

**650 V Variable Output Current/Voltage ZVS PFC/LED Driver Controller**

No. EA-364-190108

**OVERVIEW**

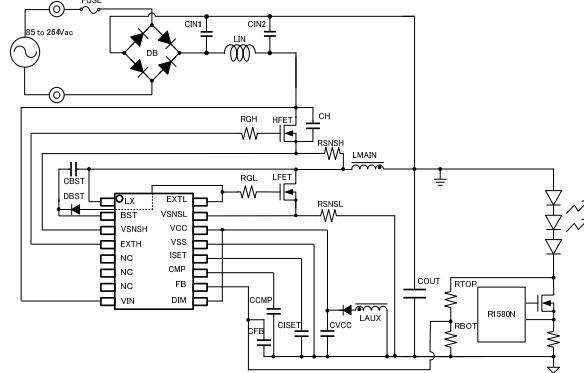
The R1700V is a zero-voltage switching (ZVS) PFC/LED driver controller with a variable output current/voltage. It is ideal for improving power factors of LED lightings and consumer appliances. This device features the arbitrary setting of output voltage based on buck-boost (inverting) topology. Integration of this device and the R1580N allows the two-stage architecture and a flicker-free operation in LED lighting applications.

**KEY BENEFITS**

- Edge Resonant Control of ZVS helps to achieve Low Switching Loss and Low EMI.
- R1700V is capable of Arbitrary Setting an Output Voltage based on Buck-boost (Inverting) Topology.
- Integration of R1700V and R1580N realizes Flicker-free Operation in LED Lighting Applications.

**KEY SPECIFICATIONS**

- Input Voltage Range: 8 V to 650 V
- PWM Linear Dimming Control Range: 5% to 100%
- Built-in Max. 650-V Operating Regulator
- Built-in Half Bridge Gate Driver
- Corresponding Topologies
  - Buck-boost (Inverting) PFC
  - Variable Output Current PFC, Linear Dimmable
  - Variable Output Voltage PFC
  - Boost PFC
  - Buck PFC

**TYPICAL APPLICATION**

Buck-boost (Inverting) PFC for LED Lighting

**PROTECTION FEATURES**

- Overcurrent Protection (OCP)
- Thermal Shutdown (TSD)
- BST/VCC Pin Undervoltage Lockout (UVLO)
- VCC Pin Overvoltage Lockout (OVLO)
- Overvoltage Protection (FBOVP)
- Latch-type Protection (Selectable)

**APPLICATIONS**

- LED Lighting PFCs, Linear Dimmable
- Flicker-free LED Lighting using R1580N
- PFCs for PAM Controlled Motor Drivers
- Low Output Voltage PFCs
- DC/DC Converters

**PACKAGE**

SSOP-16  
5.1 × 6.4 × 1.15 (mm)

**OPTIONAL FUNCTIONS**

Select the optional functions from below.

Product Name	Latch-type Protection	FB Pin UVD	FB Pin OVP
R1700V001A	Yes	No	Typ. 1.2 V (Rising)
R1700V001B	No		
R1700V001C	Yes	Yes	Typ. 3.65 V (Rising)
R1700V001D	No		

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## R1700V

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## SELECTION GUIDE

The latch-type protection, the FB pin UVD function and the FB pin OVP voltage are user-selectable options.

### Selection Guide

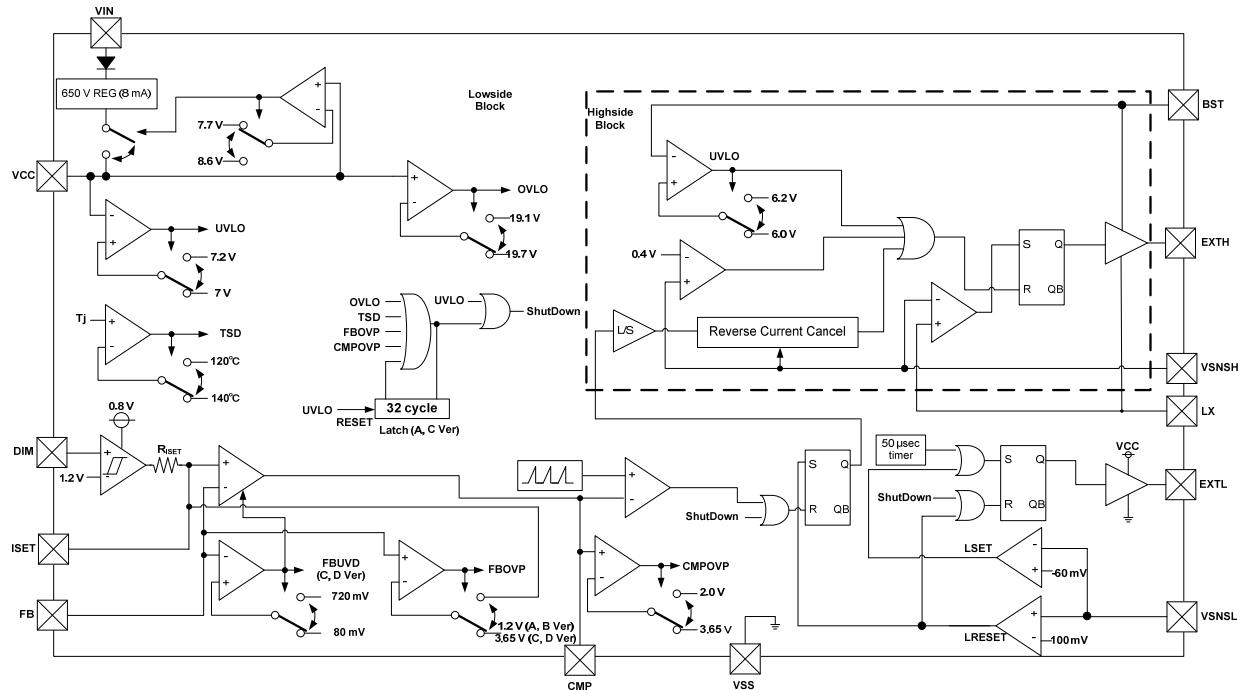
Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1700V001*-E2-FE	SSOP-16	2,000 pcs	Yes	Yes

\*: Select the optional functions from below.

*	Latch-type Protection	FB Pin UVD	FB Pin OVP Voltage
A	Yes	No	Typ. 1.2 V (Rising)
B	No	No	Typ. 1.2 V (Rising)
C	Yes	Yes	Typ. 3.65 V (Rising)
D	No	Yes	Typ. 3.65 V (Rising)

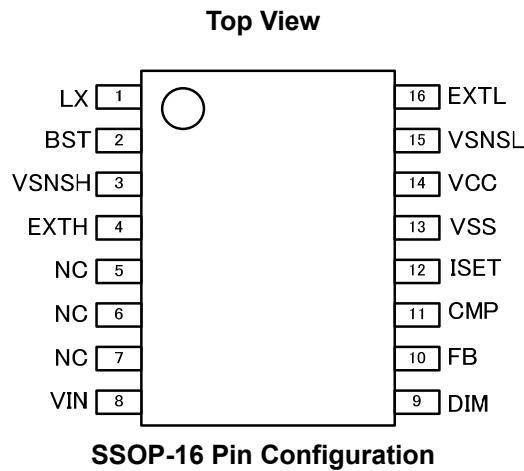
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## BLOCK DIAGRAM



R1700V Block Diagram

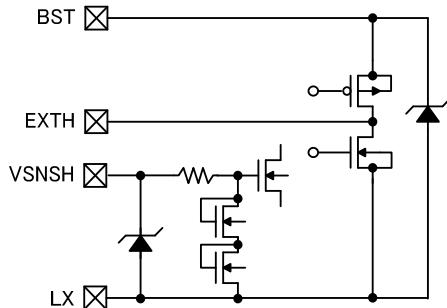
## PIN DESCRIPTIONS



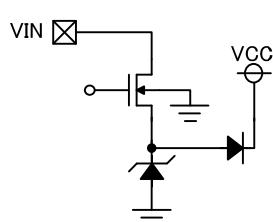
### SSOP-16 Pin Descriptions

Pin No.	Symbol	Description
1	LX	Switching Pin
2	BST	Bootstrap Pin
3	VSNSH	High-side Current Sensing Pin
4	EXTH	High-side Driver Operating Pin
5	NC	No Connection
6	NC	No Connection
7	NC	No Connection
8	VIN	Start-up Regulator Power Source Pin
9	DIM	PWM Signal Input Pin
10	FB	Feedback Pin
11	CMP	Phase Compensation Capacitance Pin
12	ISET	Current Setting Pin
13	VSS	Ground Pin
14	VCC	Power Source Pin for Controlling Circuit
15	VSNSL	Low-side Current Sensing Pin
16	EXTL	Low-side Driver Operating Pin

