DC/DC converter for start-up operates and boost the power supply V_{REG} of internal circuits.
② When V_{REG} is beyond the threshold, the boost DC/DC converter for start-up stops, and the main DC/ DC converter starts the operation. While V_{REG} maintains more than a certain voltage, the main DC/ DC converter operates and boost V_{OUT} voltage.
③ Since the main DC/DC converter operates, the voltage of V_{REG} becomes down due to the consumption current of internal circuits. When the voltage of V_{REG} becomes lower than a certain voltage, the main DC/DC converter stops and the boost DC/DC converter for start-up boosts the voltage of V_{REG}.
④ When the voltage of V_{REG} becomes more than the threshold, the boost DC/DC converter for start-up stops and the main DC/DC converter starts operation.
By repeating ③ and ④, the main converter boosts the voltage of VOUT pin until set output voltage, V_{SET}.

Output Voltage Feedback Control

Under the conditions that the cold start is completed and V_{OUT} is boosted by the main DC/DC converter, when the voltage of V_{OUT} reaches the $V_{OUTUVLO}$ released voltage, $V_{OUTUVLO}$, the internal power supply V_{REG} and V_{OUT} are connected. This allows the main DC/DC converter to continue the operation without returning to the cold start condition, and to boost the output voltage until the set output voltage efficiently.

Output Generation Function



The R1810x stops boost operation when the output voltage exceeds V_{SET}. The output voltage (V_{OUT}) is tied to the internal power supply V_{REG} by the output voltage feedback control. When the voltage of V_{OUT} becomes lower than V_{SET} due to the internal circuit consumption current or the external load current, the boost operation starts again until (V_{OUT}) exceeds V_{SET}. When a large capacitance electrical storage device described in "*TYPICAL APPLICATION CIRCUIT*" is connected, the ripple voltage will be extremely small.

Reverse Current Protection Function

While the main DC/DC converter is operating, when the high-side MOSFET turns on, C_{OUT} connected V_{OUT} pin is charged, but due to the boost DC/DC converter's topology, $V_{IN} < V_{OUT}$ is true.
After the charge is transferred to the output capacitor, when the reverse condition of V_{OUT} and V_{IN} is detected by comparing Lx and V_{OUT}, the R1810x turns off the high-side driver not to flow the reverse current.
By shading, the power generation level by a photovoltaic element decreases, the charge of C_{IN} consumes by the consumption current of the IC and input voltage, V_{IN} gradually decreases. Even if the input voltage is zero, reverse current protection function can operate. If input voltage becomes lower than output voltage, V_{OUT}, by the reverse current protection function, the storage charge of C_{OUT} or a large capacitance electrical storage device is not drained in reverse.

Application Information

Set Output Voltage and Input Voltage Range.

Depending on the setting value of the output voltage, the lower limit of the operable input voltage after the IC start-up is different.

Refer to the table below.

V_{SET} [V]	Input Voltage Range [V]
$2.3 \leq V_{SET} \leq 2.7$	$0.20 \leq V_{IN} \leq 2.10$
$2.3 \leq V_{SET} \leq 3.3$	$0.25 \leq V_{IN} \leq 2.10$
$2.3 \leq V_{SET} \leq 3.6$	$0.30 \leq V_{IN} \leq 2.10$
$2.3 \leq V_{SET} \leq 4.5$	$0.35 \leq V_{IN} \leq 2.10$

Case 1: The R1810 is connected to a Photovoltaic Element.

In Figure 1, 2 shown below are graphs of the input voltage dependence of the output voltage of the R1810 series.
When the R1810 is connected to an energy harvesting element (photovoltaic element), the input voltage V_{IN} depends on the power generation amount of the photovoltaic device and the load current.
When the voltage, V_{OUT} of the R1810 reaches V_{SET}, V_{IN} becomes the value $V_{IN}1$, which is determined by the relationship between the IV curve of the photovoltaic element and the quiescent VIN pin current (400nA) of R1810. (Fig. 3).
Input voltage $V_{IN}1$ is higher than V_{MP}. Therefore, when the switching is resumed, the average value of V_{OUT} will be higher than V_{SET}. When the input charge is consumed by the switching and V_{IN} drops, V_{OUT} is controlled by the V_{MP} again, and the average value of V_{OUT} drops to the nominal value.
If the amount of the power generated by the photovoltaic element is greater than the power consumed by the switching of the R1810, even if the switching is resumed, V_{IN} does not drop to V_{MP}, the average value of V_{OUT} rises. The graphs shown below are typical characteristics of the average value of V_{OUT}.
Select the device connected to the R1810 which can operate with the average value of V_{OUT}.

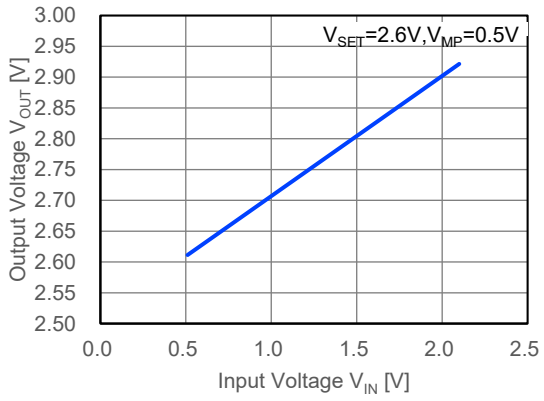


Figure1

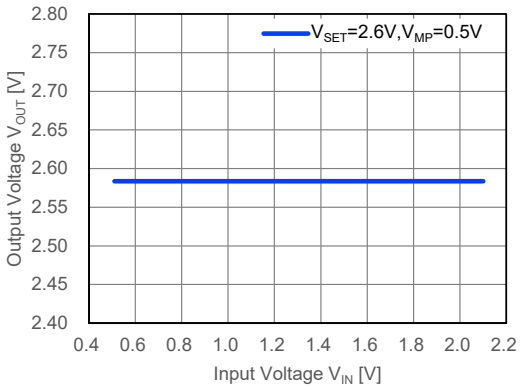


Figure2

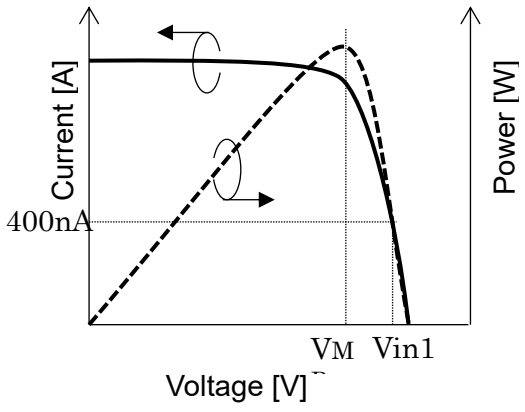


Figure3

Figure 1 : Input voltage dependence of the average value of the output voltage.
Figure 2 : Input voltage dependence of Bottom voltage (*) of output voltage.
* Bottom Voltage ; Minimum value of the output ripple.
Figure 3 : Characteristics of Photovoltaic Elements.

