FUJITSU SEMICONDUCTOR
DATA SHEET

DS04-27216-4E

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) .

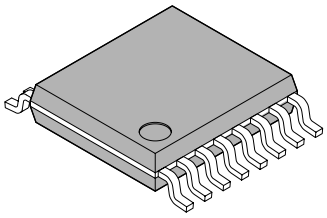
With fewer external components and faster operating speed, the MB3817 enables reduction in power supply unit size, making it ideal for use with internal power supplies in compact, high-performance portable devices.

■ FEATURES

- Wide range of operating power supply voltages : 2.5 V to 18 V
- Built-in high-precision reference voltage generator : 1.5 V ± 2%
- High speed operation is possible : Max 500 kHz
- Wide input voltage range of error amplifier : 0 V 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

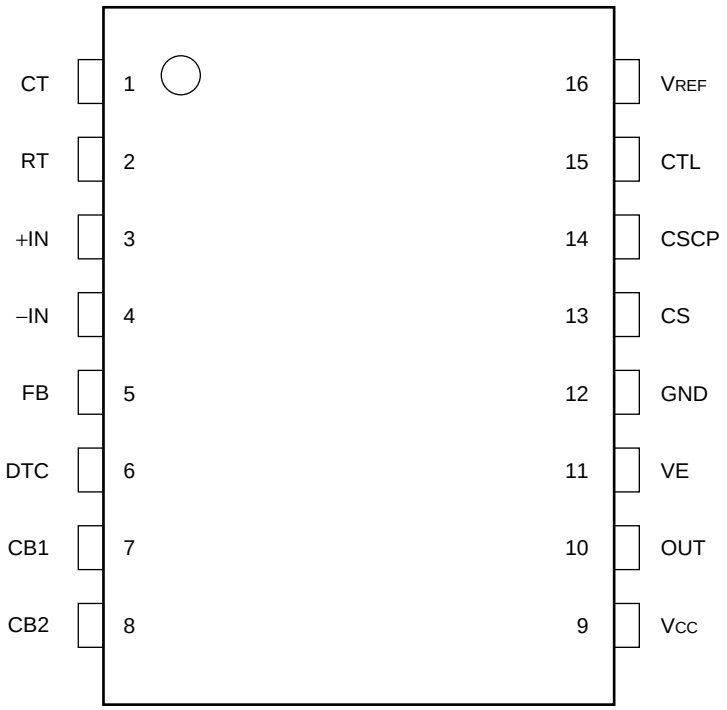


(FPT-16P-M05)

FUJITSU

■ PIN ASSIGNMENT

(TOP VIEW)

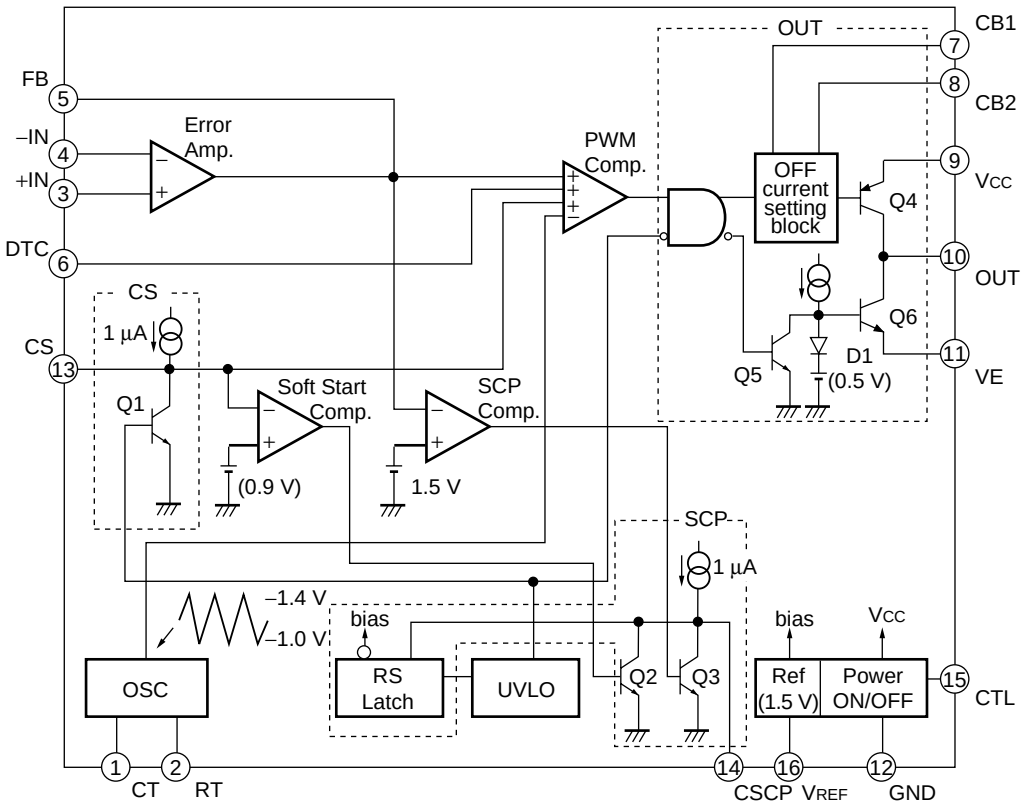


(FPT-16P-M05)

■ PIN DESCRIPTION

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

■ 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: The recommended operating conditions are required in order to ensure the normal operation of the semiconductor device. All of the device's electrical characteristics are warranted when the device is operated within these ranges.

Always use semiconductor devices within their recommended operating condition ranges. 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 representatives beforehand.

■ ELECTRICAL CHARACTERISTICS

(V_{CC} = 6 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.

