

RAA223021

700V AC/DC Buck Regulator with Ultra-Low Standby Power

The RAA223021 is a universal input AC/DC switching buck regulator with ultra-low standby power that features a 700V integrated MOSFET capable of delivering up to 8W output power. It supports output voltage as low as 5V.

The RAA223021 combines constant off-time control for heavy load and Pulse Frequency Modulation (PFM) for light-load operation. Constant off-time controls switching frequency above the audible frequency around 43kHz. PFM eliminates any potential audible noises while offering superior light-load efficiency and ultra-low power consumption (<20mW at no load). The efficiency is achieved up to 80%. The built-in frequency dithering further reduces EMI noise spectrum.

The RAA223021 also features input brownout protection that prevents input circuitry from the overcurrent at low input voltage, and hiccup protections for output fault conditions such as short-circuit, overload, overvoltage, and open feedback.

The RAA223021 is available in a small 7 Ld SOIC package.

Features

- Ultra-low standby power (<20mW)
- No audible noise
- Low quiescent current (<80μA)
- Output voltage as low as 3.3V
- Low EMI with frequency dithering
- 7 Ld SOIC package
- Programmable PFM allows optimization of C<sub>OUT</sub> for various standby power requirements
- Protection features: Short-Circuit Protection (SCP), Overload Protection (OLP), Overvoltage Protection (OVP), open feedback protection, and Over-Temperature Protection (OTP).

Applications

- Home appliances
- Home automation, IoT, and sensors
- Metering and Industry control
- Bias power

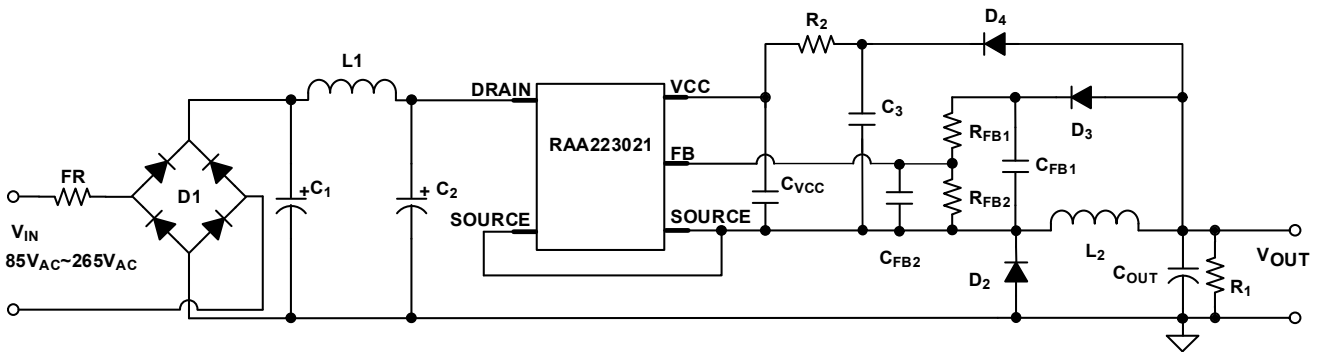


Figure 1. Typical RAA223021 Buck Application Circuit

Table 1. Maximum Output Current (Maximum Ambient 85°C)

Output Setting Voltage (V)	120V <sub>AC</sub>	230V <sub>AC</sub>	90V <sub>AC</sub> ~265V <sub>AC</sub>
3.3	0.67A	0.58A	0.56A
5	0.67A	0.66A	0.6A
9	0.64A	0.6A	0.56A
12	0.56A	0.54A	0.5A
15	0.56A	0.52A	0.5A
24	0.49A	0.5A	0.46A

## Contents

<b>1. Overview</b>	<b>4</b>
1.1 Block Diagram	4
<b>2. Pin Information</b>	<b>5</b>
2.1 Pin Assignments	5
2.2 Pin Descriptions	5
<b>3. Specifications</b>	<b>6</b>
3.1 Absolute Maximum Ratings	6
3.2 Thermal Information	6
3.3 Recommended Operating Conditions	6
3.4 Electrical Specifications	7
<b>4. Typical Characterization Graphs</b>	<b>9</b>
<b>5. Detailed Description</b>	<b>12</b>
5.1 Constant Off-Time Mode	12
5.2 PFM Mode	12
5.3 Output Voltage Sampling	13
5.4 Soft Start-Up	13
5.5 Overload Protection	14
5.6 Short-Circuit Protection	14
<b>6. Application Topologies</b>	<b>16</b>
<b>7. Design Guidance</b>	<b>17</b>
7.1 Feedback Resistor Selection	17
7.2 Output Inductor Selection	17
7.3 Feedback Capacitor (CFB1) Selection	17
7.4 Output Capacitor Selection	18
7.5 Bias Capacitor Selection	19
7.6 Dummy Resistor Selection	20
7.7 Power Capability	20
7.8 PCB Layout Guidance	20
<b>8. EMI Performance</b>	<b>21</b>
<b>9. Package Outline Drawing</b>	<b>22</b>
<b>10. Ordering Information</b>	<b>23</b>
<b>11. Revision History</b>	<b>23</b>

# 1. Overview

## 1.1 Block Diagram

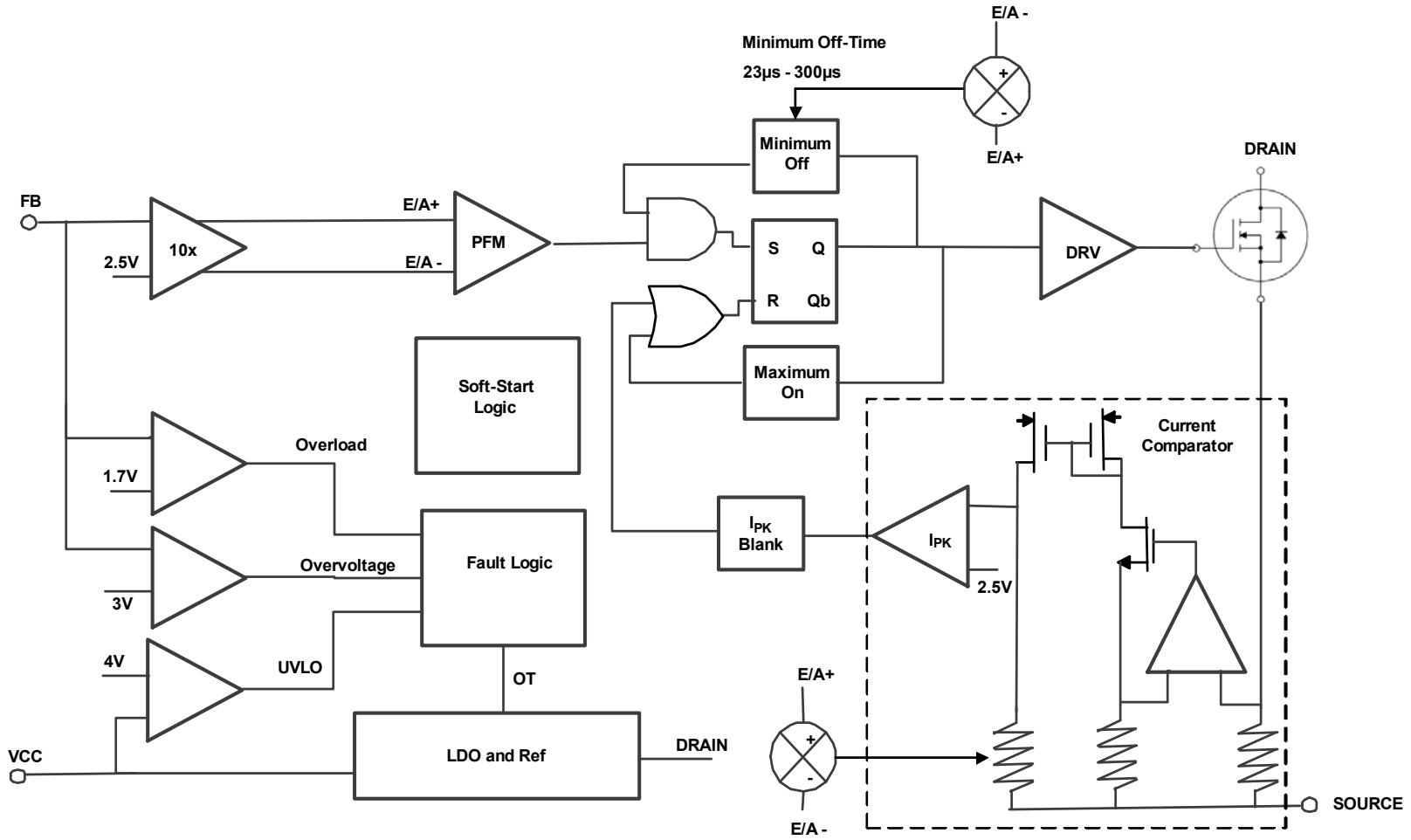
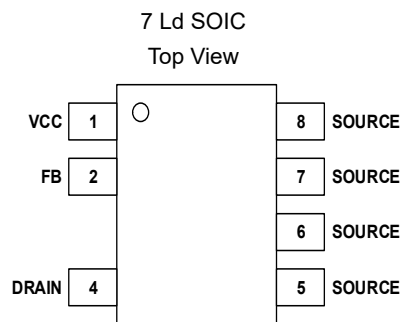


Figure 2. Block Diagram of RAA223021

## 2. Pin Information

### 2.1 Pin Assignments



### 2.2 Pin Descriptions

Pin Number	Pin Name	Description
1	VCC	IC supply voltage
2	FB	Feedback pin
4	DRAIN	Internal power MOSFET drain
5-8	SOURCE	Internal power MOSFET source

### 3. Specifications

#### 3.1 Absolute Maximum Ratings

**CAUTION:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions can adversely impact product reliability and result in failures not covered by warranty.

