ASSP For Power Supply Applications

BIPOLAR

Switching Regulator Controller

MB3817

■ DESCRIPTION

The MB3817 is a pulse width modulator (PWM) type switching regulator controller IC designed for low-voltage and high-speed operation. This can be used in applications as down-conversion or down/up-conversion (Zeta method).
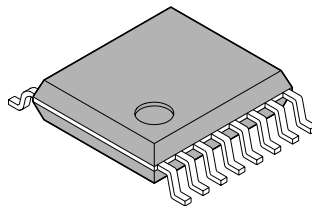
With fewer external components and faster operating speed, the MB3817 enables reduction in power supply unit size, making it ideal for use with internal power supplies in compact, high-performance portable devices.

■ FEATURES

- Wide range of operating power supply voltages: 2.5 V to 18 V
- Built-in high-precision reference voltage generator: 1.5 V $\pm$ 2%
- High speed operation is possible: Max. 500 kHz
- Wide input voltage range of error amplifier: 0 to V_{CC} – 0.9 V
- Built-in soft start function
- Built-in timer/latch-actuated short-circuiting protection circuit
- Totem-pole type output with adjustable on/off current (for PNP transistors)
- Built-in standby function
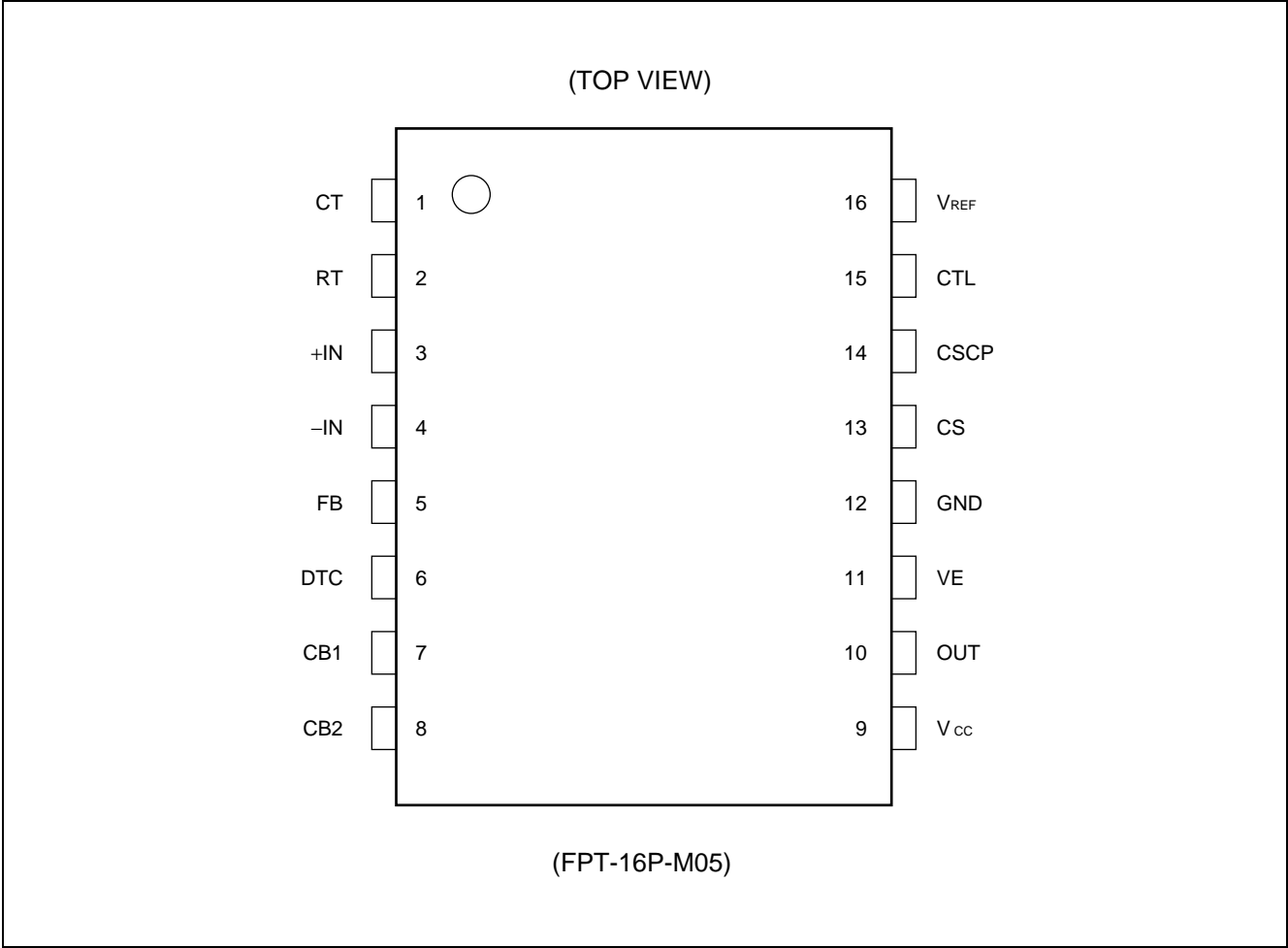- Small package: SSOP-16P (FPT-16P-M05)

■ PACKAGE

16-pin Plastic SSOP

(FPT-16P-M05)

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■ PIN ASSIGNMENT

(TOP VIEW)

Pin	Signal		Pin	Signal
1	CT		16	V_{REF}
2	RT		15	CTL
3	+IN		14	CSCP
4	−IN		13	CS
5	FB		12	GND
6	DTC		11	VE
7	CB1		10	OUT
8	CB2		9	V_{CC}

(FPT-16P-M05)

■ PIN DESCRIPTION

Pin no.	Pin name	I/O	Descriptions
1	CT	—	This pin connects to a capacitor for setting the triangular-wave frequency.
2	RT	—	This pin connects to a resistor for setting the triangular-wave frequency.
3	+IN	I	Error amplifier non-inverted input pin
4	–IN	I	Error amplifier inverted input pin
5	FB	O	Error amplifier output pin
6	DTC	I	Dead time control pin
7	CB1	—	Boot capacitor connection pin
8	CB2	—	Boot capacitor connection pin
9	V_{CC}	—	Power supply pin
10	OUT	O	Totem-pole type output pin
11	VE	—	Output current setting pin
12	GND	—	Ground pin
13	CS	—	Soft start setting capacitor connection pin
14	CSCP	—	Short detection setting capacitor connection pin
15	CTL	I	Power supply control pin When this pin is High, IC is inactive state When this pin is Low, IC is standby state
16	V_{REF}	O	Reference voltage output pin

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■ BLOCK DIAGRAM
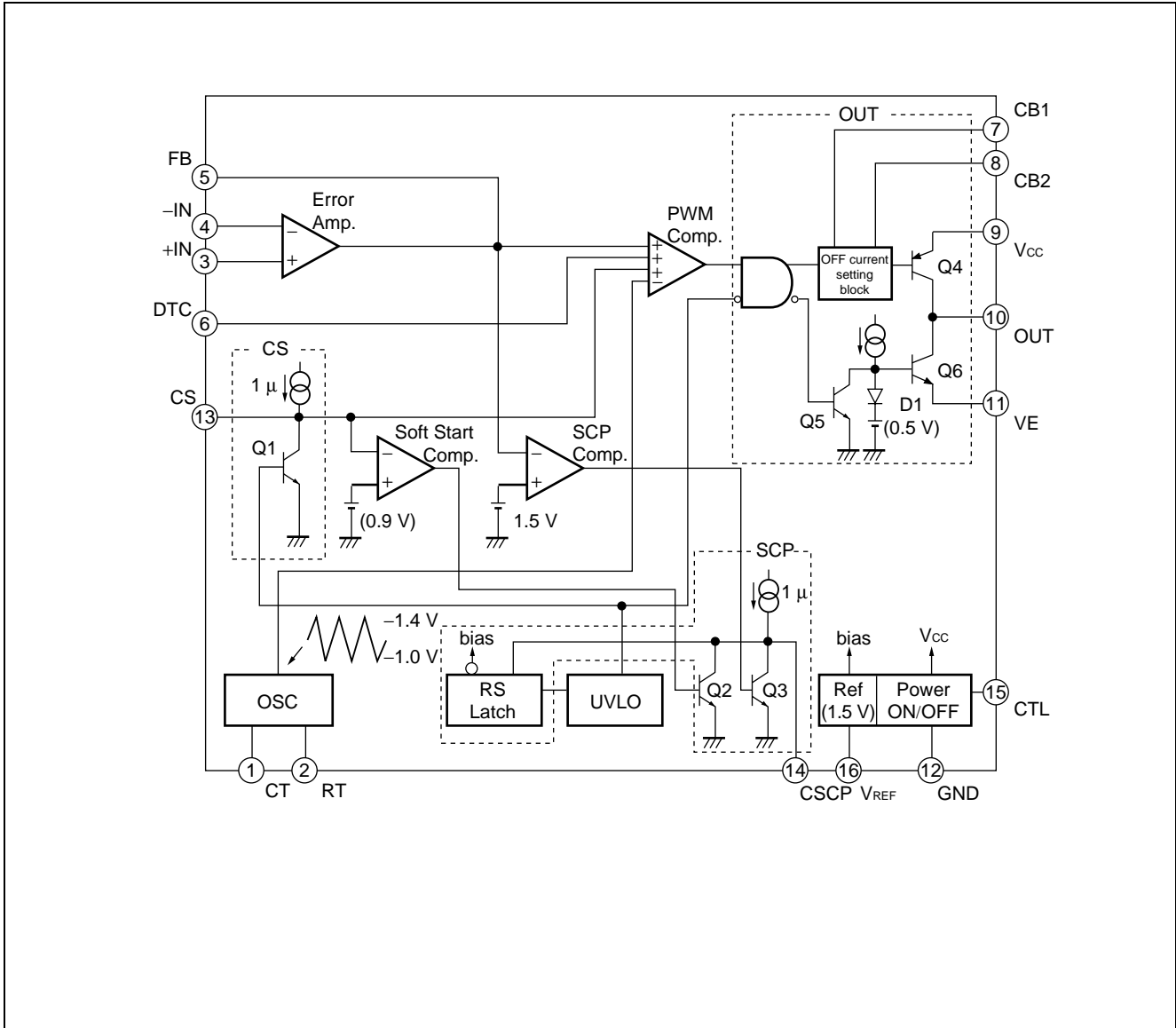
■ **ABSOLUTE MAXIMUM RATINGS**

Parameter	Symbol	Condition	Rating		Unit
			Min.	Max.	
Power supply voltage	V_{CC}	—	—	20	V
Power dissipation	P_D	Ta ≦ +25°C	—	440*	mW
Storage temperature	Tstg	—	–55	+125	°C

* : The package is mounted on the epoxy board (10 cm × 10 cm).

