R2A20135SP

Application Note

R19AN0011EJ0100
Rev.1.00
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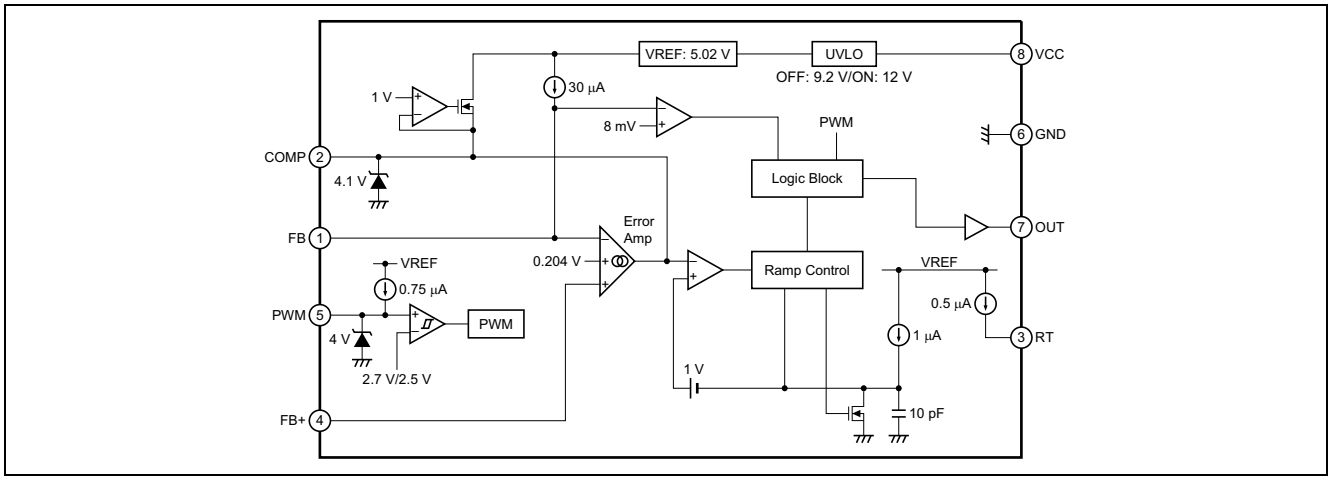
1. General Description

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

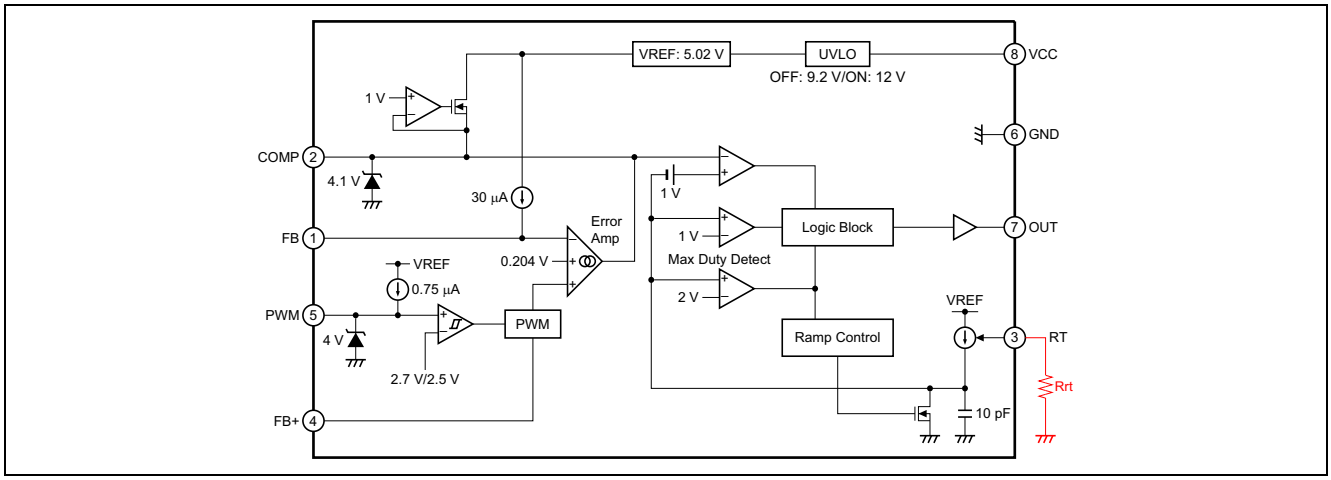
2.1 Critical Conduction Mode ("RT" pin is Open)

When you connect Rrt 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 Rrt 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 Rrt.