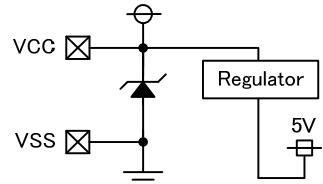
## Equivalent Circuits for the Individual Terminals



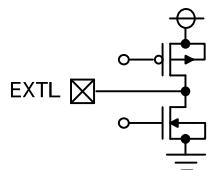
## Equivalent Circuit for BST Pin, EXTH Pin, VSNSH Pin and LX Pin



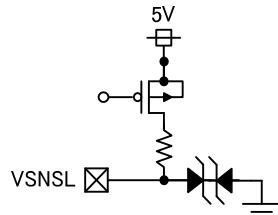
## Equivalent Circuit for VIN Pin



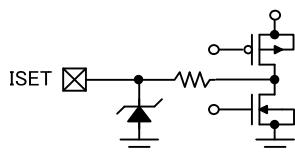
## Equivalent Circuit for VCC Pin and VSS Pin



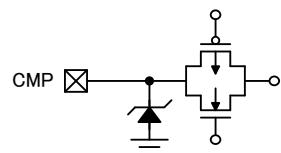
## Equivalent Circuit for EXTL Pin



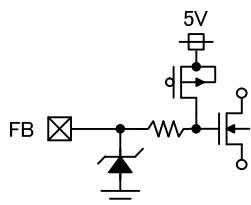
## Equivalent Circuit for VSNSL Pin



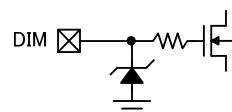
## Equivalent Circuit for ISET Pin



## Equivalent Circuit for CMP Pin



## Equivalent Circuit for FB Pin



## Equivalent Circuit for DIM Pin

## ABSOLUTE MAXIMUM RATINGS

### Absolute Maximum Ratings

Symbol	Parameter			Rating	Unit
$V_{IN}$	VIN Pin Input Voltage			-0.3 to 650	V
$V_{BST}$	BST Pin Voltage			$V_{LX}$ -0.3 to 20	V
$V_{EXTH}$	EXTH Pin Voltage			$V_{LX}$ -0.3 to 20	V
$V_{SNSH}$	VSNSH Pin Voltage			$V_{LX}$ -0.3 to 5.5	V
$V_{LX}$	LX Pin Voltage			-0.3 to 650	V
$V_{EXTL}$	EXTL Pin Voltage			-0.3 to 20	V
$V_{SNSL}$	VSNSL Pin Voltage			-0.3 to 5.5	V
$V_{DIM}$	DIM Pin Voltage			-0.3 to 20	V
$V_{FB}$	FB Pin Voltage			-0.3 to 5.5	V
$V_{CMP}$	CMP Pin Voltage			-0.3 to 5.5	V
$V_{ISET}$	ISET Pin Voltage			-0.3 to 5.5	V
$V_{CC}$	VCC Pin Voltage			-0.3 to 20	V
$P_D$	Power Dissipation <sup>(1)</sup>	SSOP-16	Standard Land Pattern	$(T_{TSD1} - 25)/146$	W
$T_j$	Junction Temperature Range			-40 to $T_{TSD1}^{(2)}$	°C
Tstg	Storage Temperature Range			-55 to 150	°C

### ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages 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
$V_{IN}$	VIN Pin Operating Input Voltage	8 to 650	V
$V_{BST}$	BST Pin Operating Input Voltage	6.25 to 17.6	V
$V_{CC}$	VCC Pin Operating Input Voltage	8.0 to 19.0	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 when 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.

<sup>(1)</sup> Refer to *POWER DISSIPATION* for detailed information.

<sup>(2)</sup> The maximum junction temperature depends on the Thermal Shutdown Threshold Temperature listed in the *ELECTRICAL CHARACTERISTICS*.

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## R1700V

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No. EA-364-190108

### ELECTRICAL CHARACTERISTICS

$V_{IN} = 30\text{ V}$ ,  $V_{CC} = 15\text{ V}$ ,  $V_{BST} = 15\text{ V}$  unless otherwise noted.

The specifications surrounded by  are guaranteed by design engineering at  $-40^\circ\text{C} \leq Ta \leq 85^\circ\text{C}$ .

#### R1700V Electrical Characteristics

( $Ta = 25^\circ\text{C}$ )

Symbol	Parameter	Test Conditions/ Comments	Min.	Typ.	Max.	Unit
$I_{IN1}$	Supply Current 1			1.3	1.6	mA
$I_{IN2}$	Supply Current 2	$V_{CC} = 6\text{ V}$ , $V_{BST} = 5\text{ V}$		0.43	0.55	mA

#### High-Side Driver Section

$V_{CZERO}$	Zero Current Threshold Voltage		-7		7	mV
$I_{SNSH}$	VSNSH Pin Pull-up Current		-53.5	-48	-41.8	$\mu\text{A}$
$V_{OCPH}$	Overcurrent Protection Threshold Voltage		0.37		0.43	V
$R_{ONHH}$	High-side Driver High Resistance	$V_{BST} = 15\text{ V}$		6.7		$\Omega$
$R_{ONHL}$	High-side Driver Low Resistance	$V_{BST} = 15\text{ V}$		2.3		$\Omega$
$V_{UVLO2\_BST}$	BST Pin UVLO Threshold Voltage	$V_{BST}$ Falling	6.05	6.15	6.25	V
$V_{UVLO1\_BST}$		$V_{BST}$ Rising	$V_{UVLO2\_BST} + 0.12$		$V_{UVLO2\_BST} + 0.23$	V

#### Low-Side Driver Section

$t_{LMAXON}$	Max. Low-side On Time		45		55	$\mu\text{sec}$
$t_{LMAXOFF}$	Max. Low-side Off Time		45		55	$\mu\text{sec}$
$t_{LMINON}$	Min. Low-side On Time		0.38		0.62	$\mu\text{sec}$
$V_{REV}$	Reverse Current Threshold Voltage		90	98	105	mV
$V_{FOR}$	Forward Current Threshold Voltage		-80	-60	-40	mV
$R_{ONLH}$	Low-side Driver High Resistance			5.8		$\Omega$
$R_{ONLL}$	Low-side Driver Low Resistance			1.9		$\Omega$

#### Protection Circuits Section

$V_{UVLO2}$	VCC Pin UVLO Threshold Voltage	$V_{CC}$ Falling	6.7	7	7.3	V
$V_{UVLO1}$		$V_{CC}$ Rising	$V_{UVLO2} + 0.15$		$V_{UVLO2} + 0.23$	V
$V_{OVLO2}$	VCC Pin OVLO Threshold Voltage	$V_{CC}$ Rising	19.1	19.7	20.3	V
$V_{OVLO1}$		$V_{CC}$ Falling	$V_{OVLO2} - 0.64$		$V_{OVLO2} - 0.57$	V
$T_{TSD1}$	Thermal Shutdown Threshold Temperature	$T_j$ Rising		140		$^\circ\text{C}$
$T_{TSD2}$		$T_j$ Falling		120		$^\circ\text{C}$
$V_{OVP2\_FB}$	FB Pin OVP Threshold Voltage (R1700V001A/ R1700V001B)	$V_{FB}$ Rising	1.15		1.25	V
$V_{OVP1\_FB}$		$V_{FB}$ Falling		$V_{ISET}$		V
$V_{OVP2\_FB}$	FB Pin OVP Threshold Voltage (R1700V001C/ R1700V001D)	$V_{FB}$ Rising	3.55		3.80	V
$V_{OVP1\_FB}$		$V_{FB}$ Falling		$V_{ISET}$		V

## ELECTRICAL CHARACTERISTICS (continued)

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$  unless otherwise noted.