WARNING: Semiconductor devices can be permanently damaged by application of stress (voltage, current, temperature, etc.) in excess of absolute maximum ratings. Do not exceed these ratings.

■ **RECOMMENDED OPERATING CONDITIONS**

Parameter	Symbol	Condition	Value			Unit
			Min.	Typ.	Max.	
Power supply voltage	V_{CC}	—	2.5	6.0	18	V
Reference voltage output current	I_{OR}	—	–1	—	0	mA
Error amp. input voltage	V_{IN}	—	0	—	$V_{CC} - 0.9$	V
Control input voltage	V_{CTL}	—	0	—	18	V
Output current	I_O	—	3	—	30	mA
Timing capacitance	C_T	—	150	—	1500	pF
Timing resistance	R_T	—	5.1	—	100	kΩ
Oscillation frequency	f_{OSC}	—	10	200	500	kHz
Soft start capacitance	C_S	—	—	0.1	1.0	μF
Short detection capacitance	C_{SCP}	—	—	0.1	1.0	μF
Boot capacitance	C_B	—	—	—	0.1	μF
Operating temperature	Ta	—	–40	+25	+85	°C

WARNING: Recommended operating conditions are normal operating ranges for the semiconductor device. All the device's electrical characteristics are warranted when operated within these ranges.

Always use semiconductor devices within the recommended operating conditions. Operation outside these ranges may adversely affect reliability and could result in device failure.

No warranty is made with respect to uses, operating conditions, or combinations not represented on the data sheet. Users considering application outside the listed conditions are advised to contact their FUJITSU representative beforehand.

■ ELECTRICAL CHARACTERISTICS

$(V_{CC} = 6 \text{ V}, Ta = +25°C)$

Parameter		Symbol	Pin no.	Condition	Value			Unit
					Min.	Typ.	Max.	
Reference section (Ref)	Output voltage	V_{REF}	16	—	1.47	1.50	1.53	V
	Output temperature stability	$\Delta V_{REF}/V_{REF}$	16	Ta = –40°C to +85°C	—	0.5*	—	%
	Input stability	Line	16	V_{CC} = 2.5 V to 18 V	—	2	10	mV
	Load stability	Load	16	I_{OR} = 0 mA to –1 mA	—	2	10	mV
	Short circuit output current	I_{OS}	16	V_{REF} = 1 V	–10	–5	–2	mA
Under voltage lockout protection section (UVLO)	Threshold voltage	V_{TH}	13	V_{CC} = ⌐	—	2.0	2.3	V
		V_{TL}	13	V_{CC} = ⌐	1.5	1.8	—	V
	Hysteresis width	V_H	13	—	0.1	0.2	—	V
	Reset voltage	V_R	13	—	0.6	1.0	—	V
Soft start section (CS)	Threshold voltage	V_{T0}	10	Duty cycle = 0 %	0.9	1.0	—	V
		V_{T100}	10	Duty cycle = 100 %	—	1.4	1.5	V
	Input standby voltage	V_{STB}	13	—	—	50	100	mV
	Charge current	I_{CHG}	13	—	–1.4	–1.0	–0.6	µA
Short circuit detection section (SCP)	Threshold voltage	V_{TH}	14	—	0.60	0.65	0.70	V
	Input standby voltage	V_{STB}	14	—	—	50	100	mV
	Input latch voltage	V_I	14	—	—	50	100	mV
	Input source current	I_I	14	—	–1.4	–1.0	–0.6	µA
Triangular waveform oscillator section (OSC)	Oscillator frequency	f_{OSC}	10	C_T = 330 pF R_T = 6.2 kΩ	450	500	550	kHz
	Frequency voltage stability	$\Delta f/f_{dv}$	10	V_{CC} = 3.6 V to 16 V	—	1	10	%
	Frequency temperature stability	$\Delta f/f_{dt}$	10	Ta = –40°C to +85°C	—	1*	—	%

* : Standard design value.

(Continued)

(V_{CC} = 6 V, Ta = +25°C)

$(V_{CC} = 6$ V, Ta $= +25°C)$

Parameter		Symbol	Pin no.	Condition	Value			Unit
					Min.	Typ.	Max.	
Error amp. section (Error Amp.)	Input offset voltage	V_{IO}	3, 4	$V_{FB} = 1.2$ V	—	—	10	mV
	Input offset current	I_{IO}	3, 4	$V_{FB} = 1.2$ V	—	—	100	nA
	Input bias current	I_I	3, 4	$V_{FB} = 1.2$ V	−200	−100	—	nA
	Common mode input voltage range	V_{CM}	3, 4	—	0	—	$V_{CC} - 0.9$	V
	Common mode rejection ratio	CMRR	5	DC	60	100	—	dB
	Voltage gain	A_V	5	DC	60	100	—	dB
	Frequency bandwidth	BW	5	$A_V = 0$ dB	—	800*	—	kHz
	Maximum output voltage width	V_{OM}^+	5	—	1.8	2.0	—	V
		V_{OM}^-	5	—	—	50	500	mV
	Output sink current	I_O^+	5	$V_{FB} = 1.2$ V	60	120	—	μA
	Output source current	I_O^-	5	$V_{FB} = 1.2$ V	—	−2.0	−0.6	mA
Dead time control section (DTC)	Threshold voltage	V_{T0}	10	Duty cycle = 0 %	0.9	1.0	—	V
		V_{T100}	10	Duty cycle = 100 %	—	1.4	1.5	V
	ON duty cycle	Dtr	10	$V_{DTC} = V_{REF} \times 0.88$ $C_T = 330$ pF, $R_T = 6.2$ kΩ	70	80	90	%
	Input current	I_{DTC}	6	$V_{DTC} = 0$ V	−500	−250	—	nA
PWM comparator section (PWM Comp.)	Threshold voltage	V_{T0}	10	Duty cycle = 0 %	0.9	1.0	—	V
		V_{T100}	10	Duty cycle = 100 %	—	1.4	1.5	V
	Input sink current	I_I^+	5	—	60	120	—	μA
	Input source current	I_I^-	5	—	—	−2.0	−0.6	mA
Output section (OUT)	Output sink current	I_O^+	10	$R_E = 15$ kΩ	18	30	42	mA
	Output source current	I_O^-	10	Duty $\leqq$ 5 %	—	−100	−50	mA
	Standby leakage current	I_{LO}	10	$V_{CC} = 18$ V, $V_O = 18$ V	—	—	10	μA
Control section (CTL)	Input on condition	V_{ON}	11	—	2.1	—	18	V
	Input off condition	V_{OFF}	11	—	0	—	0.7	V
Input current		I_I	15	$V_{CTL} = 5$ V	—	100	200	μA
Standby current		I_{CCS}	9	$V_{CTL} = 0$ V	—	—	10	μA
Power supply current		I_{CC}	9	Output "H"	—	2.7	4.0	mA

* : Standard design value.