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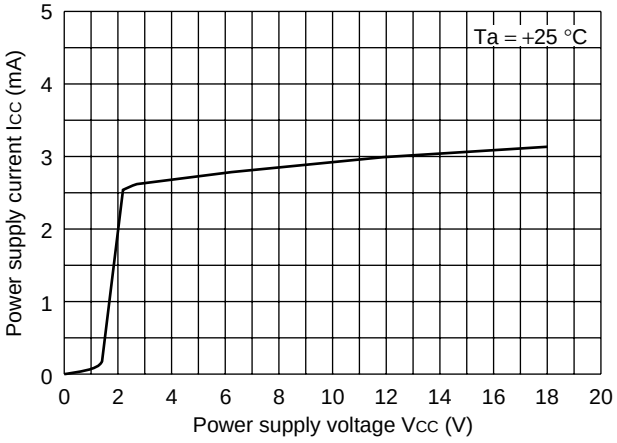
(V_{CC} = 6 V, Ta = +25 °C)

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 ≤ 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

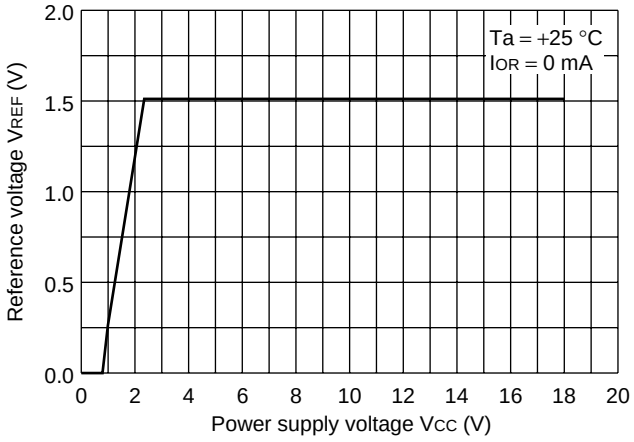
* : Standard design value.

■ TYPICAL CHARACTERISTICS

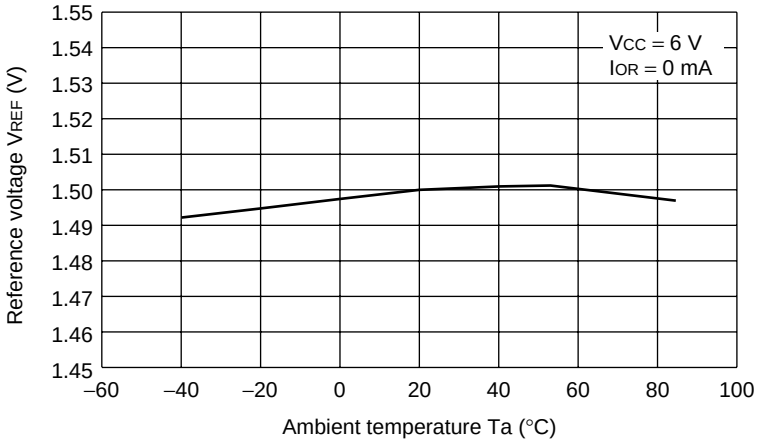
Power supply current vs. power supply voltage



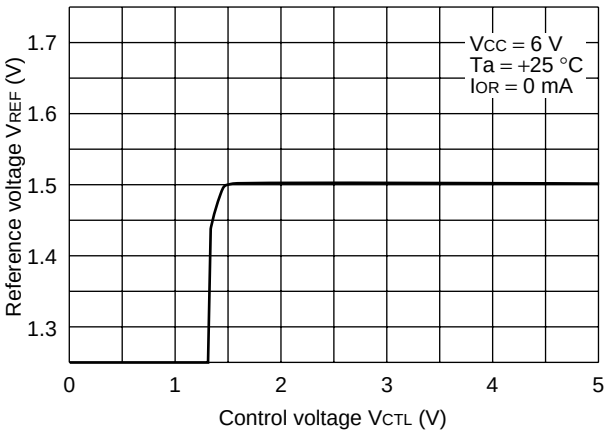
Reference voltage vs. power supply voltage



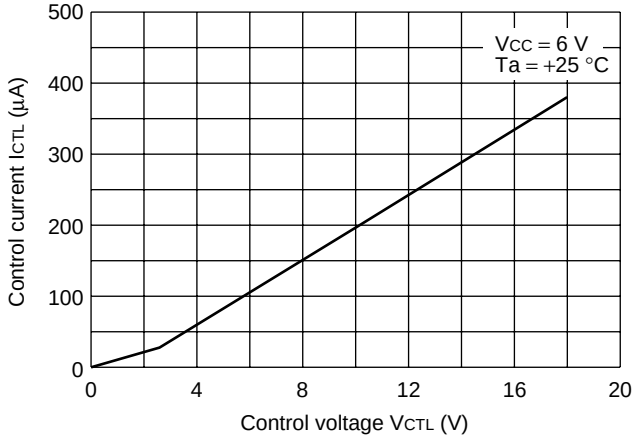
Reference voltage vs. ambient temperature