Parameter	Minimum	Maximum	Unit
VCC	-0.3	+6.5	V
VFB	-0.3	+6.5	V
DRAIN (to SOURCE)	- 0.3	700V	V
Continuous Power Dissipation (T <sub>A</sub> = +25°C)		1	W
ESD Rating	Value		Unit
Human Body Model (Tested per JS-001-2017)	1.2		kV
Charged Device Model (Tested per JS-002-2014)	1		kV
Latch-Up (Tested per JESD78E; Class 2, Level A)	100		mA

#### 3.2 Thermal Information

Thermal Resistance (Typical)	$\theta_{JA}$ (°C/W) <sup>[1]</sup>	$\theta_{JC}$ (°C/W) <sup>[2]</sup>
7 Ld SOIC	50	23

1.  $\theta_{JA}$  is measured in free air with the component mounted on a 1-layer test board with thermal copper 555mm<sup>2</sup> in size and 1oz Cu (35µm) thickness.
2. For  $\theta_{JC}$ , the case temperature location is taken at the package top center.

Parameter	Minimum	Maximum	Unit
Maximum Junction Temperature		+150	°C
Maximum Storage Temperature Range	-60	+150	°C
Pb-Free Reflow Profile	See <a href="#">TB493</a>		

#### 3.3 Recommended Operating Conditions

Parameter	Minimum	Maximum	Unit
Supply Voltage, V <sub>DRAIN</sub>		375	V
Ambient Temperature	-40	+85	°C
Output Voltage	3.3		V

### 3.4 Electrical Specifications

Typical operating conditions at 25°C,  $V_{DRAIN} = 100V$ ,  $V_{CC} = 5.6V$ ,  $T_J = -40$  to  $+125^\circ C$ , unless otherwise specified.

Parameter	Symbol	Test Conditions	Min <sup>[1]</sup>	Typ	Max <sup>[1]</sup>	Unit
<b>Startup and Power FET</b>						
Internal $V_{CC}$ Startup Current	$I_{VCC\_START}$	$V_{CC} = 4V$		2.5		mA
Drain Leakage Current	$I_{D\_LEAK}$	$V_{CC} = 0V$ , $V_{DRAIN} = 325V$ , $V_{FB} = 2.6V$		1		$\mu A$
$I_{DRAIN}$ Bias	$I_{D\_BIAS}$	$V_{DRAIN} = 375V$			10	$\mu A$
Power FET Breakdown Voltage	$V_{DS(BR)}$	$T_J = 25^\circ C$	700			V
Power FET On-Resistance	$r_{DS(ON)}$	$T_J = 25^\circ C$ , $I_{DS} = 30mA$ , $V_{CC} = 5.8V$		4	5.5	$\Omega$
		$T_J = 125^\circ C$		7	8.5	$\Omega$
<b><math>V_{CC}</math> Supply</b>						
$V_{CC}$ Start (Rising)	$V_{CC\_START}$		5.6	6	6.4	V
$V_{CC}$ when Internal Regulator Off	$V_{CC\_OFF}$		5.6	6	6.4	V
$V_{CC}$ (Falling) Regulator On at Startup	$V_{CC\_ON}$		5.45	5.9	6.25	V
Internal $V_{CC}$ On/Off Hysteresis	$V_{CC\_HYS}$		0.10	0.15		V
$V_{CC}$ (Falling) Regulator On after Startup	$V_{CC\_ON\_SS}$		4.3	4.5	4.9	V
$V_{CC}$ Undervoltage Threshold (Falling)	$V_{CC\_UVLO}$	IC stop switching	3.8	4	4.4	V
$V_{CC}$ Shunt Regulator On (Rise)	$V_{CC\_SON}$	External $V_{CC}$ supply, internal shunt on		6.2	6.5	V
$V_{CC}$ Shunt Regulator Off (Fall)	$V_{CC\_SOFF}$	External $V_{CC}$ supply, internal shunt off		6.1	6.45	V
$V_{CC}$ Quiescent Current	$I_{VCC\_Q}$	$V_{FB} > 2.5V$ , no switching		80	125	$\mu A$
$V_{CC}$ Current During Switching	$I_{VCC}$	$V_{FB} < 2.5V$ , switching frequency = 43kHz, $D = 0.15$ , $V_{CC} = V_{CC\_ON} + 0.1V$		225	325	$\mu A$
$V_{CC}$ Discharging Current Hiccup Timing	$I_{QVCC3}$	$V_{CC}$ discharge timing for fault hiccup delay		20	33	$\mu A$
<b>Current Sense</b>						
Peak Current Limit	$I_{PK}$	$di/dt = 600mA/\mu s$ , $T_J = 25^\circ C$ , $V_{CC} = 5.8V$	875	1100	1325	mA
SCP Threshold <sup>[2]</sup>	$I_{SC\_TH}$			1.73		A
Minimum Peak Current	$I_{PKMIN}$	$V_{IN} = 85V_{AC}$ , $I_{OUT} = 0$ , $V_{CC} = 5.8V$		158		mA
Leading Edge Blank Time	$t_{LEB}$	$T_J = 25^\circ C$ , $V_{CC} = 5.8V$	200	250		ns
<b>Feedback</b>						
Feedback Voltage	$V_{FB}$	$T_J = 25^\circ C$ , $V_{CC} = 5.8V$	2.4	2.5	2.64	V
Transconductance	GM	$I_{PK}$ GM, $V_{CC} = 5.8V$		22		S
Feedback Undervoltage Threshold	$V_{FBUV}$	$V_{CC} = 5.7V$	1.6	1.7	1.8	V
Feedback Threshold for Increased Off-Time	$V_{FB\_TOFFMIN}$	$V_{CC} = 5.0V$		0.88		V
Feedback Overvoltage	$V_{FBOV}$		2.8	3	3.35	V
<b>Timing</b>						
Minimum Off-Time	$t_{OFF\_MIN}$	$V_{CC} = 5.0V$	18	23	32	$\mu s$

Typical operating conditions at 25°C,  $V_{DRAIN} = 100V$ ,  $V_{CC} = 5.6V$ ,  $T_J = -40$  to  $+125^\circ C$ , unless otherwise specified.

Parameter	Symbol	Test Conditions	Min <sup>[1]</sup>	Typ	Max <sup>[1]</sup>	Unit
Maximum On-Time	$t_{ON\_MAX}$	$V_{CC} = 5.0V$	11	14	18	$\mu s$
Minimum Off-Time in Short-Circuit	$t_{OFFMIN\_SC}$	$V_{CC} = 5.0V$		150		$\mu s$
Hiccup Restart Delay	$t_{HICC}$	$C_{VCC} = 1\mu F$		90		ms
OLP Timer	$t_{OLP}$	$f_{SW} = 43kHz$ , $V_{FB} < 1.7V$ , $V_{CC} = 5.0V$		1032		cycle
<b>Thermal</b>						
Over-Temperature Threshold	$OTP_{TH}$			150		$^\circ C$
Over-Temperature Hysteresis	$OTP_{HYS}$			45		$^\circ C$

1. Compliance to datasheet limits is assured by one or more methods: production test, characterization, and/or design.
2. Compliance to limits is established by design.



## 4. Typical Characterization Graphs

Typical operating conditions at 25°C,  $V_{DRAIN} = 100V$ ,  $V_{CC} = 5.6V$ ,  $V_{OUT} = 12V$ ,  $I_{OUT} = 667mA$ ,  $L2 = 680\mu H$ ,  $C_{OUT} = 330\mu F$ , unless otherwise specified.