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■ **TYPICAL CHARACTERISTICS**

Power supply current vs. power supply voltage

Ta = +25 °C

Power supply current ICC (mA) vs. Power supply voltage VCC (V)

Reference voltage vs. power supply voltage

Ta = +25 °C
IOR = 0 mA

Reference voltage VREF (V) vs. Power supply voltage VCC (V)

Reference voltage vs. ambient temperature

VCC = 6 V
IOR = 0 mA

Reference voltage VREF (V) vs. Ambient temperature Ta (°C)

Reference voltage vs. control voltage

VCC = 6 V
Ta = +25 °C
IOR = 0 mA

Reference voltage VREF (V) vs. Control voltage VCTL (V)

Control current vs. control voltage

VCC = 6 V
Ta = +25 °C

Control current ICTL (μA) vs. Control voltage VCTL (V)

(Continued)

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Triangular wave frequency vs. timing resistance

Triangular wave frequency f_{OSC} (Hz)

Timing resistance R_T (Ω)

V_{CC} = 6V
Ta = +25 °C

C_T = 150 pF
C_T = 1500 pF
C_T = 15000 pF
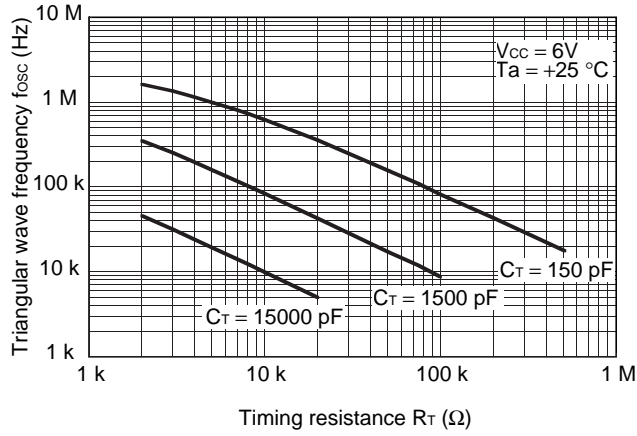
Triangular wave maximum amplitude voltage vs. timing capacitance

Triangular wave maximum amplitude voltage V_{CT} (V)

Timing capacitance C_T (pF)

V_{CC} = 6 V
Ta = +25 °C
R_T = 6.2 kΩ
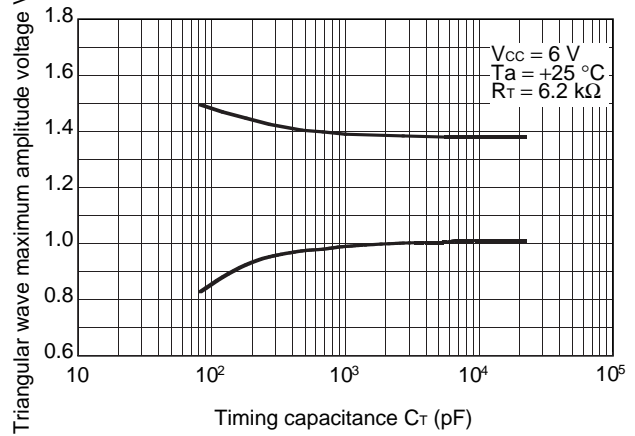
Duty vs. triangular wave frequency

Duty D_{tr} (%)

Triangular wave frequency f_{OSC} (Hz)

V_{CC} = 6 V
Ta = +25 °C
R_T = 6.2 kΩ
V_{DTC} = V_{REF} × 0.88
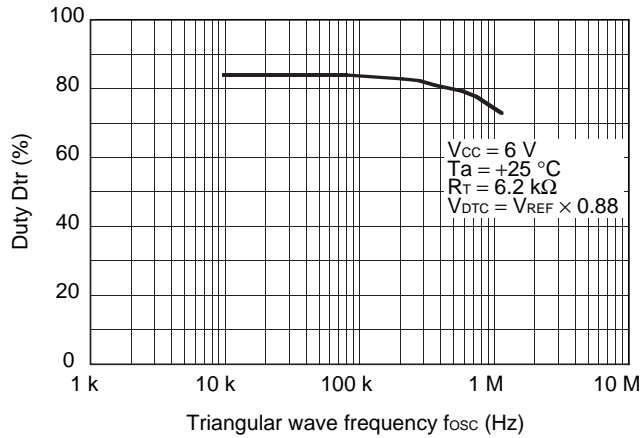
Triangular wave cycle vs. timing capacitance

Triangular wave cycle t_{OSC} (μsec)

Timing capacitance C_T (pF)

V_{CC} = 6 V
Ta = +25 °C
R_T = 6.2 kΩ
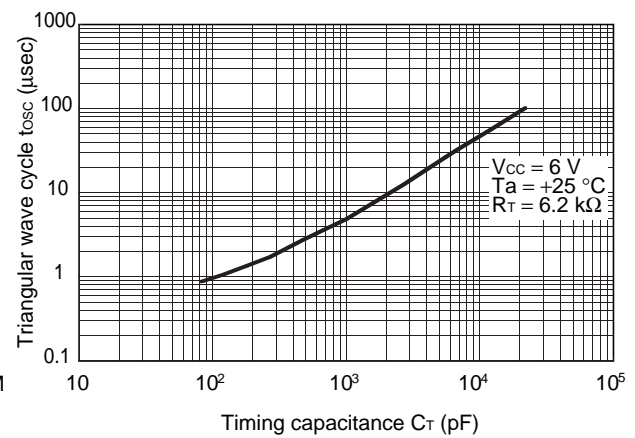
Frequency stability vs. ambient temperature

Frequency stability (%)

Ambient temperature Ta (°C)

V_{CC} = 6 V
f_{OSC} = 500 kHz
(C_T = 330 pF, R_T = 6.2 kΩ)

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Error amp. frequency

• Measurement circuit

Output current setting pin voltage vs. output current setting pin current

Power dissipation vs. ambient temperature

10
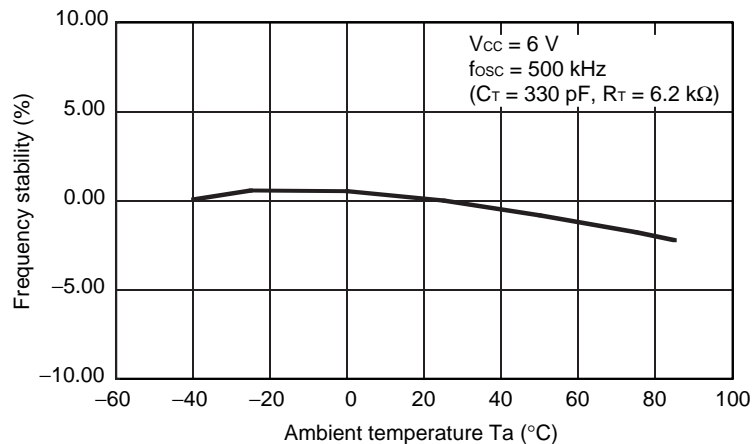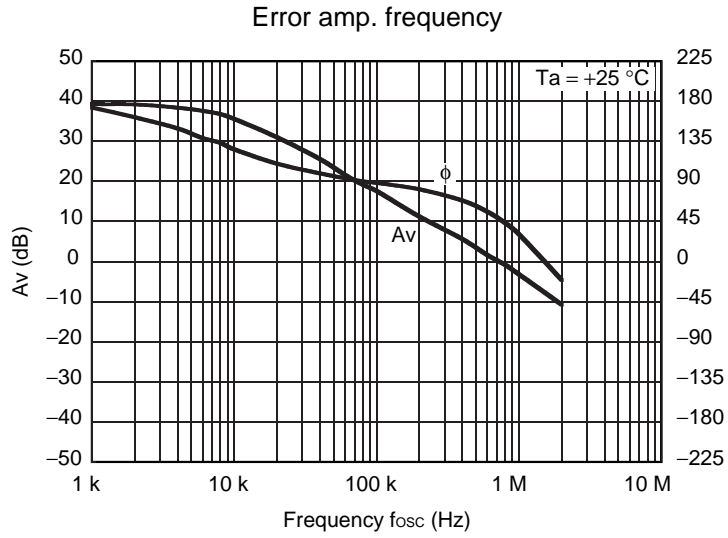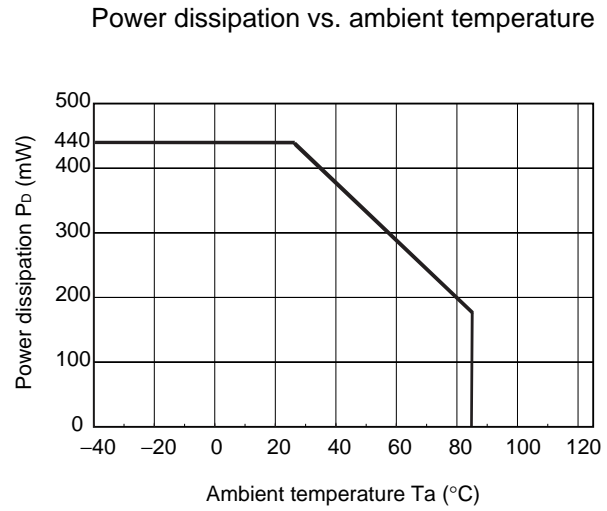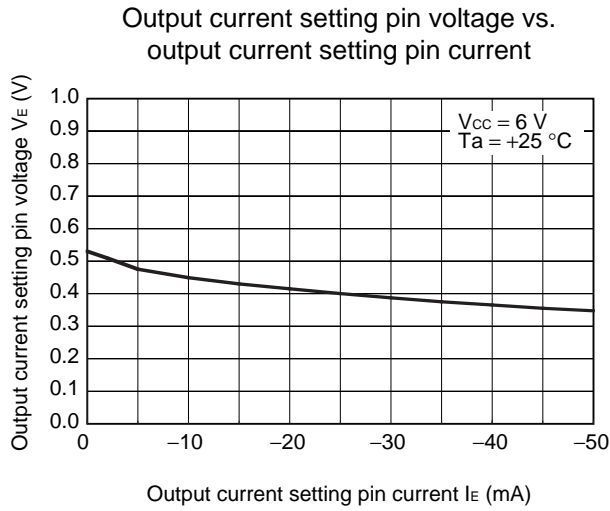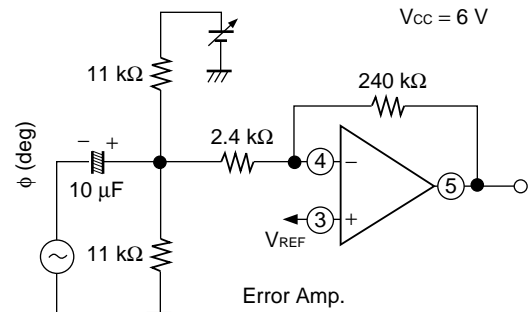
■ FUNCTIONAL DESCRIPTION

1. Switching Regulator Functions

(1) Reference voltage circuit (Ref)

The reference voltage circuit generates a temperature-compensated stable voltage ($\fallingdotseq$ 1.50 V). This reference voltage is used as the reference voltage and bias level for the power control unit.