Reference voltage vs. control voltage



Control current vs. control voltage



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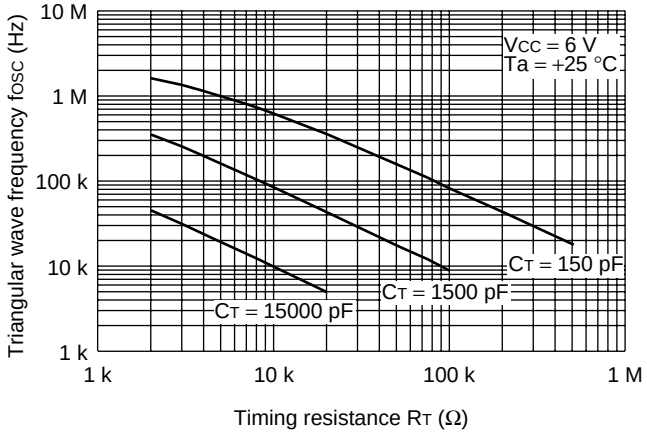
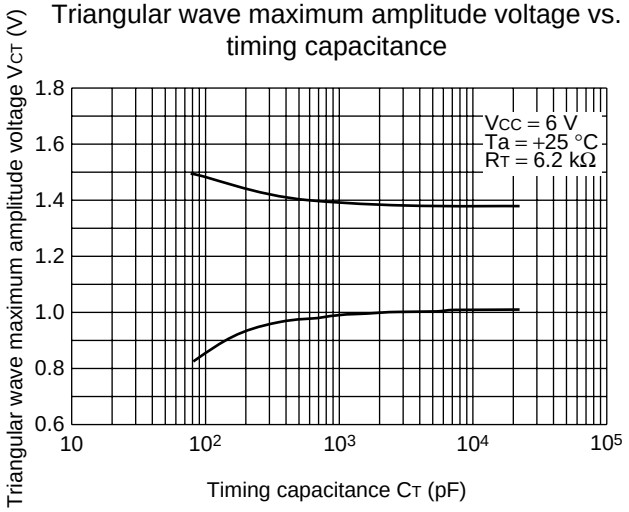
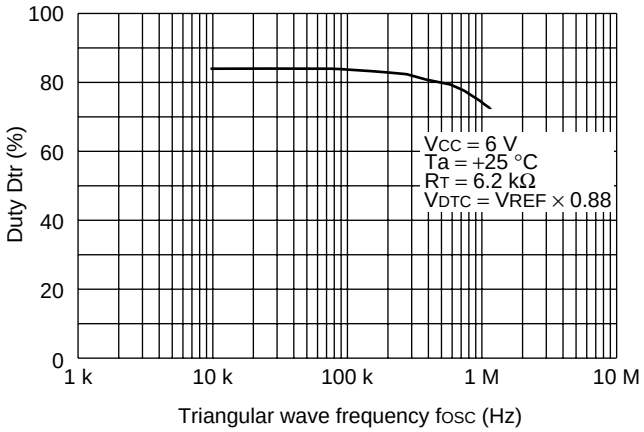
Triangular wave frequency vs. timing resistance



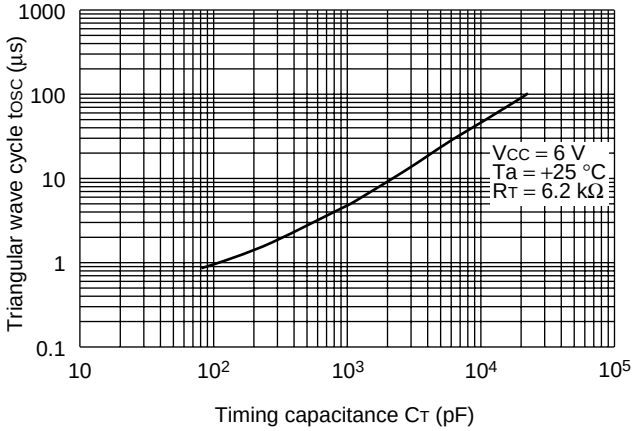
Triangular wave maximum amplitude voltage vs. timing capacitance



