Application Note

Phase-out/Discontinued

μPD16901GS

PCMCIA STEP-UP DC/DC CONVERTER IC

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The application circuits and their parameters are for reference only and are not intended for use in actual design-ins.

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1. INTRODUCTION

In order to save more space and to ensure longer running hours, the switching power unit for battery-driven devices needs both further down-sizing and higher efficiency. As various error-protection circuits are being incorporated, the performance level of such units is becoming higher.

To meet such needs, NEC has released the μPD16901GS, which incorporates a CMOS switching regulator control IC and a switching power MOSFET in a single chip.

The step-up converter μPD16901GS converts 5 V logic voltage into 12 V which is necessary especially for write/erase of PCMCIA cards, and is best suited for use in note-type PCs.

This document contains explanations regarding the features of the μPD16901GS, general specifications, general performance, setting procedures of the control circuit, etc.

2. FEATURES OF THE μPD16901GS

The μPD16901GS, an IC for switching power units, employs the PNM (pulse number modulation) method, and has the following features:

(1) A switching regulator control circuit and a power MOSFET are incorporated in a single chip.
↓
No need for selection or design of the power transistor and the power MOSFET
↓
The mounting board space can be reduced.

(2) Full CMOS configuration
↓
CMOS process reduces the current of the power supply during the operation state.
↓
High efficiency in conversion even in the low-level output current range

(3) The output voltage and the oscillation frequency are preset.
↓
No need for adjustment in the application set

(4) The ON/OFF control is incorporated.
$I_{CC(OFF)} \leq 100\ \mu A$ (OFF status: stand-by mode)

(5) A timer-latch-type excess current protection unit is incorporated.
The unit cuts off output when the output voltage goes lower due to excessive output current.

(6) The package is 14-pin plastic SOP (300 mil).

3. PIN CONFIGURATION

The pin configuration of the μPD16901 is shown in Figure 1, and the function of each pin in Table 1.

Figure 1. Pin Configuration

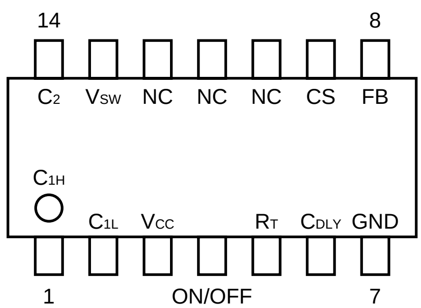


Table 1. Pin Functions

Pin Number	Pin Name	Function
1	C_{1H}	Charge pump capacitor (0.1 μF) connection
2	C_{1L}	
3	V_{CC}	Power supply
4	ON/OFF	ON/OFF control ON: open OFF: low
5	R_T	Resistor connection (68 kΩ) for the setting of oscillation circuit charge current
6	C_{DLY}	Connection pin for timer latch delay capacitor
7	GND	GND
8	FB	Output voltage detection
9	Cur.SENSE	Excess current detection
10	NC	NC
11	NC	NC
12	NC	NC
13	V_{SW}	Switching MOSFET drain
14	C_2	Charge pump capacitor (0.1 μF) connection

4. SPECIFICATIONS

(1) Absolute Maximum Ratings (T_A = 25°C)

Table 2. Absolute Maximum Ratings

Parameter	Symbol	Condition	Rating	Unit
Supply voltage	V_{DD}		7.0	V
Output voltage	V_{SW}		20	V
Total power dissipation	P_T	When mounted on a 90 mm × 90 mm × 1.6 mm (thickness) glass-epoxy board	0.9	W
Operating ambient temperature	T_A		–20 to +85	°C
Storage temperature range	T_{stg}		–55 to +150	°C

(2) Recommended Operating Conditions

Table 3. Recommended Operating Conditions

Parameter	Symbol	MIN.	TYP.	MAX.	Unit
Supply voltage	V_{DD}	4.5	5.0	5.5	V
Operating ambient temperature	T_A	0		70	°C
Charge pump capacitor	C_1, C_2	0.033	0.1	0.47	μF

(3) Electrical Characteristics (T_A = 25°C, V_{IN} = 5 V)

Table 4. Electrical Characteristics

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
(Oscillation unit)						
Oscillation frequency	f_{OSC}	R_T = 68 kΩ	153	167	181	kHz
On-duty	DUTY			67		%
(Low-voltage error prevention circuit)						
Operation start voltage	$V_{IN\ (start\text{-}up)}$		3.3	3.7	4.3	V
Operation stop voltage	$V_{IN\ (stop)}$		2.7	3.2	3.8	V
Hysteresis range	V_{HYS}		0.3	0.5	0.7	V
(Excess current detection unit)						
Excess current detection voltage	V_{DET}		270	300	330	mV
(ON/OFF control unit)						
ON/OFF pin input voltage	V_{IH}	4.5 V ≤ V_{IN} ≤ 5.5 V	V_{IN}*0.7			V
	V_{IL}	4.5 V ≤ V_{IN} ≤ 5.5 V			V_{IN}*0.3	V
ON/OFF pin input current	I_{IL}	ON/OFF pin voltage = 0	–20	–5	–1	μA
(Charge pump circuit unit)						
Output voltage	V_{CHG}	4.5 V ≤ V_{IN} ≤ 5.5 V 0°C ≤ T_A ≤ 70°C	8		11	V
(Short-circuit protection circuit)						
Timer latch detection current	I_{SCP}	R_T = 68 kΩ	2.0	3.3	4.5	μA
Timer latch detection voltage	V_{DETT}		0.85	1.0	1.15	V
(Output unit)						
Output stage on resistance	$R_{DS(ON)}$	I_{SW} = 0.5 A		0.3	0.5	Ω
Output stage leak current	$I_{DS(OFF)}$	V_{DS} = 20 V			1.0	μA

5. Block Diagram and Operating Waveform

The block diagram of this product is shown in Figure 2, and its operating waveform in Figure 3.