Case 2: The R1810 is connected to a Large-Capacity Power Storage Device.

If the capacitance value of ceramic capacitor is small, output ripple becomes large, then the output ripple may exceed the voltage rating of the storage battery or rear-stage devices.
Please adjust the set output voltage and the value of the ceramic capacitor not to exceed the voltage rating with considering the ripple with the total capacity that can be calculated with the ceramic capacitor and the storage battery.
The guideline for the output ripple value from the total capacity of the ceramic capacitor and storage battery is calculated by the next formula.

1.35 ÷ C[μF](Total Capacitance Value) ÷ (V_{OUT}[V] - V_{IN}[V]) + V_{OUT}[V] < $V_{ABSOLUTE}$[V](Absolute maximum rating value)

Recommended example of large-capacity power storage device

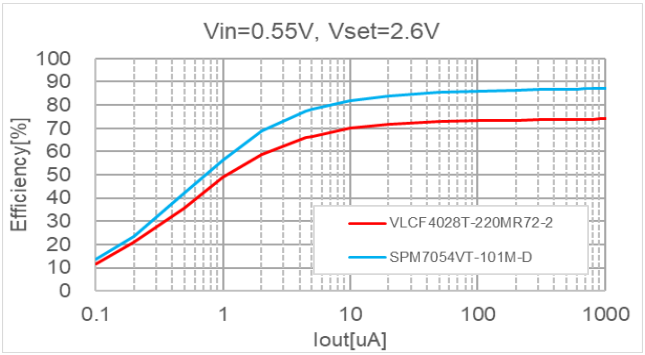
Manufacturer	Product	Part#	Capacity	Type	Notes
TDK	CeraCharge™	BCT1812M101AG	100μAh	All-solid-state Li-ion	CeraCharge™ is a trademark of TDK.
Nichicon	SLB series	SLB03070LR35 SLB03090LR80 SLB04255L040 SLB08115L140	0.35 mAh 0.8 mAh 4 mAh 14 mAh	LiB(LTO*)	
NGK	EnerCera®	ET1210C-H ET2016C-R ET382704P-H	4 mAh 25mAh 20mAh	LiB(LTO*)	EnerCera® is a trademark of NGK.

*Lithium-titanium-oxide

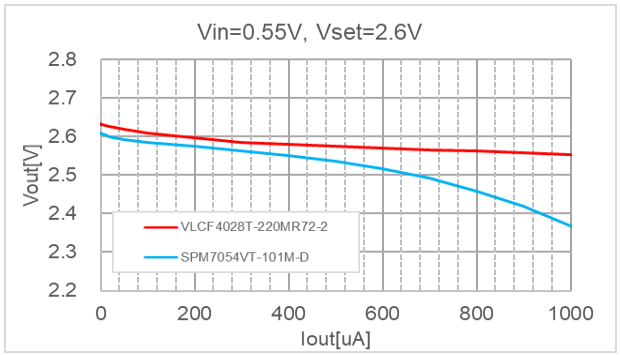
Case 3: Efficiency Improvement Proposal Using 100μH Inductor.

The efficiency of the R1810 can be significantly improved by changing the external inductor from 22μH to 100μH as shown in the left plot below.
However, please note that electrical characteristics specified in this part are not guaranteed with the 100μH inductor. Especially, the load regulation degrades as shown in the right plot below. Also, when Vmp≥1.1V or boosting rate is high, the electric characteristics could change significantly. Please carefully evaluate the electric characteristics using the inductance value of 100μH.
The 100μH inductor should have equivalent characteristics to the 22μH inductor "VLCF4028T-220MR72-2", which was used for characterization for this datasheet, on the maximum rated current, equivalent DC resistance, and DC superimposed characteristics. (Example: SPM7054VT-101M-D)

