

## R2A20135SP

R19AN0011EJ0200

Rev.2.00

Jul 24, 2013

### Application Note

## 1. General Description

R2A20135SP is LED lighting controller IC with dimming function. High accuracy LED current feed-back system make more effect LED performance. This IC builds in the dimming function and can control many types dimming mode such as Triac, PWM, and DC dimming.

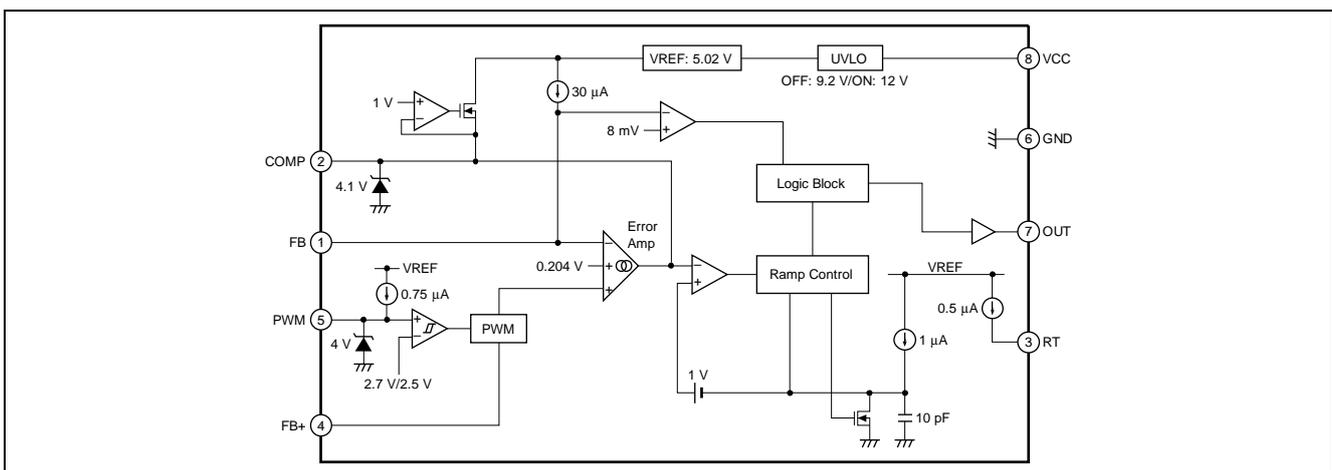
Switching mode can chosen Zero Current detect Mode or Fixed Frequency Mode according to the required features. By the Constant On Time control, both modes have power factor correct function.

Zero Current detect Mode is better performance for noise immunity, and Fixed Frequency Mode is for power factor correction and THD.

## 2. Block Diagram

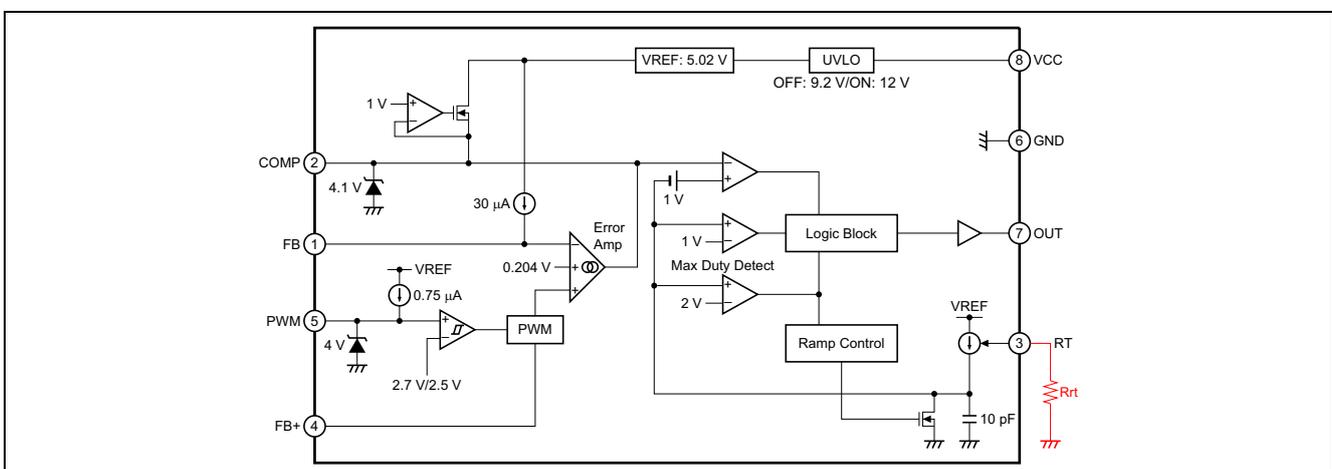
### 2.1 Critical Conduction Mode ("RT" pin is Open)

When you connect  $R_{rt}$  between "RT" pin and "Vcc" pin or "RT" is Open, R2A20135SP works in Critical Conduction mode with Zero Current switching. At this mode, this IC turns the external MOSFET on at the timing when the inductor current becomes zero.