Figure 2. μPD16901 Circuit Block Diagram

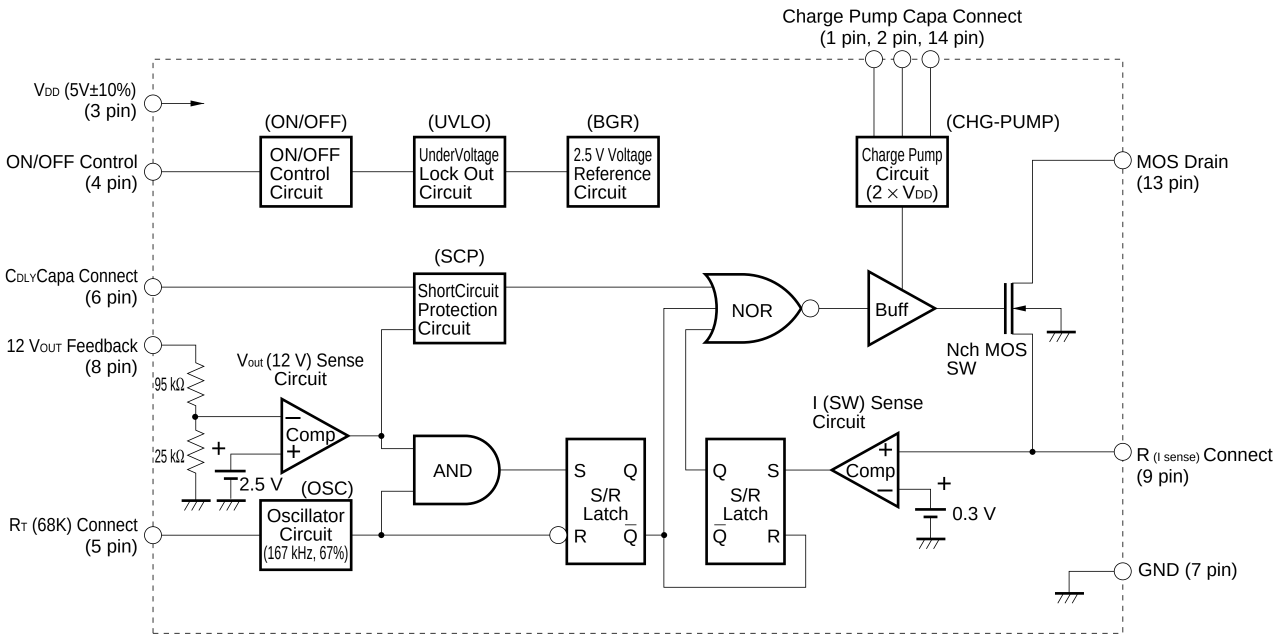
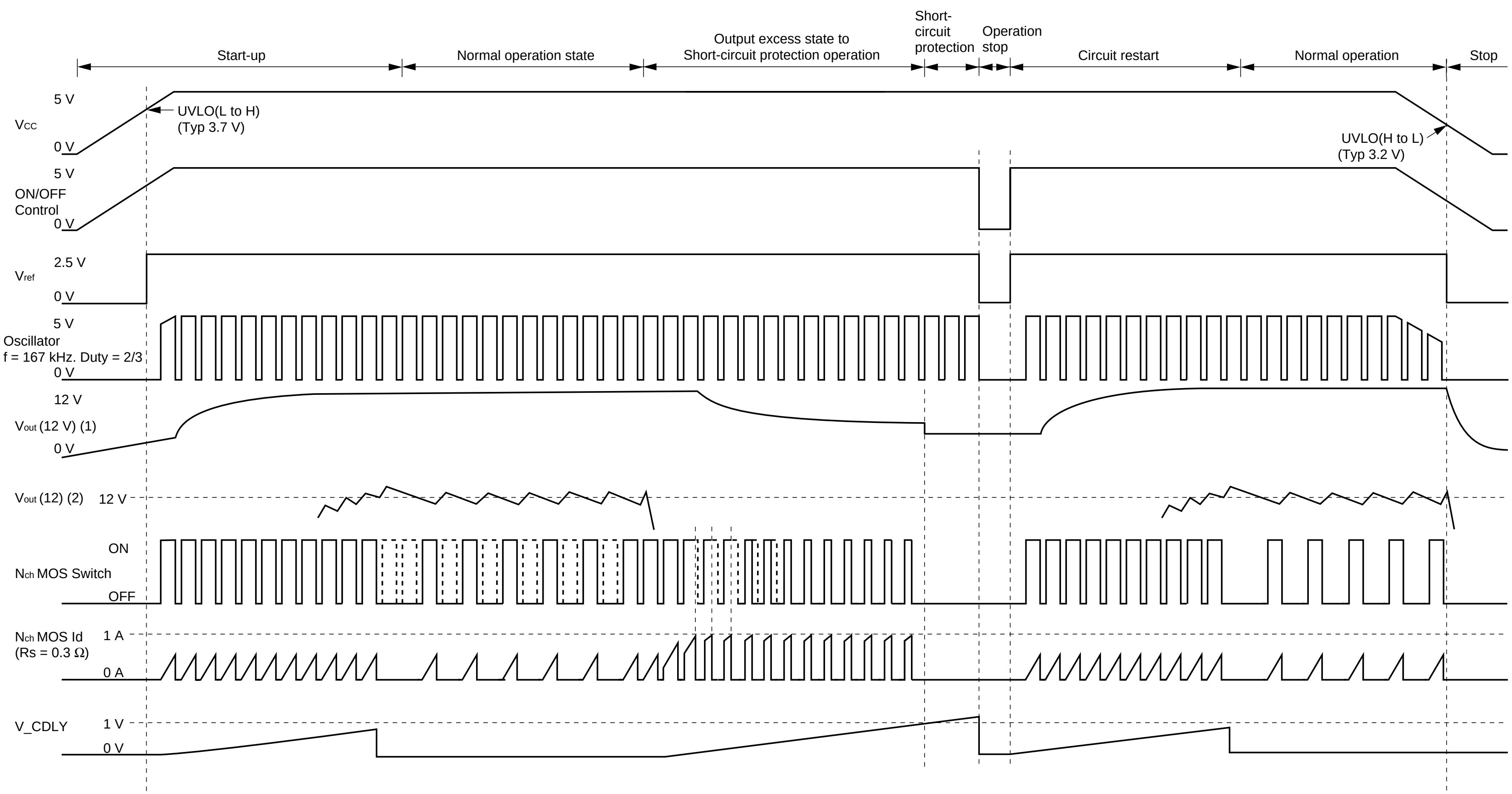