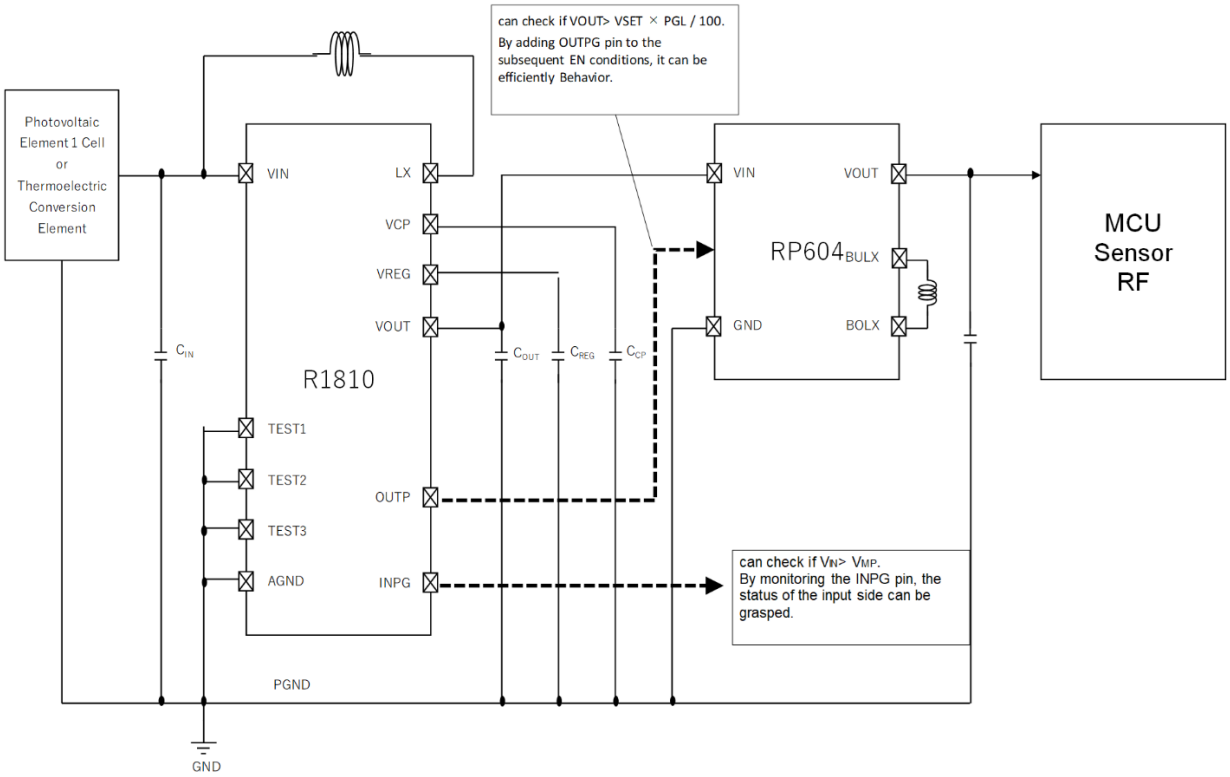
Efficiency vs Iout



Vout vs Iout

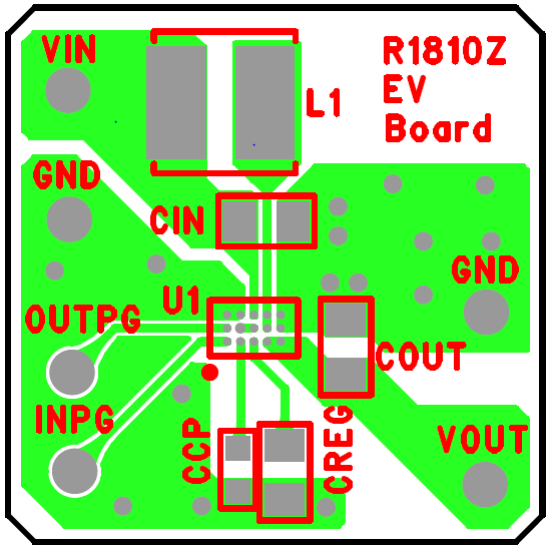


Case 4: The R1810 is used with a Sensor.

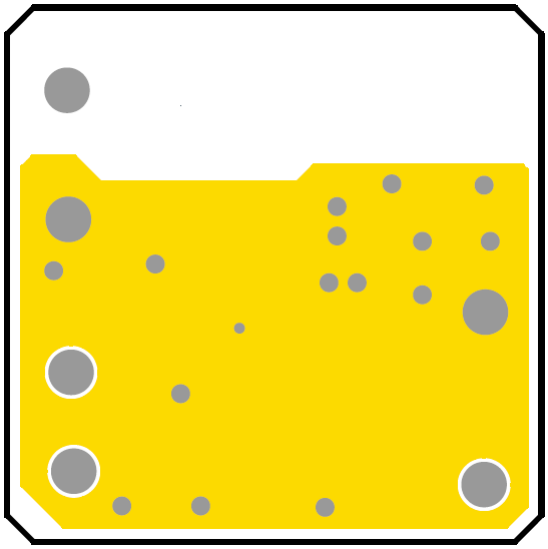


PCB Layout

R1810Z (WLCSP-15-P1) Board Layout Diagram

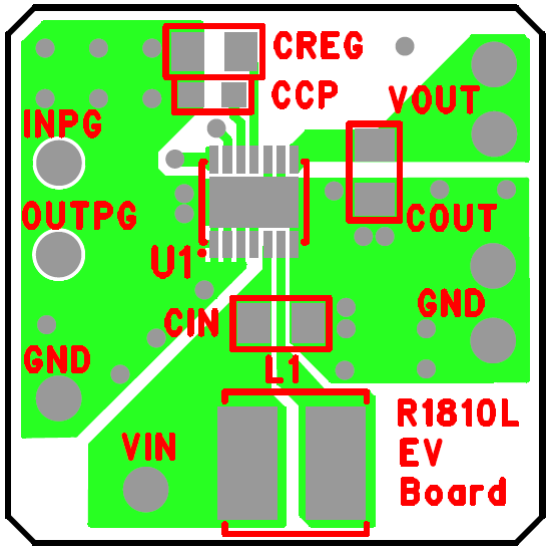


Top Layer

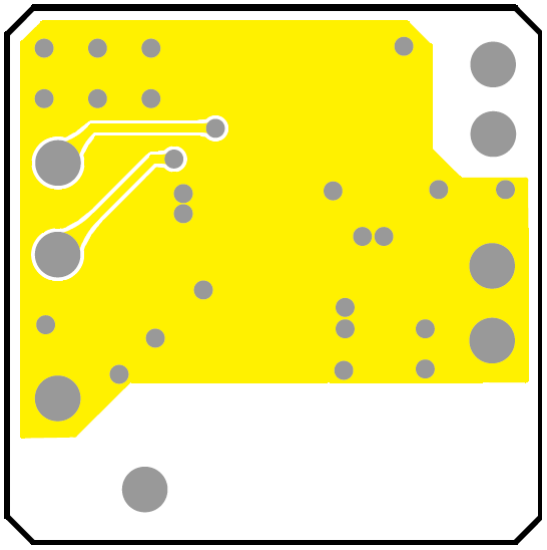


Bottom Layer

R1810L (DFN2735-14) Board Layout Diagram



Top Layer



Bottom Layer

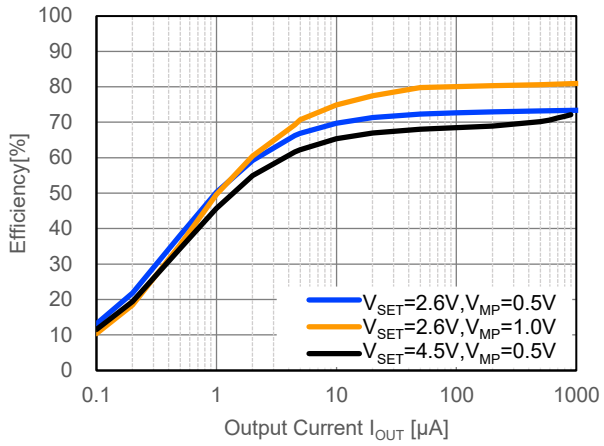
Notes for PCB Layout.