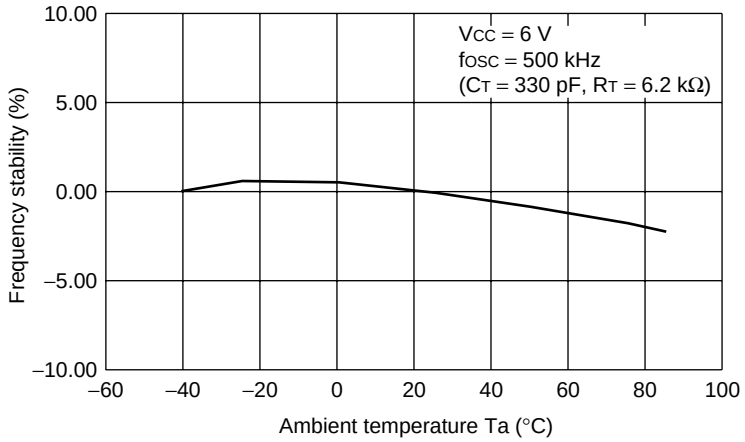
Duty vs. triangular wave frequency



Triangular wave cycle vs. timing capacitance



Frequency stability vs. ambient temperature



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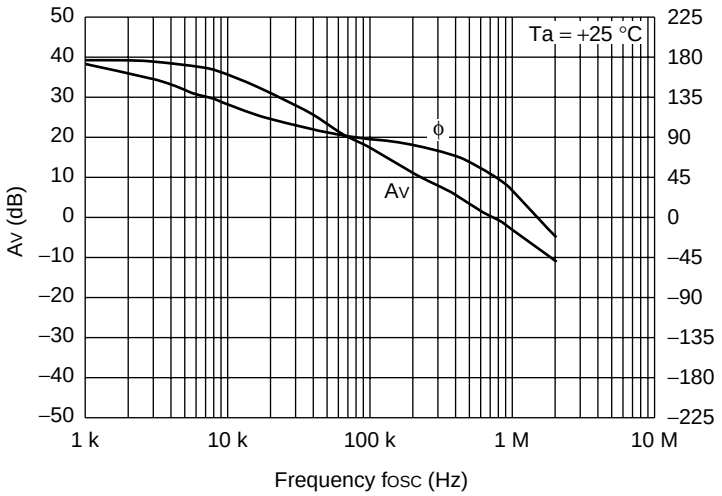
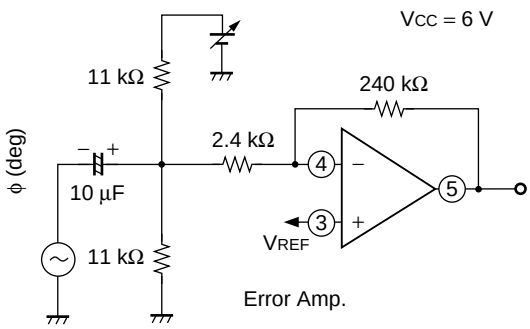
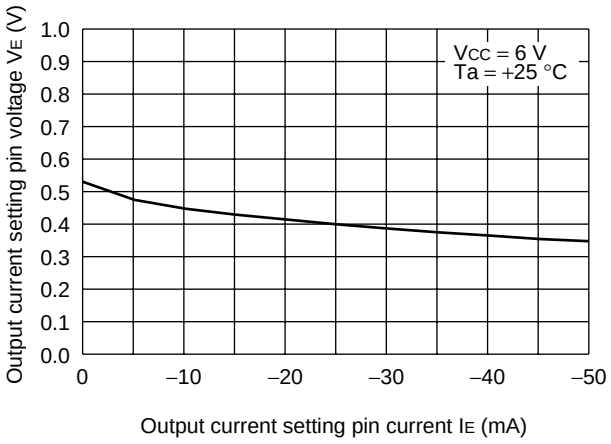
Error amp. frequency



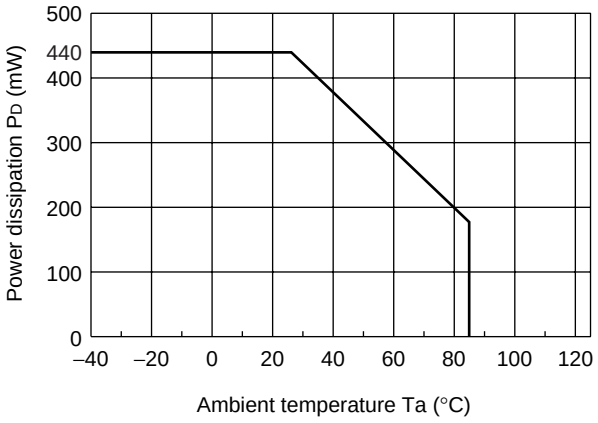
• Measurement circuit



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



Power dissipation vs. ambient temperature



■ FUNCTIONAL DESCRIPTION

1. Switching Regulator Functions

(1) Reference voltage circuit (Ref)

The reference voltage circuit generates a temperature-compensated stable voltage (≒ 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 terminal (FB terminal (pin 5)) and the inverse input terminal (–IN terminal (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 terminal (pin 5)) , soft start set voltage (CS terminal (pin 13)) , or dwell time setting voltage (DTC terminal (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 terminal (pin 11) .

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

2. Power Supply Control Functions

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

CTL terminal voltage level	Channel on/off status
L (≤ 0.7 V)	Standby mode*
H (≥ 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 terminal (pin 13) .

After the soft start operation is completed, the CSCP terminal (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 terminal (pin 10) to be fixed at “H” level and the dwell time to be set to 100%, and the CSCP terminal (pin 14) is held at “L” level.

Once the protection circuit has been activated, the power supply must be reset to restore operation.

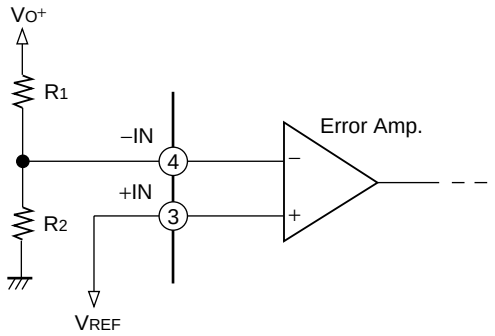
(2) Low input voltage error prevention circuit (UVLO)

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 terminal (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.

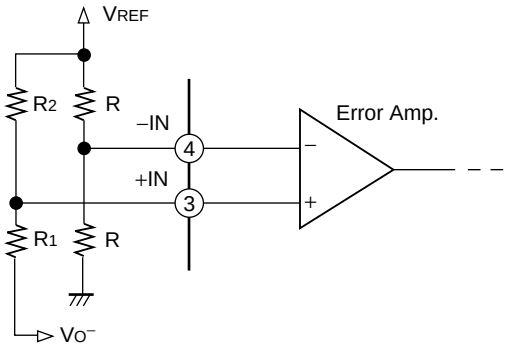
■ SETTING OUTPUT VOLTAGE

- **Output voltage V_O is plus**



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

- **Output voltage V_O is minus**



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

■ OSCILATOR FREQUENCY SETTING

The oscillator frequency can be set by connecting a timing capacitor (C_T) to the CT terminal (pin1) and a timing resistor (R_T) to the RT terminal (pin2) .