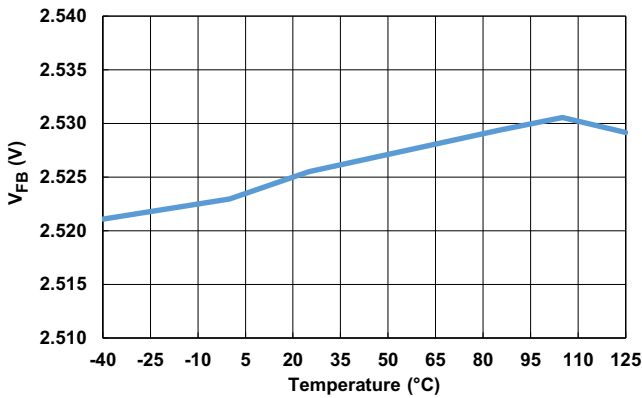


Figure 3. Feedback Voltage vs Temperature

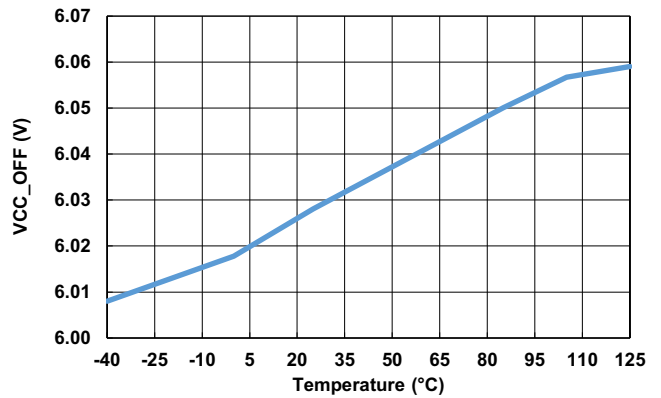


Figure 4. V<sub>CC</sub> Start/Upper Limit vs Temperature

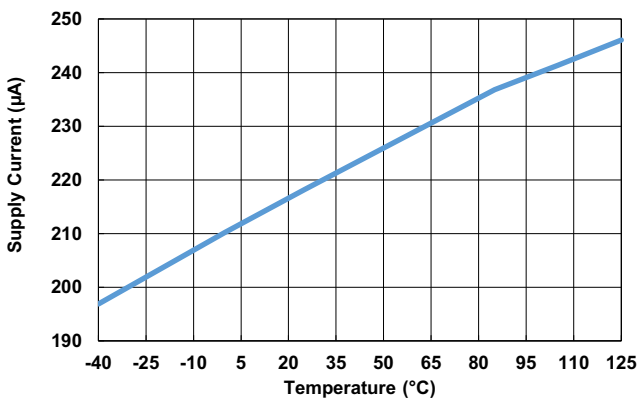


Figure 5. IC Supply Current vs Temperature

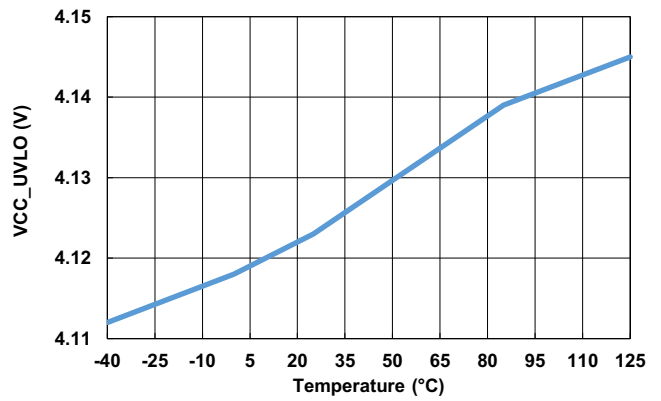


Figure 6. V<sub>CC</sub> Undervoltage Threshold vs Temperature

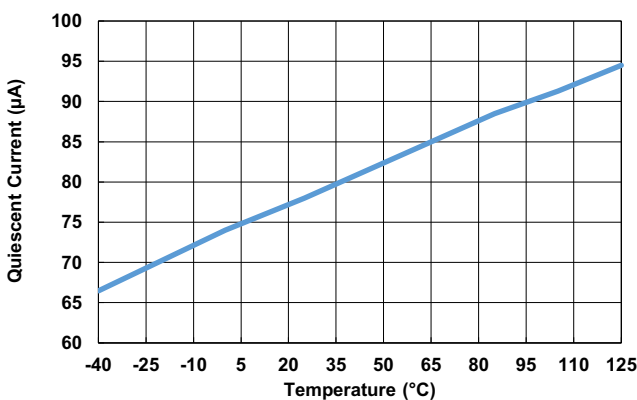


Figure 7. IC Quiescent Current vs Temperature

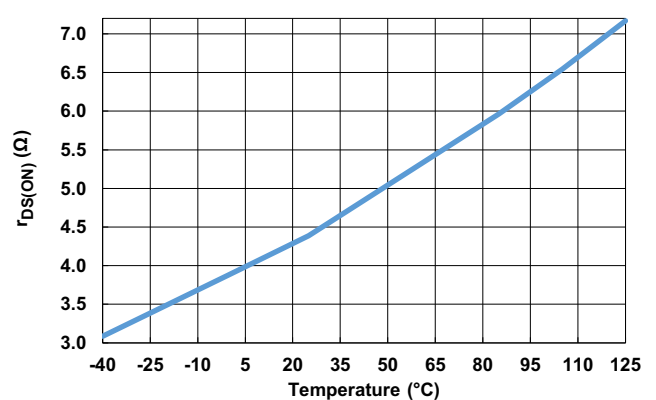


Figure 8. On-Resistance vs Temperature

Typical operating conditions at 25°C,  $V_{DRAIN} = 100V$ ,  $V_{CC} = 5.6V$ ,  $V_{OUT} = 12V$ ,  $I_{OUT} = 667mA$ ,  $L_2 = 680\mu H$ ,  $C_{OUT} = 330\mu F$ , unless otherwise specified. (Cont.)

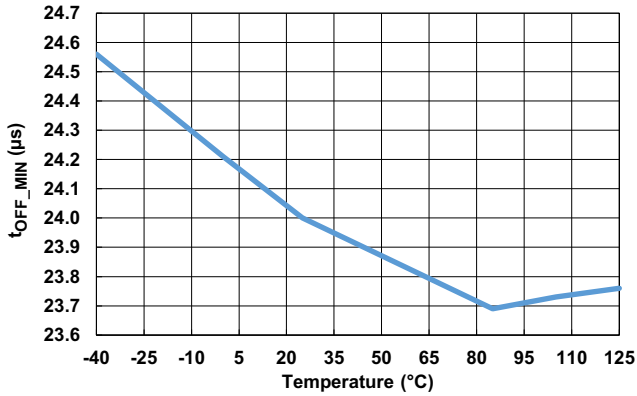


Figure 9. Minimum Off-Time vs Temperature

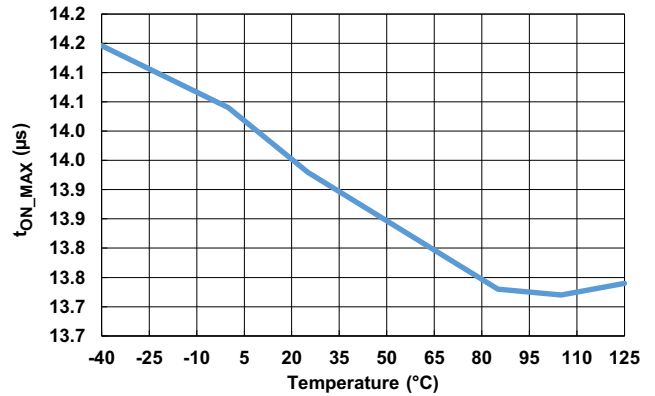


Figure 10. Maximum On-Time vs Temperature

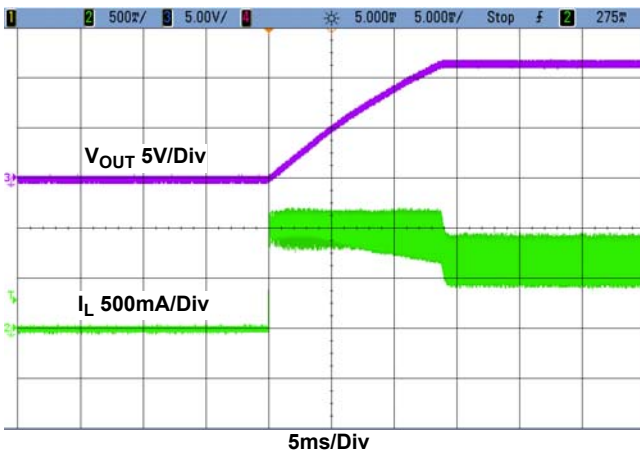


Figure 11. Startup ( $V_{IN} = 230V_{AC}$ )

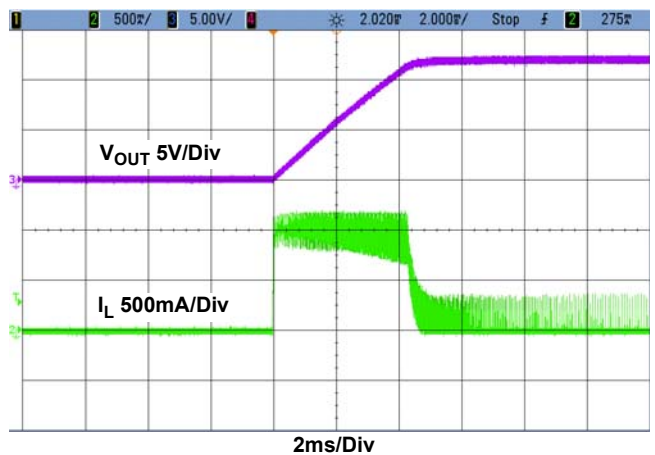


Figure 12. Startup ( $V_{IN} = 230V_{AC}$ , No Load)

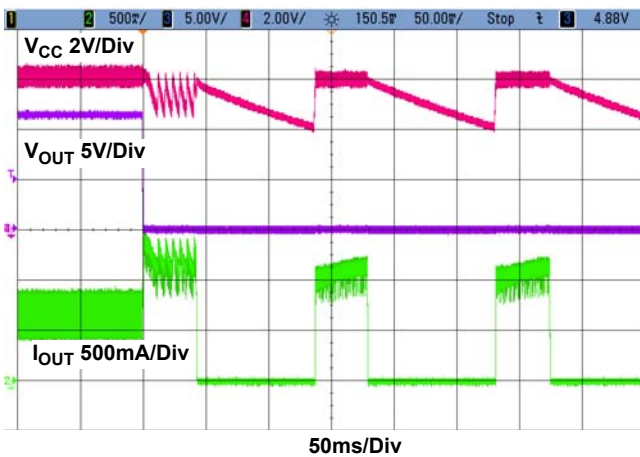


Figure 13. Short-Circuit Protection ( $V_{IN} = 230V_{AC}$ )

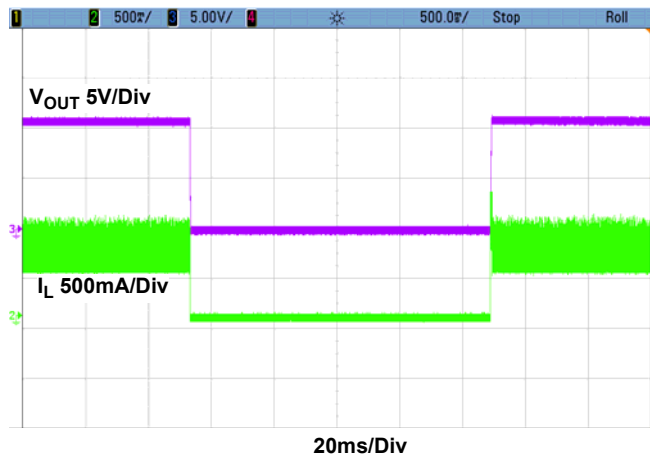


Figure 14. Over-Temperature Protection ( $V_{IN} = 230V_{AC}$ )

Typical operating conditions at 25°C,  $V_{DRAIN} = 100V$ ,  $V_{CC} = 5.6V$ ,  $V_{OUT} = 12V$ ,  $I_{OUT} = 667mA$ ,  $L_2 = 680\mu H$ ,  $C_{OUT} = 330\mu F$ , unless otherwise specified. (Cont.)