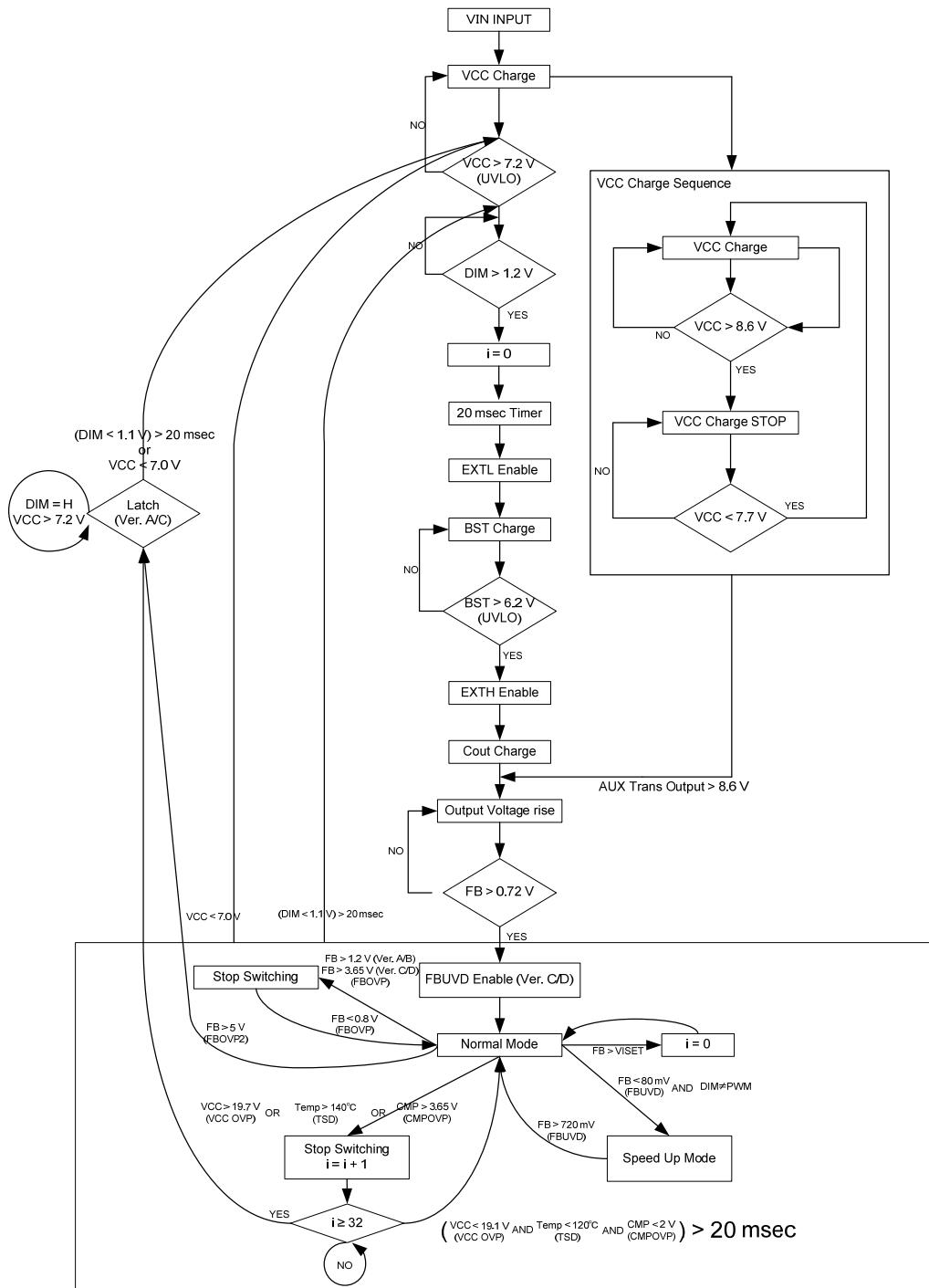
The specifications surrounded by  are guaranteed by design engineering at  $-40^\circ\text{C} \leq Ta \leq 85^\circ\text{C}$ .

### R1700V Electrical Characteristics

(Ta = 25°C)

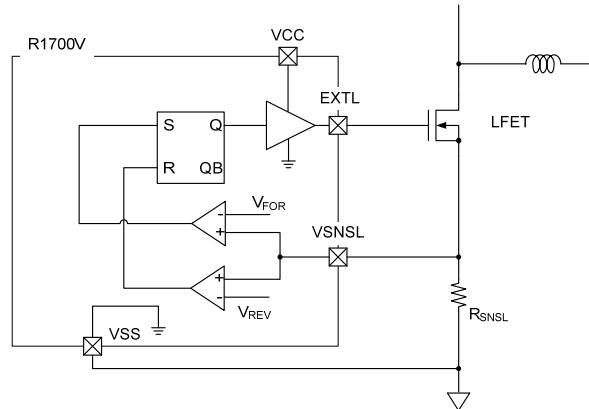
Symbol	Parameter	Test Conditions/ Comments	Min.	Typ.	Max.	Unit
<b>Protection Circuit Section (continued)</b>						
$V_{OVP1\_CMP}$	CMP Pin OVP Threshold Voltage	$V_{CMP}$ Rising	3.60		3.75	V
$V_{OVP2\_CMP}$		$V_{CMP}$ Falling	1.9		2.1	V
$t_{DET\Delta}$	Release Protection Delay Time		14		24	msec
$C_{LAT}$	Latch Protection (R1700V001A/ R1700V001C)			32		cycle
<b>Current Control Circuit Section</b>						
$V_{OFFSET}$	Error Amplifier Offset		-5		5	mV
$I_{ERSOURCE}$	Error Amplifier Source Current	$V_{FB} = 0.75 \text{ V}$ , $V_{ISET} = 0.8 \text{ V}$ $V_{CMP} = 1.5 \text{ V}$	-4.1		-2.9	µA
$I_{ERSINK}$	Error Amplifier Sink Current	$V_{FB} = 0.85 \text{ V}$ , $V_{ISET} = 0.8 \text{ V}$ $V_{CMP} = 1.5 \text{ V}$	2.9		4.1	µA
$G_m$	Error Amplifier Trans-conductance	$V_{CMP} = 1.5 \text{ V}$	60		78	µS
$t_{EXTHSLOPE}$	High-side On Time Inclination	$V_{CMP} = 1.3 \text{ V}$ , $2.0 \text{ V}$	4.5		7.2	µsec/V
$I_{FBPU}$	FB Pin Pull-up Current	$V_{FB} = 0 \text{ V}$	<input type="checkbox"/> -2.1	-1.7	<input type="checkbox"/> -1.0	µA
<b>Internal Regulator Section</b>						
$I_{REG}$	Internal Regulator VCC Pin Charging Current	$V_{CC} = 6.8 \text{ V}$	9		14	mA
$V_{CHGEN}$	Internal Regulator VCC Pin Charge-Starting Voltage		7.4		8.0	V
$V_{CHGSLP}$	Internal Regulator VCC Pin Charge-Stopping Voltage		8.3		8.9	V
<b>Variable Control Circuit Section</b>						
$V_{DIMH}$	PWM Signal Threshold Voltage, High		1.13		1.25	V
$V_{DIML}$	PWM Signal Threshold Voltage, Low		1.09		1.18	V
$f_{DIMMIN}$	PWM Signal Input Frequency		0.5		100	kHz
$t_{DIMMIN}$	PWM Signal Input Error			±10		nsec
$R_{ISETIN}$	ISET Pin Impedance		263	300	342	kΩ
$V_{ISETIN}$	ISET Pin Controlling Voltage	PWM Duty = 100% $Ta = 25^\circ\text{C}$	0.792	0.800	0.807	V
		PWM Duty = 100% $-40^\circ\text{C} \leq Ta \leq 85^\circ\text{C}$	0.782		0.814	
<b>Others</b>						
$V_{UVD2\_FB}$	FB Pin UVD Threshold Voltage (R1700V001C/ R1700V001D)	$V_{FB}$ Rising	695		745	mV
$V_{UVD1\_FB}$		$V_{FB}$ Falling	65		95	mV
$I_{ERSOURCE\_UVD}$	Error Amplifier Source Current during UVD	$V_{FB} = 0 \text{ V}$ , $V_{ISET} = 0.8 \text{ V}$ $V_{CMP} = 1.5 \text{ V}$	-90		-44	µA

## THEORY OF OPERATION



### • Low-side Switching Operation

The R1700V controls the low-side switch by monitoring the voltage generated in a resistor ( $R_{SNSL}$ ).



