

### DC-DC CONVERTER CONTROL IC

#### DESCRIPTION

The  $\mu$  PC1933 is an IC that controls a low-voltage input DC-DC converter. This IC is suitable for an operation with 3-V, 3.3-V input or a lithium ion secondary battery input, because the minimum operating supply voltage is 2.5 V.

Because of its wide operating voltage range, it can also be used to control DC-DC converters that use an AC adapter for input.

#### FEATURES

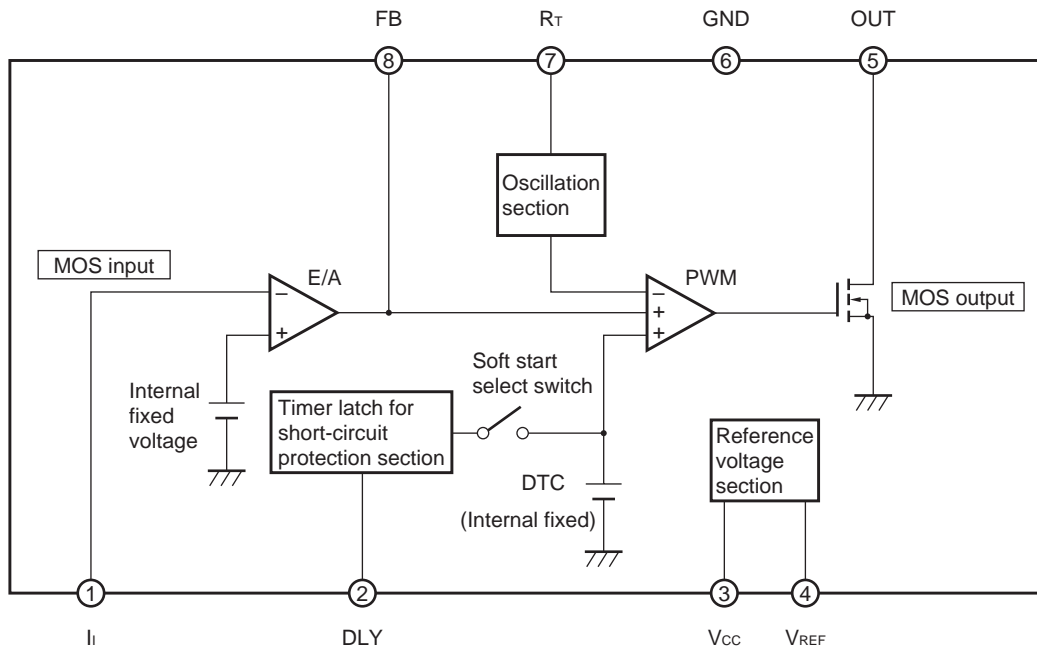
- Low supply voltage: 2.5 V (MIN.)
- Operating voltage range: 2.5 to 20 V (breakdown voltage: 30 V)
- Timer latch circuit for short-circuit protection.
- Ceramic capacitor with low capacitance (0.1  $\mu$  F) can be used for short-circuit protection.
- Open drain output (1 channel: This output can be used to control a step-down converter, a step-up converter.)
- Dead time is internally fixed to 85 %.
- Soft start function (with a circuit to convert the timer latch circuit.)

#### ORDERING INFORMATION

Part Number	Package
$\mu$ PC1933GR	8-pin plastic SOP (5.72 mm (225))

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Not all devices/types available in every country. Please check with local NEC representative for availability and additional information.

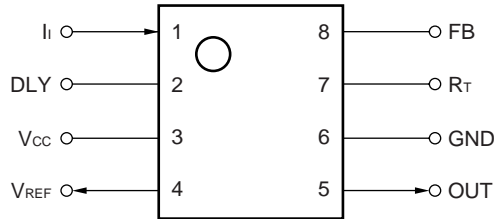
BLOCK DIAGRAM



**PIN CONFIGURATION (Top View)**

8-pin plastic SOP (5.72 mm (225))

•  $\mu$ PC1933GR



**PIN FUNCTIONS**

Pin No.	Symbol	Function	Pin No.	Symbol	Function
1	I <sub>i</sub>	Error amplifier inverted input	5	OUT	Open-drain output
2	DLY	Short-circuit protection	6	GND	Ground
3	V <sub>CC</sub>	Power supply	7	R <sub>f</sub>	Frequency setting resistor connection
4	V <sub>REF</sub>	Reference voltage output	8	FB	Error amplifier output

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1. ELECTRICAL SPECIFICATIONS

**Absolute Maximum Ratings (unless otherwise specified, T<sub>A</sub> = 25 °C)**

Parameter	Symbol	Ratings	Unit
Supply voltage	V <sub>CC</sub>	30	V
Output voltage	V <sub>O</sub>	30	V
Output current (open drain output)	I <sub>O</sub>	21	mA
Total power dissipation	P <sub>T</sub>	480	mW
Operating ambient temperature	T <sub>A</sub>	-20 to + 85	°C
Storage temperature	T <sub>stg</sub>	-55 to + 150	°C

**Caution** Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

**Recommended Operating Conditions**

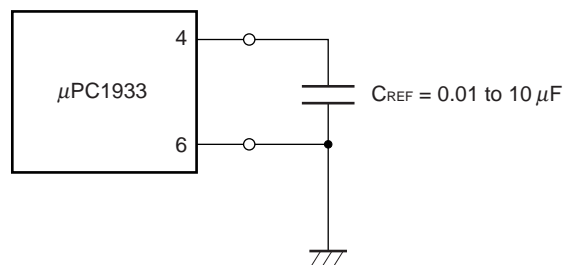
Parameter	Symbol	Ratings			Unit
Supply voltage	V <sub>CC</sub>	2.5		20	V
Output voltage	V <sub>O</sub>	0		20	V
Output current	I <sub>O</sub>			20	mA
Operating temperature	T <sub>A</sub>	-20		+85	°C
Oscillation frequency	f <sub>osc</sub>	20		800	kHz

★ **Caution** The recommended operating range may be exceeded without causing any problems provided that the absolute maximum ratings are not exceeded. However, if the device is operated in a way that exceeds the recommended operating conditions, the margin between the actual conditions of use and the absolute maximum ratings is small, and therefore thorough evaluation is necessary. The recommended operating conditions do not imply that the device can be used with all values at their maximum values.