Figure 3. Operating Waveform



Detailed Descriptions

(1) Reference voltage circuit (BGR)

The reference voltage circuit is composed of band gap reference circuits, and generates the temperature-compensated reference voltage (2.5 V).

(2) Low voltage error prevention circuit (UVLO)

The low voltage error prevention circuit is the circuit which cuts off output in order to prevent circuit errors caused by supply voltage shortage at the time of start-up or power cutoff.

The circuit operation stops if the level goes lower than 3.7 V ($V_{IN(L-H)}$) during power rise, and lower than 3.2 V($V_{IN(H-L)}$) during power fall.

Caution: The circuit does not operate if the ON/OFF pin is set from the low level into open state within the hysteresis voltage range between $V_{IN(L-H)}$ and $V_{IN(H-L)}$.

(3) ON/OFF control circuit (ON/OFF)

This circuit stops internal oscillation and switching operation by setting the ON/OFF control pin at the low level (grounding). In this case, the circuit current goes as low as 100 μA (MAX).

(4) Oscillation circuit (OSC)

This circuit generates the 167-kHz/on-duty 67% signal by connecting 68 kΩ to the R_T pin.

(5) Timer-latch-type short-circuit protection circuit (SCP)

When output is in either the short-circuit or overload state, the FET that keeps the C_{DLY} pin in the low level is turned off, then the charge current starts flowing from the internal constant current circuit to the delay capacitor which is externally connected to the C_{DLY} pin.

If the output of the output voltage detection converter is not restored before the C_{DLY} pin voltage reaches approx. 1 V, the latch circuit starts operation to turn off the output transistor.

To release the latch, lower the supply voltage or turn off the ON/OFF control circuit signal so that the latch circuit is reset. While the latch circuit is in operation, the circuit remains inactivated if the output is restored normally.

(6) Output voltage detection comparator (V_SENSE)

This comparator stabilizes output by detecting the output voltage (12 V) as switching power to compare it with the internal reference voltage.

(7) Excess current detection comparator (I_SENSE)

This comparator monitors the current value in the output MOSFET and turns off the output MOSFET when the current value goes beyond the level set in the external resistor.

Excess current detection voltage is set at 0.3 V.

(8) Charge pump circuit (CHG_PUMP)

This is a step-up circuit which generates the gate voltage of the output MOSFET. This circuit is able to boost input voltage twice as high by connecting two external capacitors.

With the charge pump circuit incorporated, low Ron (0.5 Ω MAX) of the output MOSFET is attained.

