2 A PWM/VFM Step-down DC/DC Converter with Synchronous Rectifier Evaluation Board

NO.EEV-296-012-190517

RP506K001F012-EV is the evaluation board for RP506 which has the below features, benefits and specifications.

OUTLINE

The RP506K is a low supply current CMOS-based PWM/VFM step-down DC/DC converter with synchronous rectifier featuring 2 A(1) output current. Internally, a single converter consists of an oscillator, a reference voltage unit, an error amplifier, a switching control circuit, a mode control circuit, a soft start circuit, a latch type protection circuit, an under-voltage lockout (UVLO) circuit, a thermal shutdown circuit, and switching transistors.
The RP506K is employing synchronous rectification for improving the efficiency of rectification by replacing diodes with built-in switching transistors. Using synchronous rectification not only increases circuit performance but also allows a design to reduce parts count.
Power controlling method can be selected from forced PWM control type or PWM/VFM auto switching control type by inputting a signal to the MODE pin. In low output current, forced PWM control switches at fixed frequency rate in order to reduce noise. Likewise, in low output current, PWM/VFM auto switching control automatically switches from PWM mode to VFM mode in order to achieve high efficiency.
Output voltage type can be selected from an internally fixed output voltage type (RP506Kxx1A/B/D/E) or an externally adjustable output voltage type (RP506K001C/F). The output voltage of the RP506Kxx1A/B/D/E can be set by 0.1 V step and the output voltage accuracy is as high as ±1.5% or ±18 mV. The output voltage of the RP506K001C/F can be set by using the external resistors.
Oscillator frequency can be selected from 2.25 MHz (RP506Kxx1A/B/C) or 1.2 MHz (RP506Kxx1D/E/F). Soft-start time is Typ. 0.15 ms, and by connecting an external capacitor to the TSS pin, soft-start time is adjustable.
Power good (PG) function monitors the V_{OUT} pin voltage or the feedback pin voltage (V_{FB}), and switches the PG pin to low if any abnormal condition is detected.
Protection circuits included in the RP506K are over current protection circuit, latch type protection circuit and thermal shutdown circuit. Over current protection circuit supervises the inductor peak current in each switching cycle, and if the current exceeds the L_X current limit (I_{LXLIM}), it turns off Pch Tr. Latch type protection circuit latches the built-in driver to the OFF state and stops the operation of the step-down DC/DC converter if the over current status continues or V_{OUT} continues being the half of the setting voltage for equal or longer than protection delay time (tprot). Thermal shutdown circuit detects overheating of the converter if the output pin is shorted to the ground pin (GND) etc. and stops the converter operation to protect it from damage if the junction temperature exceeds the specified temperature.

The RP506K is available in DFN(PLP)2527-10 which achieves high-density mounting on boards.

(1) This is an approximate value. The output current is dependent on conditions and external components.

FEATURES

- Supply Current ····· Typ. 48 µA (VFM mode, Lx at no load)
- Standby Current ····· Typ. 0 µA
- Input Voltage Range ····· 2.5 V to 5.5 V (Absolute Maximum Ratings: 6.5 V)
- Output Voltage Range ····· Adjustable output voltage type (RP506K001F) : to 4.0 V

Version	Forced PWM Control	PWM/VFM Auto Switching Control
RP506K001F	0.6 V to 4.0 V	

- Output Voltage Accuracy ····· ± 1.5% (V_{SET}[1] ≥ 1.2 V)
  ····· ±18 mV (V_{SET} < 1.2 V) (RP506Kxx1A/B/D/E)
- Feedback Voltage Accuracy ····· ±9 mV (V_{FB} = 0.6 V) (RP506K001F)
- Output Voltage/Feedback Voltage Temperature Coefficient ····· ±100 ppm/ºC
- Oscillator Frequency ····· Typ. 1.2 MHz (RP506Kxx1F)
- Oscillator Maximum Duty ····· Min. 100%
- Built-in Driver ON Resistance ····· Typ. Pch. 0.130 Ω, Nch. 0.125 Ω (V_{IN} = 3.6 V)
- UVLO Detector Threshold ····· Typ. 2.2 V
- Inductor Current Limit Circuit ····· Current limit Typ. 2.8 A
- Latch Type Protection Circuit ····· Typ. 1.5 ms
- Package ····· DFN(PLP)2527−10
- For more details on RP506 IC, please refer to https://www.e-devices.ricoh.co.jp/en/products/power/dcdc/rp506/rp506-ea.pdf.