Oscillator frequency : f_{OSC}

$$f_{OSC}\ (kHz) \fallingdotseq \frac{1023000}{C_T\ (pF) \bullet R_T\ (k\Omega)}$$

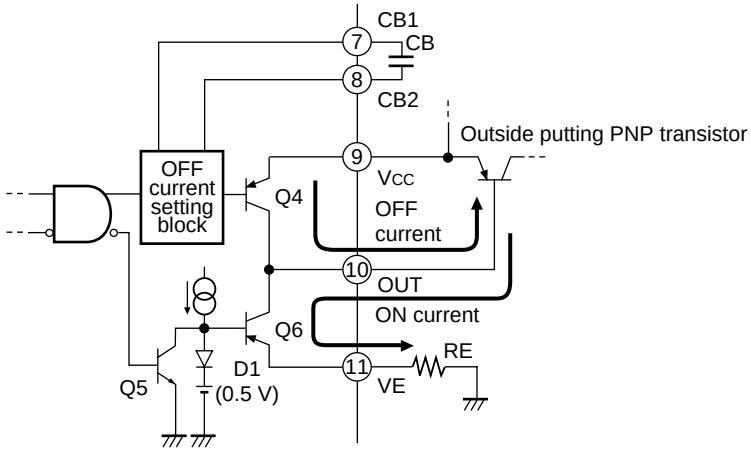
■ METHOD OF SETTING THE OUTPUT CURRENT

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.

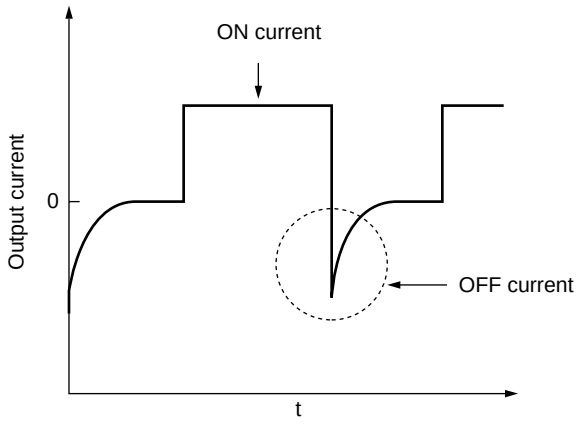
ON current : I_{O^+} [mA] $\fallingdotseq \frac{500}{R_E\ [\Omega]}$ (Voltage on output current-setting pin $V_E = 0.5$ V)

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

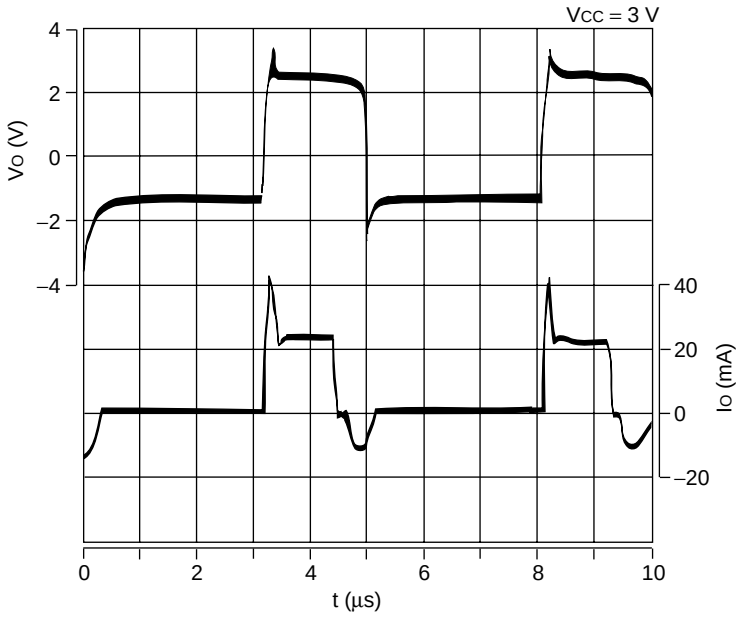
- **Output circuit**



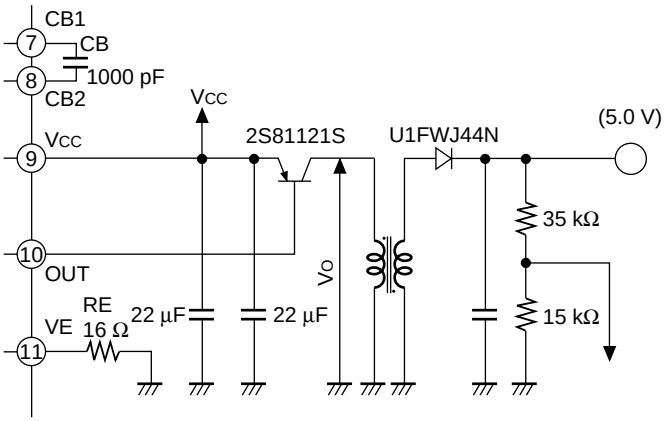
- **Output current waveform**



- **Voltage and current waveforms on output terminal**



- **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 terminal (pin14) holds the input standby voltage V_{STB} which is 50 mV.