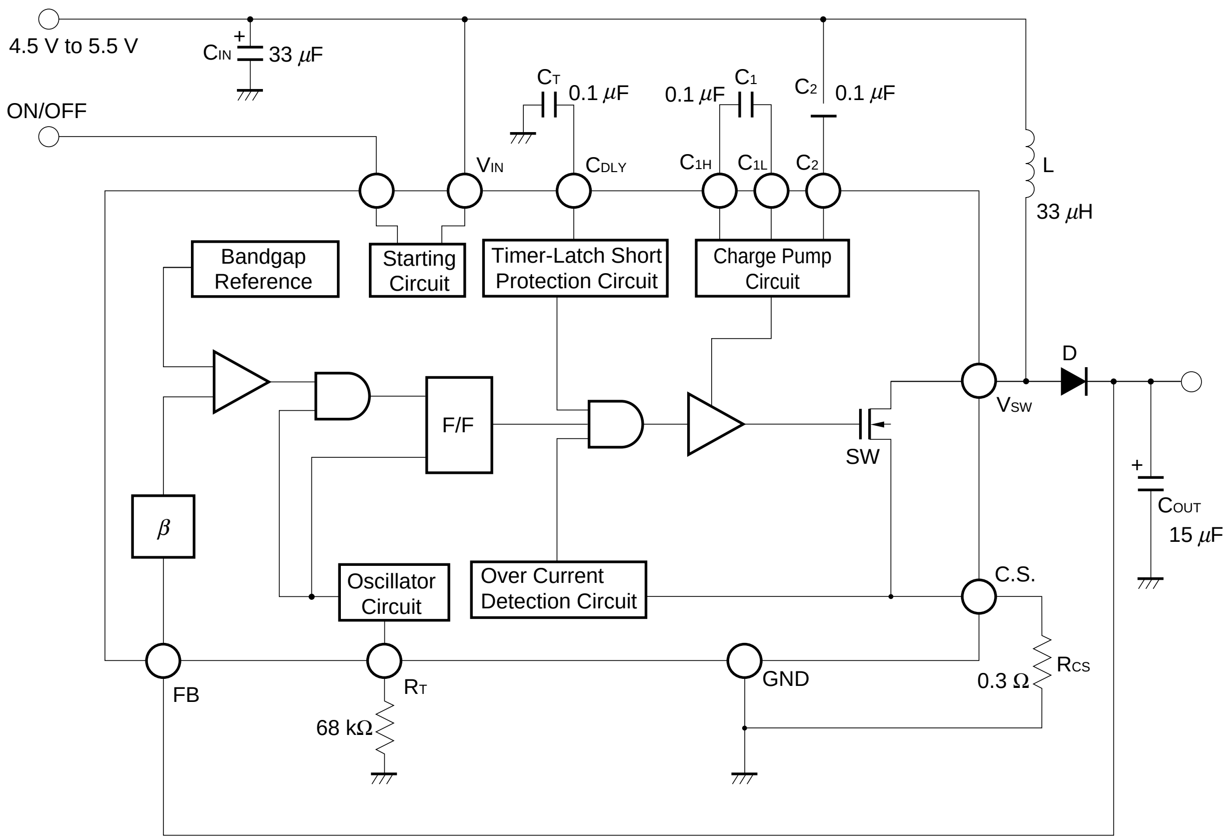
(9) Output SW MOSFET (Output SW)

The output circuit has the open drain configuration of N channel MOSFET, and has the capability of 1-A output current.

6. Designing a Step-up Converter with μPD16901

6.1 Circuit Diagram of the Board

Figure 4. 5 V/12 V Step-Up Converter Using μPD16901



* It is recommended to connect pins of No. 10, 11 and 12 to the GND pin.

6.2 Designing an Evaluation Board

To configure the 5 V → 12 V step-up power supply using the μPD16901, the following devices will be necessary.

Table 5. Devices Needed to Create DC/DC Converter

Device used	Purpose	Number of unit
μPD16901	DC/DC converter IC for 5 V → 12 V step-up	1
C_1, C_2	Charge pump capacitor (0.1 μF)	1 each
C_{DLY}	Delay capacitor for timer latch short-circuit prevention	1
R_T	Timing resistor for the setting of oscillation frequency (68 kΩ)	1
R_{CS}	Excess current detection resistor	1
L	Choke coil	1
C_{IN}	Input smoothing capacitor	1
C_{OUT}	Output smoothing capacitor	1
D	Schottky barrier diode	1

In this section, how to select these devices will be briefly explained.

6.2.1 Charge pump capacitor (C_1, C_2)

The charge pump circuit of the μPD16901 is composed of double step-up circuits for supply voltage (V_{DD}), and requires two external charge pump capacitors.

As recommended in Table 3, a 0.1 μF capacitor for charge pump shall be connected to the pins between C_{1H} and C_{1L}, and to the pins between C_2 and GND.

By connecting charge pump capacitors, approx. 10 V will be applied to the gate of output stage MOSFET, and ON resistance can be reduced.

The charge pump dependency of the supply voltage and of the ambient temperature are shown in Figures 5 and 6 respectively.

Figure 5. Charge Pump Voltage - Supply Voltage Characteristics

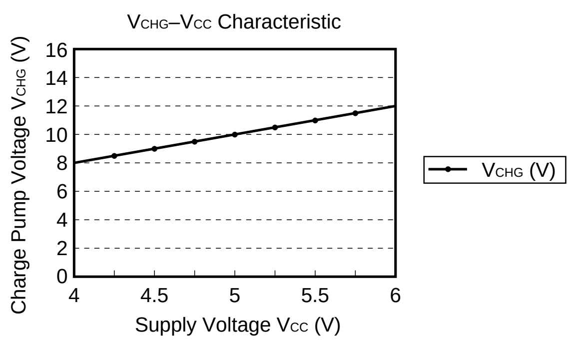
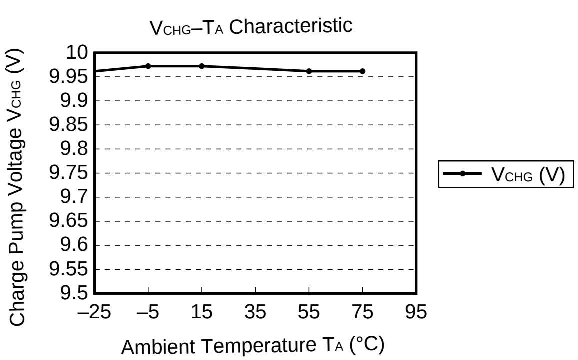


Figure 6. Charge Pump Voltage - Temperature Characteristics



6.2.2 Delay Capacitor for Timer Latch Short-Circuit Prevention (C_{DLY})

The timer latch circuit is a latch-type protection circuit that prevents heat damage to ICs when the power remains either in an output short-circuit state or in an overload state for a longer time than is set by the external delay capacitor (C_{DLY}).