### Low-side Switch Turn-on Operation

The forward current of inductor flows  $R_{SNSL}$  through the body diode of the low-side switch due to the high-side switch turned off. This leads the  $VSNSL$  voltage drops to the forward current threshold voltage ( $V_{FOR}$ ) or lower, and the low-side switch is turned on.

The R1700V uses a bootstrap method which enables to use Nch MOSFET as a high-side switch. The ceramic capacitor ( $C_{BST}$ ) between LX and BST needs to be charged during the low-period of LX.

The charging current of  $C_{BST}$  pulls up the LX. If the low-side's power source  $V_{CC}$  is the charging source, the  $VSNSL$  voltage does not go below  $V_{FOR}$  when the peak current of inductor is not enough at a light load. This may cause a low-side switch cannot be turned on.

As this countermeasure, set the charging source of  $C_{BST}$  as EXTL, and make a structure of charging  $C_{BST}$  after the low-side switch is turned on.

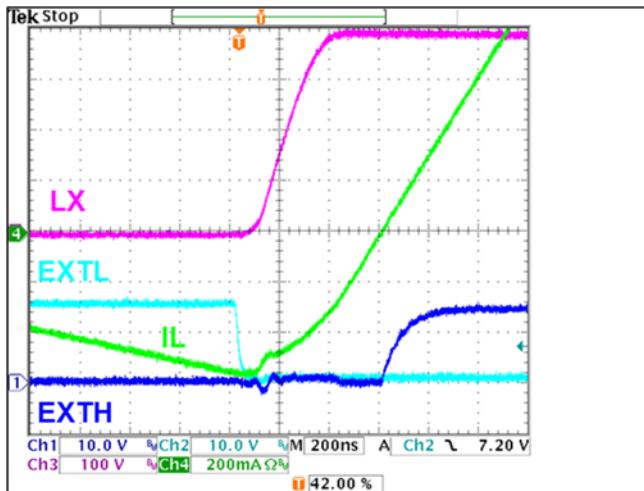
### Low-side Switch Turn-off Operation

The R1700V makes the inductor current flow reverse to perform a zero-voltage-switching (ZVS) which can significantly reduce switching loss and switching noise. The reverse current of inductor should be set to enable ZVS when the maximum input voltage is applied. The reverse current of inductor ( $I_{REV}$ ) can be calculated as follows.

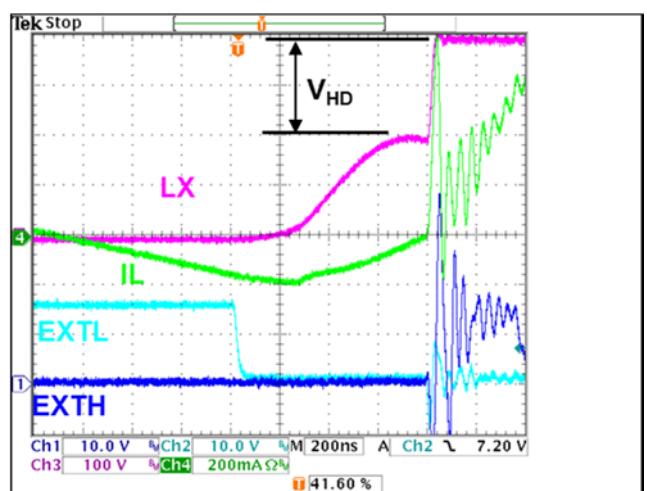
$$I_{REV} = V_{REV}/R_{SNSL}$$

$$V_{REV} = 98 \text{ [mV] Typ.}$$

Figure 1 shows the resonant operation waveform and Figure 2 shows the off-resonant operation waveform.



**Figure 1. The Resonant Operation Waveform**



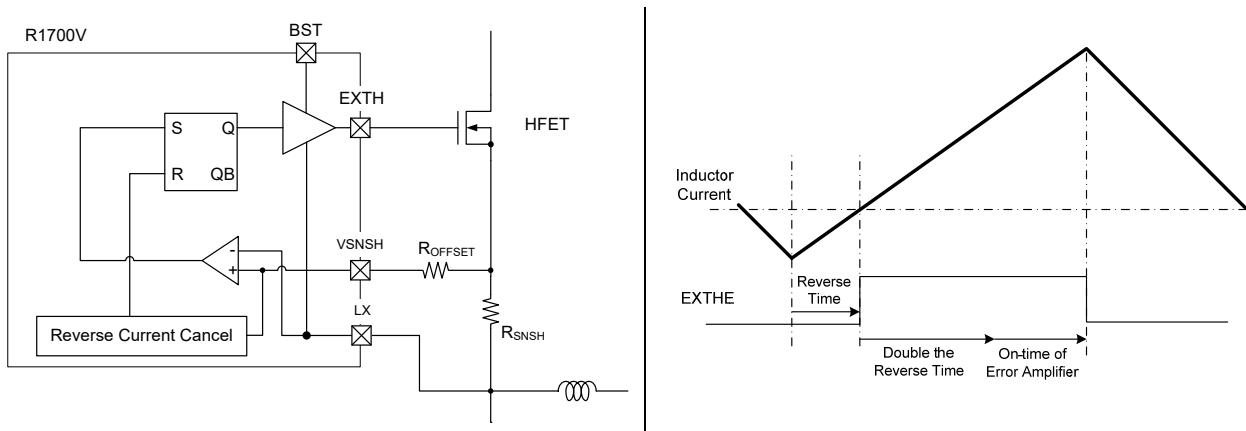
**Figure 2. The Off-resonant Operation Waveform**

Figure 1 shows that the high-side switch is turned on with ZVS after  $V_{IN} - LX = 0$  V.

Figure 2 shows that the reverse current of inductor is not enough, so the high-side switch is turned on when  $V_{DS}$  of high-side switch is  $V_{HD}$ . In this case, high-side switch produces a switching loss:  $f_{osc} \times 1/2 \times C_{ds} \times V_{HD}^2$ .  $C_{ds}$  is the sum of drain-source capacities of high-side switch and low-side switch. For example, if  $f_{osc} = 500$  kHz,  $C_{ds} = 100$  pF, and  $V_{HD} = 200$  V, the switching loss will be 1.0 W. The switching noise increases when ZVS cannot be performed, and it may cause a malfunction.

### • High-side Switching Operation

The R1700V controls the high-side switch by monitoring the voltage generated in a resistor ( $R_{SNSH}$ ).



### High-side Switch Turn-on Operation

The reverse current of inductor flows input side through the body diode of the high-side switch due to the low-side switch turned off. At this timing, when the VSNSH voltage exceeds zero ( $V_{CZERO}$ ), that is when the inductor current becomes zero, the high-side switch is turned on.

The pull-up current ( $I_{SNSH}$ ) flows constantly from the VSNSH pin. The turn-on timing of the high-side switch can be changed by setting the offset resistor ( $R_{OFFSET}$ ) between the high-side switch source and the VSNSH pin. Harmonics can be changed by adding this offset resistor to make the cancel time of reverse current adjustable.

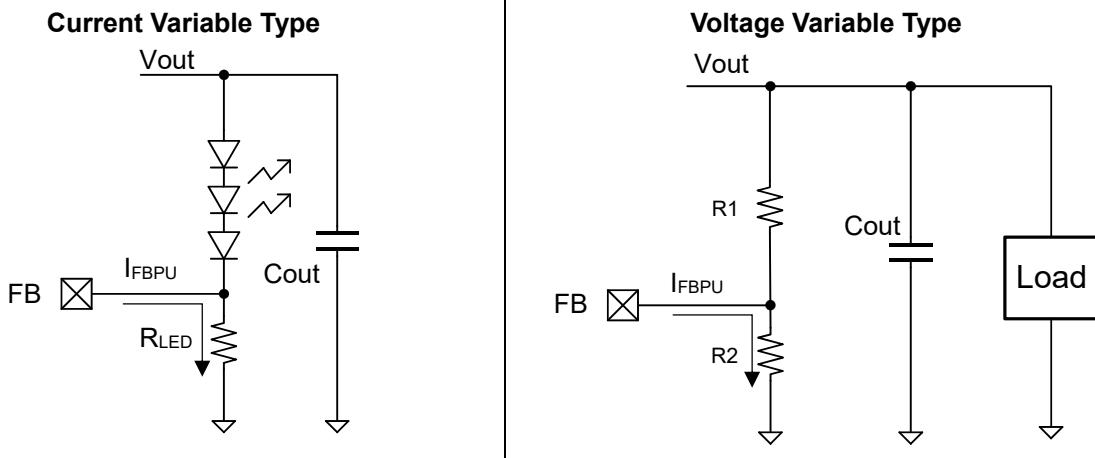
### High-side Switch On-Time

The R1700V uses a critical current mode for improving power factor. However, the device makes the inductor current flow reverse to achieve a zero-voltage-switching (ZVS). The reverse flowing inductor current causes a period which generally cannot supply power to the output, therefore the power factor deteriorates. As this countermeasure, the double the time of flowing reverse current is added to the fixed on-time determined by an error amplifier. It cancels the reverse current and improves power factors. The previously mentioned  $R_{OFFSET}$  allows the reverse current flowing time adjustable. This enables a countermeasure for the frequency drop at a low input and the change of harmonic.