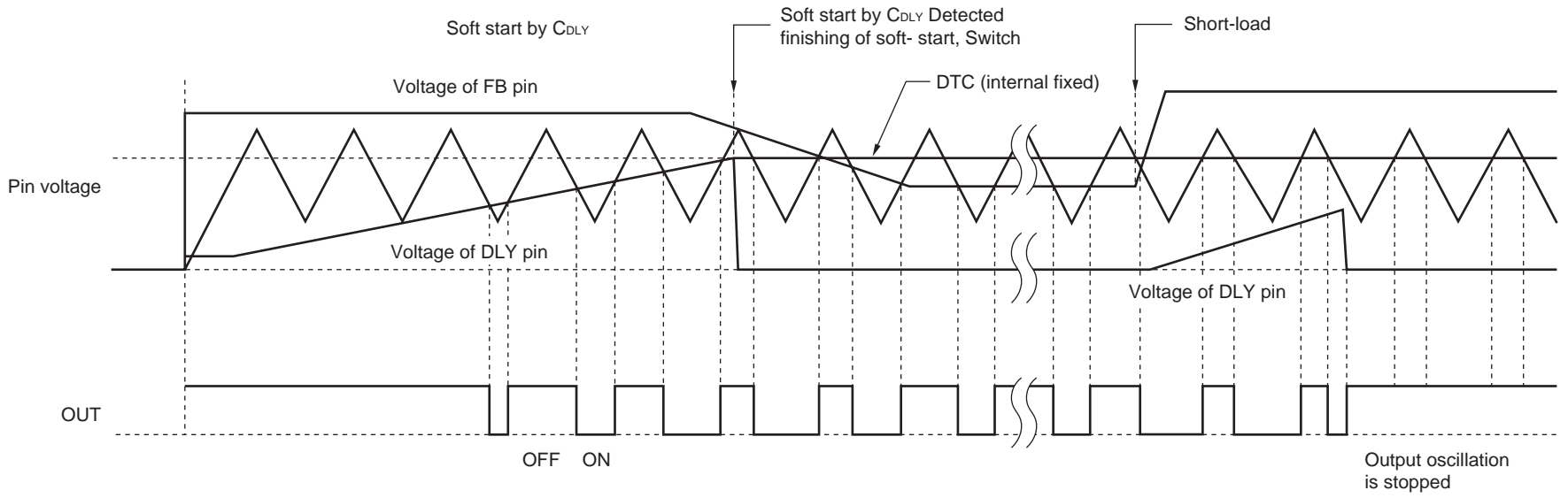
Electrical Characteristics (unless otherwise specified,  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{CC} = 3\text{ V}$ ,  $f_{osc} = 100\text{ kHz}$ )

Block	Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Under voltage	Start-up voltage	$V_{CC(L-H)}$	$I_{REF} = 0.1\text{ mA}$		1.57		V
	Operation stop voltage	$V_{CC(H-L)}$	$I_{REF} = 0.1\text{ mA}$		1.5		V
Lock-out section	Hysteresis voltage	$V_H$	$I_{REF} = 0.1\text{ mA}$	30	70		mV
	Reset voltage (timer latch)	$V_{CCR}$	$I_{REF} = 0.1\text{ mA}$		1.0		V
★ Voltage section	Reference voltage	$V_{REF}$	$I_{REF} = 1\text{ mA}$	2.0	2.1	2.2	V
	Line regulation	$REG_{IN}$	$2.5\text{ V} \leq V_{CC} \leq 20\text{ V}$		2	12.5	mV
	Load regulation	$REG_L$	$0.1\text{ mA} \leq I_{REF} \leq 1\text{ mA}$		2	7.5	mV
	Temperature coefficient	$\Delta V_{REF}/\Delta T$	$-20\text{ }^\circ\text{C} \leq T_A \leq +85\text{ }^\circ\text{C}$ , $I_{REF} = 0\text{ A}$		0.5		%
Oscillation section	$f_{osc}$ setting accuracy	$\Delta f_{osc}$	$R_T = 18\text{ k}\Omega$	-20		+30	%
	$f_{osc}$ total stability	$\Delta f_{osc}$	$-20\text{ }^\circ\text{C} \leq T_A \leq +85\text{ }^\circ\text{C}$ , $2.5\text{ V} \leq V_{CC} \leq 20\text{ V}$	-20		+50	%
PWM comparator section	Maximum duty	$D_{MAX.}$			85		%
	Soft start time	$t_{SS}$	$C_{DLY} = 0.1\text{ }\mu\text{F}$		50		ms
★ Error Amplifier section	Input threshold voltage	$V_{ITH}$		0.285	0.3	0.315	V
	Input bias current	$I_B$		-100		+100	nA
	Open loop gain	$A_v$	$V_O = 0.3\text{ V}$	70	80		dB
	Unity gain	$f_{unity}$	$V_O = 0.3\text{ V}$		1.5		MHz
	Maximum output voltage (+)	$V_{OM}^+$	$I_O = -45\text{ }\mu\text{A}$	1.6	2		V
	Maximum output voltage (-)	$V_{OM}^-$	$I_O = 45\text{ }\mu\text{A}$		0.02	0.5	V
	Output sink current	$I_{Osink}$	$V_{FB} = 0.5\text{ V}$	0.8	1.4		mA
	Output source current	$I_{Osource}$	$V_{FB} = 1.6\text{ V}$		-70	-45	$\mu\text{A}$
★ Output section	Drain cutoff current	$I_{LEAK}$	$V_O = 30\text{ V}$			100	$\mu\text{A}$
	Output ON voltage	$V_{OL}$	$R_L = 150\text{ }\Omega$		0.2	0.6	V
	Rise time	$t_r$	$R_L = 150\text{ }\Omega$		50		ns
	Fall time	$t_f$	$R_L = 150\text{ }\Omega$		60		ns
★ Short-circuit Protection section	Input sense voltage	$V_{TH}$		1.75	1.92	2.05	V
	UV sense voltage	$V_{UV}$			0.8	0.85	V
	Source current on short-circuiting	$I_{OUV}$		1.0	1.6	2.7	$\mu\text{A}$
	Delay time	$t_{DLY}$	$C_{DLY} = 0.1\text{ }\mu\text{F}$		50		ms
★ Overall	Circuit operation current	$I_{CC}$	$V_{CC} = 3\text{ V}$	1.4	2.6	3.9	mA