The circuit block diagram of the timer latch short-circuit protection circuit is shown in Figure 7.

As shown in Table 4, the output current of the timer latch circuit is 3.3 μA (TYP), and the timer latch detection voltage is 1.0 V (TYP). Therefore, the delay time before operation start of the latch circuit changes depending on the value of the delay capacitor.

Capacitor (C), current (i), voltage (v), time (t) are generally expressed as follows:

$$v = \int (i)dt / C \quad \text{.................................} \quad (1)$$

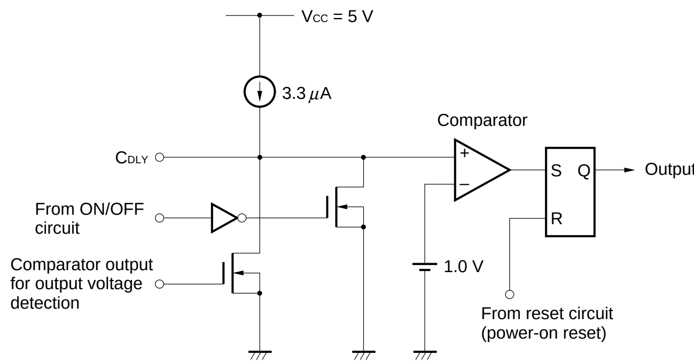
If the timer latch detection voltage 1.0 V is substituted in Formula (1) , the formula can be transformed as follows:

$$\text{Delay time } (t_{DLY}) = C / 3.3 \text{ (s)} \text{.......} \quad (2) \quad \text{(Remark: C is } \mu\text{F)}$$

Therefore, the delay time is proportional to the timer latch capacitor.

Be sure to connect C_{DLY} to the GND when not used.

Figure 7. Timer Latch Short-Circuit Protection Circuit



6.2.3 Timing resistor for the setting of oscillation frequency (R_T)

With a 68-kΩ timing resistor connected to the R_T pin, this resistor generates the reference current of approximately 15 μA and the frequency of 167 kHz (Duty: 67%).

In the case of the μPD16901, the oscillation frequency cannot be changed by means of external setting. Connect a 68-kΩ timing resistor to the R_T pin.

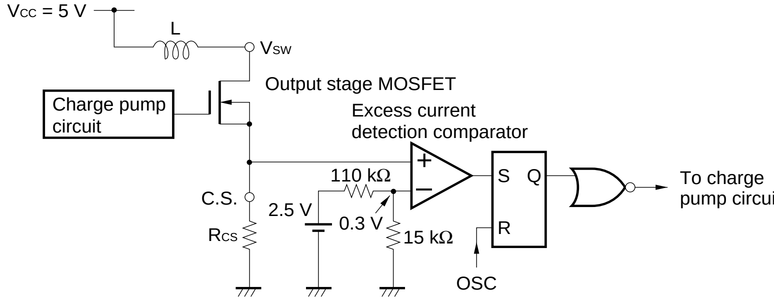
6.2.4 Excess current detection resistor (R_{CS})

The diagram chart of the excess current detection comparator is shown in Figure 8.

To the reversal input pin of the detection comparator is input the voltage (0.3 V), which is the reference voltage (= 2.5 V) divided by 110 kΩ and 15 kΩ. The CS pin is connected to the non-reversal input pin of the excess current detection comparator. The excess current limit can be set by connecting the excess current detection resistor (R_{CS}) to the CS pin externally.

Since the current rating of the output stage MOSFET in the μPD16901 is 1 A, set the R_{CS} to 0.3 Ω or higher.

Figure 8. Excess Current Detection Comparator



6.2.5 Choke coil (L)

The size of the choke coil influences the level of ripple current caused by MOSFET switching.

The ripple current (turn-on mode) is expressed as follows:

$\Delta I_L \fallingdotseq (V_I - V_{DS}) \times T_{ON} / L$ • • • • • • • • • • • (3)

Since the current rating of the μPD16901 is 1 A, the inductance of the choke coil can be calculated based on Formula (3) as:

$L = (V_I - V_{DS}) \times T_{ON} / \Delta I_L$

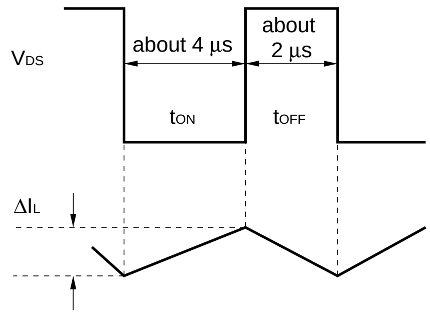
$= (5V - 0.3\ V) \times 4\mu s / 1A$

$\fallingdotseq 19\ \mu H$

To ensure continuous operation, inductance of 19 μH or higher has to be added.

($V_I = V_{CC} = 5$ V, V_{DS}: drain-source voltage of output stage MOSFET t_{ON}: turn-on time, t_{OFF}: turn-off time, L: inductance)

Figure 9. Current Waveform of Output Coil



But the larger the inductance becomes, the smaller the allowable current value of the choke coil becomes. It is preferable to set the inductance somewhere between 33 μH and 47 μH.