### • DIM Pin Input

The R1700V outputs the ISET pin voltage according to the high duty of PWM signal to the DIM Pin. To minimize the influence by the PWM signal input error ( $t_{DIMMIN}$ ), use a low PWM frequency of 500 Hz or more. When using the device for dimmable LED lighting, it is recommended to use a PWM frequency from 1 kHz to 10 kHz. The ISET pin voltage is the smoothed PWM Duty with a capacitor ( $C_{ISET}$ ). The R1700V varies the output current/voltage by according the FB pin voltage and the ISET pin voltage. Connect a large enough  $C_{ISET}$  to the ISET pin to avoid a ripple voltage problem. The low PWM signal should be lower than the low PWM signal threshold voltage ( $V_{DIML}$ ), and the high PWM signal should be higher than the PWM signal threshold voltage ( $V_{DIMH}$ ). The R1700V can be shut down by applying a low signal to the DIM pin for 25 msec or more typically. If the control by PWM signal to DIM pin or a shutdown function is not needed, connect the DIM pin to the VCC pin.

- **Output Setting**

**Current Variable Type (LED Driver)**

The R1700V adjusts the source voltage of resistor ( $R_{LED}$ ) connected between LED and VSS to the ISET pin output voltage ( $V_{ISET}$ ) level.  $V_{ISET}$  can be calculated as follows.

$$V_{ISET} = V_{ISETIN} \times \text{PWM Duty}$$

$$V_{ISETIN} = 0.8 \text{ [V] Typ.}$$

LED current can be calculated by using  $R_{LED}$ .

Where  $V_{OFFSET}$  is the offset voltage of error amplifier and  $I_{FBPU}$  is the pull-up current of FB pin.

$$I_{LED} = (V_{ISET} + V_{OFFSET}) / R_{LED} + I_{FBPU}$$

$$V_{OFFSET} = \pm 5 \text{ [mV]}$$

$$I_{FBPU} = -1.7 \text{ [\mu A] Typ.}$$

The offset voltage ( $V_{OFFSET}$ ) can be affected if  $V_{ISET}$  is low, so it should be taken into account if low-dimming-control is necessary.

**Voltage Variable Type**

As for the constant voltage output, the R1700V sets the output voltage by the ratio of the resistor ( $R_1/R_2$ ) connected between  $V_{out}$  and VSS. The output voltage ( $V_{out}$ ) is calculated as follows.

$$V_{out} = (V_{ISET} + V_{OFFSET}) \times (R_1 + R_2) / R_2 + R_1 \times I_{FBPU}$$

The pull-up current of FB pin ( $I_{FBPU}$ ) can be affected by high resistance of  $R_1$ , so it should be taken into account when setting  $R_1/R_2$ .

As similar to the current variable type, the  $V_{ISET}$  can be changed by the PWM signal to the DIM pin. The  $V_{CC}$  varies according to the output voltage when supplying  $V_{CC}$  with the auxiliary winding, therefore set the output voltage within the operating range of  $V_{CC}$  or supply the  $V_{CC}$  with the external power source.

### ● Oscillation Frequency

The oscillation frequency ( $f_{osc}$ ) can be determined by input voltage ( $V_{IN}$ ), output voltage ( $V_{OUT}$ ), LED current ( $I_{LED}$ ), inductance ( $L$ ), and inductor reverse current ( $I_{REV}$ ).

#### Buck Converter

$$f_{osc} = V_{IN} \times (V_{IN} - V_{OUT}) / (V_{IN} \times L \times (I_{LED} + I_{REV}) \times 2)$$

#### Boost Converter

$$f_{osc} = (1 - V_{IN} / V_{OUT}) / (((I_{REV} + V_{OUT} \times I_{LED} / V_{IN}) / (1 - V_{IN} / V_{OUT})) \times 2) \times L / V_{IN}$$

#### Buck-boost (Inverting) Converter

$$f_{osc} = V_{OUT} \times V_{IN} / (2 \times L \times (V_{OUT} + V_{IN}) \times (I_{LED} \times (V_{OUT} + V_{IN}) / V_{IN} + I_{REV}))$$

### ● Power Source

At start-up, the high-voltage internal regulator connected to the VIN pin starts charging the VCC pin. When the VCC pin voltage becomes higher than the UVLO threshold voltage ( $V_{UVLO1}$ ) and the BST pin voltage becomes higher than the BST pin UVLO threshold voltage ( $V_{UVLO1\_BST}$ ), the R1700V starts operation. If the VCC pin voltage becomes higher than the internal regulator VCC pin charge-stopping voltage ( $V_{CHGSLP}$ ),  $V_{CHGSLP} = 8.6$  V (Typ.), the high-voltage internal regulator stops the operation, and the auxiliary power source (auxiliary winding, inductor divided voltage, external power source) starts up. If power is supplied to the VCC pin through the auxiliary power source, the high-voltage internal regulator maintains the off state to save the consumption current of R1700V. If the external power source is not activated yet, the VCC pin voltage drops. If it drops below the internal regulator VCC pin charge-starting voltage ( $V_{CHGEN}$ ), the high-voltage internal regulator restarts the operation and charges the VCC pin.

### ● Low Voltage Detection on FB Pin: R1700V001C/ R1700V001D

The R1700V increases the operation speed of error amplifier when the FB pin voltage goes below the FB pin UVD threshold voltage ( $V_{UVD1\_FB}$ ), so it can quickly respond to the sudden drop in input voltage or the sudden increase in the load. The R1700V increases the operation speed until the FB pin voltage exceeds the FB pin UVD threshold voltage ( $V_{UVD2\_FB}$ ). This low voltage detection is disabled at start up because it is enabled only when the FB pin voltage exceeds  $V_{UVD1\_FB}$ . If a PWM signal is inputted to the DIM pin, this detection is disabled.

### ● Overcurrent Protection Setting

The R1700V monitors the inductor current when the high-side switch is turned on by the voltage generated at a resistor ( $R_{SNSH}$ ) connected between the high-side switch and the LX pin. The overcurrent protection current ( $I_{OCP}$ ) can be calculated as follows.

$$I_{OCP} = V_{OCPH} / R_{SNSH}$$

$$V_{OCPH} = 0.4$$
 [V] Typ.

$I_{OCP}$  should be set at the rated current of inductor or lower.

### ● Overvoltage Protection on VCC Pin

The R1700V stops the switching operation if the VCC pin goes beyond the OVLO threshold voltage ( $V_{OVLO2}$ ) and restarts the switching operation after the release protection delay time ( $t_{DETD}$ ) if the VCC pin drops below the OVLO threshold voltage ( $V_{OVLO1}$ ). The overvoltage protection is effective during LED open mode when there is an auxiliary power source which is dependent on  $V_{OUT}$  such as auxiliary windings and inductor dividing voltage.

- **Thermal Shutdown**

The R1700V stops the switching operation if the junction temperature goes beyond the thermal shutdown threshold temperature ( $T_{TSD1}$ ) and restarts the switching operation after  $t_{DETD}$  if the junction temperature drops below the thermal shutdown threshold temperature ( $T_{TSD2}$ ).

- **Overvoltage Detection on FB Pin**

The R1700V stops the switching operation if the FB pin voltage exceeds the FB pin OVP threshold voltage ( $V_{OVP2\_FB}$ ). Once the FB pin voltage goes below the FB pin OVP threshold voltage ( $V_{OVP1\_FB}$ ), it restarts the switching operation.