(2) Triangular-wave oscillator circuit

By connecting a timing capacitor and a resistor to the C_T (pin1) and the R_T (pin2) terminals, it is possible to generate any desired triangular oscillation waveform.

(3) Error amplifier

The error amp. is an amplifier circuit that detects the output voltage from the switching regulator and produces the PWM control signal. The broad in-phase input voltage range of 0 V to Vcc – 0.9 V provides easy setting from external power supplies and enables use with applications such as DC motor speed control systems.

Also, it is possible to provide stable phase compensation for a system by setting up any desired level of loop gain, by connecting feedback resistance and a capacitor between the error amp. output pin (FB pin (pin 5)) and the inverse input pin (–IN pin (pin 4)).

(4) PWM comparator (PWM Comp.)

This is a voltage comparator with one inverted input and three non-inverted inputs, and operates as a voltage-pulse width modulator controlling output duty in relation to input voltage.

The output transistor is turned on during the interval in which the triangular waveform is lower than any of three voltages: the error amp. output voltage (FB pin (pin 5)), soft start set voltage (CS pin (pin 13)), or dwell time setting voltage (DTC pin (pin 6)).

(5) Output circuits (OUT)

The output circuit has totem pole type configuration, and can drive an external PNP transistor.

The on current value can be set up to a maximum of 30 mA using the resistance (RE) connected to the VE pin (pin 11).

The off current is set by connecting a bootstrap capacitor C_B between the CP1 pin (pin 7) and CP2 pin (pin 8).

2. Power Supply Control Functions

The output is switched on and off according to the voltage level at the CTL pin (pin 15).

CTL pin voltage level	Channel on/off status
L ($\leqq$ 0.7 V)	Standby mode*
H ($\geqq$ 2.1 V)	Operating mode

* : Supply current in standby mode is 10 μA or less.

3. Protective Circuit Functions

(1) Soft start and short protection circuits (CS, SCP)

Soft starting, by preventing a rush current at power-on, can be provided by connecting a capacitor C_S to the CS pin (pin 13).

After the soft start operation is completed, the CSCP pin (pin 14) is held at "L" level (standby voltage V_{STB}), which functions as short detection standby mode. If an output short causes the error amp. output to rise above 1.5 V, capacitor C_{SCP} begins charging, and after reaching threshold voltage V_{TH} of 0.65 V causes the OUT pin (pin 10) to be fixed at "H" level and the dwell time to be set to 100%, and the CSCP pin (pin 14) is held at "L" level.

Once the protection circuit has been activated, the power supply must be reset to restore operation.
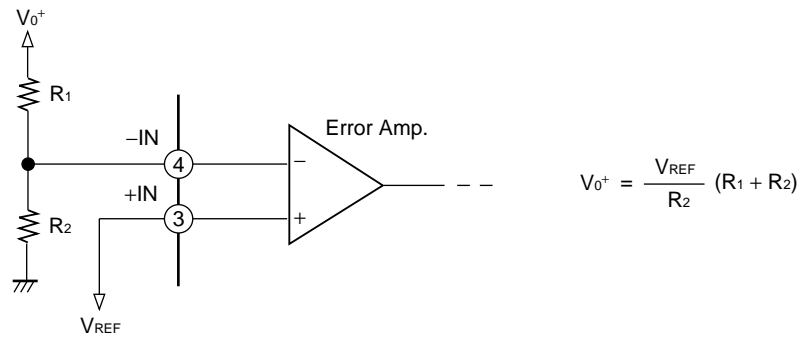
(2)   Low input voltage error prevention circuit (UVLO)

Power-on surges and momentary drops in power supply voltage can cause errors in control IC operation, which can destroy or damage systems. The low input voltage error protection circuit compares the supply voltage to the internal reference voltage, and sets the OUT pin (pin 10) to "H" level in the event of a drop in supply voltage.
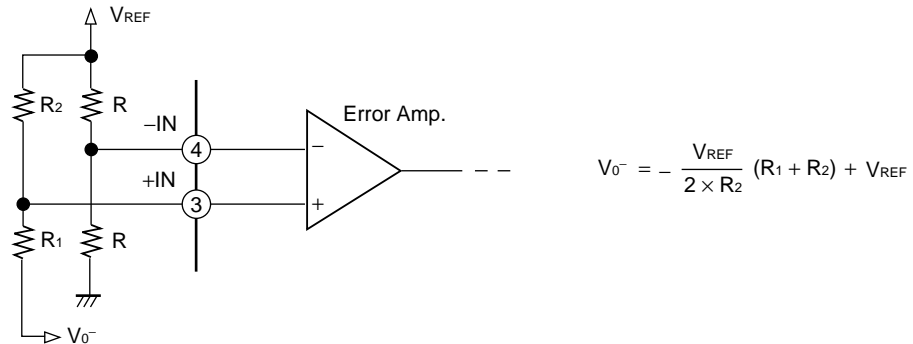
Operation is restored when the power supply voltage returns above the threshold voltage of the low input voltage error prevention circuit.

■ SETTING OUTPUT VOLTAGE

• **Output voltage V$_O$ is plus**

V$_0$+

R$_1$

−IN
④

+IN
③

Error Amp.

−

+

V$_{REF}$

$$V_0{}^+ = \frac{V_{REF}}{R_2}(R_1 + R_2)$$

R$_2$

• **Output voltage V$_O$ is minus**

V$_{REF}$

R$_2$ R

−IN
④

+IN
③

R$_1$ R

V$_0$−

Error Amp.

−

+

$$V_0{}^- = - \frac{V_{REF}}{2 \times R_2}(R_1 + R_2) + V_{REF}$$

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■ METHOD OF SETTING THE OUTPUT CURRENT

The output circuit is comprised of a totem-pole configuration. Its output current waveform is such that the ON-current value is set by constant current and the OFF-current value is set by a time constant. These output currents are set using the equations below.

ON current: $I_O{}^+$ [mA] $\fallingdotseq \dfrac{500}{R_E\ [\Omega]}$ (Voltage on output current-setting pin $V_E = 0.5$ V)

OFF current: OFF-current time constant = proportional to the value of C_B

• **Output circuit**

• **Output current waveform**

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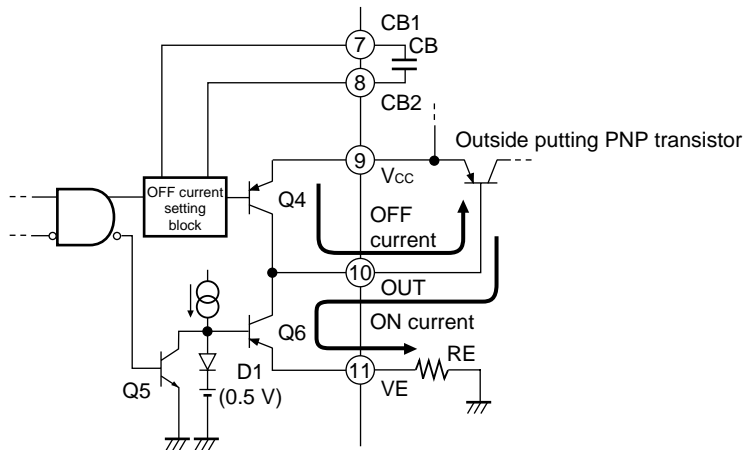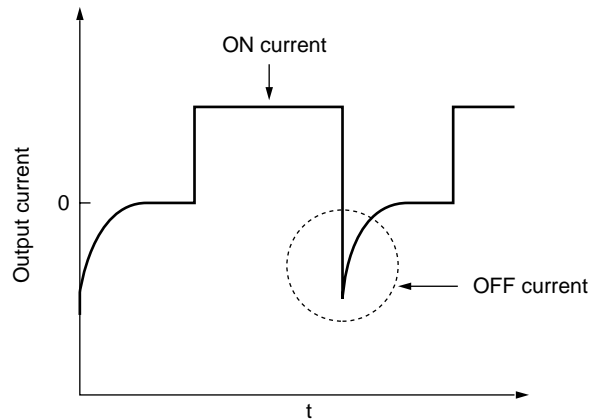
• **Voltage and current waveforms on output pin**
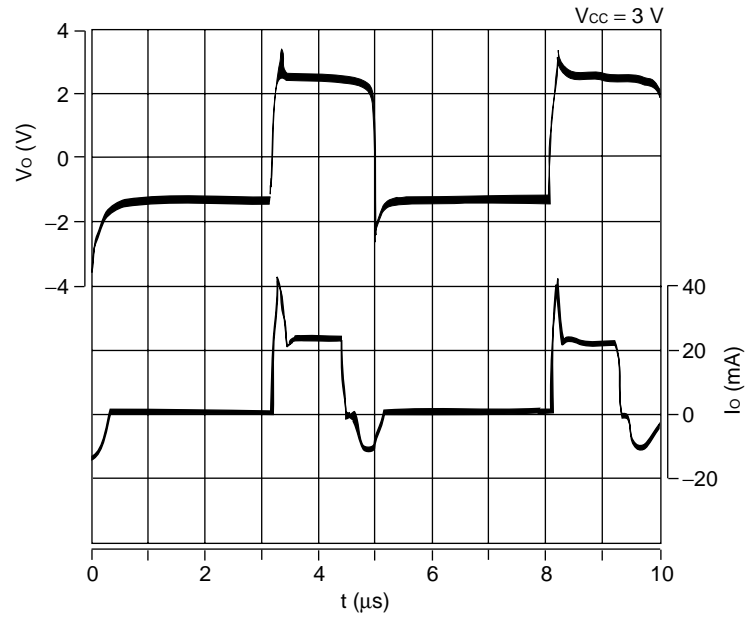
• **Measuring circuit diagram**
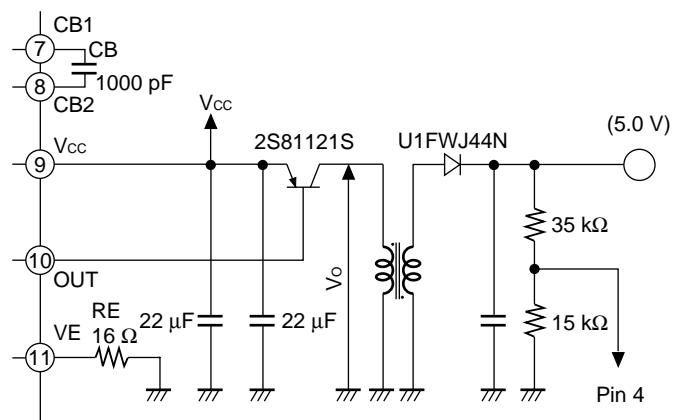
■ METHOD OF SETTING THE SHORT DETECTION TIME