Since large current may flow through the V_{IN}, V_{REG}, V_{OUT}, AGND, and PGND wiring, if the impedance of the wiring is high, unexpected noise or the unstable operation may result. Therefore, the impedance of wiring should be as low as possible.
As for C_{IN}, C_{CP}, and C_{OUT}, make the wiring as short as possible to the VIN pin, VCP pin, and VOUT pin, respectively.
Connect the AGND and PGND with low impedance point of the same board layer as the layer mounted the IC.
Be sure to leave the NC pin node to "Open".

TYPICAL CHARACTERISTICS

Note: Typical Characteristics are just reference data; not guaranteed with the value shown in the graphs.

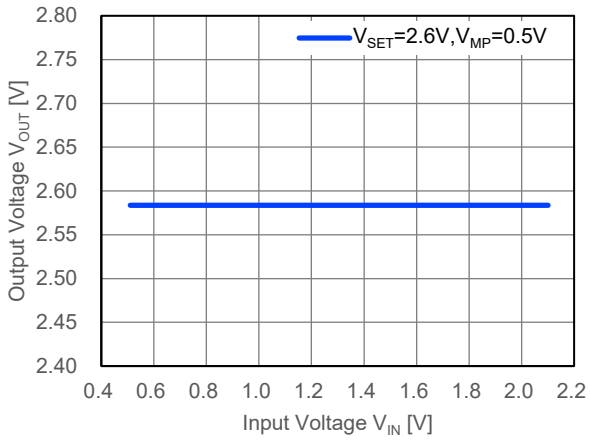
1) Efficiency vs. Output Current Ta = 25°C



2) Input Voltage vs. Output Voltage

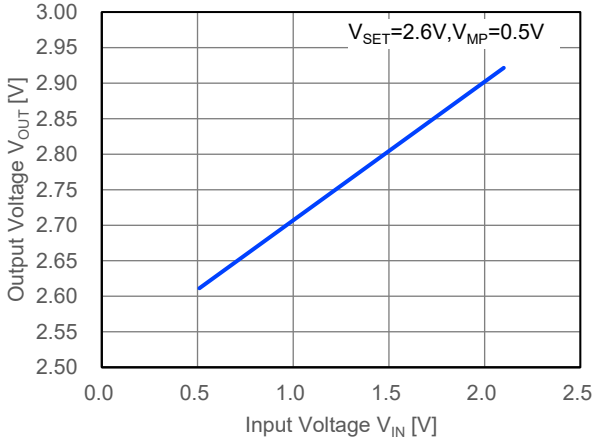
V_{SET} = 2.6V, V_{MP} = 0.5V Ta = 25°C

Bottom Voltage



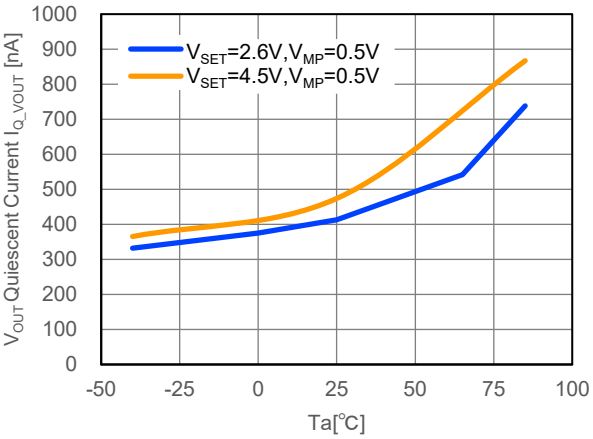
V_{SET} = 2.6V, V_{MP} = 0.5V Ta = 25°C

Average(Ripple Included）

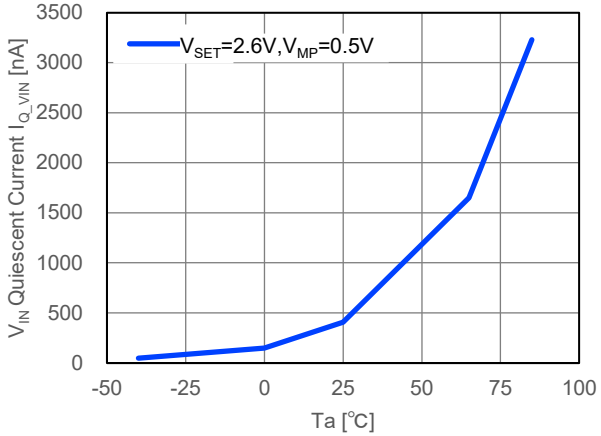


3) Operating Quiescent Current vs. Temperature

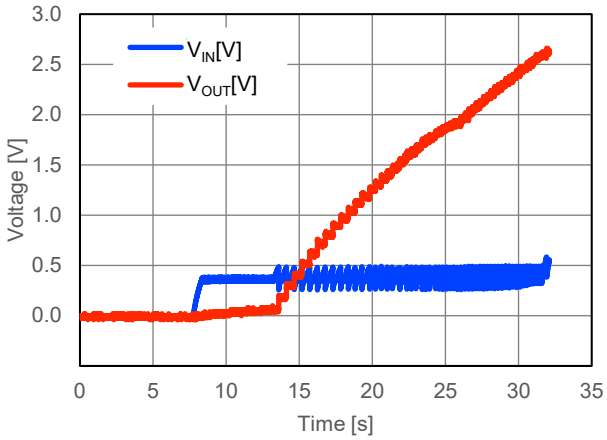
V_{MP} = 0.5V



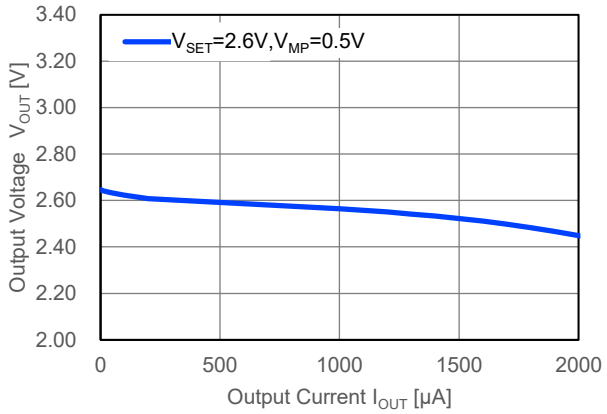
4) Operating Quiescent Current vs. Temperature
V_{SET} = 2.6V, V_{MP} = 0.5V