Part Number Information

Product Name	Package
RP506K001F012-TR	DFN(PLP)2527-10

001F: Ajustable output voltage type, without auto-discharge function, 1.2 MHz

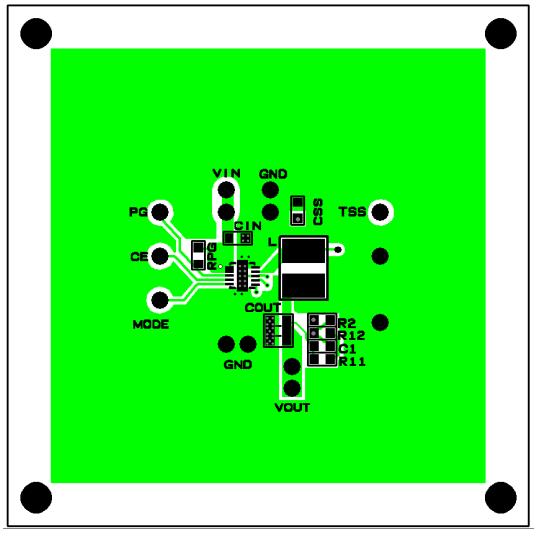
012: 1.2 V, Output voltage

[1] V_{SET} = Set Output Voltage

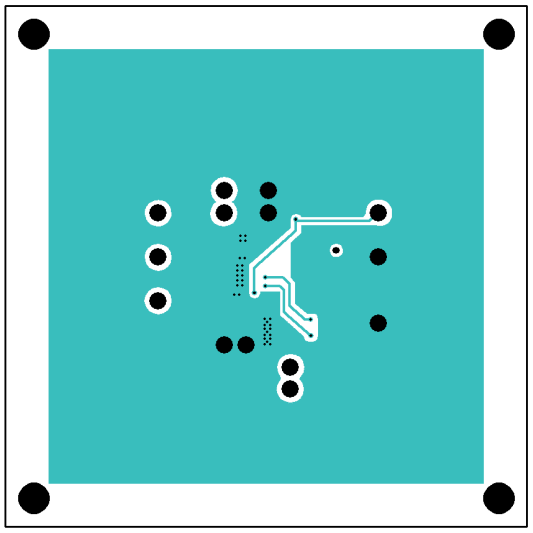
Reference PCB Layouts

RP506K001F (PKG: DFN(PLP)2527−10pin) PCB Layout

Topside

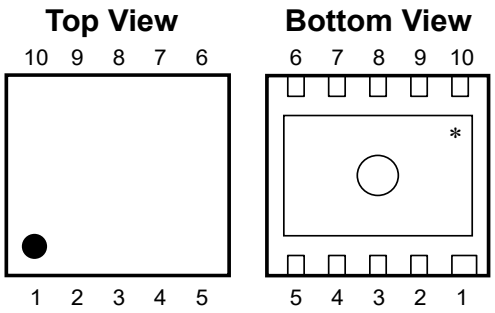


Backside



∗ R11 and R12 are arranged as a substitute for R1 so that two resistors can be connected in series.

PIN DESCRIPTIONS



DFN(PLP)2527-10 Pin Configurations

DFN(PLP)2527-10 Pin Descriptions

Pin No.	Symbol	Description
1	PV_{IN}	PV_{IN} Input Voltage Pin(1)
2	AV_{IN}	AV_{IN} Input Voltage Pin(1)
3	PG	Power Good Pin
4	CE	Chip Enable Pin (Active “H”)
5	MODE	Mode Control Pin (“H”: forced PWM control, “L”: PWM/VFM auto switching control)
6	TSS	Soft-start Pin
7	V_{OUT}/ V_{FB}	Output/ Feedback Voltage Pin
8	AGND	Analog Ground Pin(2)
9	L_X	Switching Pin
10	PGND	Power Ground Pin(2)

∗ The tab on the bottom of the package enhances thermal performance and is electrically connected to GND (substrate level). It is recommended that the tab be connected to the ground plane on the board, or otherwise be left floating.

(1) No.1 pin and No.2 pin must be wired to the V_{IN} plane when mounting on boards.
(2) No.8 pin and No.10 pin must wired to the GND plane when mounting on boards.