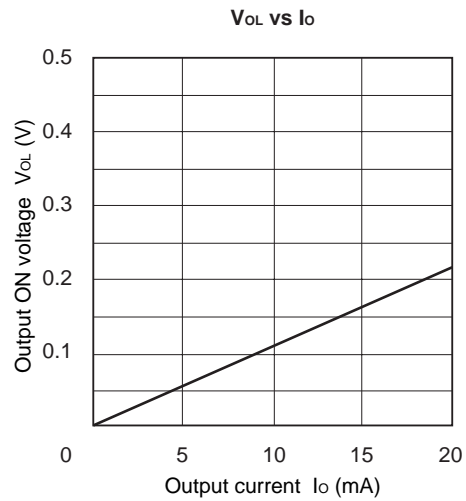
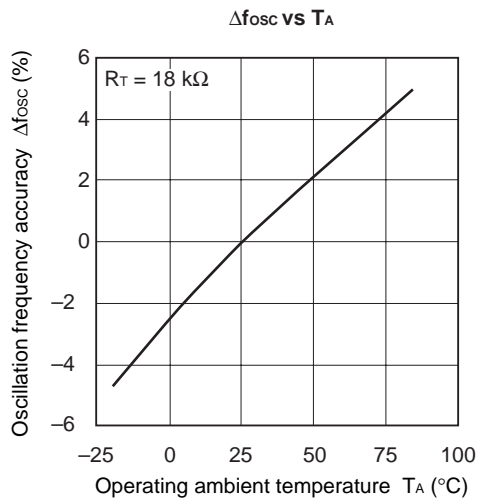
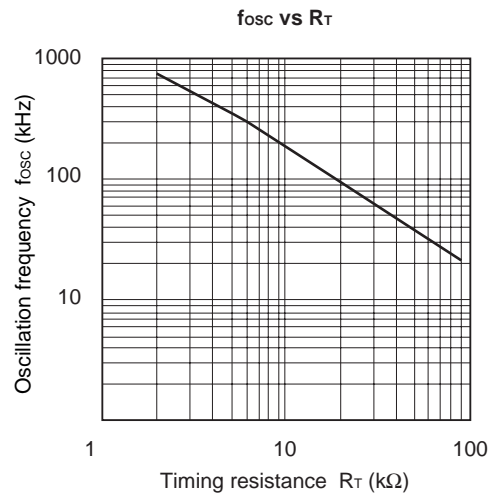
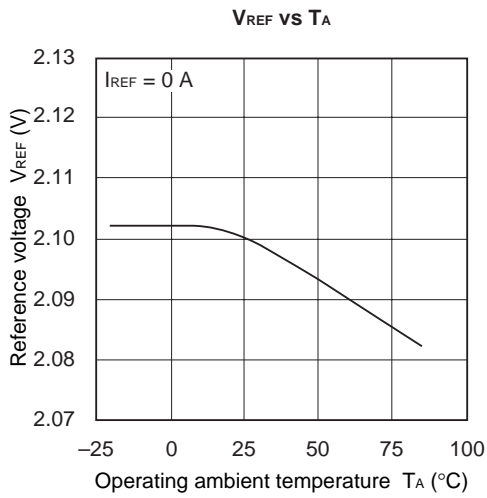
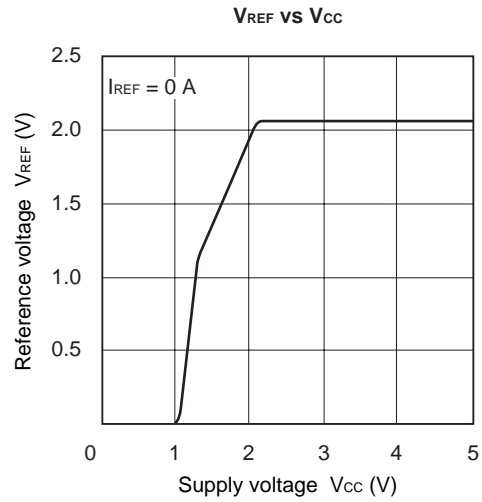
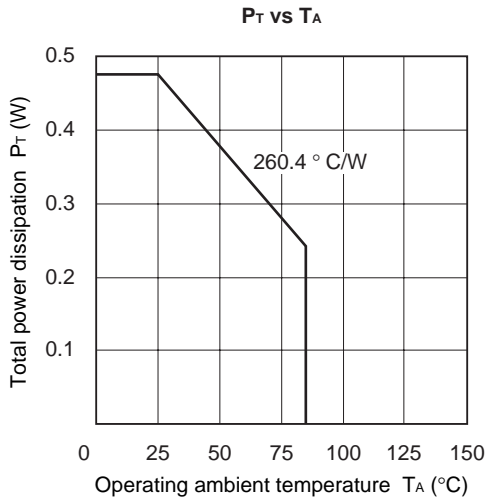
Caution Connect a capacitor of 0.01 to 10 μF to the VREF pin.