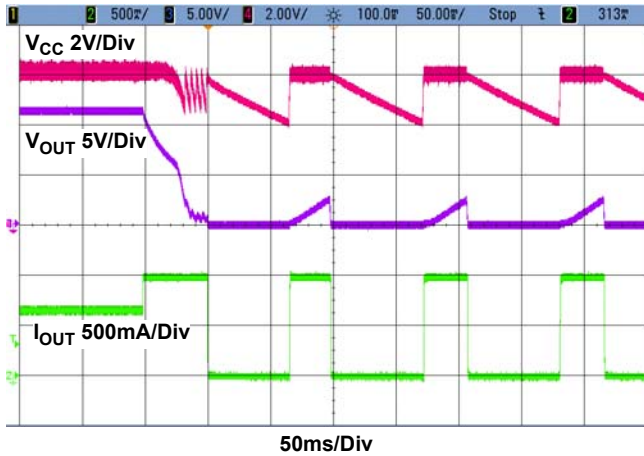


Figure 15. Overload Protection ( $V_{IN} = 230V_{AC}$ )

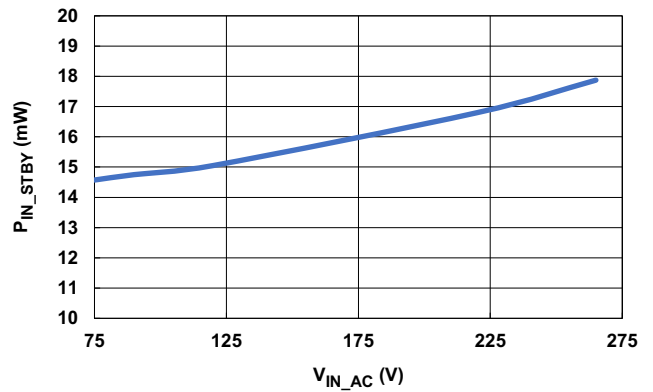


Figure 16. No Load Power Loss

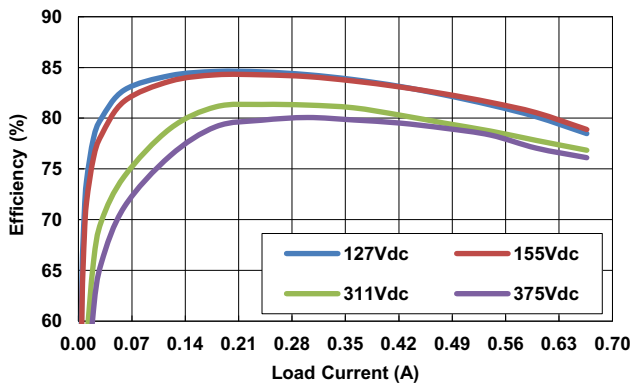


Figure 17. Efficiency with 12V Output

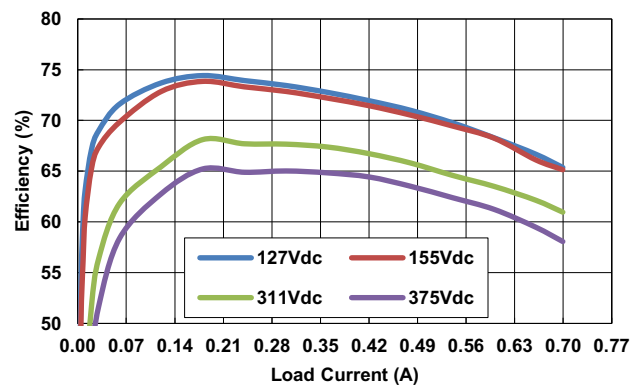


Figure 18. Efficiency with 5V Output

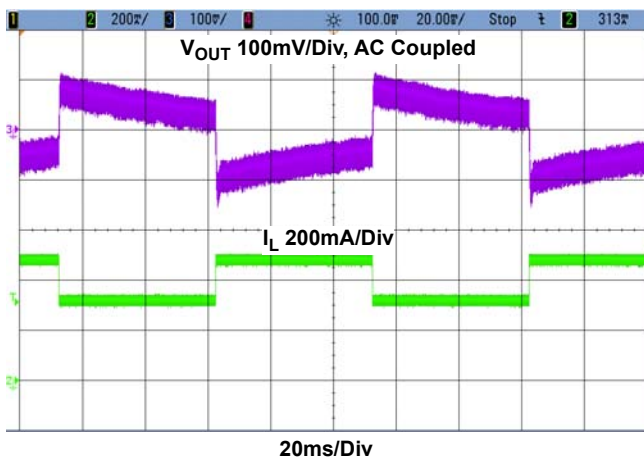


Figure 19. Dynamic Load ( $V_{IN} = 230V_{AC}$ )

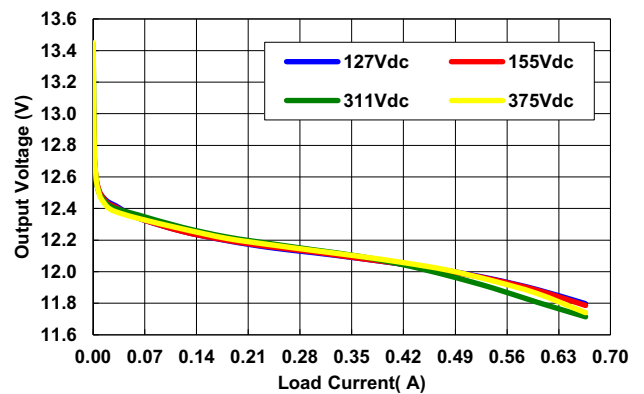


Figure 20. Load Regulation

## 5. Detailed Description

The RAA223021 adopts the high-side float switching topology as Figure 1 shows. A floating VCC supplies IC operation. The output voltage is sensed on the FB pin from an RC sampling network connected to the output, and compared with the internal reference through an error amplifier that controls the peak current accordingly.

### 5.1 Constant Off-Time Mode

In heavy load, the power FET is turned on after a constant off-time. Because the on-time is comparably much smaller than the off-time, the IC operates with quasi-constant frequency. When the load current goes lower, the peak current becomes lower while still switching around 43kHz until it hits the minimum peak current limit. Because the switching frequency is always kept around 43kHz in the operation, no audible noises can be heard.

### 5.2 PFM Mode

When the load current decreases below a certain value, the peak current is kept at the minimum level, while the off-time is gradually increased to maintain the output regulation. The IC goes into Pulse Frequency Modulation (PFM) operation as Figure 21 shows; therefore, losses are reduced because of switching frequency reduction. During this mode, while the switching frequency is reduced below 1kHz at no load, the audible noise is minimized by keeping the peak current at the minimum level. In the meantime, because of the low IC biasing current and small peak current, the standby power can be achieved below 20mW. The above operation is illustrated in Figure 22 and Figure 23.

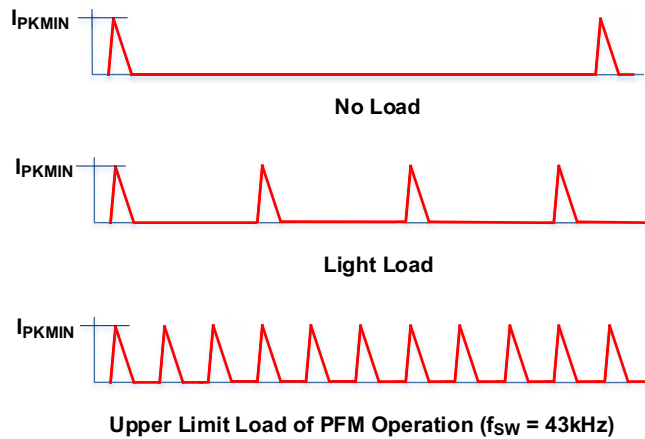


Figure 21. PFM Operation in Light Load

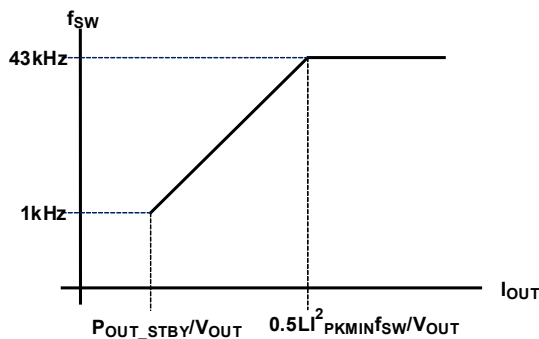


Figure 22. Switching Frequency vs  $I_{OUT}$

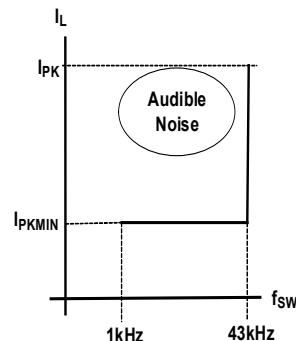


Figure 23. Peak Current vs Switching Frequency

### 5.3 Output Voltage Sampling

The RC sampling network samples the output voltage through a forward-biased  $D_3$  when  $D_2$  is free-wheeling. When the  $D_2$  cathode goes high and  $D_2$  stops conducting current, the sampled voltage across  $C_{FB1}$  is discharged by  $R_{FB1}$  and  $R_{FB2}$ . In constant off-time operation, the FB pin voltage is slightly below the internal reference. The power FET is set on after a constant off-time. In PFM mode, when the sampled voltage on FB pin drops to internal reference, the power FET is clocked on. In this way, the light-load switching is set by the  $C_{FB1}$ ,  $R_{FB1}$ , and  $R_{FB2}$  for the corresponding load. Therefore, the required no-load standby power is achieved by choosing  $C_{FB1}$ , allowing you the flexibility to design your circuit for various standby power requirements. For detailed design guidance, see [Feedback Capacitor \(CFB1\) Selection](#).