The error amp. output is connected to the inverted input of the short detector comparator circuit (SCP Comp.), where it is constantly compared to the reference voltage of approximately 1.5 V that is connected to the non-inverted input.

If the switching regulator load conditions are stabilized, the short detector comparator output is at "H" level, transistor Q3 is on, and the CSCP pin (pin14) holds the input standby voltage V_{STB} which is 50 mV.

If load conditions change rapidly due to a cause such as a load short, so that output voltage falls, the short detector comparator circuit output changes to "L" level. When this happens, transistor Q3 turns off and the short detector capacitor C_{SCP} connected externally to the CSCP pin starts charging from the input source current I_I, which is –1.0 μA.

Short detection time (t_{PE})

$$t_{PE} [s] \fallingdotseq 0.65 \times C_{SCP} [\mu F]$$

When the short detector capacitor C_{SCP} has been charged to the threshold voltage V_{TH}, which is 0.65 V, the SR latch is set, and the external PNP transistor is turned off (setting dwell time to 100%). At this time, the SR latch input is closed, and the CSCP pin is set to input latch voltage V_I which is 50 mV.

• **Short protection circuit**
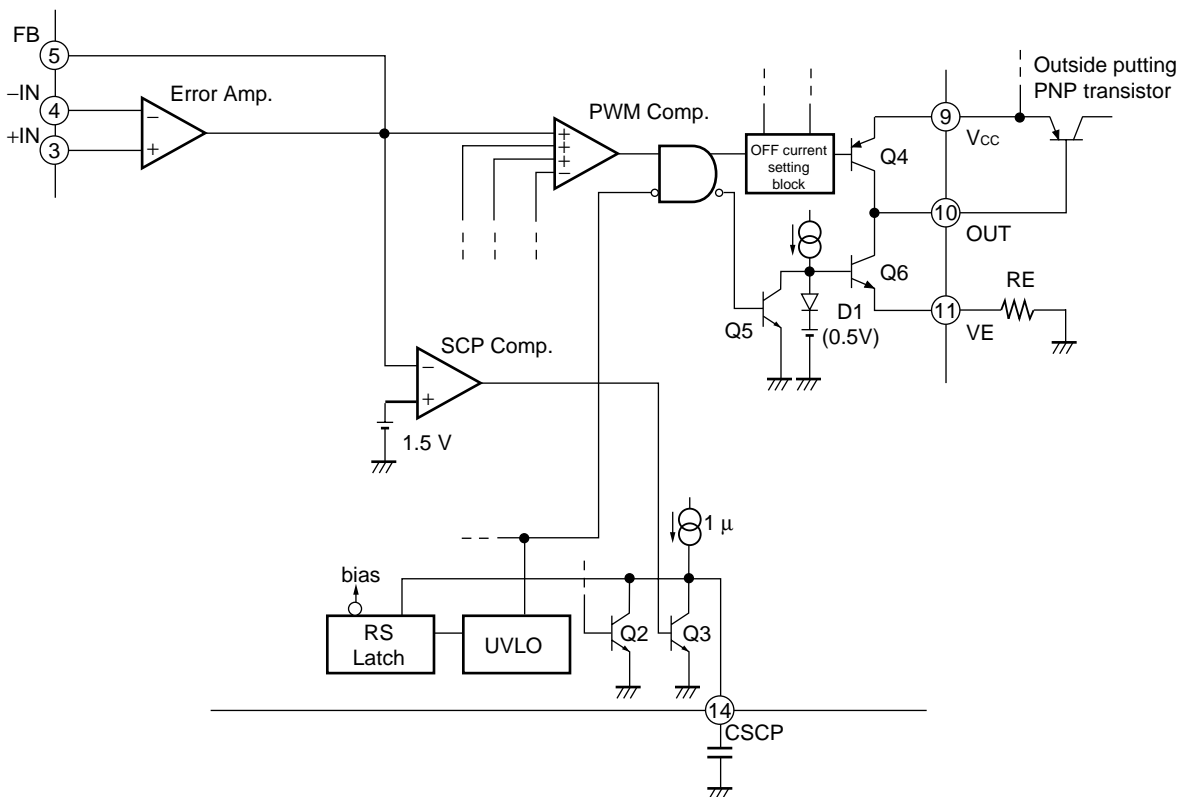
■ TREATMENT WHEN NOT USING CSCP

When you do not use the timer/latch-actuated short-circuiting protection circuit, connect the CSCP terminal (pin 14) to GND.

• Treatment when not using CSCP
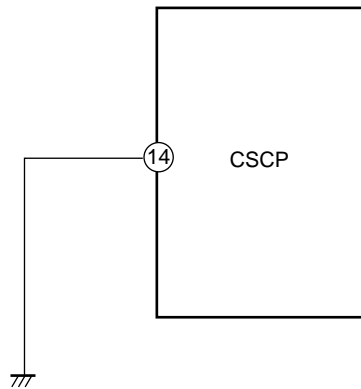
■ METHOD OF SETTING SOFT START TIME

To protect against surge currents when the IC is turned on, a soft start setting can be made by connecting a soft start capacitor (C_S) to the CS pin (pin 13).

When the IC starts up (CTL pin (pin 15) to "H" level, Vcc $\geq$ UVLO threshold voltage V_{TH}) the transistor Q1 turns off and the soft start capacitor (C_S) connected to the CS pin begins charging from the charge current I_{CHG} which is −1.0 μA.

At this time, if the CS pin voltage is less than 0.9 V, the soft start comparator circuit output goes to "H" level, transistor Q2 turns on and the CSCP pin (pin 14) holds input standby voltage V_{STB} which is 50 mV so that the short protection circuit is not activated. When the CS pin voltage is greater than or equal to 0.9 V, transistor Q2 turns off, the PWM comparator circuit compares the CS pin voltage with the triangular wave and changes the ON duty of the OUTPUT pin, thus achieving a soft start. Note that the soft start time is determined by the following formula.

Soft start time (time before output ON duty reaches 50%)

$$t_S \text{ [ms]} \doteqdot 1.2 \times C_S \text{ [μF]}$$

• **Soft start circuit**
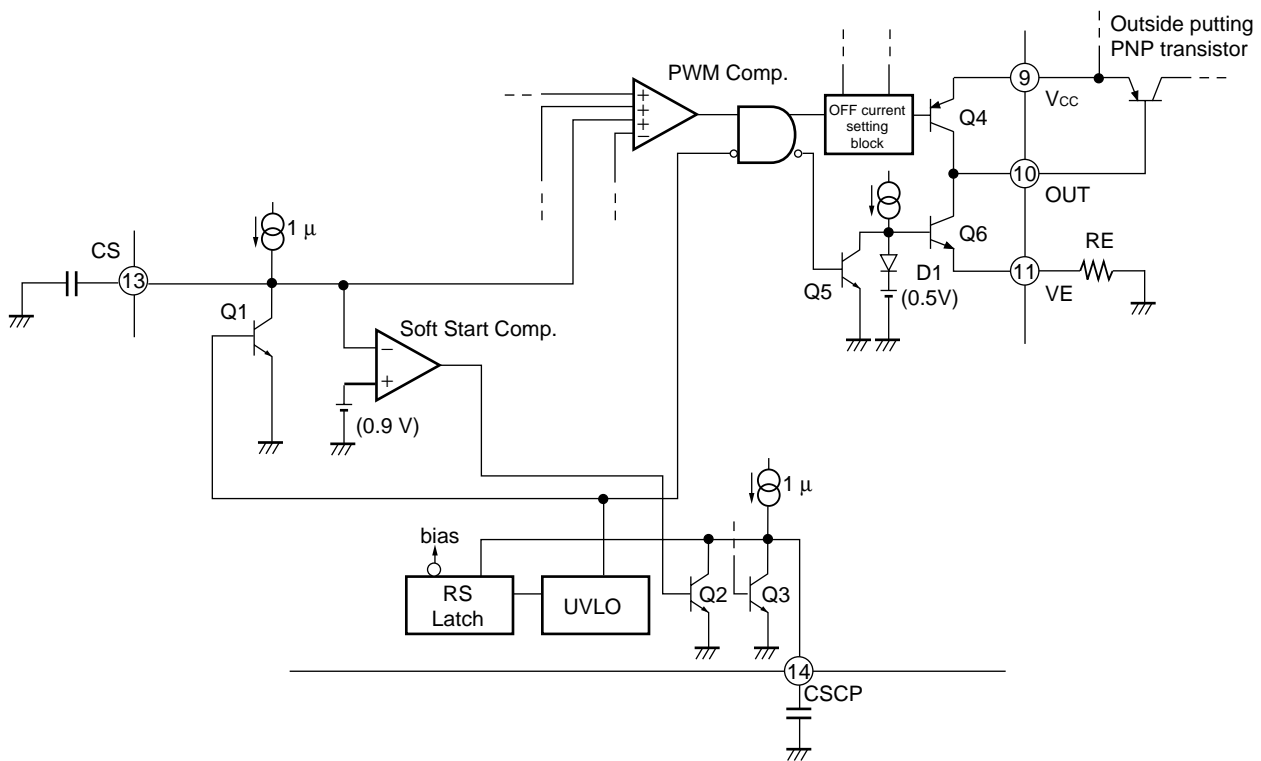
■ TREATMENT WHEN NOT USING CS