### 2.2 Fixed Switching Frequency Mode (Rrt is connected to GND)

When you connect external resistor  $R_{rt}$  between "RT" pin and GND, R2A20135SP works in Fixed Switching frequency mode. At this IC turns the external MOSFET on at the timing of internal oscillation signal. You can adjust the oscillation frequency by the value of  $R_{rt}$ .



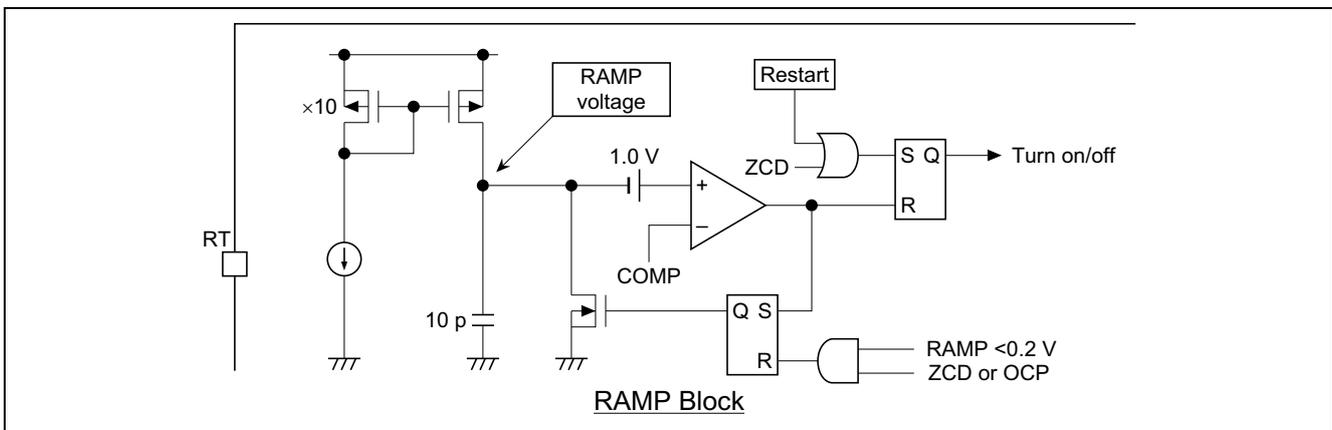
### 3. Explanation of Each Circuit Block

#### 3.1 Zero Current Detection

R2A20135SP detects zero current point. Checking the terminal voltage of Rcs which is connected in series with inductor. At critical Conduction Mode (CRM), this IC turns the external MOSFET on at this zero current point. The threshold level of zero current detect is set to 8 mV typ. And delay time from zero current detection to drain voltage lay down of MOSFET is added. This delay time is fixed to 0.8  $\mu$ s.