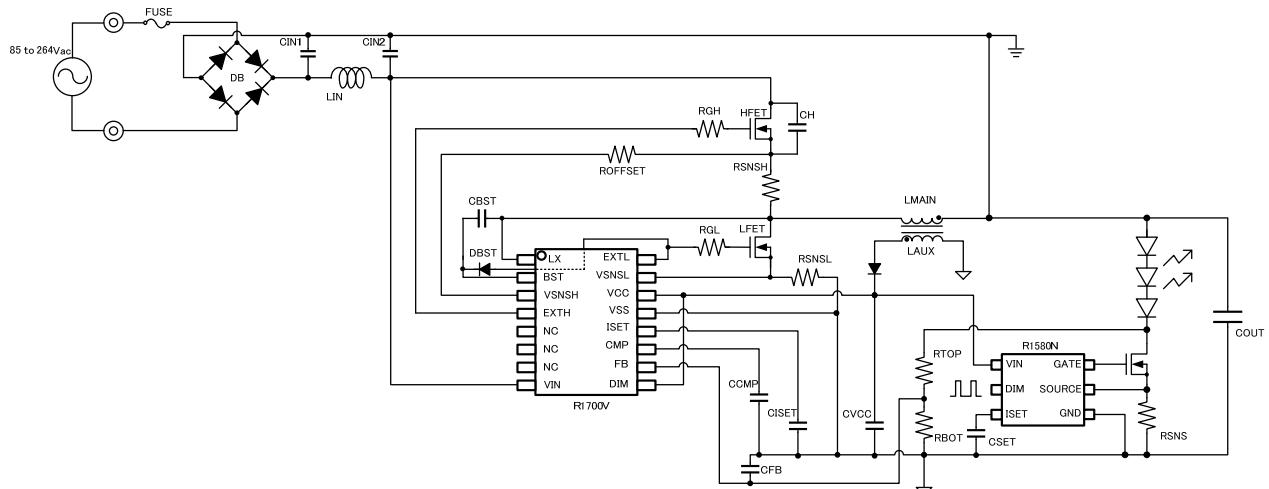
- **Overvoltage Detection on CMP Pin**

The R1700V stops the switching operation if the CMP pin voltage exceeds the CMP pin OVP threshold voltage ( $V_{OVP1\_CMP}$ ). Once the CMP pin goes below the CMP pin OVP threshold voltage ( $V_{OVP2\_CMP}$ ), it restarts the switching operation after  $t_{DETD}$ .

- **Latch-type Protection: R1700V001A/R1700V001C**

The R1700V stops the operation if an abnormal state is counted for thirty two times;  $C_{LAT} = 32$  [cycle]. The activation of the following detection can be counted as an abnormal state: the VCC pin overvoltage detection, the thermal shutdown, or the CMP pin overvoltage detection. The FB pin overvoltage detection is not included. The R1700V returns to the normal operation if the FB pin voltage becomes the ISET pin output voltage ( $V_{ISET}$ ) level, and resets the counter;  $C_{LAT} = 0$  [cycle]. To release the latch-type protection, make the VCC pin voltage below the VCC pin UVLO threshold voltage ( $V_{UVLO2}$ ) or make the device shutdown using the DIM pin. Refer to the *Operation Sequence Diagram* for detailed information.

## APPLICATION INFORMATION



**R1700V + R1580N Typical Application Circuit, Buck-boost (Inverting) Converter**

### Integration of R1700V and R1580N

The integration of R1700V and R1580N allows a smaller flicker-free operation in LED lighting applications than a conventional two-stage architecture.

The above system controls LED current by using R1580N consisting of constant current circuit in the cathode side of LED. In the constant current circuit, it generates loss due to the LED current and the potential difference between cathode voltage of LED and VSS.

Set the cathode voltage of LED as low as possible in a range of the bottom cathode voltage of LED is not below the minimum operation voltage of the constant current circuit.

### • Corresponding Topologies

The R1700V can be used as a buck converter, a boost converter or a buck-boost (inverting) converter.

#### Buck Converter

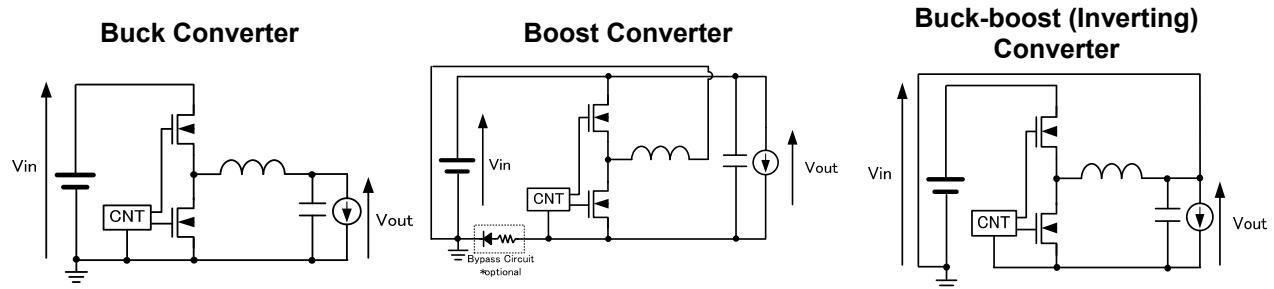
In the buck converter, the inductor current constantly flows into the load, so that the converter can operate with high efficiency. The output voltage needs to be lower than the input voltage.

#### Boost Converter

In the boost converter, the inductor current flows into the load only during the off-cycle, which means low-side switch is conducted, so that the current ripple of inductor increases. This is one of the reasons why the boost converter is not as efficient as the buck converter. It is necessary that the output voltage should be set higher than the input voltage. The inrush current flows through the body diode of low-side switch at power-on. To prevent this, it may require a bypass circuit between the input and output of the converter.

#### Buck-boost (Inverting) Converter

In the buck-boost (inverting) converter, the inductor current flows into the load only during the off-cycle, which means low-side switch is conducted, that is same as the boost converter, so that the current ripple of inductor increases. This is one of the reasons why the buck-boost (inverting) converter is not as efficient as the buck converter. This converter can be used effectively for input voltages and for power factor improvement because it can independently supply energy to the output (load) no matter what the input voltage is. Also, unlike the boost converter, it does not require any bypass circuit since there is no inrush current. The LX pin switches at  $V_{OUT} + V_{IN}$  voltage, so take the device breakdown voltage into account.



#### ● Power Factor Correction

The R1700V can be used to improve the power factor by a structure including a buck converter, a boost converter, and a buck-boost (inverting) converter. Connect a 1.0- $\mu$ F or more ceramic capacitor ( $C_{CMP}$ ) to the CMP pin for a 50-Hz or more line frequency. For use in an LED lighting, a harmonic standard IEC 61000-3-2 Class C is applied. The buck converter structure may not conform to the standard due to the input and output voltage relationship. For use in a boost converter and a buck-boost (inverting) converter is recommended.

#### ● Notes on Selecting Components

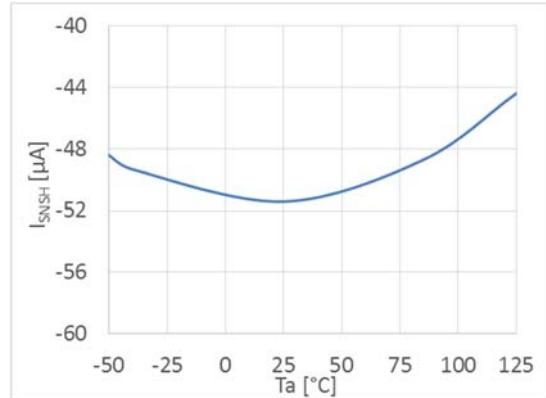
The R1700V has two power source pins: the VCC pin for low-side operation and the BST pin for high-side operation. Connect a 1.0- $\mu$ F or more ceramic capacitor ( $C_{VCC}$ ) between the VCC and VSS pins, a 1.0- $\mu$ F or more ceramic capacitor ( $C_{BST}$ ) between the BST and LX pins, and a bootstrap diode between the BST and EXTL pins.