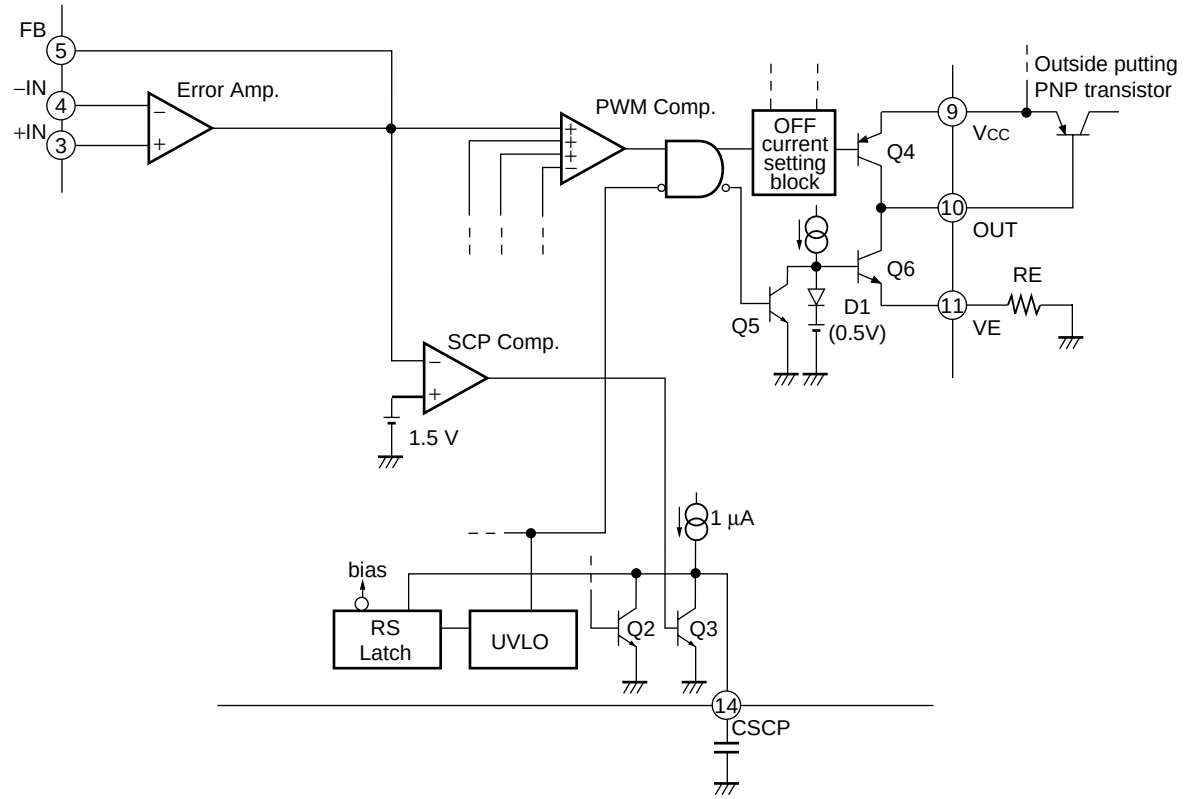
If load conditions change rapidly due to a cause such as a load short, so that output voltage falls, the short detector comparator circuit output changes to “L” level. When this happens, transistor Q3 turns off and the short detector capacitor C_{SCP} connected externally to the CSCP terminal starts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

Short detection time (t_{PE})

t_{PE} [s] ≒ 0.65 × C_{SCP} [μF]

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 terminal is set to input latch voltage V_I which is 50 mV.

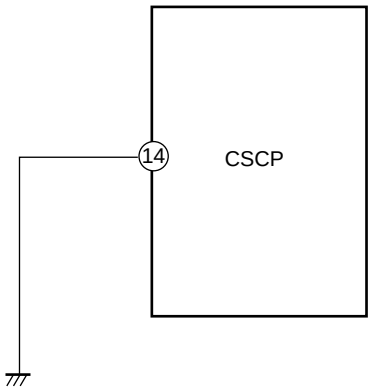
- **Short protection circuit**



■ 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 terminal (pin 13) .

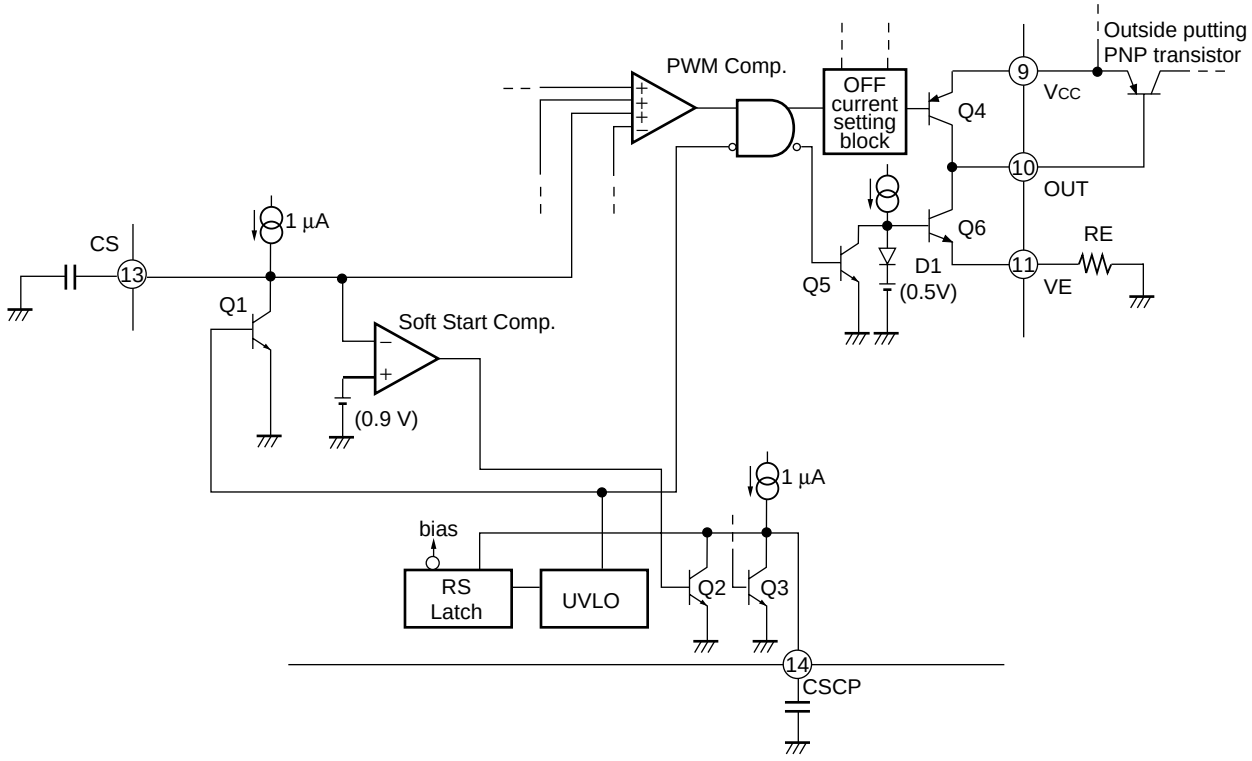
When the IC starts up (CTL terminal (pin 15) to “H” level, Vcc ≥ UVLO threshold voltage V_{TH}) the transistor Q1 turns off and the soft start capacitor (C_S) connected to the CS terminal begins charging from the charge current I_{CHG} which is −1.0 µA.