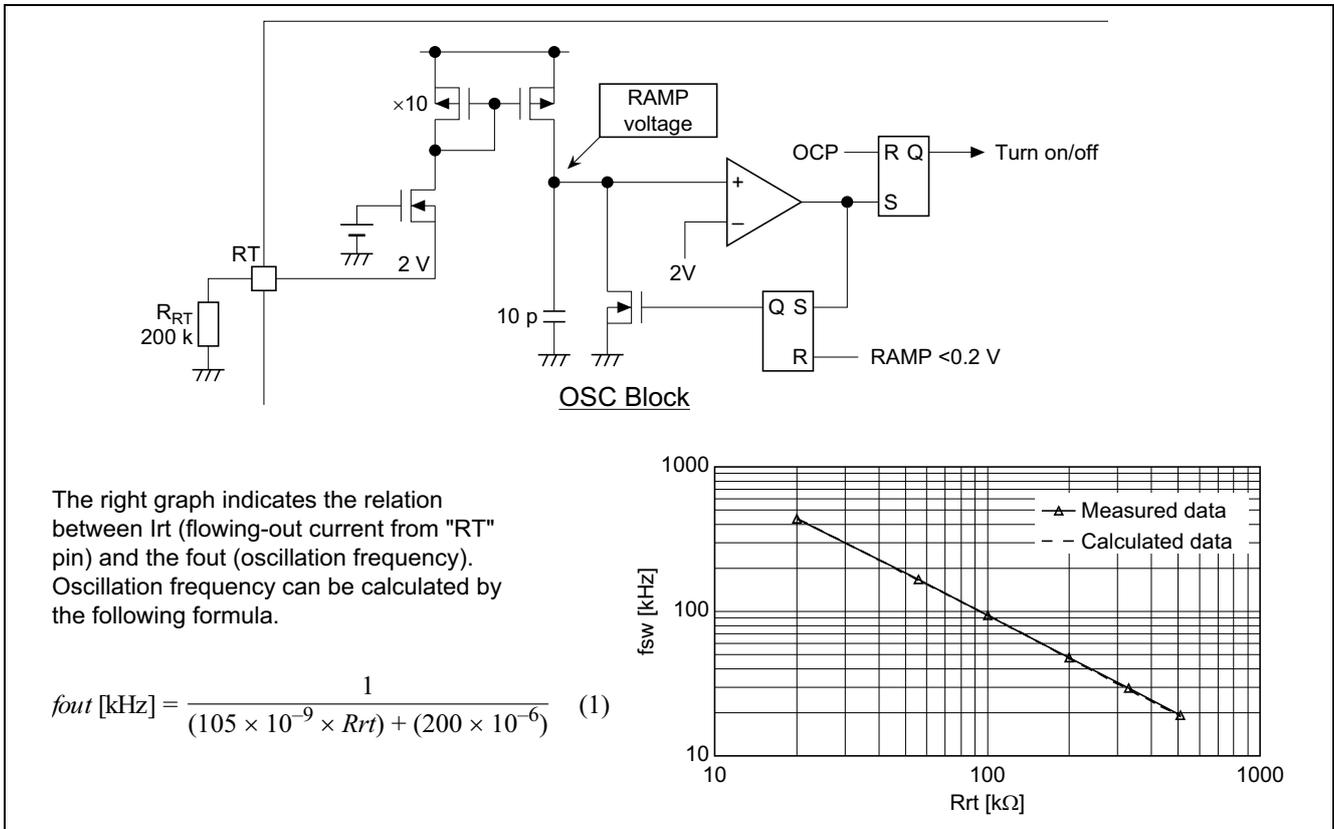
#### 3.2 RAMP Slope

The inclination of a RAMP waveform is decided by capacity of 10 pF with an internal fixed current and built-in IC. The charge current to 10 pF is 1  $\mu$ A in IC. When the output voltage of error amplifier is 4 V typ, the maximum ON time tonmax comes. A ZCD detector circuit detects the zero electric current of an inductor, and also the charge start to the RAMP capacity by a RAMP circuit is performed when a RAMP pin is less than 0.2 V. If a RAMP signal reaches to the output voltage of error amplifier, discharge of the capacity of the RAMP section will be carried out. Moreover, ON time will become zero if COMP voltage becomes less than 1 V.



### 3.3 Built-in Oscillator

If  $R_{rt}$  resistance is connected with RT pin between GND, it will become Fixed Switching Frequency mode and the internal oscillator will operate. An internal oscillator determines the on-timing of switching. The maximum ON-duty will be 50% when switching frequency is 48 kHz.