## TYPICAL CHARACTERISTICS

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

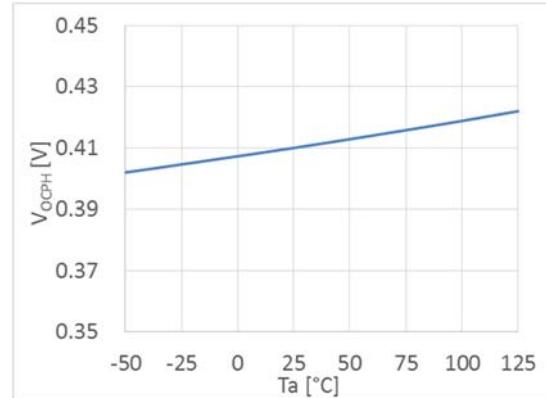
### VSNSH Pin Pull-up Current

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



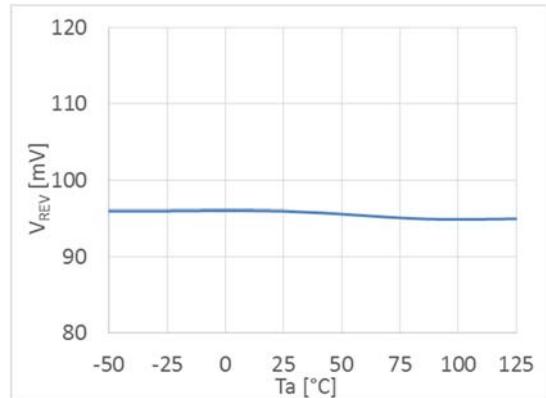
### Overcurrent Protection Threshold Voltage

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



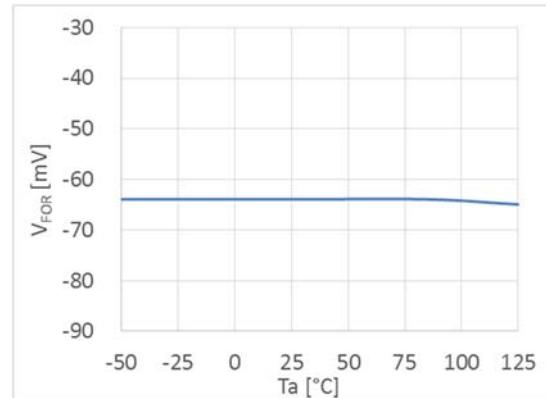
### Reverse Current Threshold Voltage

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



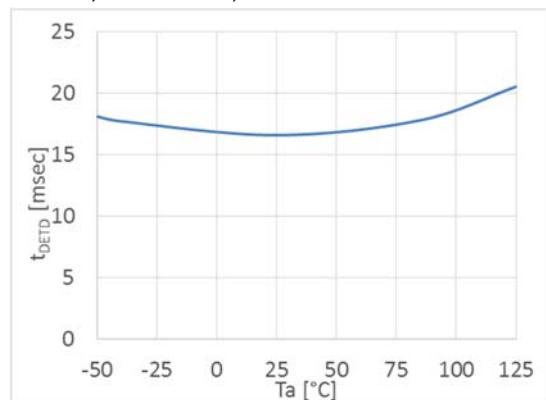
### Forward Current Threshold Voltage

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



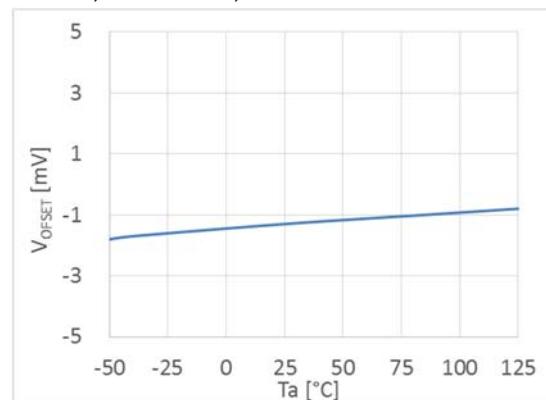
### Release Protection Delay Time

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



### Error Amplifier Offset

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



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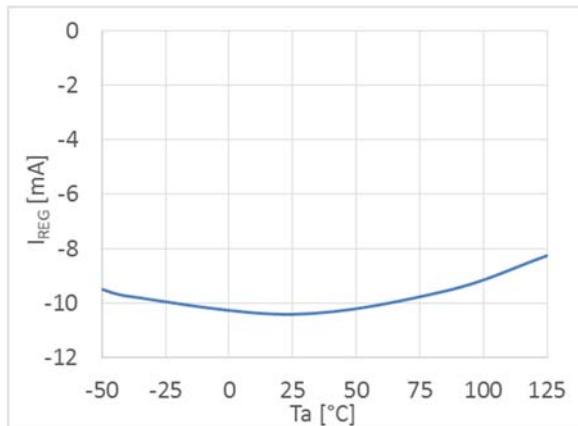
## R1700V

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No. EA-364-190108

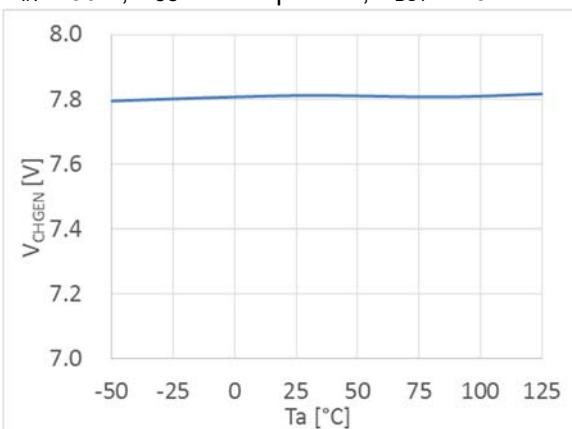
### Internal Regulator VCC Pin Charging Current

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 6.8 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



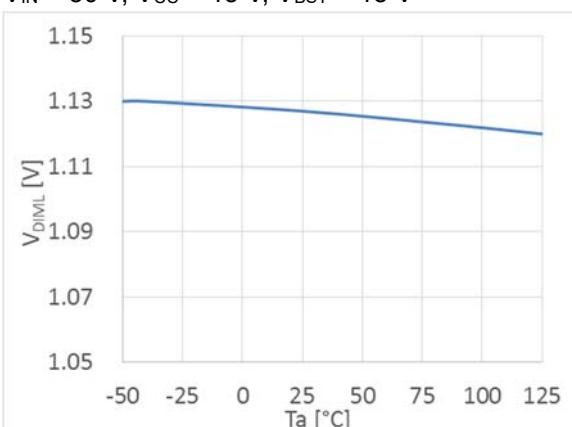
### Internal Regulator VCC Pin Charge-Starting Voltage

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = \text{Sweep down}$ ,  $V_{BST} = 15 \text{ V}$



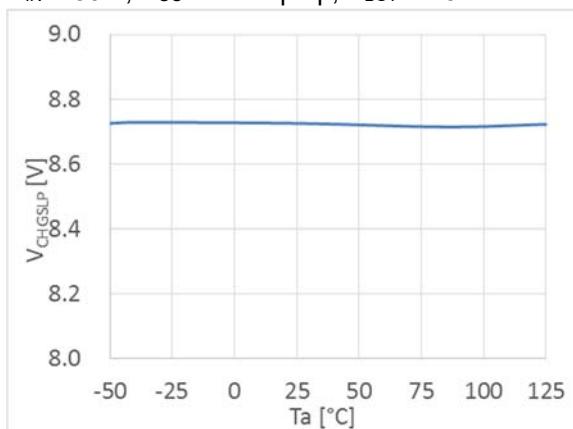
### PWM Signal Threshold Voltage, Low

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$



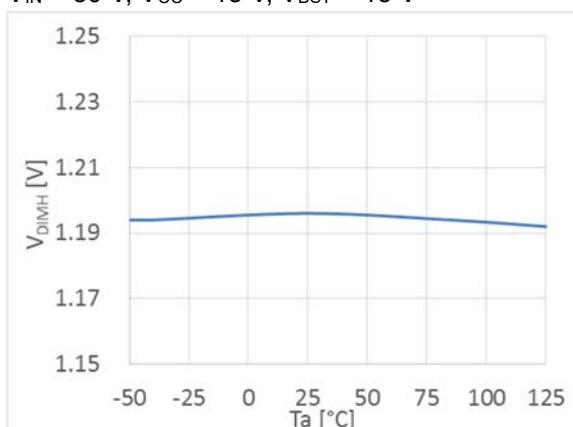
### Internal Regulator VCC Pin Charge-Stopping Voltage