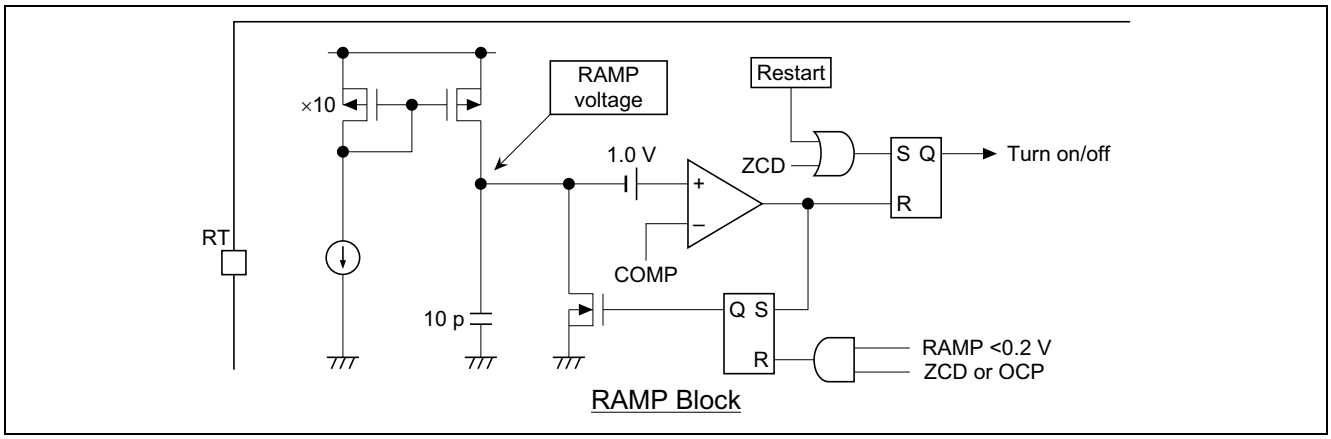
3. Explanation of Each Circuit Block

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 μs.

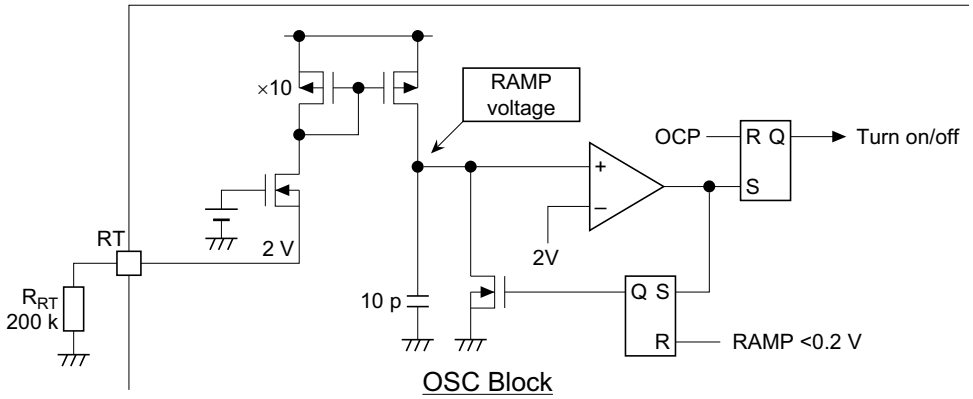
3.2 RAMP Slope

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 μA 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