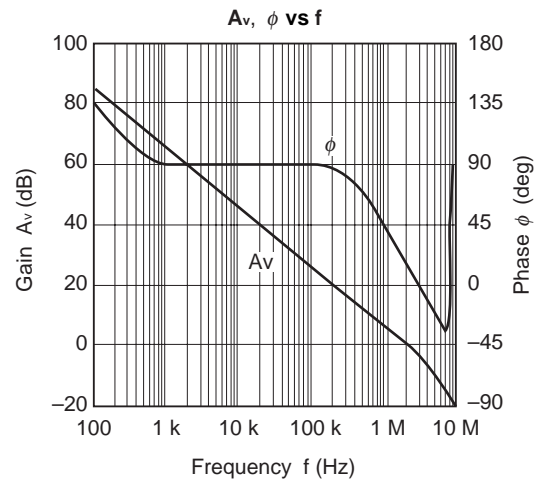
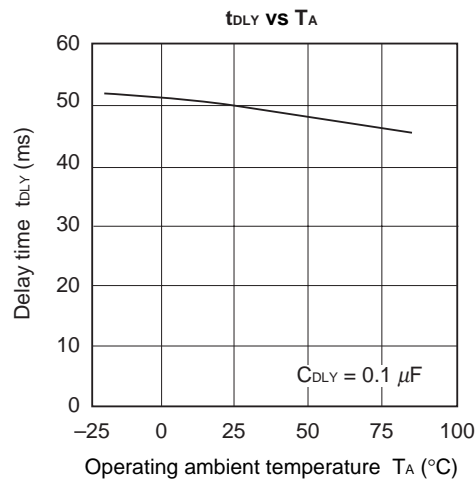
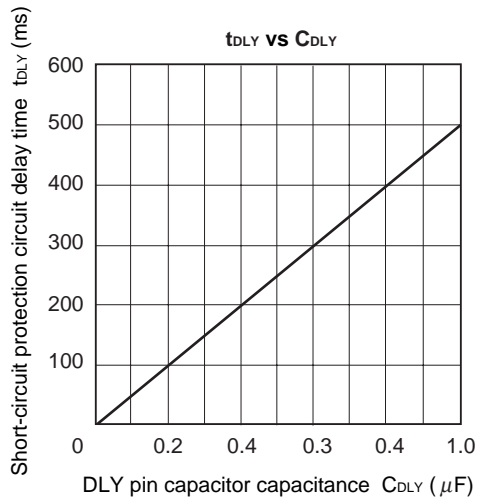
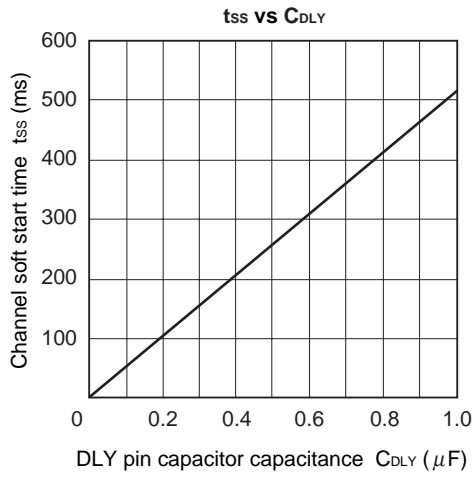
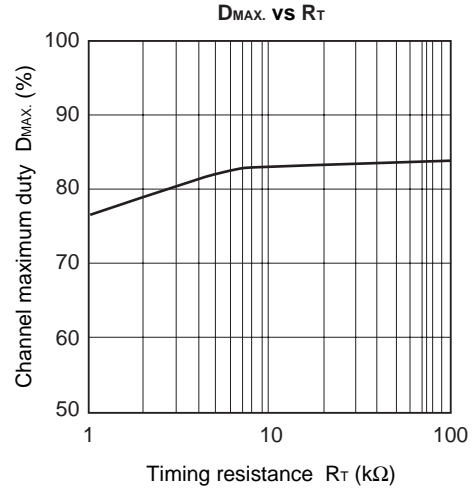
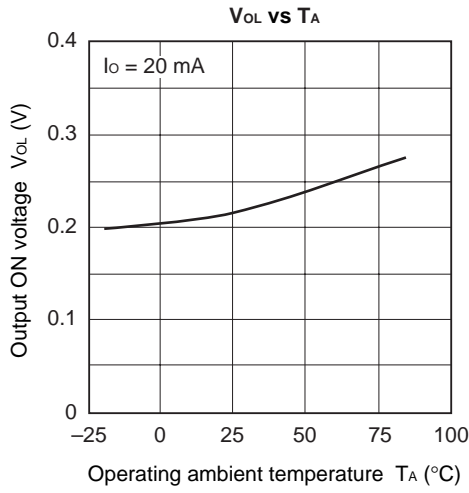
# Timing Chart