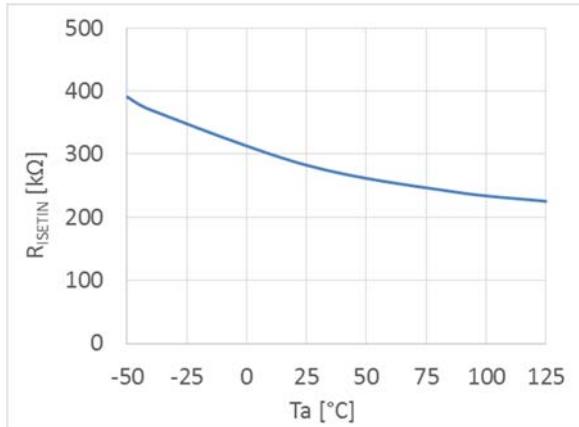
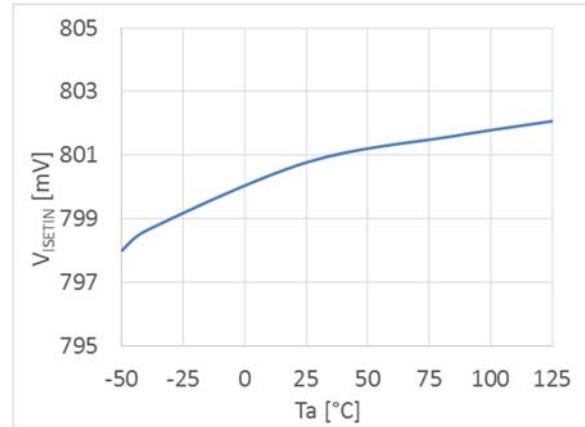
$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = \text{Sweep up}$ ,  $V_{BST} = 15 \text{ V}$



### PWM Signal Threshold Voltage, High

$V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$

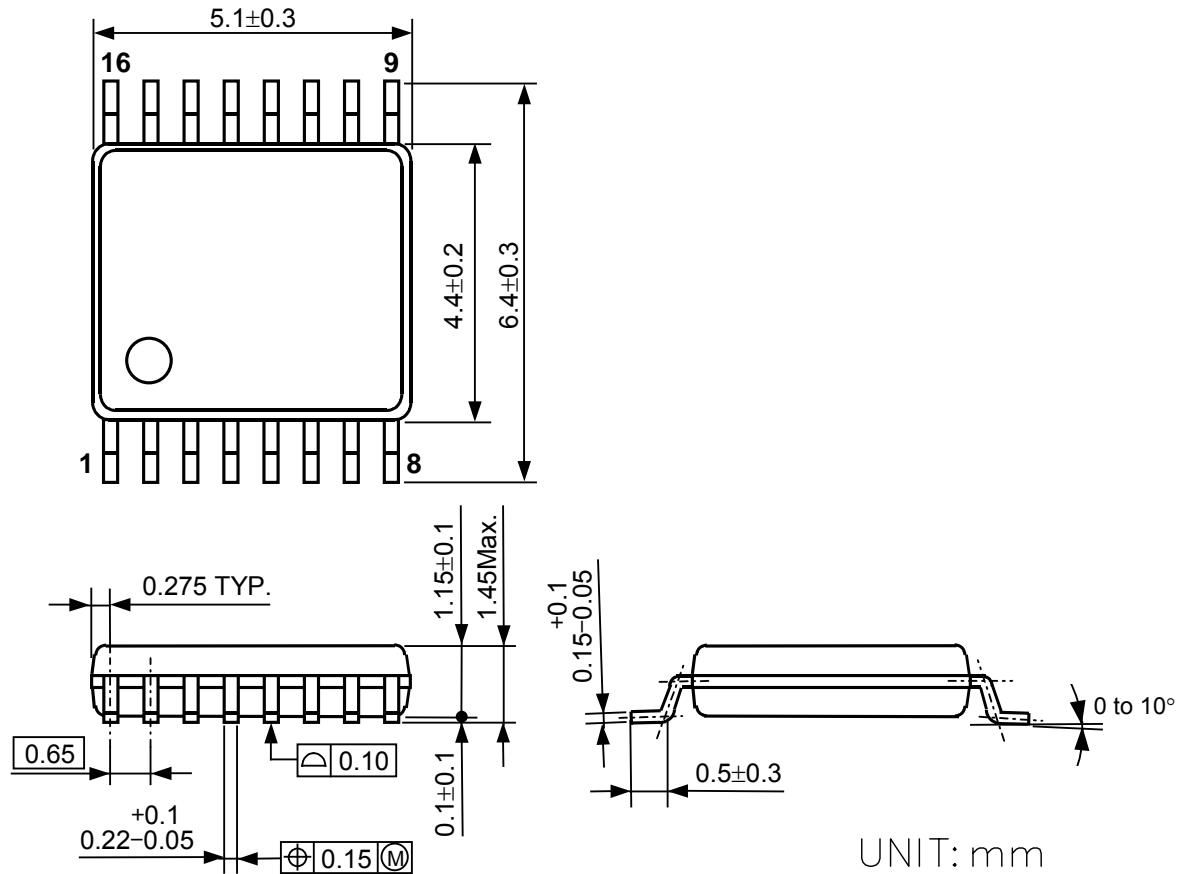


**ISET Pin Impedance** $V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$ **ISET Pin Controlling Voltage** $V_{IN} = 30 \text{ V}$ ,  $V_{CC} = 15 \text{ V}$ ,  $V_{BST} = 15 \text{ V}$ , PWM Duty = 100%

## PACKAGE DIMENSIONS

SSOP-16

Ver. A



UNIT: mm

SSOP-16 Package Dimensions

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following conditions are used in this measurement.

#### Measurement Conditions

Item	Standard Land Pattern
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Double-Sided Board)
Board Dimensions	40 mm × 40 mm × 1.6 mm
Copper Ratio	Top Side: Approx. 50% Bottom Side: Approx. 50%
Through-holes	Ø 0.5 mm × 44 pcs

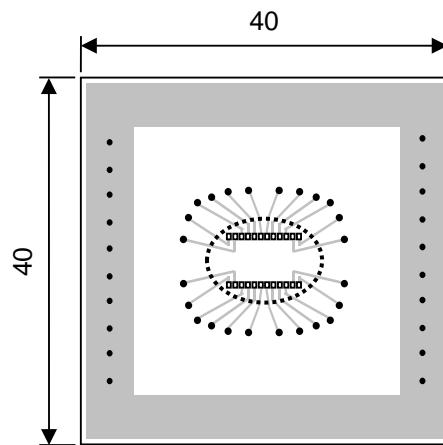
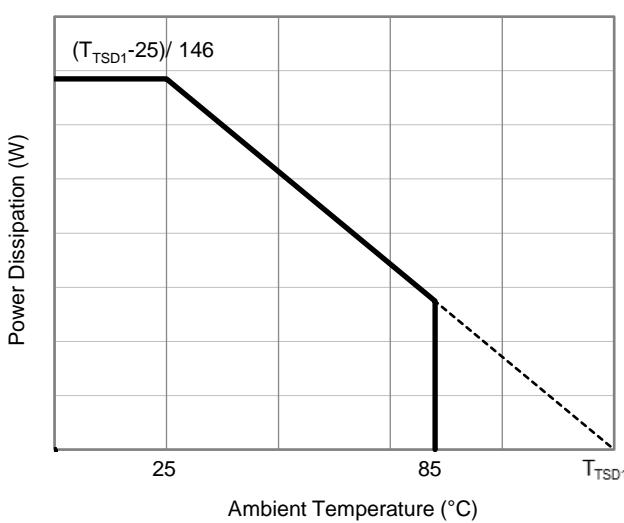
#### Measurement Result

( $T_a = 25^\circ\text{C}$ ,  $T_{j\max} = T_{TSD1}^\circ\text{C}$ )

Item	Standard Land Pattern
Power Dissipation	$(T_{TSD1}-25)/146 \text{ W}$
Thermal Resistance ( $\theta_{ja}$ )	$\theta_{ja} = 146^\circ\text{C/W}$
Thermal Characterization Parameter ( $\psi_{jt}$ )	$\psi_{jt} = 22^\circ\text{C/W}$

$\theta_{ja}$ : Junction-to-Ambient Thermal Resistance

$\psi_{jt}$ : Junction-to-Top Thermal Characterization Parameter



Power Dissipation vs. Ambient Temperature

Measurement Board Pattern



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