When not using the soft start function, the CS pin (pin 13) should be left open.

• **When no soft start time is set**

Open

⑬ CS

MB3817
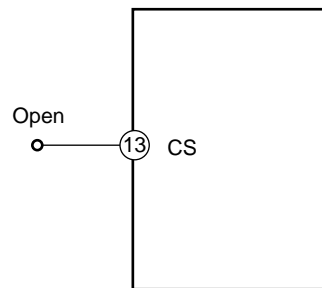
■ **METHOD OF SETTING THE DEAD TIME**

When the device is set for step-up inverted output based on the flyback method, the output transistor is fixed to a full-on state (ON-duty = 100 %) at power switch-on. To prevent this problem, you may determine the voltages on the DTC terminals (pin 6) from the V_{REF} voltage so you can easily set the output transistor's dead time (maximum ON-duty) independently for each channel as shown below.

When the voltage on the DTC terminals (pin 6) is lower than the triangular-wave output voltage from the oscillator, the output transistor turns off. The dead time calculation formula assuming that triangular-wave amplitude $\cong$ 0.4 V and triangular-wave minimum voltage $\cong$ 1.4 V is given below.

$$\text{Duty (ON)}_{MAX} \cong \frac{Vdt - 1.0 \text{ V}}{0.4} \times 100 \text{ [\%]}$$

When you do not use these DTC terminals, connect them to V_{REF} terminal.

• **When using DTC to set dead time**
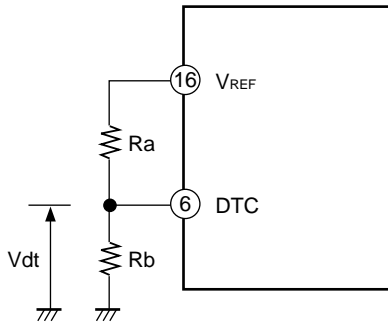
• **When not using DTC to set dead time**
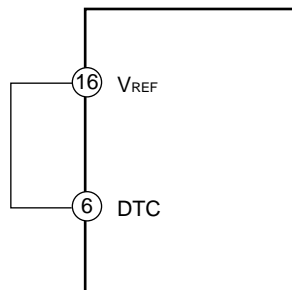
■ EQUIVALENT SERIES RESISTOR AND STABILITY OF SMOOTHING CAPACITOR

The equivalent series resistance (ESR) of a smoothing capacitor in a DC/DC converter greatly affects the phase characteristics of the loop depending on its value.

System stability is improved by ESR because it causes the phase to lead that of the ideal capacitor in high-frequency regions. (See Figures 2 and 3) Conversely, if a low-ESR smoothing capacitor is used, system stability deteriorates. Therefore, use of a low-ESR semiconductor electrolytic capacitors (ex. OS–CON) or tantalum capacitors calls for careful attention.

• **Figure 1 Basic circuit of stepdown DC/DC converter**
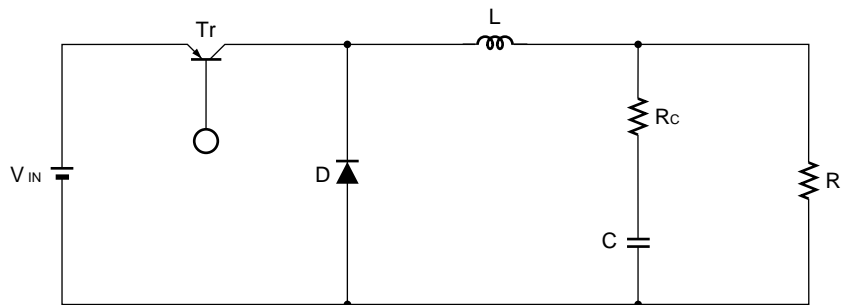
• **Figure 2 Gain-Frequency characteristic**

(1) : $R_C = 0\ \Omega$
(2) : $R_C = 31\ m\Omega$
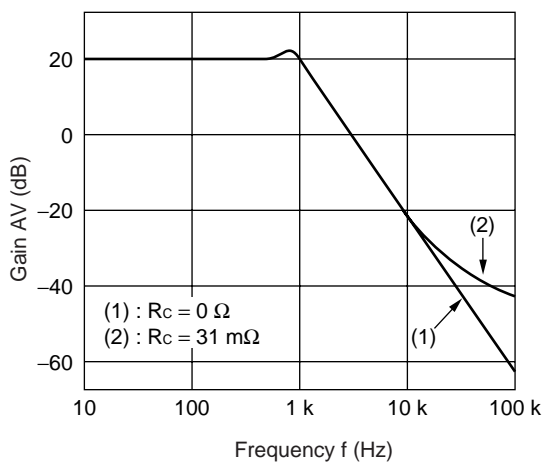
• **Figure 3 Phase-Frequency characteristic**

(1) : $R_C = 0\ \Omega$
(2) : $R_C = 31\ m\Omega$

MB3817
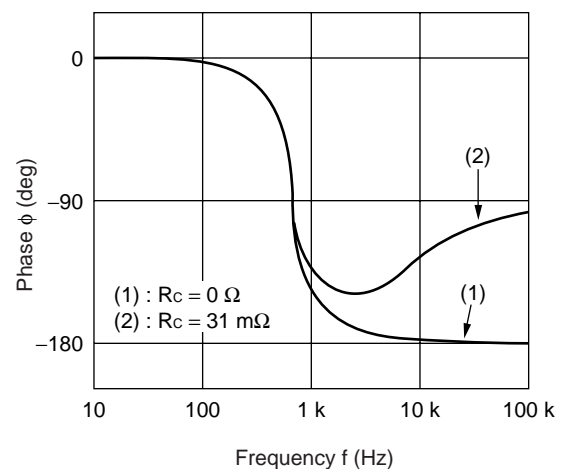
(Reference Data)

The phase margin is halved by changing the smoothing capacitor from an aluminium electrolytic capacitor ($R_C \approx 1.0\ \Omega$) to a small-ESR semiconductor electrolytic capacitor (OS – CON; $R_C \approx 0.2\ \Omega$). (See Figure 5 and 6.)