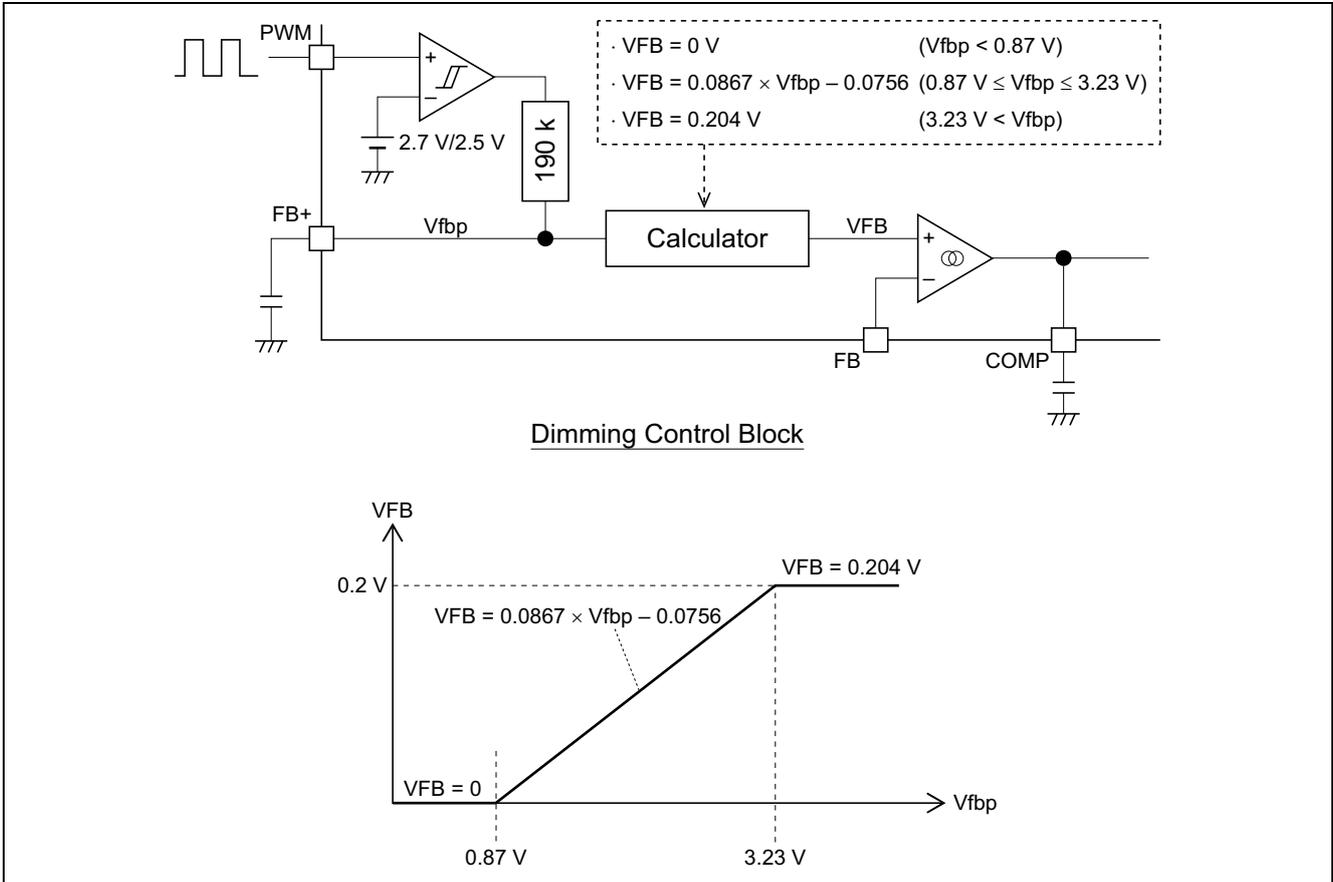
### 3.4 Error Amplifier

Trans-conduction amplifier is used as error amplifier inside. Its output current is defined by voltage difference between internal reference voltage and the voltage of "FB" pin.

### 3.5 Dimming Function

This IC fluctuates the reference voltage of error amplifier to the ON-duty of the signal inputted into a PWM pin, and controls the luminosity of LED.

An ON-duty signal is inputted from a PWM pin, and smooth is carried out within IC, and it is outputted from FB+ pin. The voltage value of FB+ at this time determines the reference voltage of error amplifier.

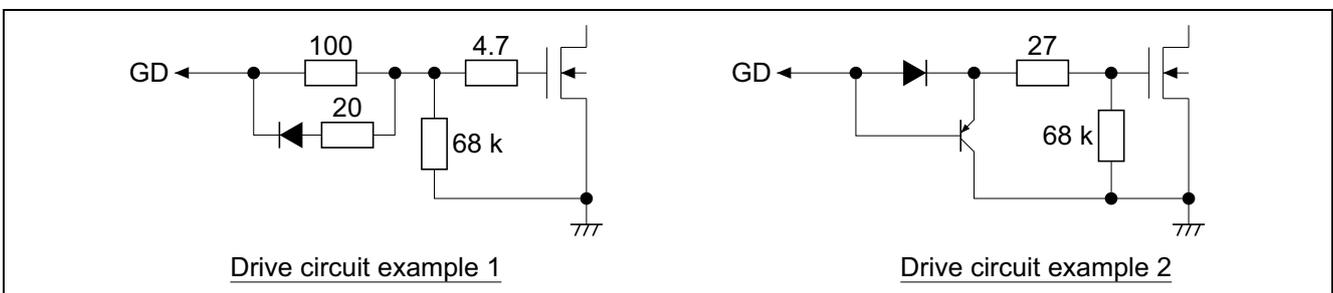


### 3.6 Output Pin to Drive External MOSFET

Totem pole output circuit is built in at "GD" pin. The Maximum drive current is 900 mA (peak).

Basically it can drive MOSFET directly, but adjustment of suitable driver circuit for each MOSFET is recommended.

In order that the IC may operate by zero-current switching, the speed of turn-off influences a loss. The example of drive circuits shown in the following figure.



## 4. The Example of an Application Circuit

### 4.1 Operation of Buck Converter/Fixed Switching Frequency Mode, and a Constant Setup

The circuit diagram of Buck converter/Fixed Switching Frequency Mode using R2A20135 is shown below.