### 5.4 Soft Start-Up

The RAA223021 starts up with the  $V_{CC}$  capacitor charged by an internal HV current source. When the  $V_{CC}$  reaches up to 6V, the IC begins switching, the internal HV current source is turned off, and a start-up timer begins. When  $V_{CC}$  drops below 5.9V, the HV current source is on again, which is determined by the actual IC supply current. During the start-up, the output voltage ramps up gradually, which is controlled by a variable off-time set by the feedback voltage. After the timer expires (start-up is finished), the HV current source is on again only when  $V_{CC}$  drops to 4.5V. When  $V_{OUT}$  is established,  $V_{CC}$  can be supplied by  $V_{OUT}$  (optional) to save power consumption for high-efficiency and low-standby power, as [Figure 24](#) shows.

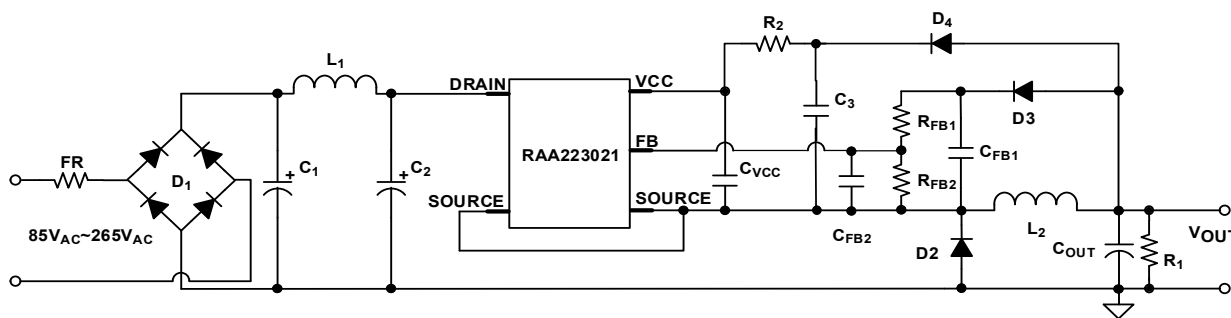


Figure 24. RAA223021 Low Standby Power Buck Regulator

Figure 25 shows the start-up diagram.

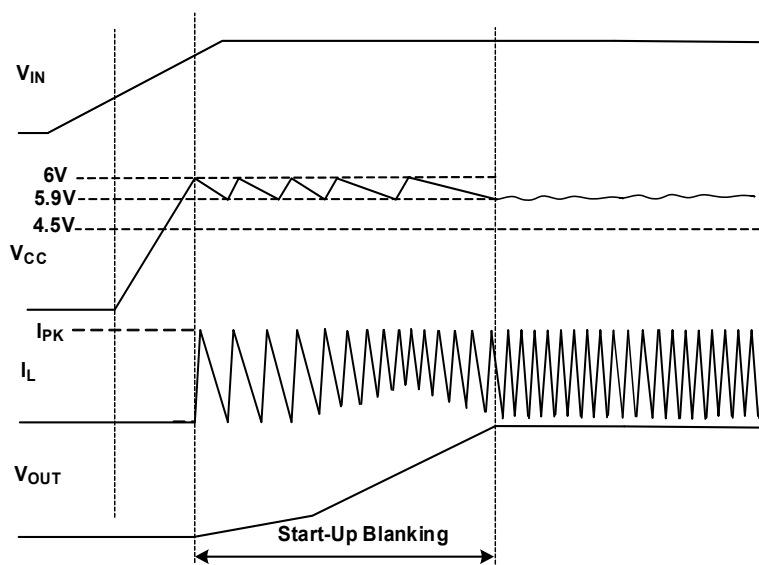


Figure 25. RAA223021 Start-Up Diagram

## 5.5 Overload Protection

With the fixed minimum off-time (when  $V_{FB} \geq 0.825V$ ), the maximum load current that the RAA223021 allows is limited for a given output voltage and inductor, and therefore, is the maximum output current. However, when the output voltage continues to drop during the overload, the FET power losses increase and can cause potential IC overheating. Therefore, when  $V_{FB}$  reaches 1.7V, an internal comparator is triggered and starts an Overload Protection (OLP) timer. When the timer is expired, the overload situation is identified and the IC is shut off.  $V_{CC}$  is discharged by a  $20\mu A$  internal current source to 4V and then charged up to 6V to resume switching (the interval without switching is the hiccup time). The overload protection time sequence is shown in Figure 26.

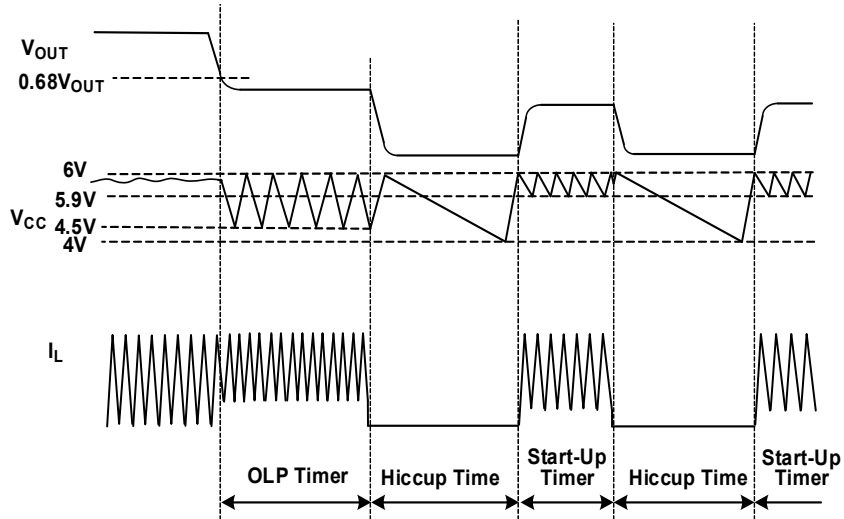


Figure 26. RAA223021 Overload Protection Diagram

## 5.6 Short-Circuit Protection

When the output is shorted,  $V_{OUT} = 0$ ,  $V_{FB}$  drops to zero because of the feedback network, introducing a delay. Before  $V_{FB}$  drops to  $V_{FB\_TOFFMIN}$ , the RAA223021 operates with  $t_{ON\_MAX}$  and  $t_{OFF\_MIN}$ , which quickly builds up a high current ( $>1.3A$ ) because the inductor peak current does not get reset. When the current reaches  $I_{SC\_TH}$ , a timer is started. If the inductor current reaches  $I_{SC\_TH}$  for four consecutive cycles, the RAA223021 determines that a short-circuit is present and immediately shuts off switching. The IC then quickly charges  $V_{CC}$  up to 6V and discharges it with a  $20\mu A$  current source to 4V. When  $V_{CC}$  drops to 4V, a  $2.5mA$  current source charges  $V_{CC}$  back to 6V where the IC resumes switching.

When the RAA223021 resumes switching, assuming  $V_{FB}$  drops to zero, the IC operates with the increased  $t_{OFFMIN\_MAX}$  so the inductor current can fully reset below the maximum peak limit. The RAA223021 operates in CCM with the inductor peak current being limited at 1100mA. The part remains in hiccup mode until the short is removed. When the short is removed,  $V_{OUT}$  returns to normal. This procedure is shown in Figure 27.