Note that since lowering of the forward voltage occurs both to impedance of the choke coil and the schottky barrier diode, these factors have to be considered at the actual designing stage.

6.2.6 Input smoothing capacitor (C_{IN})

The noises of the input power line may cause IC errors and affect the efficiency of ICs. To the input pin (V_{CC} pin), add a smoothing capacitor with a capacity of over 10 V and 33 μF.

6.2.7 Output smoothing capacitor (C_{OUT})

Selection of the type of output smoothing capacitor may affect output ripple voltage (V_{RIP}). The output ripple voltage is expressed by the product of the output ripple current (ΔI_L) shown in Figure 9 and the equivalent serial resistance (ESR) of output capacitors (Formula (4)) .

$V_{RIP} = \Delta I_L \times ESR$ • • • • • • • • • • • • • • • • • (4)

For example, when the output ripple current is equal to 0.4 A, and the output ripple voltage is lower than 100 mV, the ESR can be calculated based on Formula (4) as:

$ESR \leq V_{RIP} / \Delta I_L$

$\leq 0.1A / 0.4A$

$\leq 250\ m\Omega$ • • • • • • • • • • • • • • • • • • (5)

Therefore, a capacitor with the equivalent serial resistance of 250 mΩ or lower must be used.

Not only the condition of Formula (5) need be satisfied but also the ripple current has to be within the range of the allowable current value. The allowable current value of capacitors ($I_{r.m.s.}$) is generally expressed as effective value as in Formula (6):

$I_{r.m.s.} = \Delta I_L / 2\sqrt{3}$ • • • • • • • • • • • • • • • • • (6)

Therefore, when $\Delta I_L = 1A$,

$I_{r.m.s.} = 1A / 2\sqrt{3}$

$\fallingdotseq 290\ mA$

Hence, a capacitor with the allowable current of 290 mA or higher will be needed.

6.2.8 Schottky barrier diode (D)

The equivalent level of current to the output MOSFET flows to the schottky barrier diode. Therefore, as to current rating, a product with the same/higher rating than that of the MOSFET (higher than 1 A) should be chosen.

To improve efficiency, it is recommended to use one with a low forward voltage (V_F) of about 0.5 V.

7. EVALUATION RESULT

7.1 Evaluation board specifications

This section will mention the evaluation result of the evaluation board created based on the design procedures in Section 6. The devices chosen are shown in Table 6.

The specifications of DC/DC converter illustrated in Figure 4 are shown in Table 7.

Table 6. Devices Used for Evaluation Board

Parts used	Purpose	Specification
μPD16901	DC/DC converter IC	–
C_1, C_2	Charge pump capacitor	0.1 μF
C_{DLY}	Delay capacitor for timer latch short-circuit prevention	0.1 μF
R_T	Timing resistor for setting of oscillation frequency	68 kΩ
R_{CS}	Excess current detection resistor	0.33 Ω
L	Choke coil	33 μH
C_{IN}	Input smoothing capacitor	33 μF
C_{OUT}	Output smoothing capacitor	15 μF
D	Schottky barrier diode	0.45 V

Table 7. Electric Characteristics

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Output voltage	V_{OUT}	4.5 V $\le V_{IN} \le$ 5.5 V 0 mA $\le$ IO $\le$ 140 mA 0°C $\le T_A \le$ 60°C	11.52	12.00	12.48	V
Input stability	REG_{IN}	4.5 V $\le V_{IN} \le$ 5.5 V		0.5		% / V
Load stability	REG_L	0 mA $\le$ IO $\le$ 140 mA		0.004		% / mA
Conversion efficiency	η			83		%
Circuit operation current	I_{CC}	IO = 0			3.0	mA
Circuit current in stand-by mode	$I_{CC\ (OFF)}$	ON/OFF pin voltage = 0 V			100	μA
Start-up voltage	V_{IN} (start-up)			3.7	4.3	V

Note This connection diagram describes reference values confirmed in Figure 4, and is not intended to guarantee such characteristics.

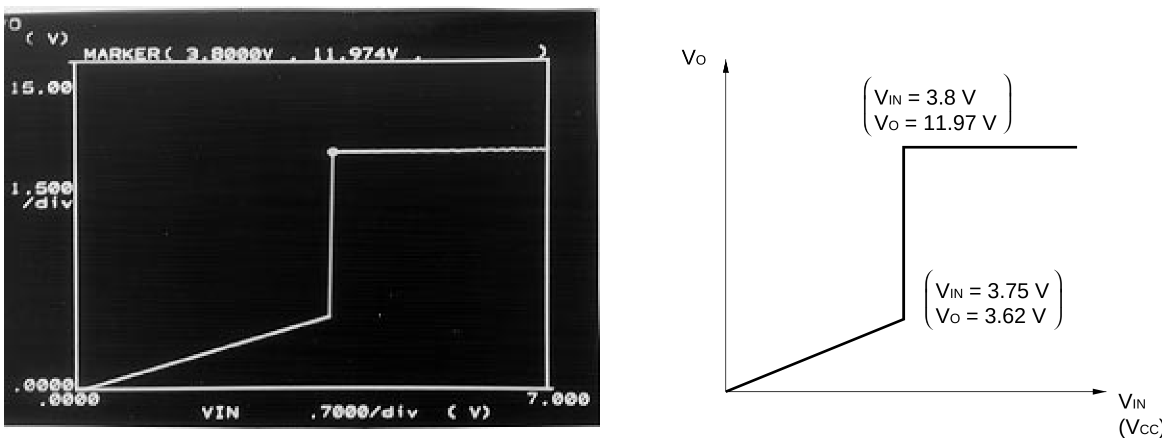
7.2. CHARACTERISTICS EVALUATION

7.2.1 V_O-V_{CC} characteristics

Figure 10 shows the change of the output voltage when the input voltage rises from 0 V to 7 V.