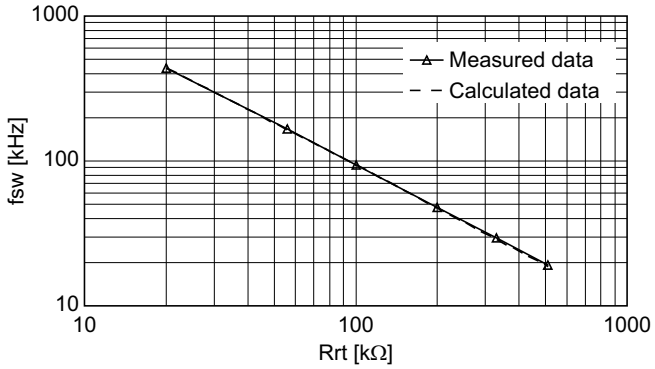
If Rrt resistance is connected with RT pin between GND, it will become Fixed Switching Frequency mode and the internal oscillator will operate. An internal oscillator determines the on-timing of switching. The maximum ON-duty will be 50% when switching frequency is 48 kHz.



OSC Block

The right graph indicates the relation between Irt (flowing-out current from "RT" pin) and the fout (oscillation frequency). Oscillation frequency can be calculated by the following formula.

$$fout\ [\text{kHz}] = \frac{1}{(105 \times 10^{-9} \times Rrt) + (200 \times 10^{-6})} \quad (1)$$

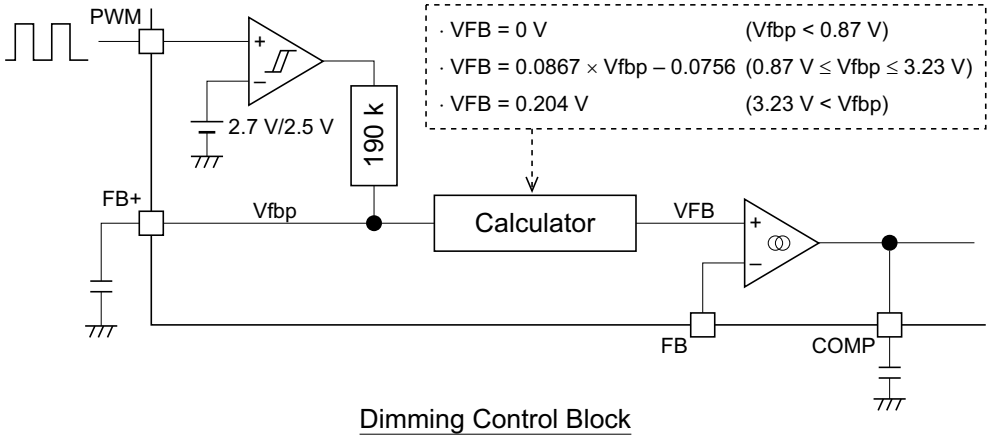


3.4 Error Amplifier

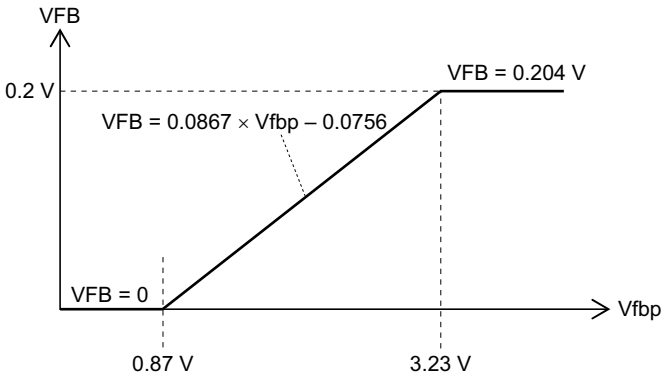
Trans-conduction amplifier is used as error amplifier inside. Its output current is defined by voltage difference between internal reference voltage and the voltage of "FB" pin.

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.