#### (1) Current Sense Circuit

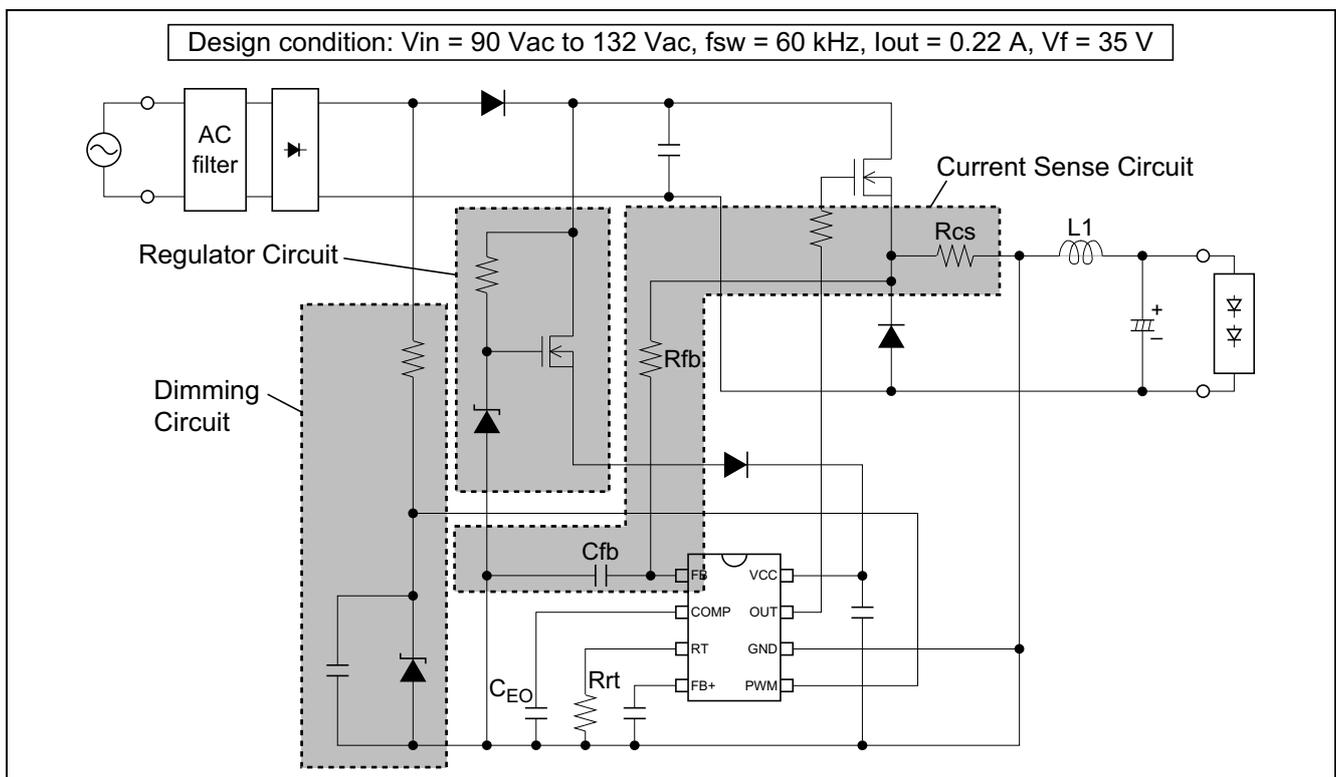
Inductor current is transformed into voltage by the current sensing resistance  $R_{cs}$  connected in series to the inductor. Inductor current (output current) is controlled by inputting this into FB pin.

#### (2) Regulator Circuit

The voltage determined by  $V_{th}$  of zener voltage and MOS is supplied to IC.

#### (3) Dimming Circuit

ON-duty is detected from the output of dimmer control, and it inputs into a PWM pin. The control signal of output current is generated from a duty signal.



### 4.2 Determination of the Main Circuit Constants

#### <Selection of $R_{cs}$ >

Target output current determines the current sensing resistor  $R_{cs}$ .

Since it is  $0.204\text{V}$ , the internal reference voltage of error amplifier is an expression of relations with the output current  $I_{out}$  and  $R_{cs}$ ,

$$R_{cs} = 0.204/I_{out}$$

$R_{cs}$  in the case of being referred to as  $I_{out} = 0.22 \text{ A}$  of a design condition is set to  $R_{cs} = 0.204/0.22 = 0.93 \text{ } [\Omega]$ .

#### <Selection of $R_{rt}$ >

RT pin external resistance  $R_{rt}$  is determined from the target switching frequency  $f_{sw}$ .