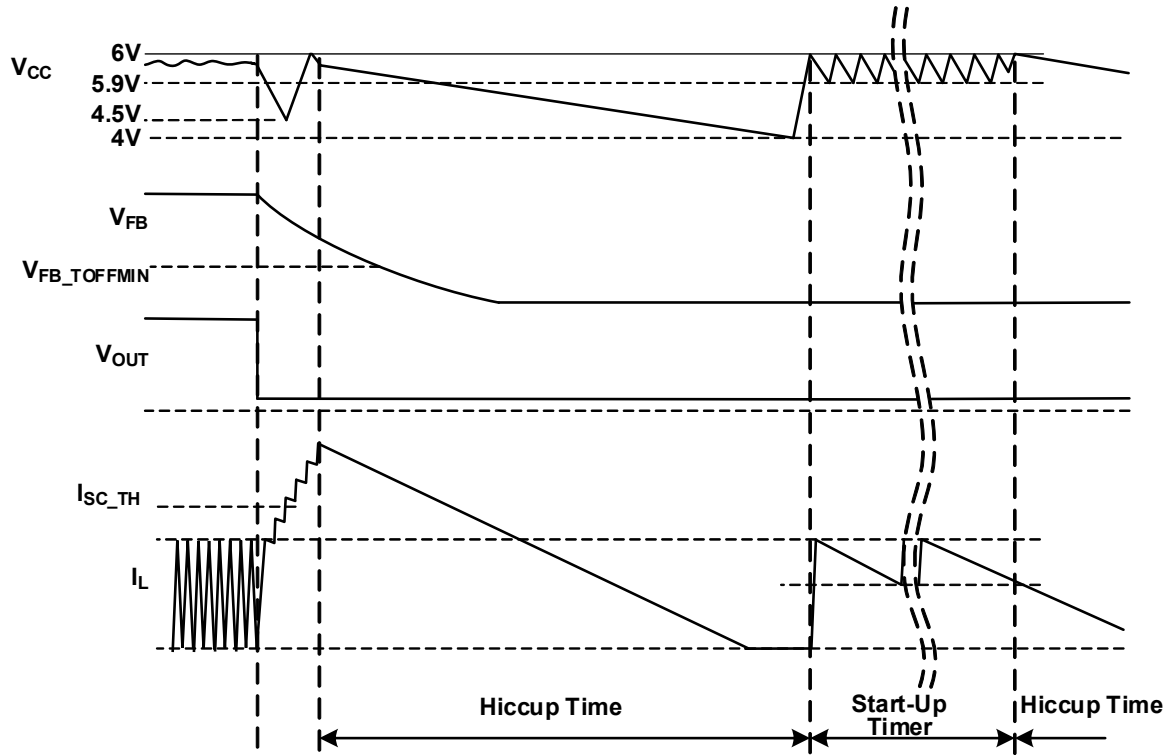


Figure 27. RAA223021 Short-Circuit Protection Diagram

## 6. Application Topologies

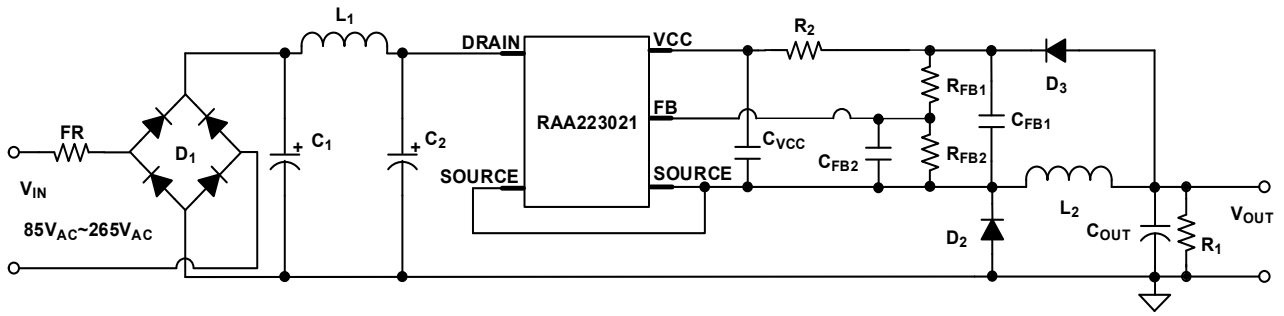


Figure 28. RAA223021 Buck with VCC Backfed from  $C_{FB1}$

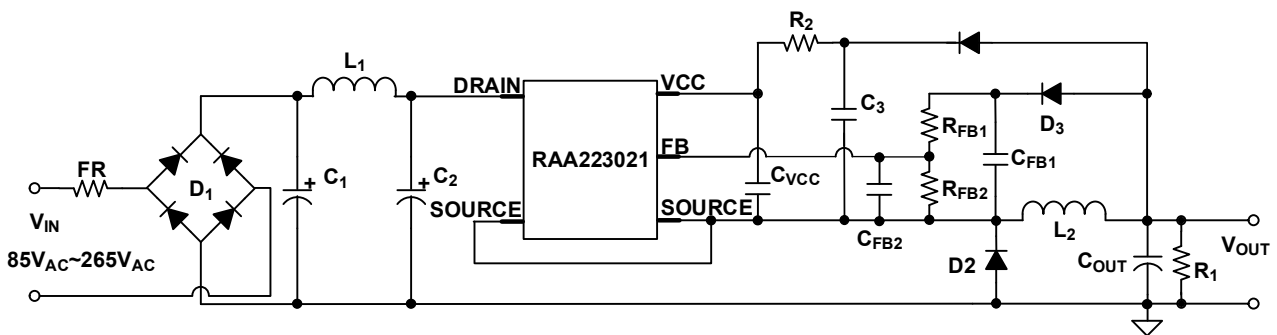


Figure 29. RAA223021 Buck with 5V Output

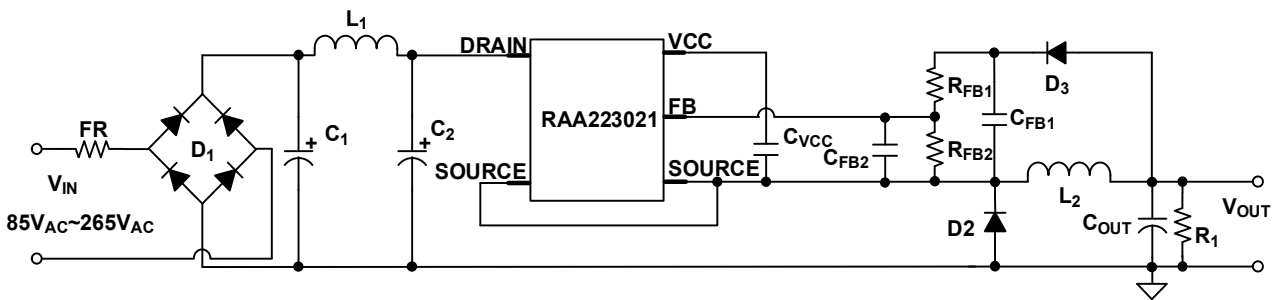


Figure 30. RAA223021 Buck with 3.3V Output

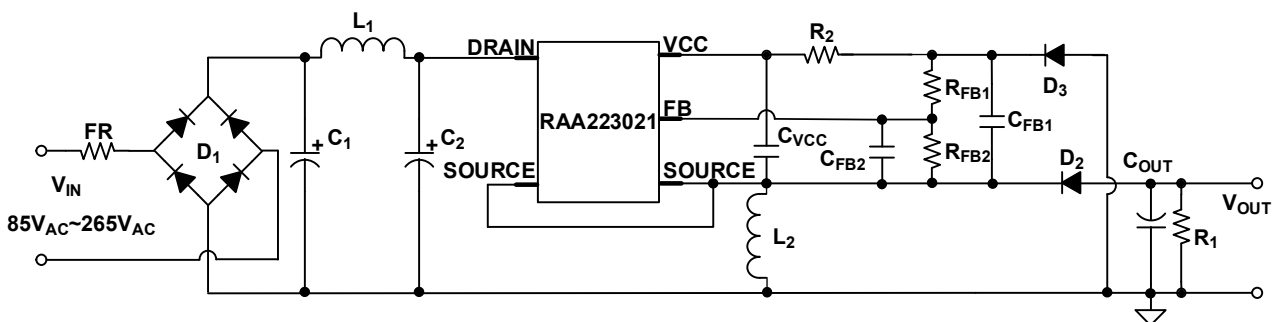


Figure 31. RAA223021 Buck/Boost



## 7. Design Guidance

To simplify the analysis, the following design guidelines are based on the circuit shown in [Figure 1](#).

### 7.1 Feedback Resistor Selection

The output voltage is set by the resistor divider of  $R_{FB1}$  and  $R_{FB2}$ . Because of the diode forward voltage mismatch between the feedback diode  $D_3$  and free-wheeling diode  $D_2$ , an additional 0.5V offset is added in [Equation 1](#) to calculate the resistor values of  $R_{FB1}$  and  $R_{FB2}$ . A series resistor with  $D_3$  can help decrease the mismatch affect.

$$(EQ. 1) \quad \frac{R_{FB1}}{R_{FB2}} = \frac{V_{OUT} + 0.5}{V_{FB}} - 1$$

### 7.2 Output Inductor Selection

Because the buck regulator is designed with a constant off-time of 23μs at full load, design the output inductor according to [Equation 2](#):

$$(EQ. 2) \quad L \geq \frac{V_{OUT} t_{OFF\_MIN}}{2(I_{PK} - I_{O\_MAX})}$$

For example, if  $V_{OUT} = 12V$ , if  $I_{O\_MAX} = 660mA$ ,  $L \geq \frac{12 \times 23 \times 10^{-6}}{2 \times (1.1 - 0.66)} = 314\mu H$

### 7.3 Feedback Capacitor (CFB1) Selection

The feedback capacitor  $C_{FB1}$  determines the pulse frequency at no load condition. The corresponding inductor current is shown in [Figure 32](#).