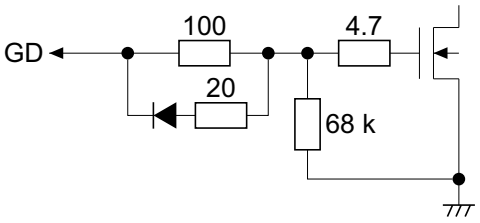


Dimming Control Block

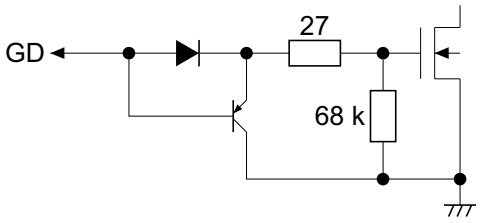


3.6 Output Pin to Drive External MOSFET

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



Drive circuit example 1



Drive circuit example 2

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

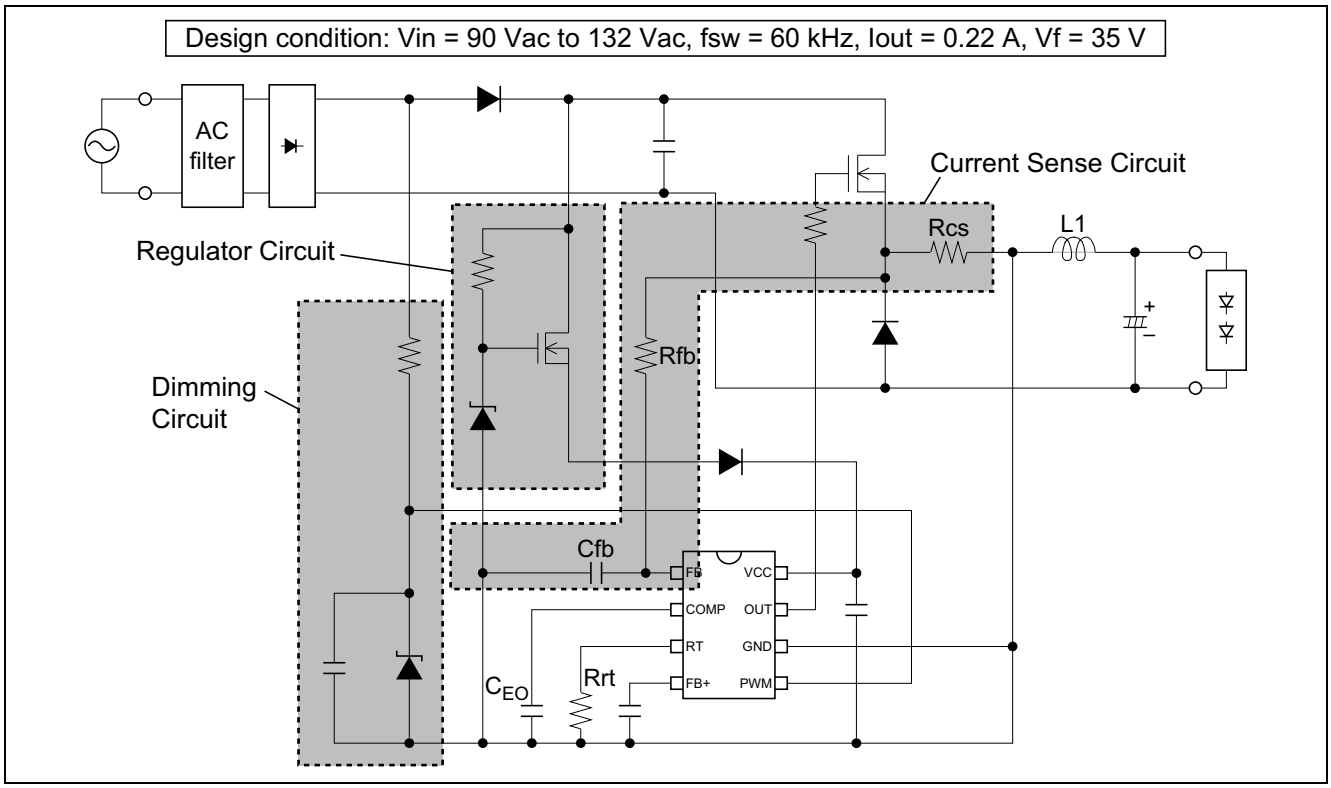
Inductor current is transformed into voltage by the current sensing resistance Rcs connected in series to the inductor. Inductor current (output current) is controlled by inputting this into FB pin.