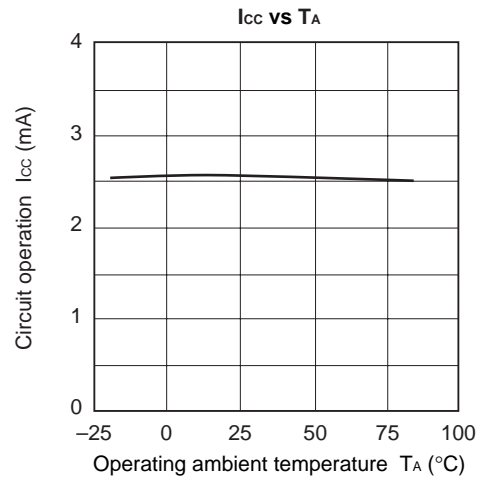
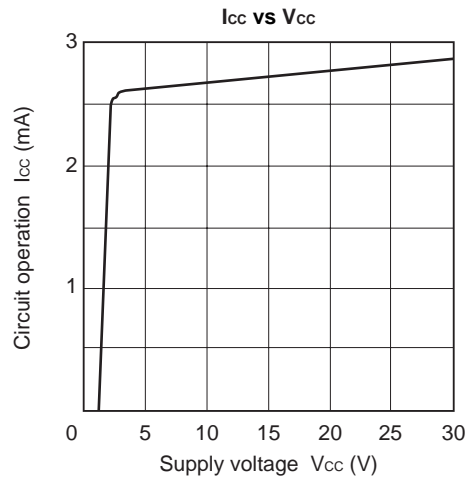


Typical Characteristic Curves (unless otherwise specified,  $V_{CC} = 3\text{ V}$ ,  $f_{osc} = 100\text{ kHz}$ ,  $T_A = 25\text{ }^\circ\text{C}$ ) (Nominal)



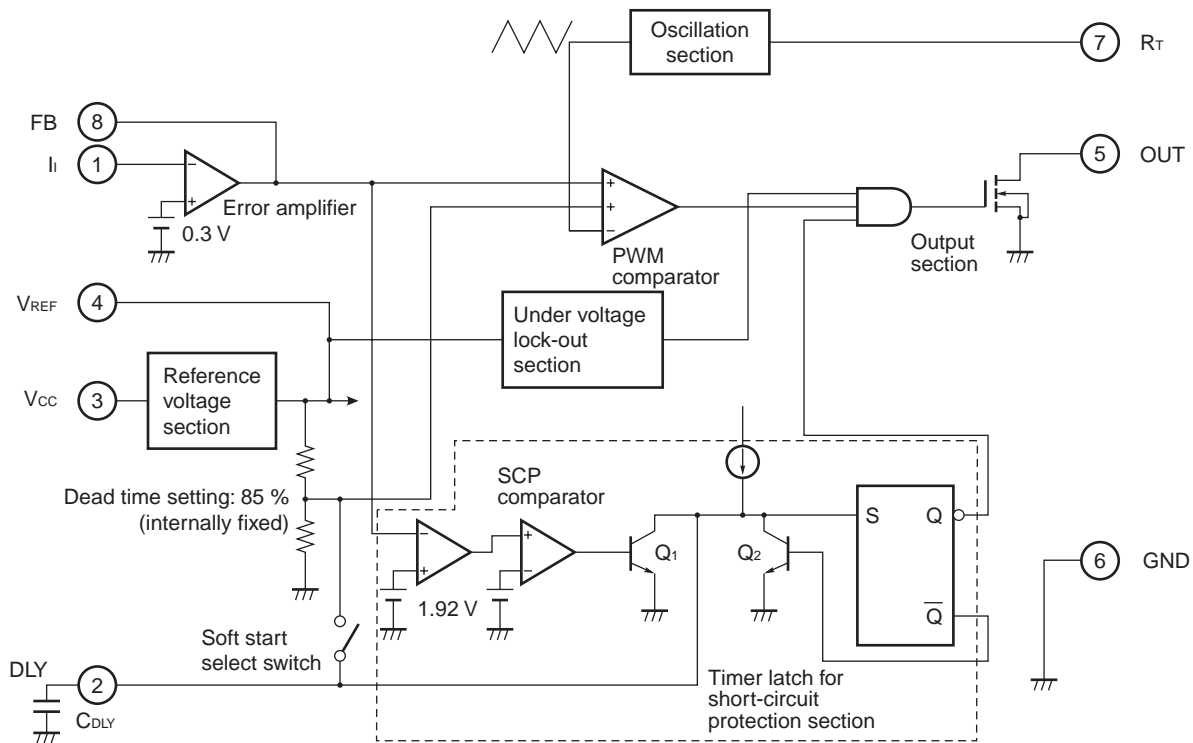






★ 2. CONFIGURATION AND OPERATION OF EACH BLOCK

Figure 2-1 Block Diagram



2.1 Reference Voltage Generator

The reference voltage generator is comprised of a band-gap reference circuit, and outputs a temperature-compensated reference voltage (2.1 V). The reference voltage can be used as the power supply for internal circuits, or as a reference voltage, and can also be accessed externally via the VREF pin (pin 4).

2.2 Oscillator

The oscillator self-oscillates if a timing resistor is attached to the Rt pin (pin 7). This oscillator waveform is input to the inverted input pin of the PWM comparator to determine the oscillation frequency.

2.3 Under Voltage Lock-out Circuit

The under voltage lock-out circuit prevents malfunctioning of the internal circuits when the supply voltage is low, such as when the supply voltage is first applied, or when the power supply is interrupted. When the voltage is low, the output transistor is cut off at the same time.

2.4 Error Amplifier

The non-inverted input pin of the error amplifier is connected internally to 0.3 V (the input threshold voltage is 0.3 V (TYP.)). The first stage of the error amplifier is a P-channel MOS transistor input.