At this time, if the CS terminal voltage is less than 0.9 V, the soft start comparator circuit output goes to “H” level, transistor Q2 turns on and the CSCP terminal (pin 14) holds input standby voltage V_{STB} which is 50 mV so that the short protection circuit is not activated. When the CS terminal voltage is greater than or equal to 0.9 V, transistor Q2 turns off, the PWM comparator circuit compares the CS terminal voltage with the triangular wave and changes the ON duty of the OUTPUT terminal, 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 [ms] ≒ 1.2 × C_S [µF]

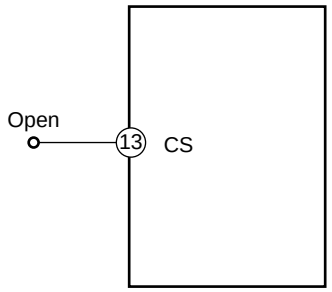
- **Soft start circuit**



■ TREATMENT WHEN NOT USING CS

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

- **When no soft start time is set**



■ METHOD OF SETTING THE DEAD TIME

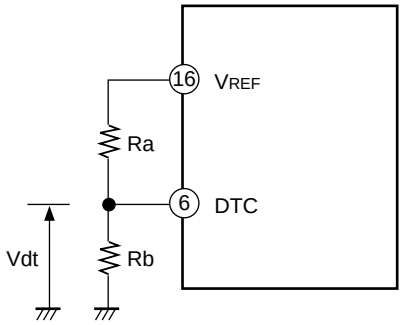
When the device is set for step-up inverted output based on the flyback method, the output transistor is fixed to a full-on state (ON-duty = 100%) at power switch-on. To prevent this problem, you may determine the voltages on the DTC terminals (pin 6) from the V_{REF} voltage so you can easily set the 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 ≅ 0.4 V and triangular-wave minimum voltage ≅ 1.4 V is given below.

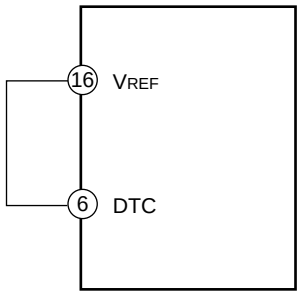
$$\text{Duty (ON)}_{MAX} \fallingdotseq \frac{Vdt - 1.0\ V}{0.4} \times 100\ [\%]$$