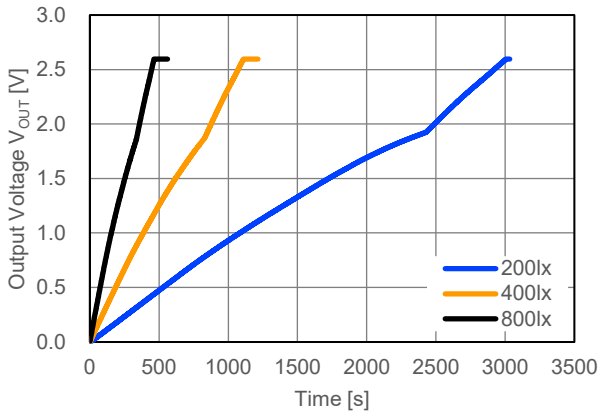
5) Minimum Starting Power Ramp up waveforms
V_{SET} = 2.6V, V_{MP} = 0.5V, I_{IN}=18μA
Ta = 25℃



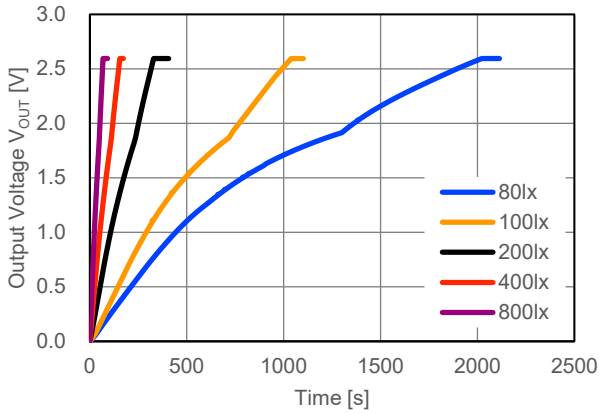
6) Output Voltage vs. Output Current
V_{SET} = 2.6V, V_{MP} = 0.5V
Ta = 25℃



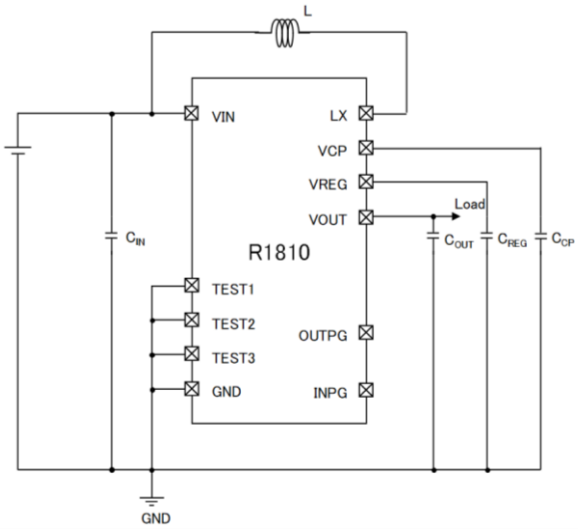
7) Start-up by the power generation element 1
R1810Z003A,
Photovoltaic Element = AM-30-11C (14.0 × 13.0mm)
V_{SET} = 2.6V, V_{MP} = 0.5V, C_{OUT} = 1mF
Ta = 25℃



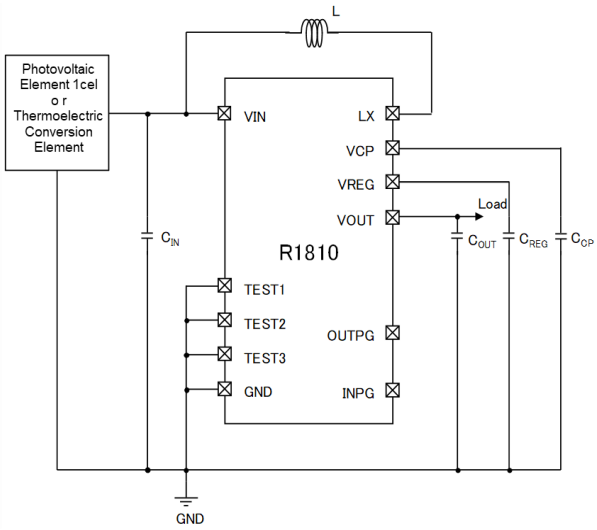
8) Start-up by the power generation element 2
R1810Z003A ,
Photovoltaic Element = FDSC-FSC6FG (44.5 × 40.5mm)
V_{SET} = 2.6V, V_{MP} = 0.5V, C_{OUT} = 1mF
Ta = 25℃



Test Circuit



Test Circuit
TYPICAL CHARACTERISTICS 1) to 6)



Test Circuit
TYPICAL CHARACTERISTICS 7)、8)

【Components list for our evaluation】

Symbol	Part#	Description
C_{IN}	C1608JB1A226M	22 µF, Ceramic Capacitor
C_{CP}	GRM155R71E223K	0.022 µF, Ceramic Capacitor
C_{REG}	C1608JB1E475K	4.7 µF, Ceramic Capacitor
C_{OUT}	C1608JB1E475K	4.7 µF, Ceramic Capacitor
L	VLCF4028T-220MR72-2	22 µH, Inductor

PD-WLCSP-15-P1-(8585)-JE-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.