## 2.5 PWM Comparator

The output ON duty is controlled according to the outputs of the error amplifier.

A triangular waveform is input to the inverted pin, and the error amplifier output and Dead Time Control pin voltage (fixed internally) are input to the non-inverted pins of the PWM comparator. Therefore, the output transistor ON period is the period when the triangular waveform is lower than the error amplifier output and Dead Time Control pin voltage (fixed internally) (refer to **Timing Chart**).

## 2.6 Timer Latch-Method Short Circuit Protection Circuit

When the output of the converter drops, the non-inverted input pin (1 pin) voltage of the error amplifier drops, and the FB output of the error amplifier of the output goes high. If the FB output exceeds the timer latch input detection voltage ( $V_{TH} = 1.92$  V), then the output of the SCP comparator goes low, and  $Q_1$  goes off.

When  $Q_1$  turns OFF, the constant-current supply charges  $C_{DLY}$  via the DLY pin. The DLY pin is internally connected to a flip-flop. When the DLY pin voltage reaches the UV detection voltage ( $V_{UV} = 0.7$  V (TYP.)), the output Q of the flip-flop goes low, and the output stage is latched to OFF (refer to **Figure 2-1 Block Diagram**).

Make the power supply voltage briefly less than the reset voltage ( $V_{CCR}$ , 1.0 V TYP.) to reset the latch circuit when the short-circuit protection circuit has operated.

## 2.7 Output Circuit

The output circuit has an N-channel open-drain output providing an output withstand voltage of 30 V (absolute maximum rating), and an output current of 21 mA (absolute maximum rating).

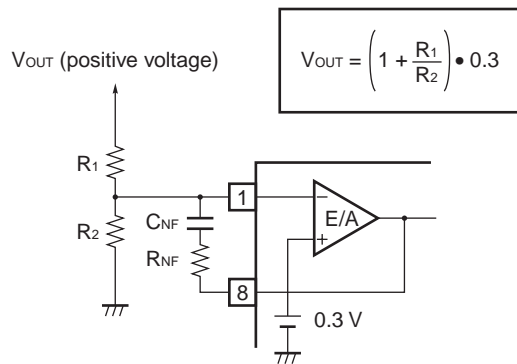
★ 3. NOTES ON USE

3.1 Setting the Output Voltage

Figure 3-1 illustrates the method of setting the output voltage. The output voltage is obtained using the formula shown in the figure.

The input threshold value of the error amplifier is 0.3 V (TYP.) for the error amplifier. Therefore, select a resistor value that gives this voltage.

Figure 3-1 Setting the Output Voltage



3.2 Setting the Oscillation Frequency

Choose  $R_T$  according to the oscillation frequency ( $f_{osc}$ ) vs timing resistor ( $R_T$ ) characteristics (refer to **Typical Characteristics Curves**  $f_{osc}$  vs  $R_T$ .) The formula below (3-1) gives an approximation of  $f_{osc}$ . However, the result of formula 3-1 is only an approximation, and the value must be confirmed in actual operation, especially for high-frequency operation.

$$f_{osc}[\text{Hz}] \cong 1.856 \times 10^9 / R_T[\Omega] \quad (3-1)$$

3.3 Preventing Malfunction of the Timer Latch-Method Short Circuit Protection Circuit

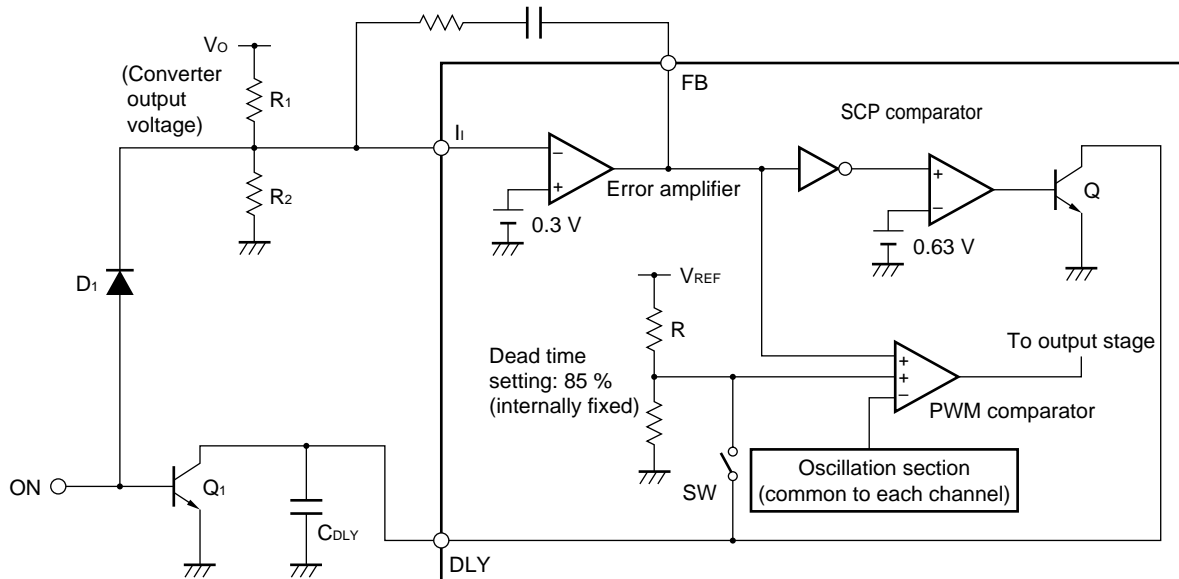
The timer latch short-circuit protection circuit operates when the error amplifier output (pin 8) exceed approximately 1.92 V, and cuts off the output. However, if the rise of the power supply voltage is fast, or if there is noise on the DLY pin (pin 2), the latch circuit may malfunction and cut the output off.