(2) Regulator Circuit

The voltage determined by Vth 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 Rcs>

Target output current determines the current sensing resistor Rcs.

Since it is 0.204V, the internal reference voltage of error amplifier is an expression of relations with the output current Iout and Rcs,

$$Rcs = 0.204/Iout$$

Rcs in the case of being referred to as Iout = 0.22 A of a design condition is set to Rcs = 0.204/0.22 = 0.93 [Ω].

<Selection of Rrt>

RT pin external resistance Rrt is determined from the target switching frequency fsw.

Since the desired value of fsw is 60 kHz,

$$Rrt\ [k\Omega] = \frac{(1/fout[kHz]) - (200 \times 10^{-6})}{105 \times 10^{-9}} = 157\ k\Omega$$

The resistance of 150 kHz which can be chosen from this result is selected.

<Selection of the inductance L>

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 mA/0.82 = 268 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 mA.

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

On-duty of MOSFET at this moment is 35V/(90 × 1.414) = 0.275. So, Ton results in Ton = 0.275/62 kHz = 4.4 μs. On the other hand,

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

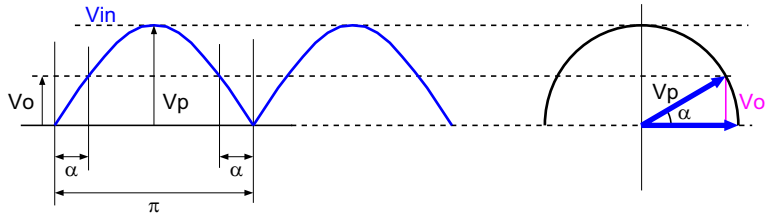
L1 is set to 533 μH at the maximum.

As mentioned above, Li selects a thing smaller than 533 μH.

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.

$\alpha = \arcsin(\text{Vo}/\text{Vpk})$

If it substitutes for the above-mentioned formula

$1 - 2 \times \arcsin(\text{Vo}/\text{Vpk})/\pi$

<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.