Since the desired value of  $f_{sw}$  is  $60 \text{ kHz}$ ,

$$R_{rt} \text{ [k}\Omega\text{]} = \frac{(1/f_{out}[\text{kHz}]) - (200 \times 10^{-6})}{105 \times 10^{-9}} = 157 \text{ k}\Omega$$

The resistance of  $150 \text{ k}\Omega$  which can be chosen from this result is selected.

## &lt;Selection of the inductance L&gt;

It is necessary to set to current discontinuous operation in fixed frequency mode. Let the maximum of L1 be a value which becomes current critical mode. For this reason, the value of L1 used as current critical mode is calculated. In the case of Buck converter, it cannot operate on the conditions that input voltage is lower than output voltage.

The time rate (conduction angle) that current is actually supplied,

$$1 - 2 \times \text{Arcsin}(35 \text{ V}/(90 \text{ V} \times 1.414))/\pi = 82\% \quad (2)$$

and average supplied current results in  $220 \text{ mA}/0.82 = 268 \text{ mA}$ .

At this moment, peak current that flows to Rcs is the peak current of triangle waveform in critical conduction mode operation, it is two times of average current, that is  $536 \text{ mA}$ .

Maximum value is about 1.4 times and it results in  $536 \text{ mA} \times 1.4 = 0.75 \text{ A}$ , because this is current waveform of power factor correction.

On-duty of MOSFET at this moment is  $35 \text{ V}/(90 \times 1.414) = 0.275$ . So, Ton results in  $T_{\text{on}} = 0.275/62 \text{ kHz} = 4.4 \mu\text{s}$ .

On the other hand,

$$L = (V_{\text{in}} - V_{\text{out}}) \times \Delta T/\Delta I = (127 \text{ V} - 35 \text{ V}) \times 4.4 \mu\text{s}/0.759 \text{ A} = 533 \mu\text{H}$$

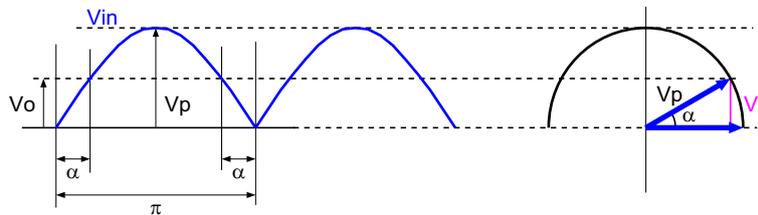
L1 is set to  $533 \mu\text{H}$  at the maximum.

As mentioned above, Li selects a thing smaller than  $533 \mu\text{H}$ .

How to draw a formula

The time rate that current is flowing only during the  $\pi - 2\alpha$ ,

$$(\pi - 2\alpha)/\pi = 1 - 2\alpha/\pi$$



When Vpk is considered by the unit circle made into a radius, alpha is as follows during the period when current does not flow.

$$\alpha = \arcsin(V_o/V_{pk})$$

If it substitutes for the above-mentioned formula

$$1 - 2 \times \arcsin(V_o/V_{pk})/\pi$$

<A setup of the loop filter of return amplifier>

The frequency characteristic of R2A20135EVB-ND1 is shown in the following figure.

Since this is the composition in current mode (single capacity lag system), it operates stably, but in order to improve power factor, please set up the value of Ccomp so that a loop gain is set to 0 dB below by AC frequency: 50 to 60 Hz twice (100 to 120 Hz). The value of Ccomp is set to 1 μF with the evaluation board.

Moreover, CR filter (Cf1, Rf1) can be inserted in FB pin and output current can be kept constant in a wide input voltage range because below the minimum switching frequency  $f_{MIN}$  carries out the pole p0 of CR filter.