To prevent this, lower the wiring impedance between the DLY pin and the GND pin (pin 6), and avoid applying noise to the DLY pin.

### 3.4 ON/OFF Control

The ON/OFF control method of the output oscillation is to input the ON/OFF signal from ON as shown in Figure 3-2. Soft start or timer latch (SCP) is internally selected. Soft start is executed when the first start signal is input. When the end of soft start is detected, the soft start select switch is turned OFF and the timer latch circuit operates.

Figure 3-2 ON/OFF Control



#### (1) When ON is high: OFF status

Q1: ON → DLY pin: Low level → Output duty of PWM comparator: 0 %  
 D1: ON → Ii pin: High level → FB output: Low level

#### (2) When ON is low: ON status (start up)

Q1: OFF → CDLY is charged in the sequence of [VREF → R1 → SW → DLY pin → CDLY] → Soft start  
 D1: OFF → Ii pin: Low level → FB output: High level

#### (3) When ON goes high again after start up (SW: OFF): OFF status

Q1: ON → DLY pin: Low level (Nothing happens because SW is OFF.)  
 D1: ON → Ii pin: High level → FB output: Low level → PWM comparator output duty: 0 %  
 → Converter output voltage (Vo) drops.

**Caution** Even if start up is executed by making ON low again after (3), soft start is not executed because the soft start select switch (SW) remains OFF. To execute soft start again, drop Vcc to 0 V once.

### 3.5 Maximum Duty Limit

$\mu$ PC1933 is switched internally between Soft Start and Timer Latch. For this reason, the DTC voltage is fixed internally, and the maximum duty is limited to 85%.

### 3.6 Notes on Actual Pattern Wiring

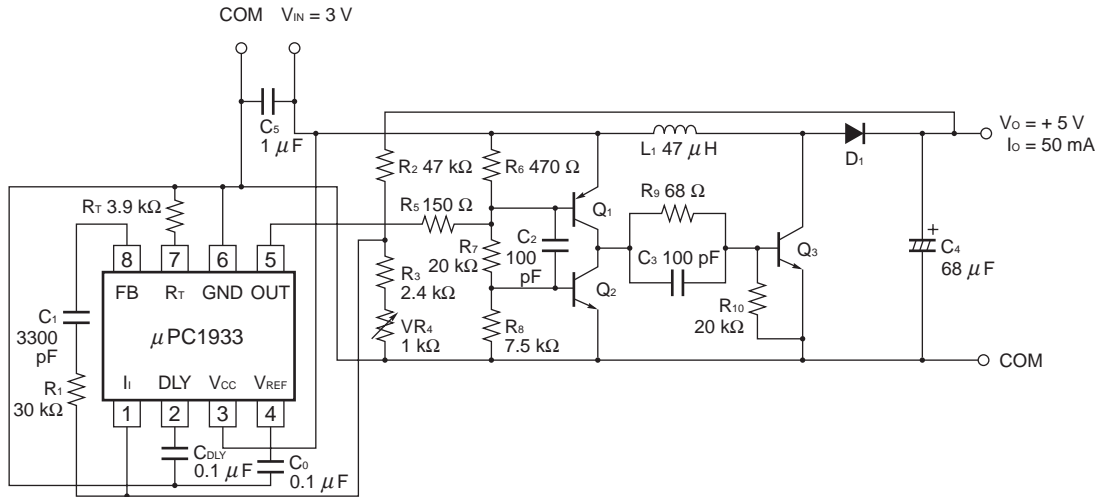
When actually carrying out the pattern wiring, it is necessary to separate control-related grounds and power-related grounds, and make sure that they do not share impedances as far as possible. In addition, make sure the high-frequency impedance is lowered using capacitors and other components to prevent noise input to the  $V_{REF}$  pin.

★ 4. APPLICATION EXAMPLE

4.1 Application Example

Figure 4-1 shows an example circuit for obtaining +5 V/50 mA from a +3 V power supply.

Figure 4-1 Application Example



4.2 List of External Parts

The list below shows the external parts.

Table 4-1 List of External Parts

Symbol	Parameter	Function	Part number	Maker	Remark
C <sub>4</sub>	68 μF	Output capacitor	20SA68M	SANYO	OS-CON, SA series
D <sub>1</sub>		Schottky diode	D1FS4	SHINDENGEN	
L <sub>1</sub>	47 μH	Choke inductor	636FY-470M	TOKO	D73F series
Q <sub>3</sub>		Switching transistor	2SD2403	NEC	
Q <sub>1</sub>		Buffer transistor	2SC1623	NEC	
Q <sub>2</sub>		Buffer transistor	2SA812	NEC	