- **Figure 4 DC/DC converter $A_V - \phi$ characteristic measuring circuit**
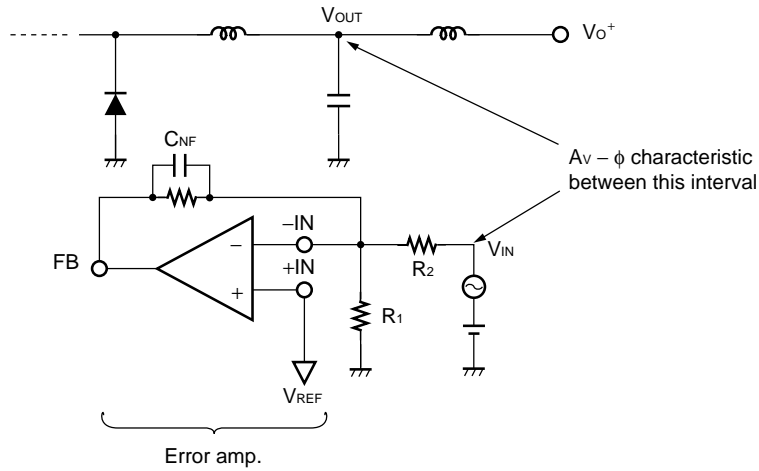
- **Figure 5 Gain-Frequency characteristic**
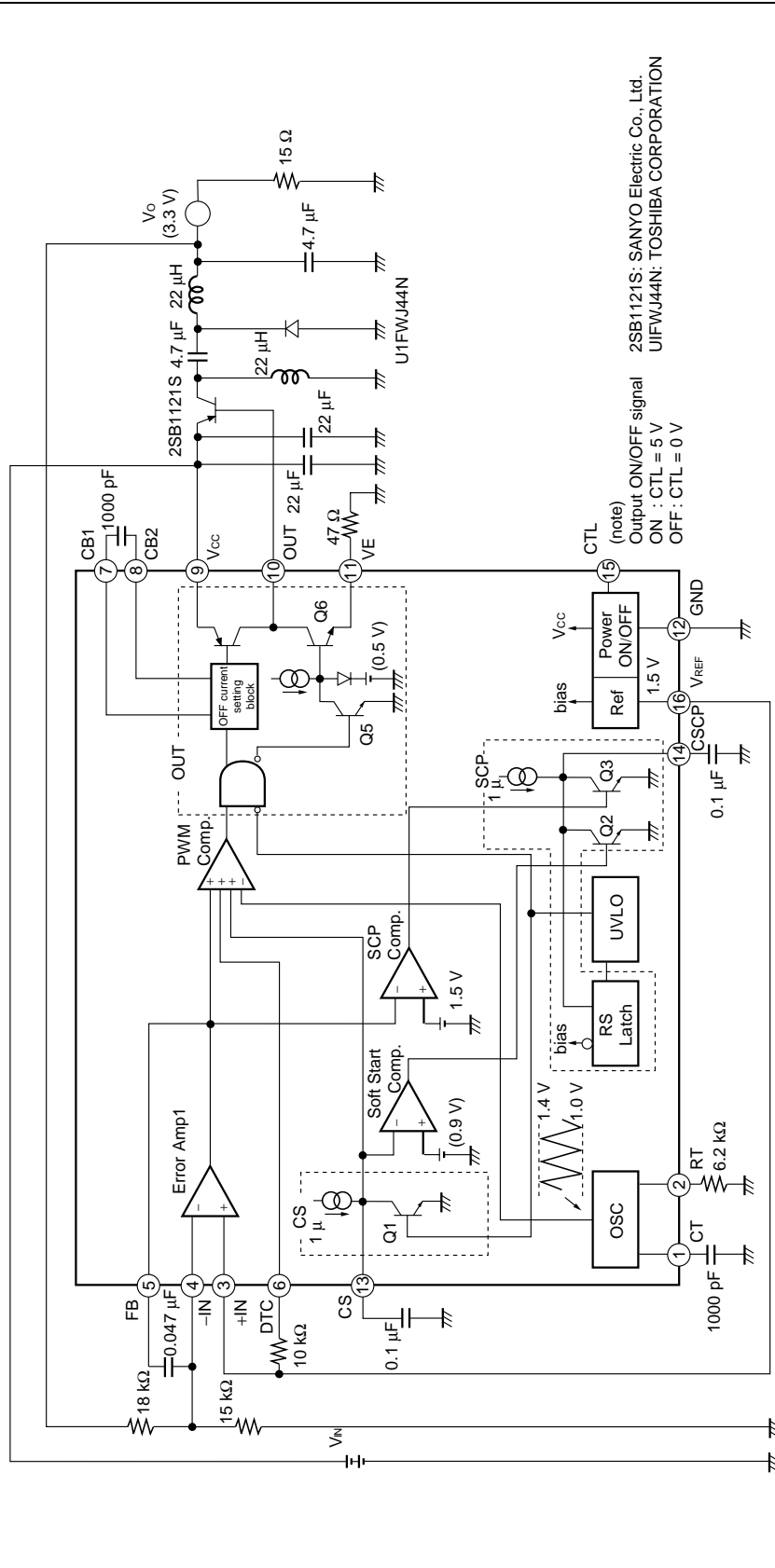
Gain - frequency and phase frequency characteristics of Al electrolytic capacitor (DC/DC converter +5 V output)
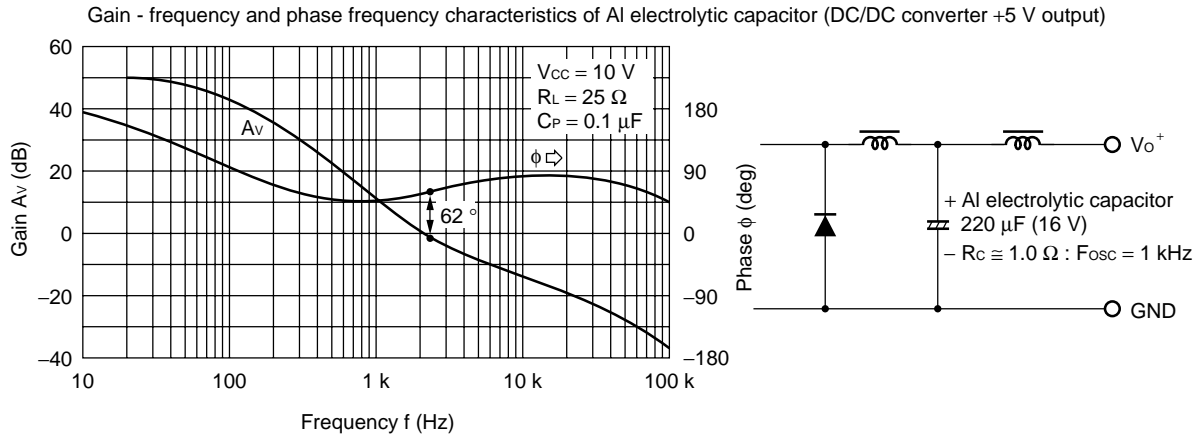
- **Figure 6 Phase-Frequency characteristic**

Gain - frequency and phase frequency characteristics of OS – CON (DC/DC converter +5 V output)
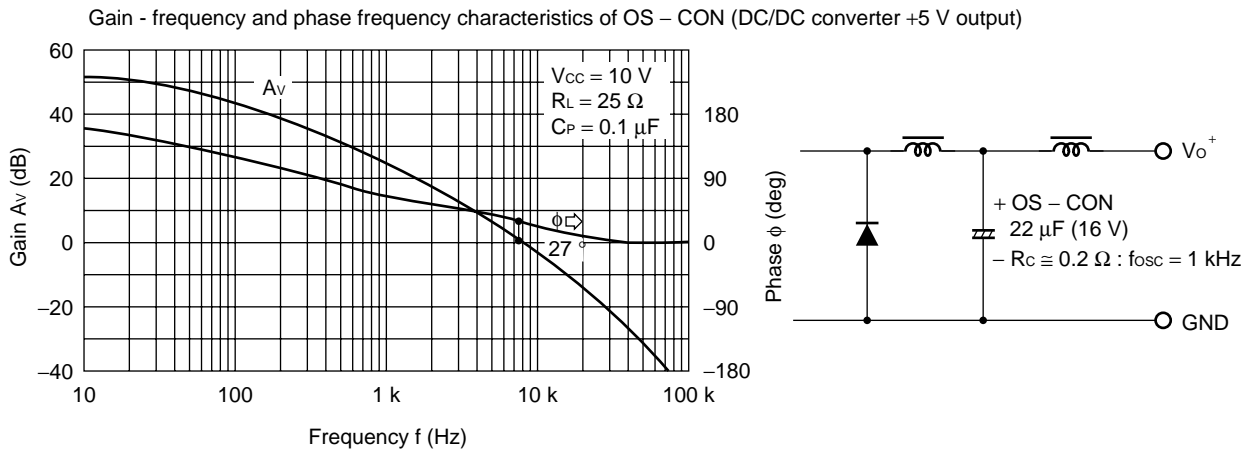
■ APPLICATION EXAMPLE