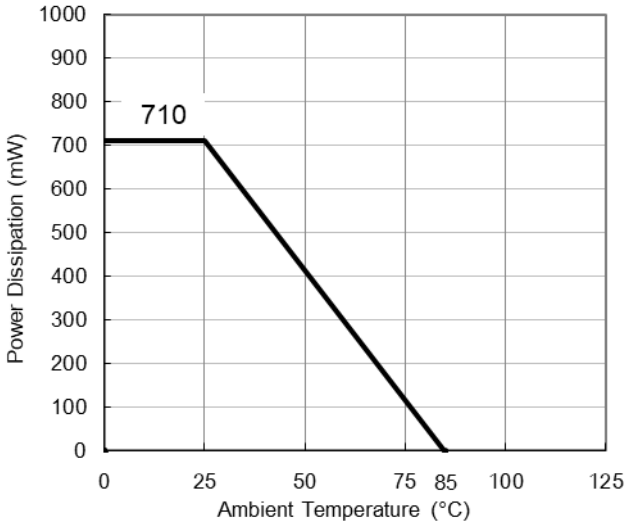
Measurement Conditions

Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	101.5 mm x 114.5 mm x 1.6 mm
Copper Ratio	Outer Layer (First Layer): 10% Inner Layers (Second and Third Layers): 99.5 x 99.5mm 100% Outer Layer (Fourth Layer): 10%

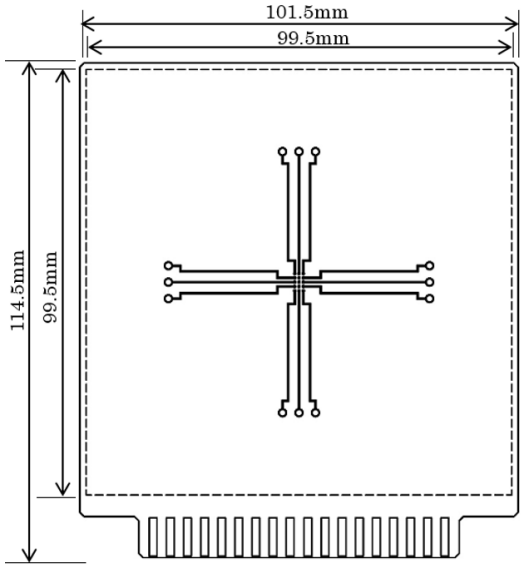
Measurement Result (Ta = 25°C, Tjmax = 85°C)

Item	Measurement Result
Power Dissipation	710 mW
Thermal Resistance (θja)	θja = 84°C/W

θja: Junction-to-Ambient Thermal Resistance

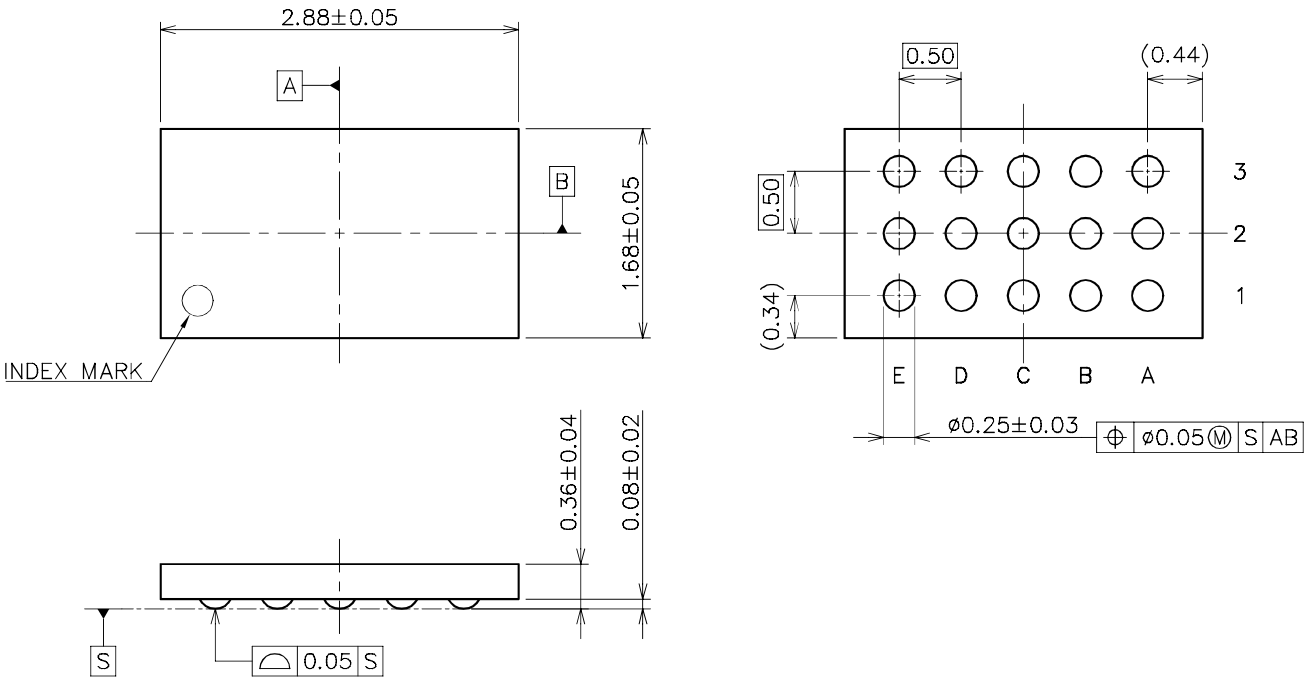


Power Dissipation vs. Ambient Temperature



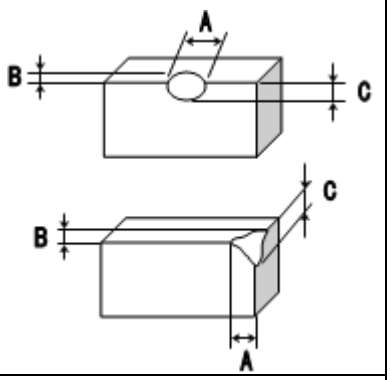
Measurement Board Pattern

DM-WLCSP-15-P1-JE-B



UNIT : mm

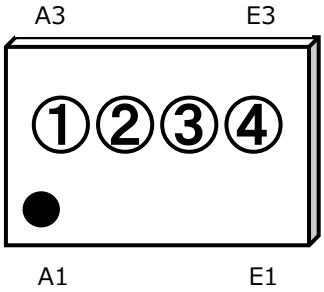
WLCSP-15-P1 Package Dimensions

No.	Inspection Items	Inspection Criteria	Figure
1	Package chipping	A≥0.2mm is rejected B≥0.2mm is rejected C≥0.2mm is rejected And, Package chipping to Si surface and to bump is rejected.	
2	Si surface chipping	A≥0.2mm is rejected B≥0.2mm is rejected C≥0.2mm is rejected But, even if A≥0.2mm, B≤0.1mm is acceptable.	
3	No bump	No bump is rejected.	
4	Marking miss	To reject incorrect marking, such as another product name marking or another lot No. marking.	
5	No marking	To reject no marking on the package.	
6	Reverse direction of marking	To reject reverse direction of marking character.	
7	Defective marking	To reject unreadable marking. (Microscope: X15/ White LED/ Viewed from vertical direction)	
8	Scratch	To reject unreadable marking character by scratch. (Microscope: X15/ White LED/ Viewed from vertical direction)	
9	Stain and Foreign material	To reject unreadable marking character by stain and foreign material. (Microscope: X15/ White LED/ Viewed from vertical direction)	

MK-R1810Z-JE-D

①②: Product Code ⋯ Refer to *Part Marking List*

③④: Lot Number ⋯ Alphanumeric Serial Number



R1810Z (WLCSP-15-P1) Part Markings

NOTICE
There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or distributor before attempting to use AOI.