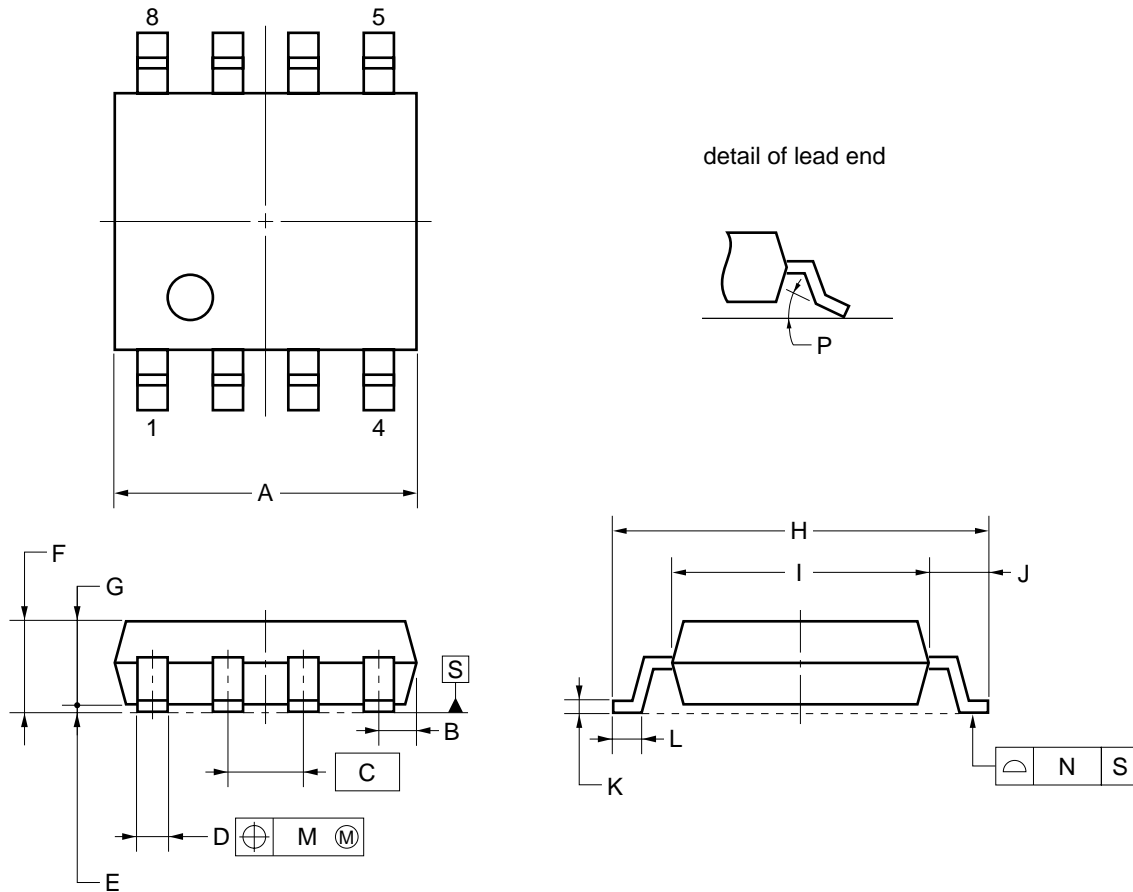
Remarks 1. The capacitors that are not specified in the above list are multilayer ceramic capacitors.

2. The resistors that are not specified in the above list are 1/4W resistors.



5. PACKAGE DRAWING

8-PIN PLASTIC SOP (5.72 mm (225))



**NOTE**

Each lead centerline is located within 0.12 mm of its true position (T.P.) at maximum material condition.

ITEM	MILLIMETERS
A	5.2 <sup>+0.17</sup> / <sub>-0.20</sub>
B	0.78 MAX.
C	1.27 (T.P.)
D	0.42 <sup>+0.08</sup> / <sub>-0.07</sub>
E	0.1±0.1
F	1.59±0.21
G	1.49
H	6.5±0.3
I	4.4±0.15
J	1.1±0.2
K	0.17 <sup>+0.08</sup> / <sub>-0.07</sub>
L	0.6±0.2
M	0.12
N	0.10
P	3° <sup>+7°</sup> / <sub>-3°</sub>

S8GM-50-225B-6

**6. RECOMMENDED SOLDERING CONDITIONS**

Recommended solder conditions for this product are described below.

For details on recommended soldering conditions, refer to Information Document “**Semiconductor Device Mounting Technology Manual**” (C10535E).

For soldering methods and conditions other than those recommended, consult NEC.

**Surface Mount Type**

**μPC1933GR: 8-pin plastic SOP (5.72 mm (225))**

Soldering Method	Soldering Conditions	Symbol of Recommended Conditions
Infrared reflow	Package peak temperature: 235 °C, Time: 30 seconds MAX. (210 °C MIN.), Number of times: 3 MAX.	IR35-00-3
VPS	Package peak temperature: 215 °C, Time: 40 seconds MAX. (200 °C MIN.), Number of times: 3 MAX.	VP15-00-3
Wave soldering	Soldering bath temperature: 260 °C MAX., Time: 10 seconds MAX., Number of times: 1, Preheating temperature: 120 °C MAX. (package surface temperature)	WS60-00-1

**Caution Do not use two or more soldering methods in combination.**

**NOTES FOR BiCMOS DEVICES****① PRECAUTION AGAINST ESD FOR SEMICONDUCTORS**

Note:

Strong electric field, when exposed to a device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it once, when it has occurred. Environmental control must be adequate. When it is dry, humidifier should be used. It is recommended to avoid using insulators that easily build static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work bench and floor should be grounded. The operator should be grounded using wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with semiconductor devices on it.

**② HANDLING OF UNUSED INPUT PINS**

Note:

No connection for device inputs can be cause of malfunction. If no connection is provided to the input pins, it is possible that an internal input level may be generated due to noise, etc., hence causing malfunction. Input levels of devices must be fixed high or low by using a pull-up or pull-down circuitry. Each unused pin should be connected to  $V_{DD}$  or GND with a resistor, if it is considered to have a possibility of being an output pin. All handling related to the unused pins must be judged device by device and related specifications governing the devices.

**③ STATUS BEFORE INITIALIZATION OF BiCMOS DEVICES**

Note:

Power-on does not necessarily define initial status of device. Production process of BiCMOS does not define the initial operation status of the device. Immediately after the power source is turned ON, the devices with reset function have not yet been initialized. Hence, power-on does not guarantee out-pin levels, I/O settings or contents of registers. Device is not initialized until the reset signal is received. Reset operation must be executed immediately after power-on for devices having reset function.

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