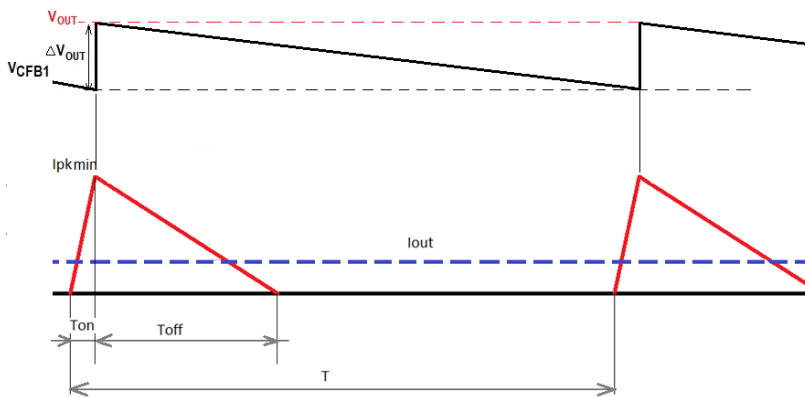


Figure 32. The Inductor Current at No Load Operation

The average output current can be written as [Equation 3](#).

$$(EQ. 3) \quad \frac{I_{PKMIN}(t_{ON} + t_{OFF})}{2T} = I_{OUT\_MIN}$$

Because  $t_{ON} \ll t_{OFF}$ ,  $I_{OUT\_MIN}$  can be written as:

$$\frac{I_{PKMIN} t_{OFF}}{2T} = I_{OUT\_MIN}, \text{ where } t_{OFF} = \frac{L I_{PKMIN}}{V_{OUT}}$$

Therefore:

$$(EQ. 4) \quad I_{OUT\_MIN} = \frac{L(I_{PKMIN})^2}{2V_{OUT}T}$$

To have the required input standby power,  $P_{IN\_STBY}$ , the power delivered to the output should satisfy Equation 5:

$$(EQ. 5) \quad V_{OUT} I_{OUT\_MIN} = P_{IN\_STBY} \eta$$

where  $\eta$  is the light-load efficiency.

Replacing  $I_{OUT\_MIN}$  with Equation 4 gives you Equation 6.

$$(EQ. 6) \quad V_{OUT} \left( \frac{L(I_{PKMIN})^2}{2V_{OUT}T} \right) = P_{IN\_STBY} \eta$$

The required time interval  $T$  is calculated using Equation 7:

$$(EQ. 7) \quad T = \frac{L(I_{PKMIN})^2}{2P_{IN\_STBY} \eta}$$

Because the time interval  $T$  is primarily determined by the sampling network, it is related to  $C_{FB1}$  in Equation 8:

$$(EQ. 8) \quad C_{FB1} = \frac{V_{OUT} T}{\Delta V_{OUT} (R_{FB1} + R_{FB2})}$$

where  $\Delta V_{OUT}$  is the output voltage increase above the nominal  $V_{OUT}$  at no load.

From Equation 8, it can be seen that a bigger sampling capacitor leads to a smaller  $\Delta V_{OUT}$ , but  $C_{FB1}$  can not be too big as it calls for a huge  $C_{OUT}$ . A small  $\Delta V_{OUT}$  can cause erratic logic function of the internal PFM comparator in mode transition. Therefore, choose  $\Delta V_{OUT}$  properly according to the highest  $V_{OUT}$  allowed in the applications. When  $\Delta V_{OUT}$  is picked,  $C_{FB1}$  is calculated by using Equation 8.

## 7.4 Output Capacitor Selection

The output capacitor needs to meet the requirement of the output ripple voltage and load transient response. Also, it needs to ensure the slew rate of the output voltage is slower than the discharging rate of the sampling capacitor ( $C_{FB1}$ ) in a defined step load transient, as shown in Figure 33. Therefore,  $C_{OUT}$  is first calculated according to  $V_{OUT}$  discharging by Equation 9.

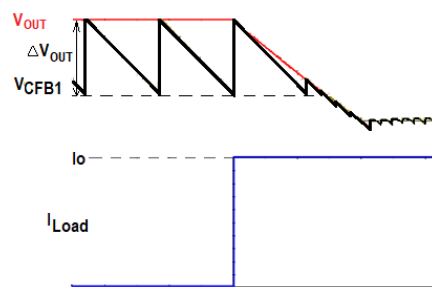


Figure 33. Output Capacitor Discharging at Step Load

$$(EQ. 9) \quad C_{OUT} \geq \frac{C_{FB1} \Delta I_{OUT} (R_{FB1} + R_{FB2})}{V_{OUT}}$$

However, the output capacitor should also be large enough to provide sufficient transient voltage support to load step (if any), as with the pulses being separated with a big time interval at no load the controller most likely cannot detect the voltage change and take action promptly.

$$(EQ. 10) \quad C_{OUT} \geq \frac{\Delta I_{OUT} T}{0.07 V_{OUT}}$$

where 7% voltage drop is used in this example.

## 7.5 Bias Capacitor Selection

### 7.5.1 V<sub>CC</sub> Hold Up Capacitor C<sub>3</sub> Selection

The C<sub>3</sub> capacitor holds up the V<sub>CC</sub> voltage during PFM mode. In PFM mode, this capacitor provides hold up energy from output to the IC during off-time. This can achieve better light-load efficiency instead of taking energy from the input side. Renesas recommends setting the output ripple voltage smaller than 1V at no load condition with maximum input voltage, which is the worst case with the output capacitor keeping the no-load output voltage from getting too high. Its value is calculated from [Equation 11](#).

$$(EQ. 11) \quad C_3 = \frac{P_{IN\_STBY} \times T \times 2}{V_{OUT}^2 - (V_{OUT} - 1)^2}$$

### 7.5.2 V<sub>CC</sub> Capacitor C<sub>VCC</sub> Selection

The C<sub>VCC</sub> capacitor filters the V<sub>CC</sub> voltage and sets the hiccup time when OLP is triggered. After OLP is triggered, the V<sub>CC</sub> capacitor is discharged by a discharge current, I<sub>QVCC3</sub>. When the voltage of C<sub>VCC</sub> drops to 4.5V, the IC restarts, and C<sub>VCC</sub> is charged by I<sub>VCC\_START</sub> to V<sub>CC\_OFF</sub> again. Therefore, choose C<sub>VCC</sub> based [Equation 12](#).

$$(EQ. 12) \quad t_{hiccup} = C_{VCC} \times 2 \times \left( \frac{1}{I_{QVCC3}} + \frac{1}{I_{VCC\_START}} \right)$$

However, C<sub>VCC</sub> also protects the V<sub>CC</sub> voltage from overshoot from C<sub>3</sub> when the chip is shut down. Therefore, for design consideration, the C<sub>VCC</sub> capacitance should be at least doubled to C<sub>3</sub>.

### 7.5.3 Input Capacitor Selection

Typically, the input capacitance affects the inrush current, and therefore the input fuse and bridge selection. When using a bridge rectifier, the input capacitor is chosen as 1.5 ~ 2μF/W for the universal input condition ([Equation 13](#)).

$$(EQ. 13) \quad C_{IN} = V_{OUT} \times I_{OUT} \times 1.5 \mu F/W \div \eta$$

where η = 0.75

## 7.6 Dummy Resistor Selection

At a no-load condition, the system standby power is determined by the IC quiescent current, feedback resistor bleeding current. If the required standby power is not low and to keep the no-load output voltage from getting too high, a dummy resistor can be added in parallel with the output capacitor. Its value is calculated using Equation 14.

$$(EQ. 14) \quad R_0 = \frac{V_{OUT}}{\left( \frac{P_{IN\_STBY} \eta}{V_{OUT}} - I_q - \frac{V_{FB}}{R_{FB2}} \right)}$$

where  $\eta = 0.4$

## 7.7 Power Capability

The maximum power the RAA223021 can deliver depends on the ambient temperature, output voltage, input voltage, and even PCB thermal design. In general, higher input voltage with lower ambient temperature allows a bit more power than a low input voltage at a higher ambient temperature. Also, it delivers more power at higher output voltages. Table 1 summarizes the maximum power the RAA223021 can deliver with ambient temperature up to 85°C. This table should be used as a reference and may vary because of actual PCB thermal design power capability.

## 7.8 PCB Layout Guidance

Proper layout is important to ensure a stable operation, good thermal behavior, EMI performance, and reliable operation for various operating environments. Pay attention to the following layout recommendations.

- Leave proper spacing (minimum 1.4mm) between high voltage (max 400V) traces and low voltage traces.
- Keep a small loop from the input filter capacitor to the IC, switching inductor, output capacitor, and to the ground of the input capacitor. Also, a small loop consisting of a switching inductor, output capacitor, and freewheeling diode.
- Keep sufficient copper area on the IC drain and/or source pin for better thermal performance
- Keep the switching inductor away from the input EMI inductor to avoid noise coupling, especially when an unshielded switching inductor is used.
- Place the  $V_{CC}$  decoupling capacitor and the FB pin decoupling capacitor close to the pins. A single-sided PCB layout example is shown in Figure 34.