1. Step-down scheme
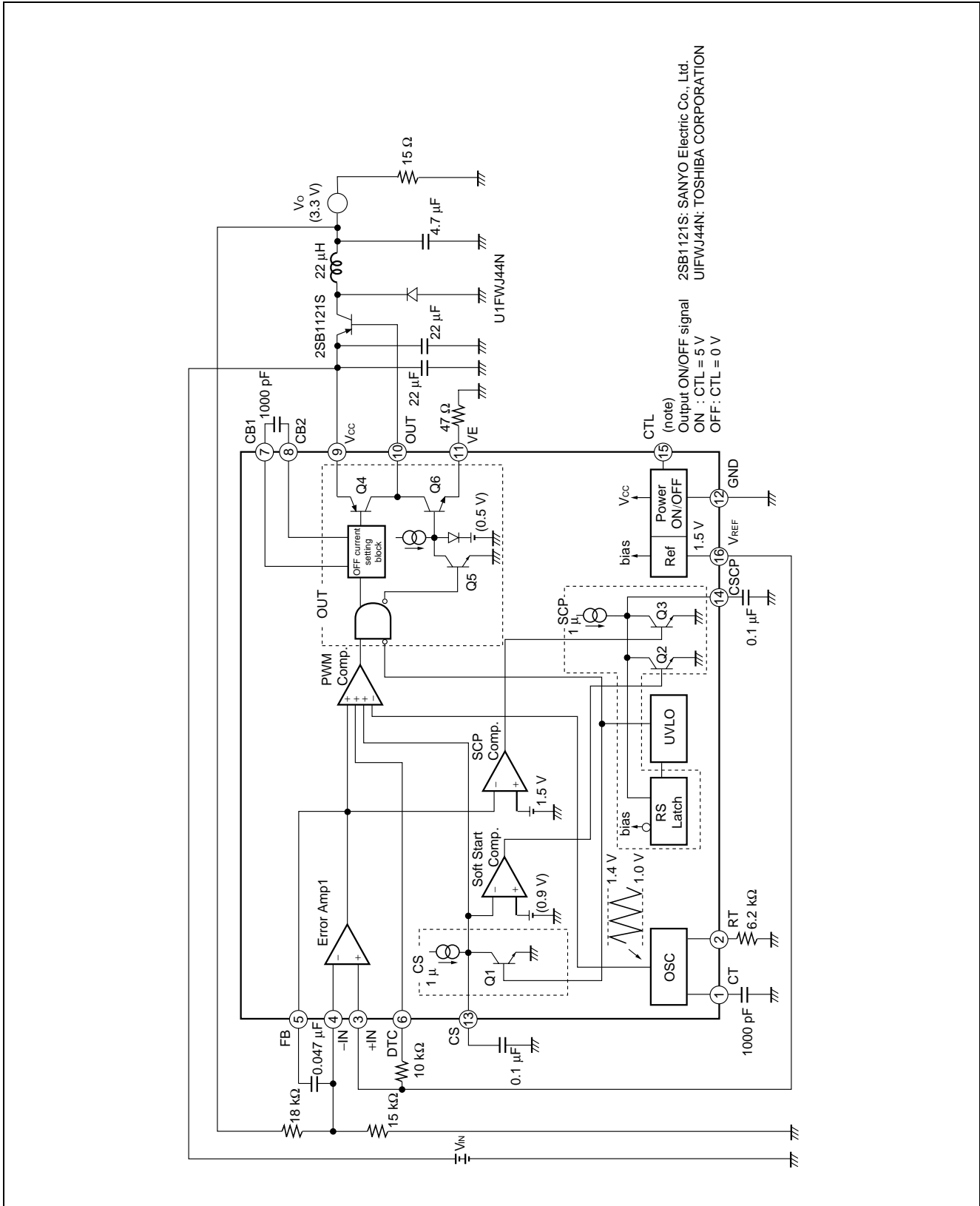
2. Zeta scheme

3. Flyback scheme
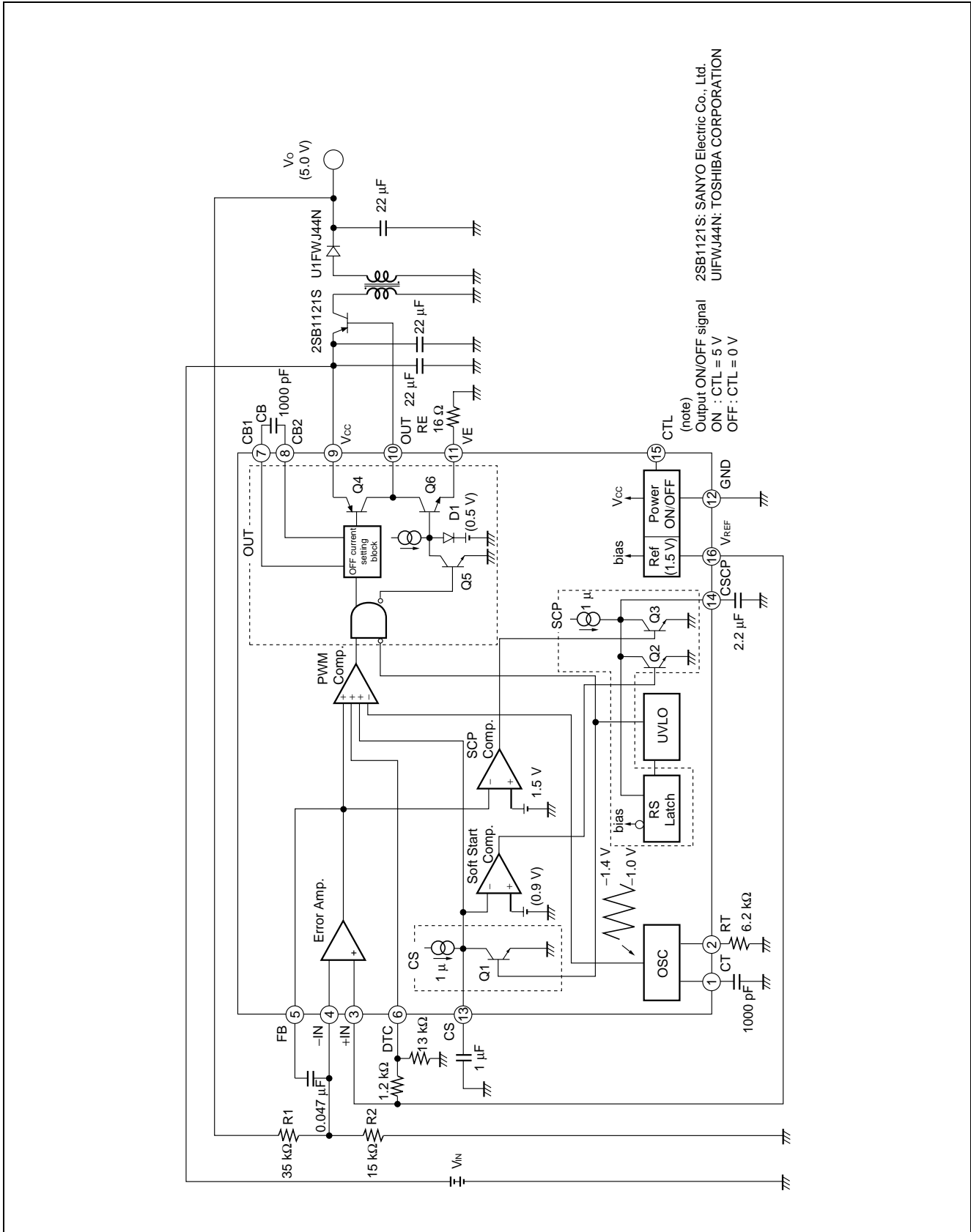
■ **USAGE PRECAUTIONS**

1.   **Never use setting exceeding maximum rated conditions.**

     Exceeding maximum rated conditions may cause permanent damage to the LSI.

     Also, it is recommended that recommended operating conditions be observed in normal use.
     Exceeding recommended operating conditions may adversely affect LSI reliability.

2.   **Use this device within recommended operating conditions.**

     Recommended operating conditions are values within which normal LSI operation is warranted.

     Standard electrical characteristics are warranted within the range of recommended operating conditions and
     within the listed conditions for each parameter.

3.   **Printed circuit board ground lines should be set up with consideration for common impedance.**

4.   **Take appropriate static electricity measures.**
     • Containers for semiconductor materials should have anti-static protection or be made of conductive material.
     • After mounting, printed circuit boards should be stored and shipped in conductive bags or containers.
     • Work platforms, tools, and instruments should be properly grounded.
     • Working personnel should be grounded with resistance of 250 kΩ to 1 MΩ between body and ground.
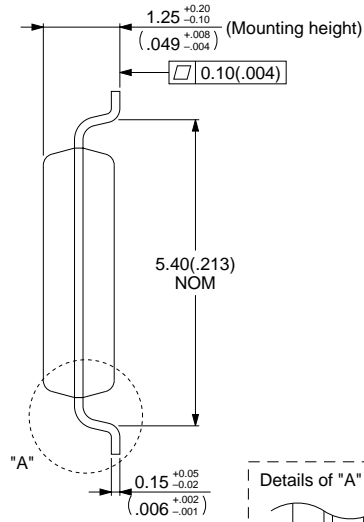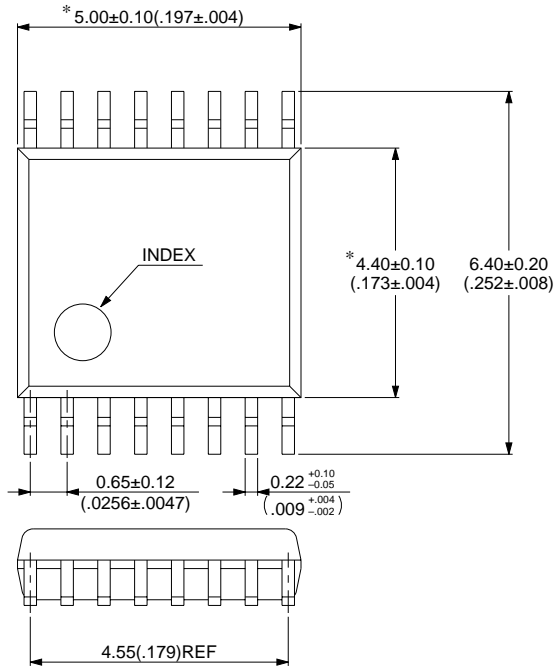
■ **ORDERING INFORMATION**

Part number	Package	Remarks
MB3817PFV	16-pin Plastic SSOP (FPT-16P-M05)	

■ PACKAGE DIMENSION

16-pin Plastic SSOP
(FPT-16P-M05)

*: These dimensions do not include resin protrusion.

*5.00±0.10(.197±.004)

INDEX

*4.40±0.10
(.173±.004)

6.40±0.20
(.252±.008)

0.65±0.12
(.0256±.0047)

$0.22^{+0.10}_{-0.05}$
$\left(.009^{+.004}_{-.002}\right)$

4.55(.179)REF

$1.25^{+0.20}_{-0.10}$
$\left(.049^{+.008}_{-.004}\right)$ (Mounting height)

⬜ 0.10(.004)

5.40(.213)
NOM

"A"

$0.15^{+0.05}_{-0.02}$
$\left(.006^{+.002}_{-.001}\right)$

Details of "A" part

0.10±0.10(.004±.004)
(STAND OFF)

0 ∼ 10°

0.50±0.20
(.020±.008)
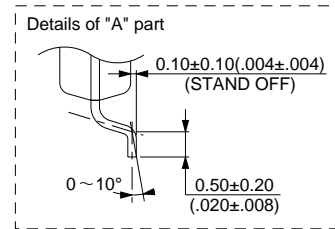
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Dimensions in mm (inches)

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