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings (AGND = PGND = 0 V)

Symbol	Item		Rating	Unit
V_{IN}	A/PV_{IN} Pin Voltage		−0.3 to 6.5	V
V_{LX}	L_X Pin Voltage		−0.3 to A/PV_{IN} +0.3	V
V_{CE}	CE Pin Voltage		−0.3 to 6.5	V
V_{OUT}/V_{FB}	V_{OUT}/V_{FB} Pin Voltage		−0.3 to 6.5	V
V_{MODE}	MODE Pin Voltage		−0.3 to 6.5	V
V_{PG}	PG Pin Voltage		−0.3 to 6.5	V
V_{TSS}	TSS Pin Voltage		−0.3 to AV_{IN}+0.3	V
I_{LX}	L_X Pin Output Current		2.8	A
P_D	Power Dissipation(1)	Standard Land Pattern	910	mW
		High Wattage Land Pattern	1400	mW
Tj	Junction Temperature		−40 to 125	°C
Tstg	Storage Temperature Range		−55 to 125	°C

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field.
The functional operation at or over these absolute maximum ratings are not assured.

RECOMMENDED OPERATING CONDITIONS

Recommended Operating Conditions

Symbol	Item	Rating	Unit
V_{IN}	Input Voltage	2.5 to 5.5	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 ratings by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

(1) Refer to *PACKAGE INFORMATION* for detailed information.

ELECTRICAL CHARACTERISTICS

RP506Kxx1 Electrical Characteristics (Ta = 25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
Istandby	Standby Current	A/PV_{IN} = 5.5 V, V_{CE} = 0 V		0	5	μA
I_{CEH}	CE “H” Input Current	A/PV_{IN} = V_{CE} = 5.5 V	−1	0	1	μA
I_{CEL}	CE “L” Input Current	A/PV_{IN} = 5.5 V, V_{CE} = 0 V	−1	0	1	μA
I_{MODEH}	MODE “H” Input Current	A/PV_{IN} = V_{MODE} = 5.5 V, V_{CE} = 0 V	−1	0	1	μA
I_{MODEL}	MODE “L” Input Current	A/PV_{IN} = 5.5 V, V_{CE} = V_{MODE} = 0 V	−1	0	1	μA
$I_{LXLEAKH}$	L_X Leakage Current “H”	A/PV_{IN} = V_{LX} = 5.5 V, V_{CE} = 0 V	−1	0	6	μA
$I_{LXLEAKL}$	L_X Leakage Current “L”	A/PV_{IN} = 5.5 V, V_{CE} = V_{LX} = 0 V	−6	0	1	μA
V_{CEH}	CE “H” Input Voltage	A/PV_{IN} = 5.5 V	1.0			V
V_{CEL}	CE “L” Input Voltage	A/PV_{IN} = 2.5 V			0.4	V
V_{MODEH}	MODE “H” Input Voltage	A/PV_{IN} = 5.5 V	1.0			V
V_{MODEL}	MODE “L” Input Voltage	A/PV_{IN} = 2.5 V			0.4	V
R_{ONP}	On Resistance of Pch Transistor	A/PV_{IN} = 3.6 V, I_{LX} = −100 mA		0.130		Ω
R_{ONN}	On Resistance of Nch Transistor	A/PV_{IN} = 3.6 V, I_{LX} = −100 mA		0.125		Ω
Maxduty	Maximum Duty Cycle		100			%
tstart1	Soft-start Time 1	A/PV_{IN} = V_{CE} = 3.6 V or V_{SET} +1 V, TSS = OPEN		150	300	μs
tstart2	Soft-start Time 2	A/PV_{IN} = V_{CE} = 3.6 V or V_{SET} +1 V, C_{SS} = 0.1 μF	15	30	45	ms
I_{LXLIM}	L_X Current Limit	A/PV_{IN} = V_{CE} = 3.6 V or V_{SET} +1 V	2300	2800		mA
tprot	Protection Delay Time	A/PV_{IN} = V_{CE} = 3.6 V or V_{SET} +1 V	0.5	1.5	5	ms
V_{UVLO1}	UVLO Detector Threshold	A/PV_{IN} = V_{CE}	2.1	2.2	2.3	V
V_{UVLO2}	UVLO Released Voltage	A/PV_{IN} = V_{CE}	2.2	2.3	2.4	V
T_{TSD}	Thermal Shutdown Temperature	Junction Temperature		150		°C
T_{TSR}	Thermal Shutdown Released Temperature	Junction Temperature		100		°C
R_{PG}	On Resistance of PG Pin When Low Output	A/PV_{IN} = 3.6 V, V_{OUT} = 0 V or V_{FB} = 0 V		45		Ω