The rise of the 12-V output voltage can be observed when the input voltage reaches about 3.8 V. With a low voltage error prevention circuit incorporated, the μPD16901 is designed to start operation when the input voltage is 3.7 V (TYP) or higher. (See Table 4)

Figure 10. V_O-V_{CC} Characteristics

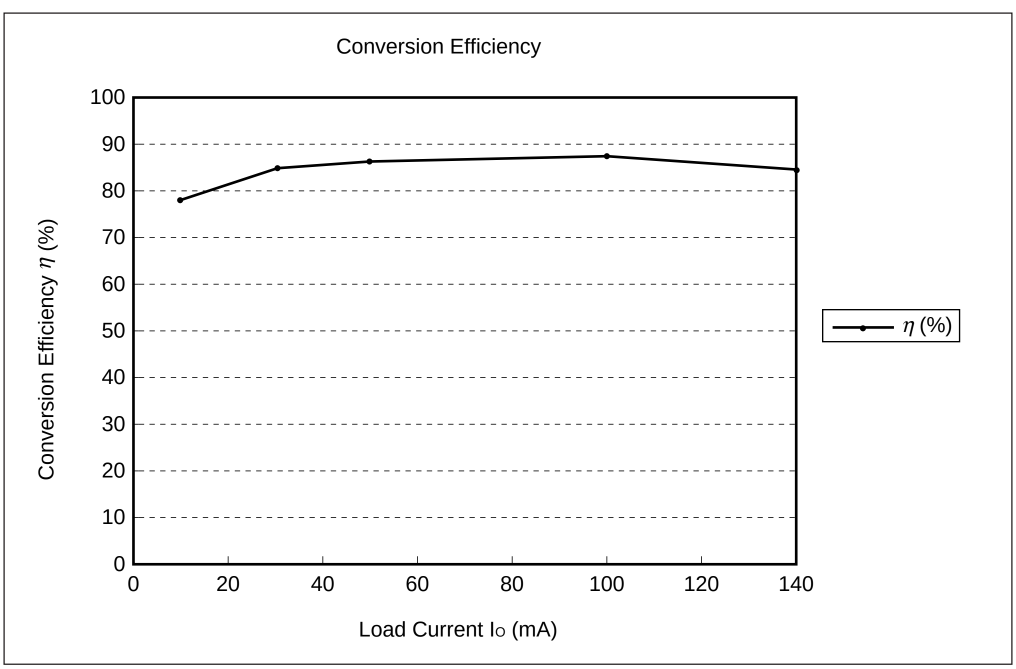


7.2.2 Conversion efficiency characteristics

The conversion efficiency indicates energy conveyance between the input and the output, and is considered to be an important characteristic because it may affect continuous operation hours especially of battery-driven devices.

Figure 11 shows the relation between conversion efficiency (η) of this estimation board and the load current characteristic (I_O). An efficiency of over 84% has been confirmed within the load current range from 30 mA to 140 mA.

Figure 11. Conversion Efficiency

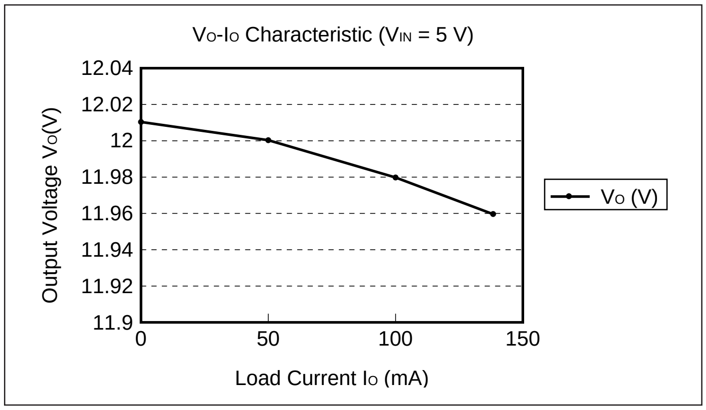


7.2.3. Load stability

The output voltage fluctuation against the load current is called load stability. The load stability characteristic is shown in Figure 12.

In the case of this evaluation board, the voltage of 12.01 V is output when there is no load, and the voltage of 11.96 V is output when the load current is at 140 mA. Therefore, the load stability of this evaluation board is –0.003%/mA.

Figure 12. Load Stability Characteristic



7.2.4 Output ripple voltage

The output ripple voltage is shown in Figures 13, 14 and 15. The output waveform in Figure 13 was measured with no load; the one in Figure 14 when the load was 50 mA; and the one in Figure 15 when the load was 140 mA.

When there is no load, such fluctuations of the output voltage as in Figure 13 are not caused by the load current. Instead, the ripples are caused by the generation frequency of 167 kHz of the μPD16901. On the other hand, the output may go lower than 12 V owing to load stability when the load is at either 50 mA or 100 mA. As mentioned at the beginning, the μPD16901 employs the pulse number modulation method (PNM) , and performs switching of the output MOSFET so that the output voltage may stay at 12 V when it fluctuates. Therefore, the ripple frequency changes depending on the level of the load current. The greater the load current becomes, the higher the frequency becomes.