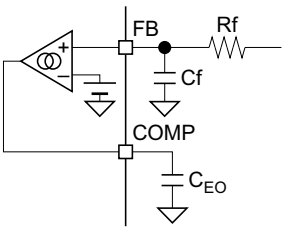


Figure 4.1 FB, COMP External Circuitry

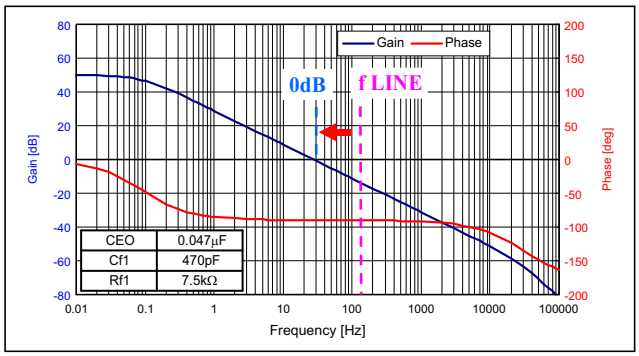


Figure 4.2 The Frequency Characteristic of R2A20135EVB-ND1

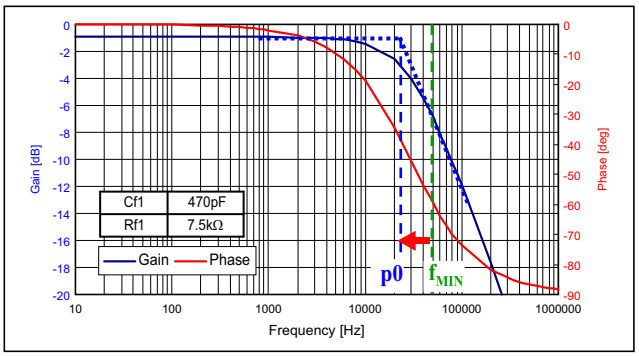


Figure 4.3 The Frequency Characteristic of a FB Pin CR Filter

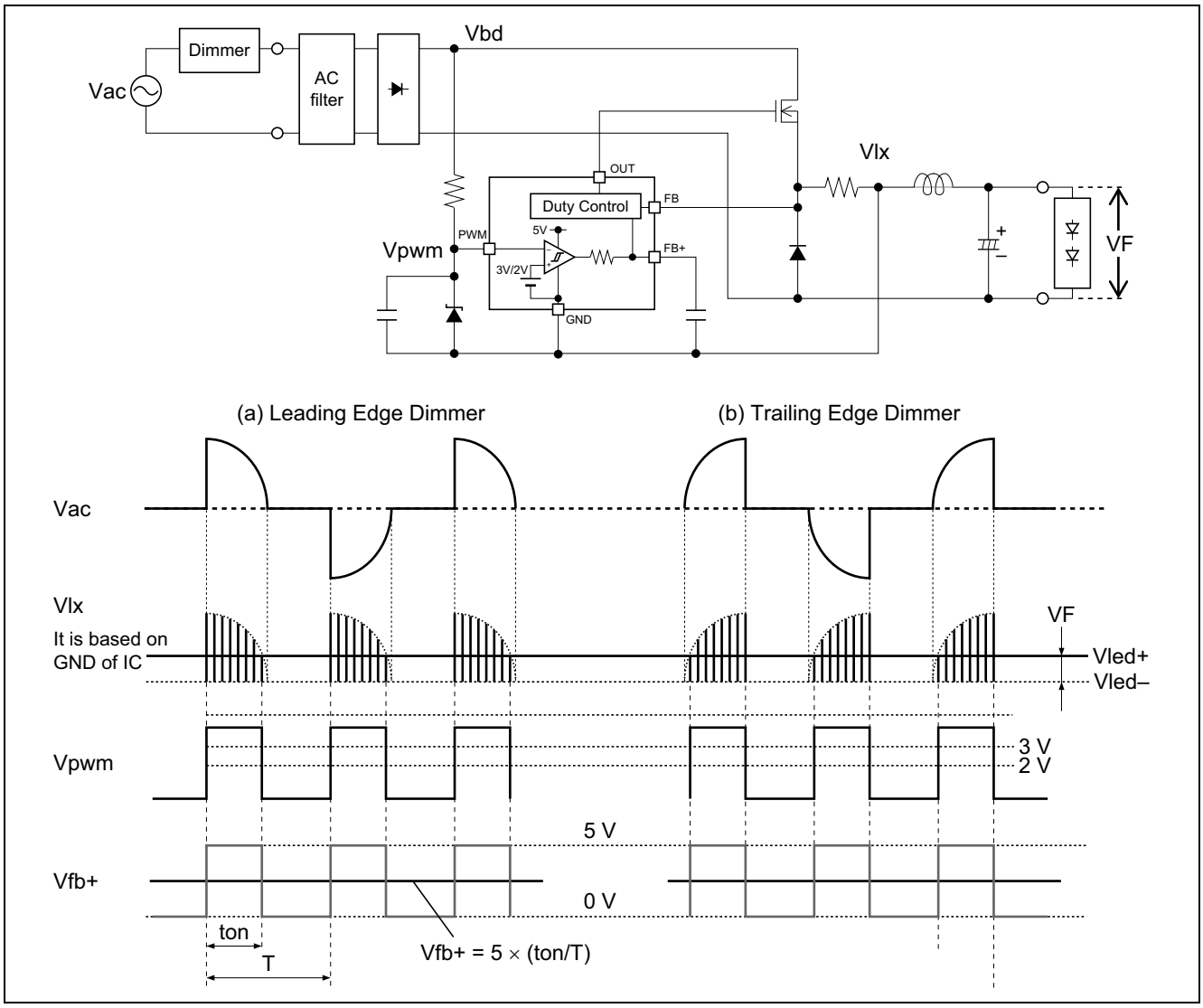
4.3 R2A20135EVB-ND1 Operation of the Circuit Corresponding to Dimmer Control

<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.



Vlx 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.

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Revision Record

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		Page	Summary
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