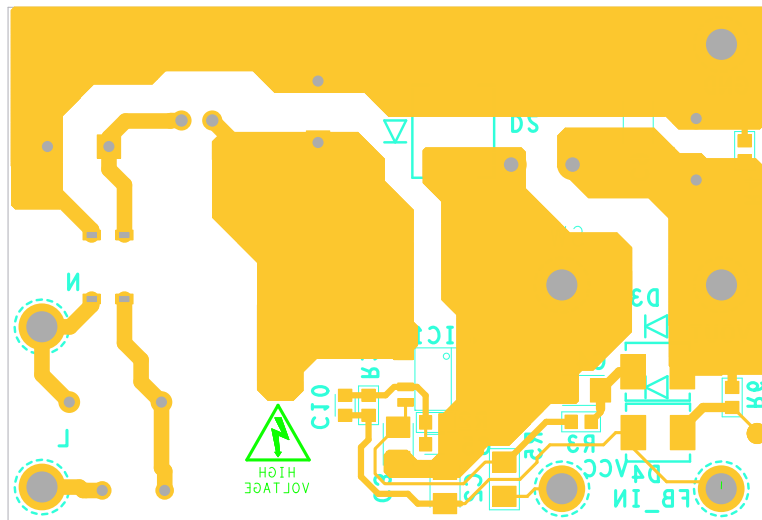


Figure 34. Example PCB Layout

## 8. EMI Performance

Conducted EMI compliance for EN55022/CISPR22 (12V/600mA output)

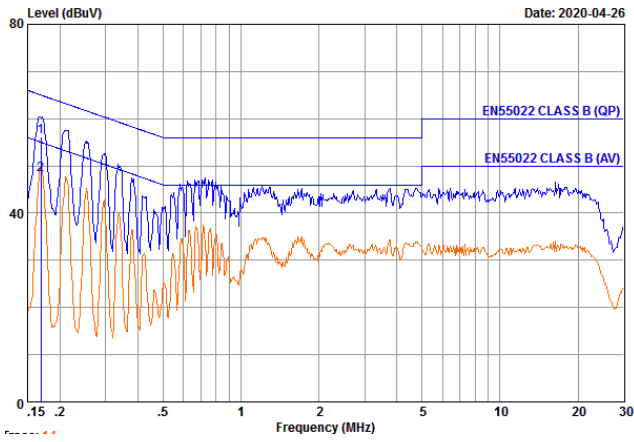


Figure 35. Line, 120V<sub>AC</sub>

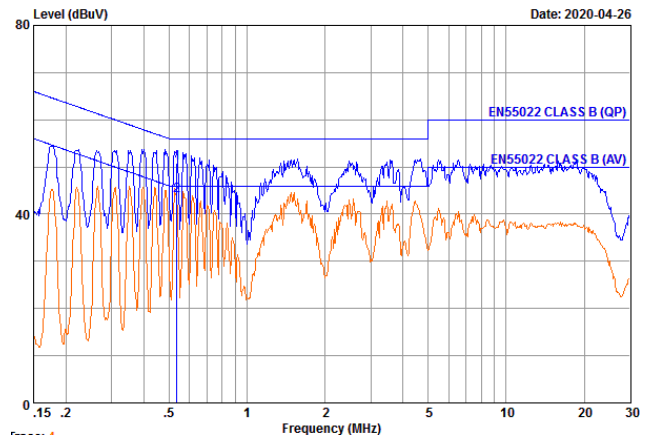


Figure 36. Line, 230V<sub>AC</sub>

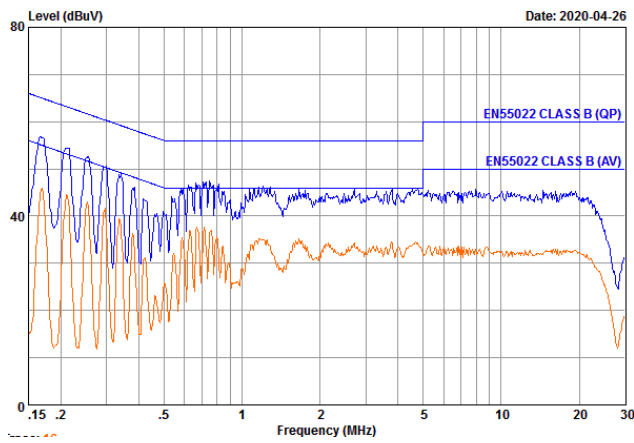


Figure 37. Neutral, 120V<sub>AC</sub>

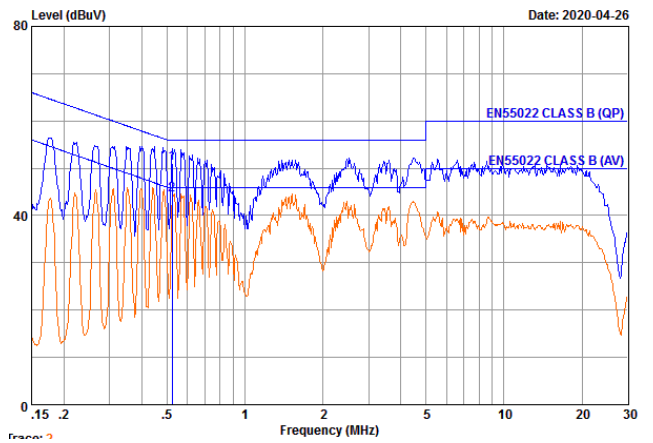


Figure 38. Neutral, 230V<sub>AC</sub>

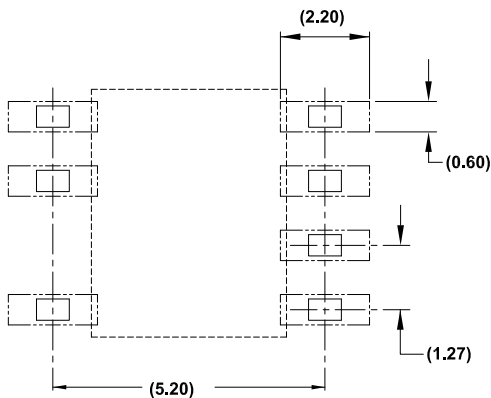
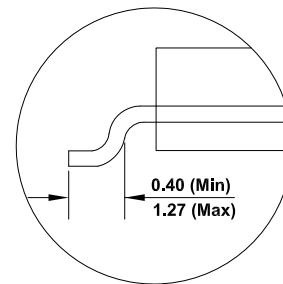
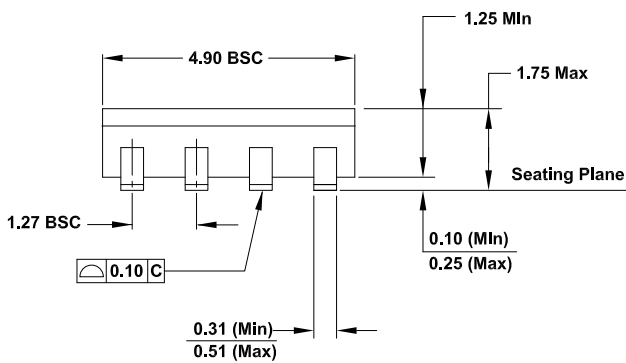
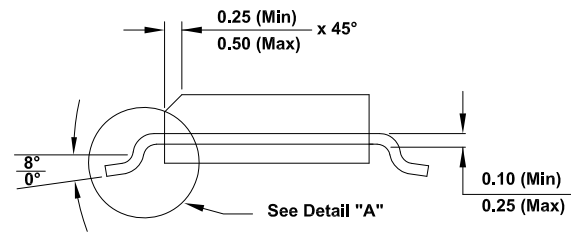
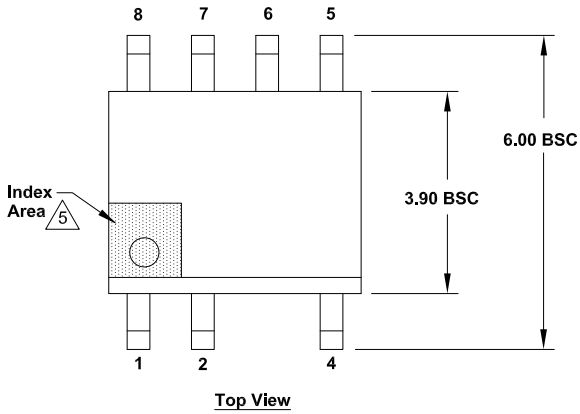
# 9. Package Outline Drawing

For the most recent package outline drawing, see [M7.15A](#).

M7.15A

7 Lead Narrow Body Small Outline Plastic Package (SOIC)

Rev 1,12/20



**Typical Recommended Land Pattern**

**Notes:**

1. Dimensions are in millimeters.  
Dimensions in ( ) for Reference Only.
2. Dimensioning and tolerancing conform to ASME Y14.5m-1994.
3. Unless otherwise specified, tolerance: Decimal  $\pm 0.05$
4. Dimension does not include interlead flash or protrusions.  
Interlead flash or protrusions shall not exceed 0.255mm per side.
5. The pin #1 identifier may be either a mold or mark feature.
6. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.

## 10. Ordering Information

Part Number <sup>[1][2]</sup>	Part Marking	Package Description (RoHS Compliant)	Pkg. Dwg. #	Carrier Type <sup>[3]</sup>	Temp Range
RAA2230214GSP#AA1	223021	7 Ld SOIC	M7.15A	Tube	-40 to +125°C
RAA2230214GSP#HA1				Reel, 2.5k	
RAA2230214GSP#MA1				Reel, 250	
RTKA223021DE0000BU	Universal input, Buck, 12V, 8W Evaluation Board				
RTKA223021DE0010BU	Universal input, Flyback, 12V, 12W Evaluation Board				

1. These Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J-STD-020.
2. For Moisture Sensitivity Level (MSL), see the [RAA223021](#) device page. For more information about MSL, see [TB363](#).
3. See [TB347](#) for details about reel specifications.

**Table 2. Key Differences between Family of Parts**

Device	$r_{DS(ON)}$ ( $\Omega$ )	$I_{PK}$ (mA)	$t_{OFF\_MIN}$ ( $\mu$ s)	Package Options
RAA223011	14.5	520	32	8 Ld SOIC, 7 Ld SOIC, 5 Ld TSOT
RAA223012	14.5	335	19	8 Ld SOIC, 5 Ld TSOT
RAA223021	4	1100	23	7 Ld SOIC

## 11. Revision History

Revision	Date	Description
1.1	May 12, 2021	Updated Table 1: added 24V output setting.
1.0	Feb 12, 2021	Initial release.

## IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers skilled in the art designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only for development of an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising out of your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Rev.1.0 Mar 2020)

### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

### Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:  
[www.renesas.com/contact/](http://www.renesas.com/contact/)

### Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.