Figure 13. Output Ripple Voltage (no load)

(50 mV/DIV, 2 ms/DIV)

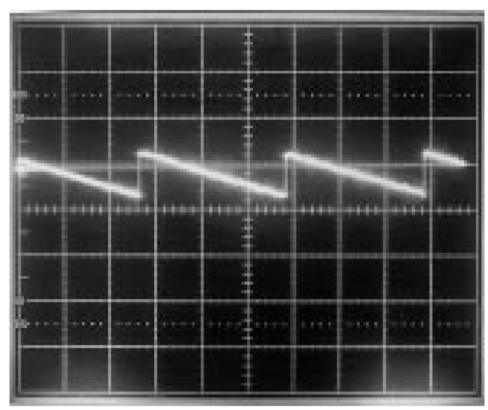


Figure 14. Output Ripple Voltage (load of 50 mA)

(50 mV/DIV, 10 μs/DIV)

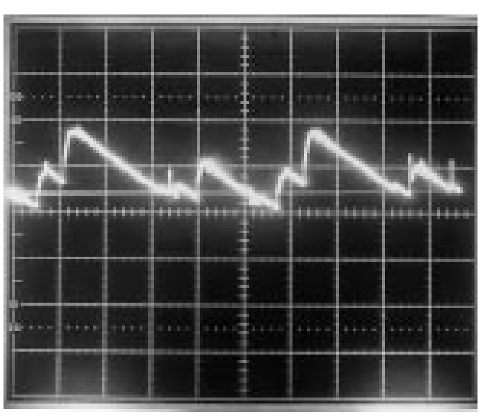
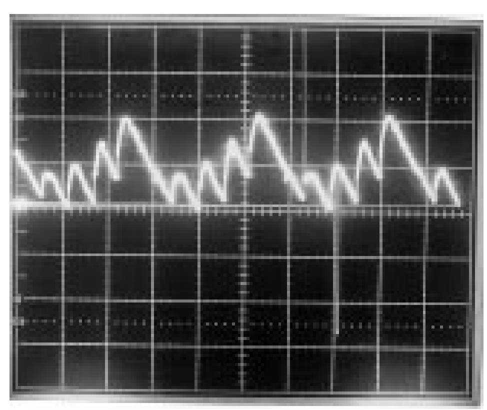


Figure 15. Output Ripple Voltage (load of 140 mA)

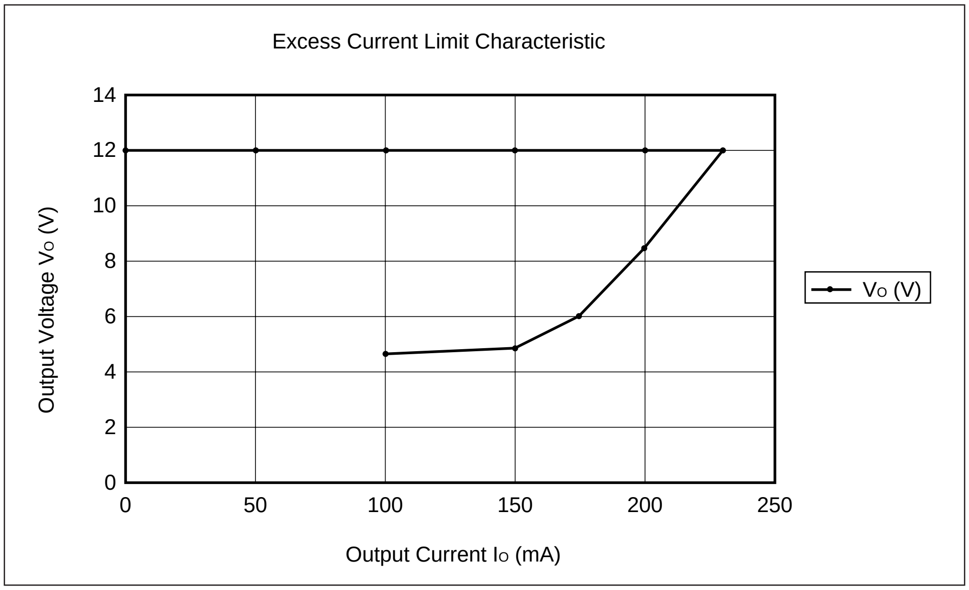
(50 mV/DIV, 10 μs/DIV)



7.2.5 Excess current limit characteristic

The current limit characteristic under the condition of R_{CS} = 0.33 Ω is shown in Figure 16.
It can be observed that the excess current limit circuit starts at about 240 mA.

Figure 16. Excess Current Limit Characteristic



The major characteristics of this evaluation board shown in Figures 10 to 16 may have a minor error range depending on pattern designing and parts used. Please be sure to perform thorough evaluation tests before actual use.

8. Referential Documents

Information: “Guide to Quality Assurance for Semiconductor Devices”
Document No. : MEI-1202

Information: “NEC Semiconductor Device Reliability/Quality Control System”
Document No. : C10983E

Information: “Semiconductor Device Mounting Technology Manual”
Document No. : C10535E

Information: “Semiconductor Device Package Manual”
Document No. : C10943X

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