R1810Z Part Marking List

Product Name	①②	Product Name	①②	Product Name	①②	Product Name	①②
R1810Z003A	10	R1810Z003B	20	R1810Z005C	30	R1810Z005D	40
R1810Z005A	12	R1810Z005B	22	R1810Z006C	31	R1810Z006D	41
R1810Z006A	13	R1810Z006B	23	R1810Z007C	32	R1810Z007D	42
R1810Z007A	14	R1810Z007B	24	R1810Z017C	33	R1810Z019D	43
R1810Z013A	15	R1810Z013B	25	R1810Z018C	34		
R1810Z015A	1V	R1810Z017B	26	R1810Z019C	35		
R1810Z016A	16	R1810Z018B	27				
R1810Z017A	17	R1810Z019B	28				
R1810Z018A	18	R1810Z022B	29				
R1810Z019A	19	R1810Z023B	2A				
R1810Z022A	1A	R1810Z024B	2C				
R1810Z023A	1C	R1810Z025B	2E				
R1810Z024A	1E	R1810Z026B	2F				
R1810Z025A	1F	R1810Z027B	2G				
R1810Z026A	1G	R1810Z028B	2H				
R1810Z027A	1H	R1810Z029B	2J				
R1810Z028A	1J	R1810Z030B	2K				
R1810Z029A	1K	R1810Z031B	2L				
R1810Z030A	1L	R1810Z032B	2N				
R1810Z031A	1N	R1810Z033B	2P				
R1810Z032A	1P	R1810Z034B	2R				
R1810Z033A	1R						
R1810Z034A	1T						
R1810Z035A	1U						

PD-DFN2735-14-(8585)-JE- B

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.

Measurement Conditions

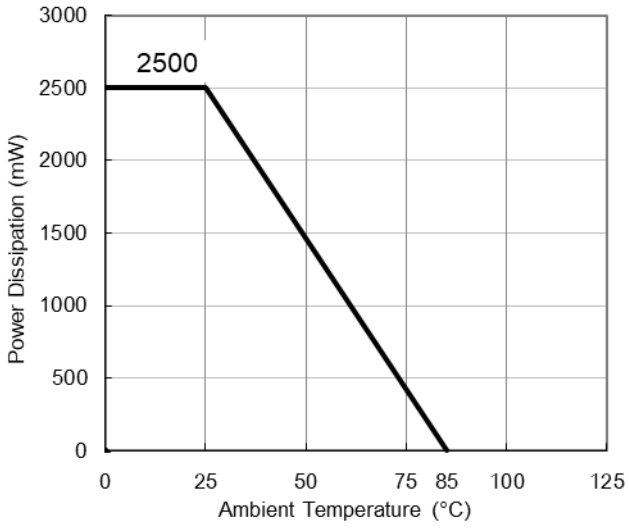
Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	Outer Layer (First Layer): Less than 95% of 50 mm Square Inner Layers (Second and Third Layers): Approx. 100% of 50 mm Square Outer Layer (Fourth Layer): Approx. 100% of 50 mm Square
Through-holes	ϕ 0.3 mm × 32 pcs

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

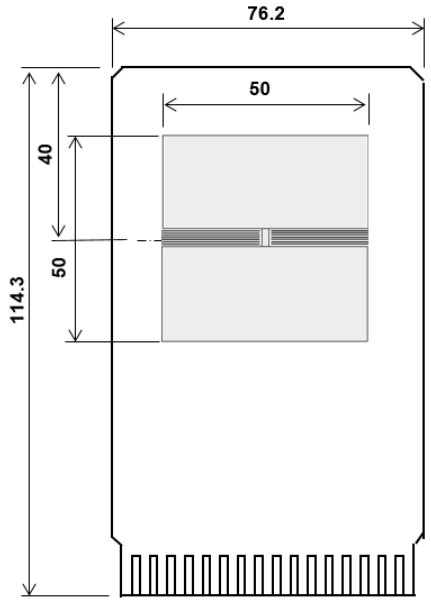
Item	Measurement Result
Power Dissipation	2500 mW
Thermal Resistance (θja)	θja = 24°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 4°C/W