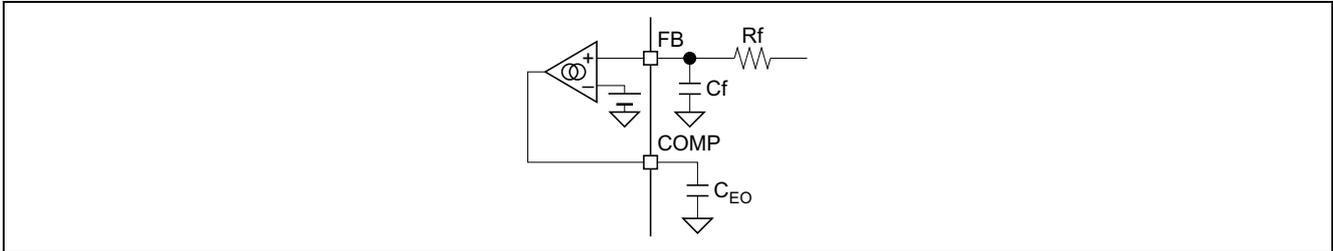


Figure 4.1 FB, COMP External Circuitry

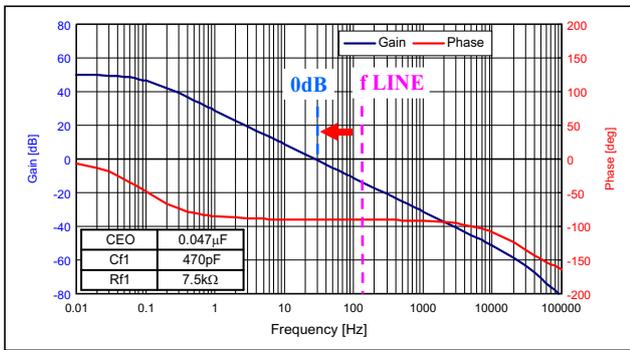


Figure 4.2 The Frequency Characteristic of R2A20135EVB-ND1

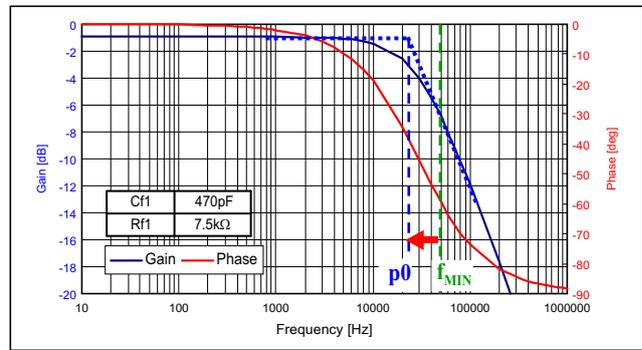


Figure 4.3 The Frequency Characteristic of a FB Pin CR Filter

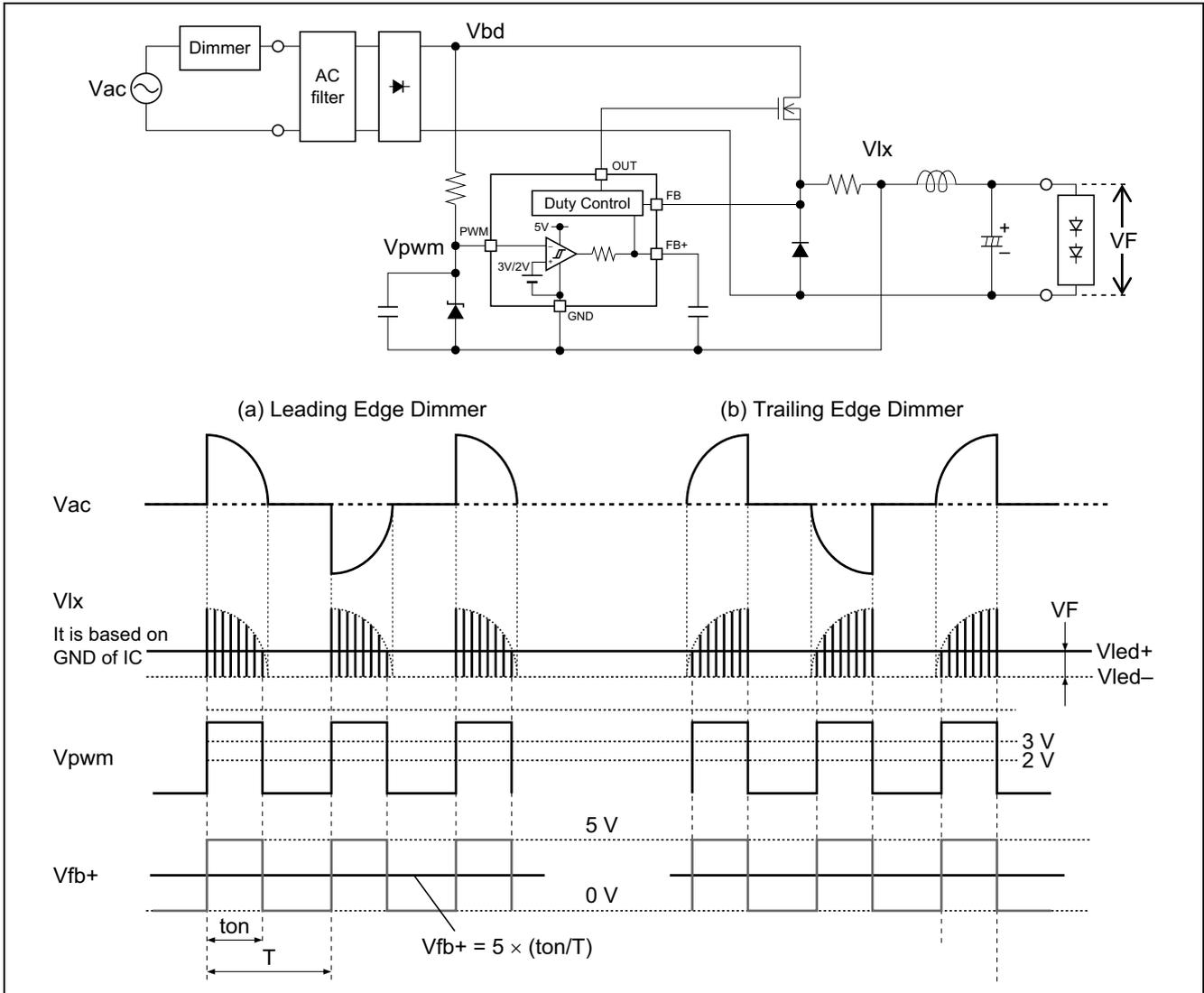
### 4.3 R2A20135EVB-ND1 Operation of the Circuit Corresponding to Dimmer Control