ELECTRICAL CHARACTERISTICS (continued)

RP506K001F (Oscillator Frequency: 1.2 MHz) Electrical Characteristics **(Ta = 25°C)**

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	When MODE = H Operating Input Voltage	0.6 V ≤ V_{SET} < 0.7 V	2.5		4.5	V
		0.7 V ≤ V_{SET}	2.5		5.5	
	When MODE = L Operating Input Voltage	0.6 V ≤ V_{SET}	2.5		5.5	
fosc	Oscillator Frequency	A/PV_{IN} = V_{CE} = 3.6 V or V_{SET} +1 V	1.00	1.20	1.40	MHz

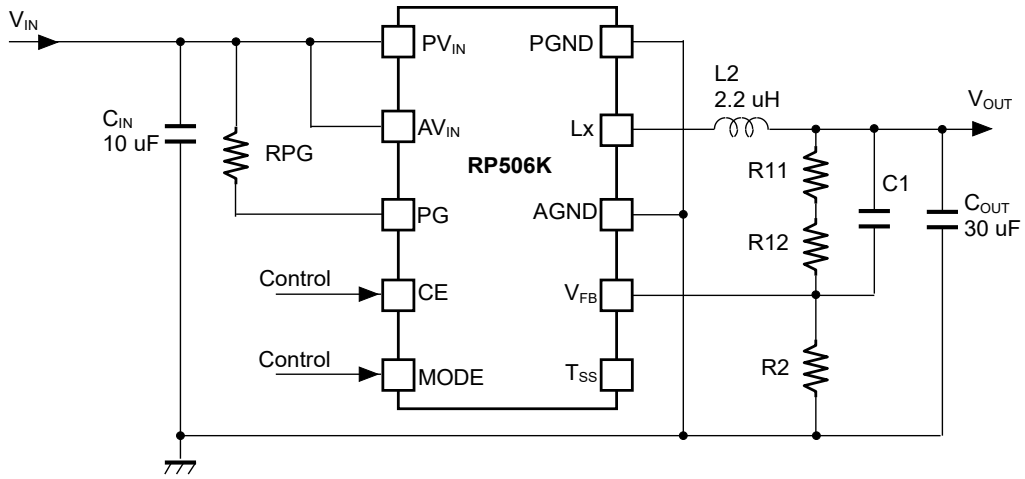
RP506K001F (Adjustable Output Voltage Type) Electrical Characteristics (Ta = 25°C)

Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
ΔV_{FB} /ΔTa	Feedback Voltage Temperature Coefficient	−40°C ≤ Ta ≤ 85°C			±100		ppm /°C
I_{DD1}	Supply Current 1	A/PV_{IN} = V_{CE} = 5.5 V, V_{FB} = 0.48 V			600		μA
I_{DD2}	Supply Current 2	A/PV_{IN} = V_{CE} = V_{FB} = 5.5 V	V_{MODE} = 0 V		48	72	μA
			V_{MODE} = 5.5 V		600		μA
I_{VFBH}	V_{FB} “H” Current	A/PV_{IN} = V_{FB} = 5.5 V, V_{CE} = 0 V		−1	0	1	μA
I_{VFBL}	V_{FB} “L” Current	A/PV_{IN} = 5.5 V, V_{CE} = V_{FB} = 0 V		−1	0	1	μA
V_{OVD}	OVD Voltage	A/PV_{IN} = 3.6 V			0.72		V
V_{UVD}	UVD Voltage	A/PV_{IN} = 3.6 V			0.48		V

All test items listed under Electrical Characteristics are done under the pulse load condition (Tj ≈ Ta = 25°C) except Output Voltage Temperature Coefficient and Feedback Voltage Temperature Coefficient.

APPLICATION INFORMATION

Typical Application



RP506K001F (Adjustable Output Voltage Type)

Recommended Components[*1]

Symbol	Value
CIN	10 μF
COUT	10 μF × 3
L	2.2 μH
C1	22 pF
CSS	OPEN[*2]
R11	220 kΩ
R12	0 Ω
R2	220 kΩ
RPG	OPEN

[*1] The bill of materials will be attached on the shipment of each purchased evaluation board.

[*2] CSS = OPEN: soft-start time = 150 μs

Soft-start Time (tstart) is adjustable by connecting a capacitor (CSS) between the TSS pin and GND. The capacitance value for CSS that is suitable for tstart can be calculated by the following equation.