θja: Junction-to-Ambient Thermal Resistance

ψjt: Junction-to-Top Thermal Characterization Parameter

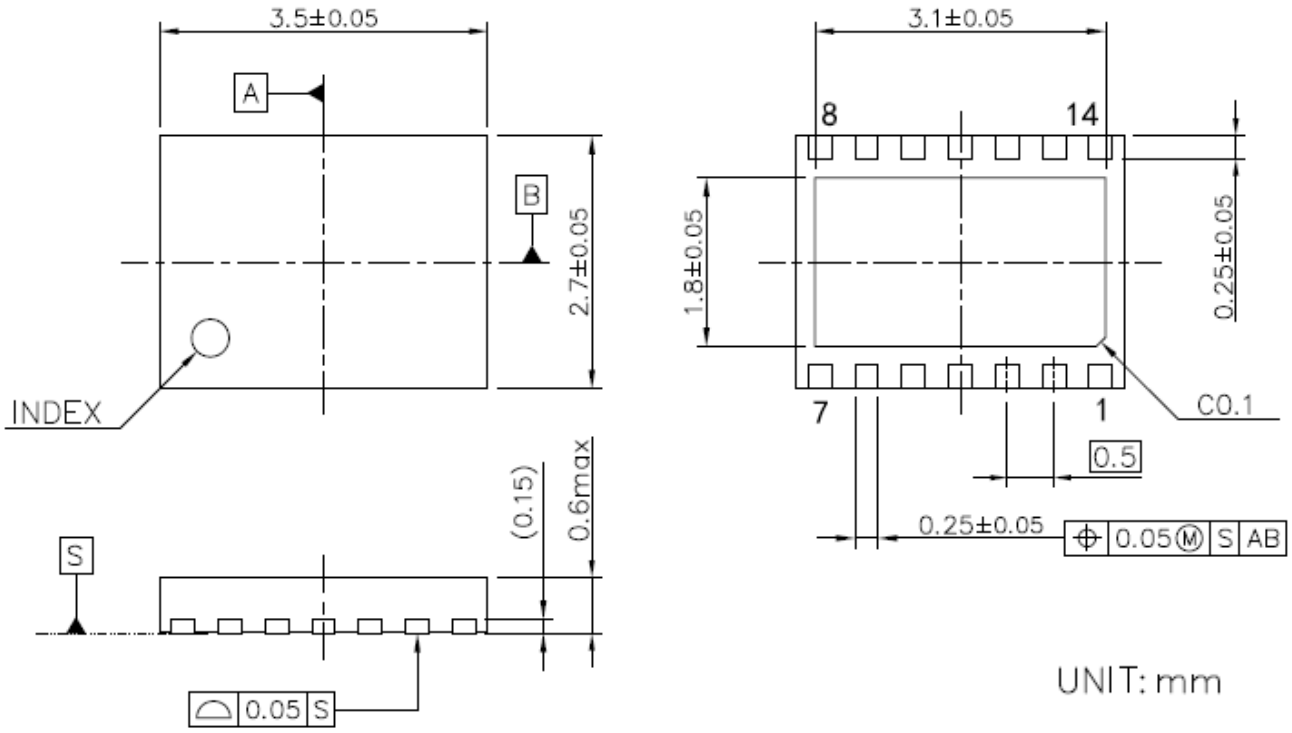


Power Dissipation vs. Ambient Temperature



Measurement Board Pattern

DM-DFN2735-14-JE-A

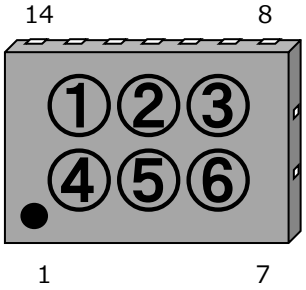


DFN2735-14 Package Dimensions

MK-R1810L-JE-C

①②③④ : Product Code ⋯ Refer to *Part Marking List*

⑤⑥ : Lot Number ⋯ Alphanumeric Serial Number



R1810L (DFN2735-14) Part Markings

NOTICE
There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or distributor before attempting to use AOI.

R1810L Part Marking List

Product Name	①②③④	Product Name	①②③④	Product Name	①②③④	Product Name	①②③④
R1810L003A	G V 0 0	R1810L003B	G W 0 0				
R1810L005A	G V 0 2	R1810L005B	G W 0 2	R1810L005C	G X 0 0	R1810L005D	G Y 0 0
R1810L006A	G V 0 3	R1810L006B	G W 0 3	R1810L006C	G X 0 1	R1810L006D	G Y 0 1
R1810L007A	G V 0 4	R1810L007B	G W 0 4	R1810L007C	G X 0 2	R1810L007D	G Y 0 2
R1810L013A	G V 0 5	R1810L013B	G W 0 5				
R1810L015A	G V 2 3						
R1810L016A	G V 0 6						
R1810L017A	G V 0 7	R1810L017B	G W 0 6	R1810L017C	G X 0 3		
R1810L018A	G V 0 8	R1810L018B	G W 0 7	R1810L018C	G X 0 4		
R1810L019A	G V 0 9	R1810L019B	G W 0 8	R1810L019C	G X 0 5	R1810L019D	G Y 0 3
R1810L022A	G V 1 0	R1810L022B	G W 0 9				
R1810L023A	G V 1 1	R1810L023B	G W 1 0				
R1810L024A	G V 1 2	R1810L024B	G W 1 1				
R1810L025A	G V 1 3	R1810L025B	G W 1 2				
R1810L026A	G V 1 4	R1810L026B	G W 1 3				
R1810L027A	G V 1 5	R1810L027B	G W 1 4				
R1810L028A	G V 1 6	R1810L028B	G W 1 5				
R1810L029A	G V 1 7	R1810L029B	G W 1 6				
R1810L030A	G V 1 8	R1810L030B	G W 1 7				
R1810L031A	G V 1 9	R1810L031B	G W 1 8				
R1810L032A	G V 2 0	R1810L032B	G W 1 9				
R1810L033A	G V 2 1	R1810L033B	G W 2 0				
R1810L034A	G V 2 2	R1810L034B	G W 2 1				

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8. Quality Warranty
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    In the case of a product purchased through an authorized distributor or directly from us, the warranty period for this product shall be one (1) year after delivery to your company. For defective products that occurred during this period, we will take the quality warranty measures described in section 8-2. However, if there is an agreement on the warranty period in the basic transaction agreement, quality assurance agreement, delivery specifications, etc., it shall be followed.
    8-2. Quality Warranty Remedies
    When it has been proved defective due to manufacturing factors as a result of defect analysis by us, we will either deliver a substitute for the defective product or refund the purchase price of the defective product.
    Note that such delivery or refund is sole and exclusive remedies to your company for the defective product.
    8-3. Remedies after Quality Warranty Period
    With respect to any defect of this product found after the quality warranty period, the defect will be analyzed by us. On the basis of the defect analysis results, the scope and amounts of damage shall be determined by mutual agreement of both parties. Then we will deal with upper limit in Section 8-2. This provision is not intended to limit any legal rights of your company.
9. Anti-radiation design is not implemented in the products described in this document.
10. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
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12. Warning for handling Gallium and Arsenic (GaAs) products (Applying to GaAs MMIC, Photo Reflector). These products use Gallium (Ga) and Arsenic (As) which are specified as poisonous chemicals by law. For the prevention of a hazard, do not burn, destroy, or process chemically to make them as gas or power. When the product is disposed of, please follow the related regulation and do not mix this with general industrial waste or household waste.
13. Please contact our sales representatives should you have any questions or comments concerning the products or the technical information.

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