<The phase of dimmer control is detected>

R2A20135 detects VAC's phase angle and changes it into the reference voltage of error amplifier from this Duty information.

And since output current is controlled according to this reference voltage, it can respond to both leading edge dimmer control and trailing edge dimmer control.

The circuit and phase control wave form chart of a phase primary detecting element at the time of using dimmer control are shown.



Vix is the reference voltage of IC in the ON period of dimmer control. It changes in the range of Vbd to Vled- by switching operation.

The filter of this voltage is carried out in a PWM external part, and it takes into a PWM pin as information on Duty. Furthermore, a filter is carried out by the capacity by which external was carried out to FB pin.

Based on this FB voltage by which smooth was carried out, the reference voltage of error amplifier is determined and it is controlled to become output current according to reference voltage.

In addition, please see "3.5 Dimming Function" about the relation between FB+ voltage and error amplifier reference voltage.

## Website and Support

Renesas Electronics Website

<http://www.renesas.com/>

Inquiries

<http://www.renesas.com/contact/>

All trademarks and registered trademarks are the property of their respective owners.

## Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	May 24, 2012	—	First edition issued
2.00	Jul 24, 2013	1	"2.1 Critical Conduction Mode ("RT" pin is Open)" is corrected

## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
  2. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
  3. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
  4. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from such alteration, modification, copy or otherwise misappropriation of Renesas Electronics product.
  5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The recommended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.  
  
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots etc.  
  
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; and safety equipment etc.  
  
Renesas Electronics products are neither intended nor authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems, surgical implantations etc.), or may cause serious property damages (nuclear reactor control systems, military equipment etc.). You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application for which it is not intended. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for which the product is not intended by Renesas Electronics.
  6. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
  7. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or systems manufactured by you.
  8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
  9. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You should not use Renesas Electronics products or technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. When exporting the Renesas Electronics products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations.
  10. It is the responsibility of the buyer or distributor of Renesas Electronics products, who distributes, disposes of, or otherwise places the product with a third party, to notify such third party in advance of the contents and conditions set forth in this document, Renesas Electronics assumes no responsibility for any losses incurred by you or third parties as a result of unauthorized use of Renesas Electronics products.
  11. This document may not be reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
  12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.  
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.



### SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

**Renesas Electronics America Inc.**  
2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.  
Tel: +1-408-588-6000, Fax: +1-408-588-6130

**Renesas Electronics Canada Limited**  
1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada  
Tel: +1-905-898-5441, Fax: +1-905-898-3220

**Renesas Electronics Europe Limited**  
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K  
Tel: +44-1628-651-700, Fax: +44-1628-651-804

**Renesas Electronics Europe GmbH**  
Arcadiastrasse 10, 40472 Düsseldorf, Germany  
Tel: +49-211-65030, Fax: +49-211-6503-1327

**Renesas Electronics (China) Co., Ltd.**  
7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, P.R.China  
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

**Renesas Electronics (Shanghai) Co., Ltd.**  
Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China  
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

**Renesas Electronics Hong Kong Limited**  
Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong  
Tel: +852-2886-9318, Fax: +852 2886-9022/9044

**Renesas Electronics Taiwan Co., Ltd.**  
13F, No. 363, Fu Shing North Road, Taipei, Taiwan  
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

**Renesas Electronics Singapore Pte. Ltd.**  
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre Singapore 339949  
Tel: +65-6213-0200, Fax: +65-6213-0300

**Renesas Electronics Malaysia Sdn.Bhd.**  
Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia  
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

**Renesas Electronics Korea Co., Ltd.**  
11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea  
Tel: +82-2-558-3737, Fax: +82-2-558-5141