C_{SS} (nF) = 3.5 × tstart (ms)

TECHNICAL NOTES

The performance of power source circuits using this IC largely depends on peripheral circuits. When selecting the peripheral components, please consider the conditions of use. Do not allow each component, PCB pattern or the IC to exceed their respected rated values (voltage, current, and power) when designing the peripheral circuits.

- AGND and PGND must be wired to the GND plane when mounting on boards.
- AV_{IN} and PV_{IN} must be wired to the V_{IN} plane when mounting on boards.
- Ensure the A/PV_{IN} and A/PGND lines are sufficiently robust. A large switching current flows through the A/ PGND line, the V_{DD} line, the V_{OUT} line, an inductor, and L_X. If their impedance is too high, noise pickup or unstable operation may result. Set the external components as close as possible to the IC and minimize the wiring between the components and the IC. Especially, place a capacitor (C_{IN}) as close as possible to the PV_{IN} pin and PGND. For the RP506K001F, separate the wiring between a resistor for setting output voltage (R1) and an inductor (L2) from the wiring between L2 and Load.
- Choose a low ESR ceramic capacitor. The ceramic capacitance of C_{IN} should be more than or equal to 10 µF. For a ceramic capacitor (C_{OUT}), it is recommended that three paralleled 10 µF ceramic capacitors or two paralleled 22 µF ceramic capacitors be used.
- When $V_{SET} \leq 3.3$ V, a 2.2 µH inductor is recommended for RP506Kxx1A/B/C/D/E/F.
  When $V_{SET} > 3.3$ V, a 4.7 µH inductor is recommended for RP506K001F. The phase compensation of this IC is designed according to the C_{OUT} and L values. Choose an inductor that has small DC resistance, has enough allowable current and is hard to cause magnetic saturation. If the inductance value of an inductor is extremely small, the peak current of L_X may increase along with the load current. As a result, over current protection circuit may start to operate when the peak current of L_X reaches to "L_X limit current".

Set Output Voltage Range vs. Inductance Range

Version	RP506K001F	
V_{SET} (V)	L = 2.2 µH	L = 4.7 µH
up to 1.5	Recommended	-
1.6 to 2.3	Recommended	-
2.4 to 3.3	Recommended	-
3.4 or more	-	Recommended

- Over current protection circuit and latch type protection circuit may be affected by self-heating or power dissipation environment.

- The output voltage (V_{SET}) is adjustable by changing the resistance values of resistors (R1, R2) as follows.

  $V_{SET} = V_{FB} \times (R1 + R2) / R2$ (Recommended V_{OUT} range for RP506K001F: 0.6 V ≤ V_{SET} ≤ 4.0 V)

  If R1 and R2 are too large, the impedances of V_{FB} also become large, as a result, the IC could be easily affected by noise. For this reason, R2 should be 220 kΩ or less. If the operation becomes unstable due to the high impedances, the impedances should be decreased.
  C1 can be calculated by the following equations. Please use the value close to the calculation result.

  If the output voltage is lower than or equal to 3.3 V:

  $C1 = 4.84 \times 10^{-6} / R2$ [F]

  If the output voltage exceeds 3.3 V:

  $C1 = 1.50 \times 10^{-6} / R2$ [F]

  The recommended resistance values for R1 and C1 when R2 = 220 kΩ or 100 kΩ are as follows.

Set Output Voltage (V_{SET}) vs. Resistors (R1, R2) and Capacitor (C1)

V_{SET} [V]	0.6	0.7	0.8	1.2	1.8	2.5	3.3	3.8	4.0
R1 [kΩ]	0	36.7	73.3	220	440	697	990	533	567
R2 [kΩ]	220	220	220	220	220	220	220	100	100
C1 [pF]	-	22	22	22	22	22	22	15	15

- Soft-start Time (tstart) is adjustable by connecting a capacitor (C_{SS}) between the TSS pin and GND. The capacitance value for C_{SS} that is suitable for tstart can be calculated by the following equation.

  C_{SS} (nF) = 3.5 × tstart (ms)

  The TSS pin must be open if Soft-start time function is not used. Soft-start time is set to typically 150 μs when the TSS pin is open.

- When using the power good function, the resistance value of a resistor (R_{PG}) should be between 10 kΩ to 100 kΩ. The PG pin must be open or connected to GND if the power good function is not used.

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