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

- **When using DTC to set dead time**

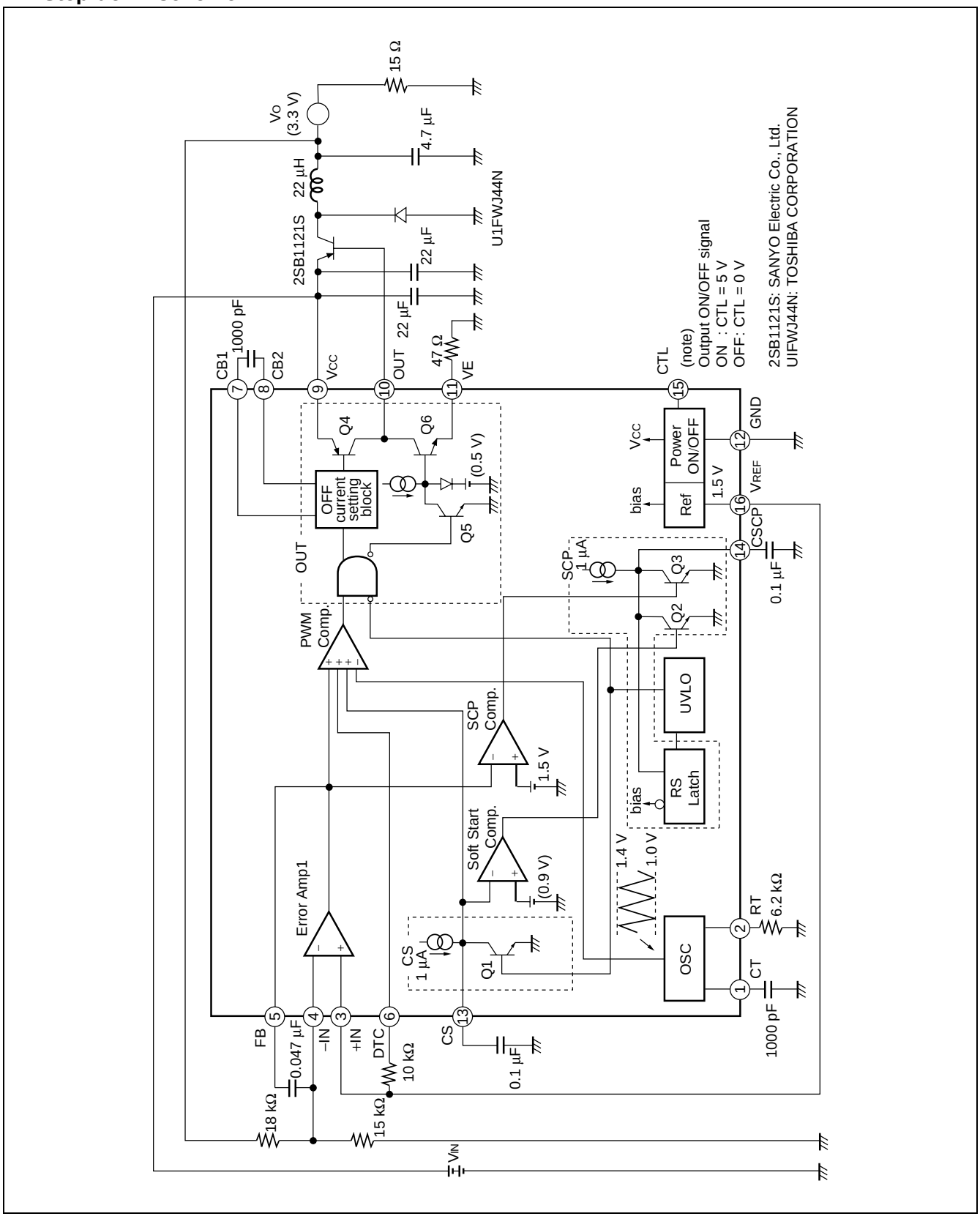


- **When not using DTC to set dead time**

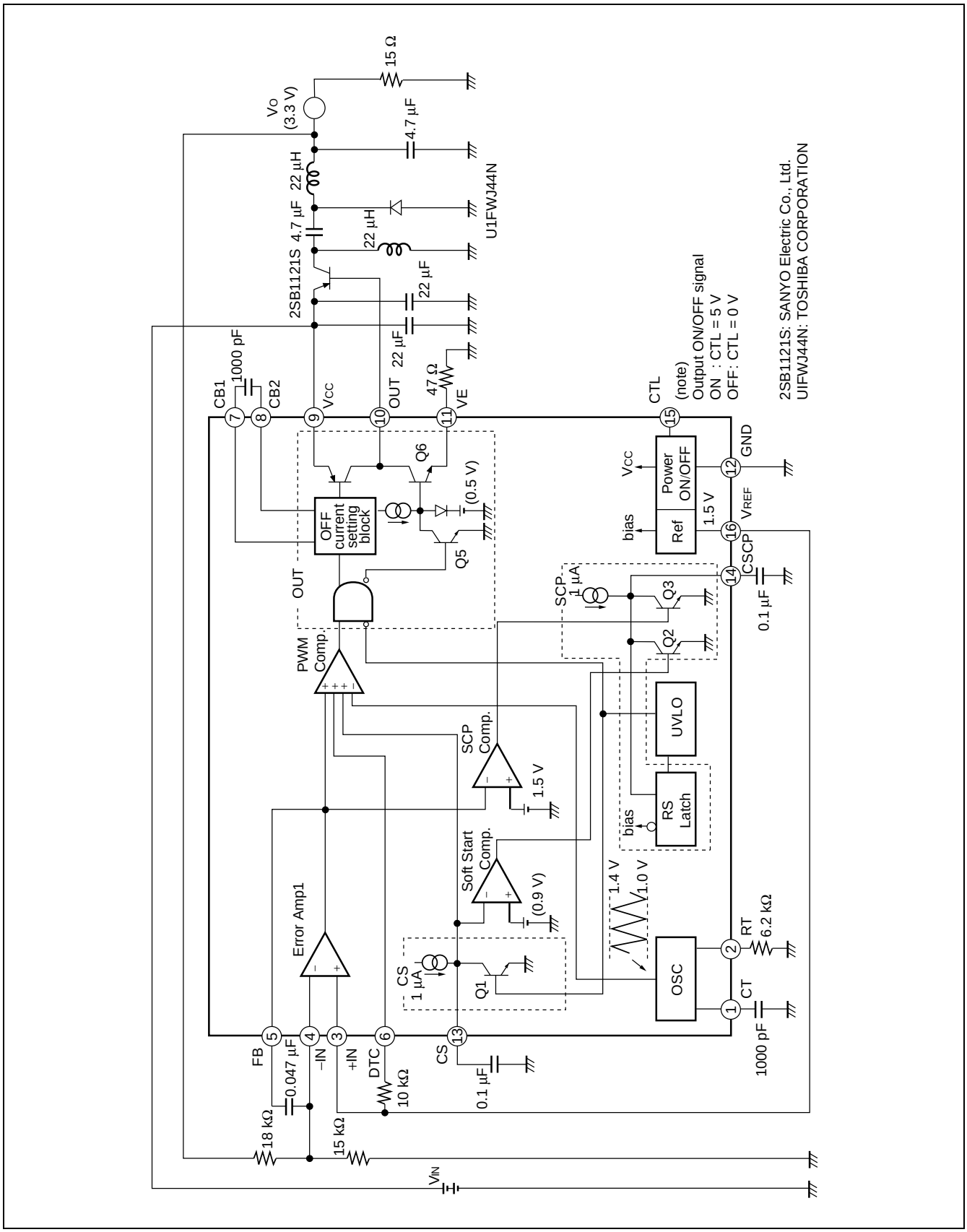


■ APPLICATION EXAMPLE

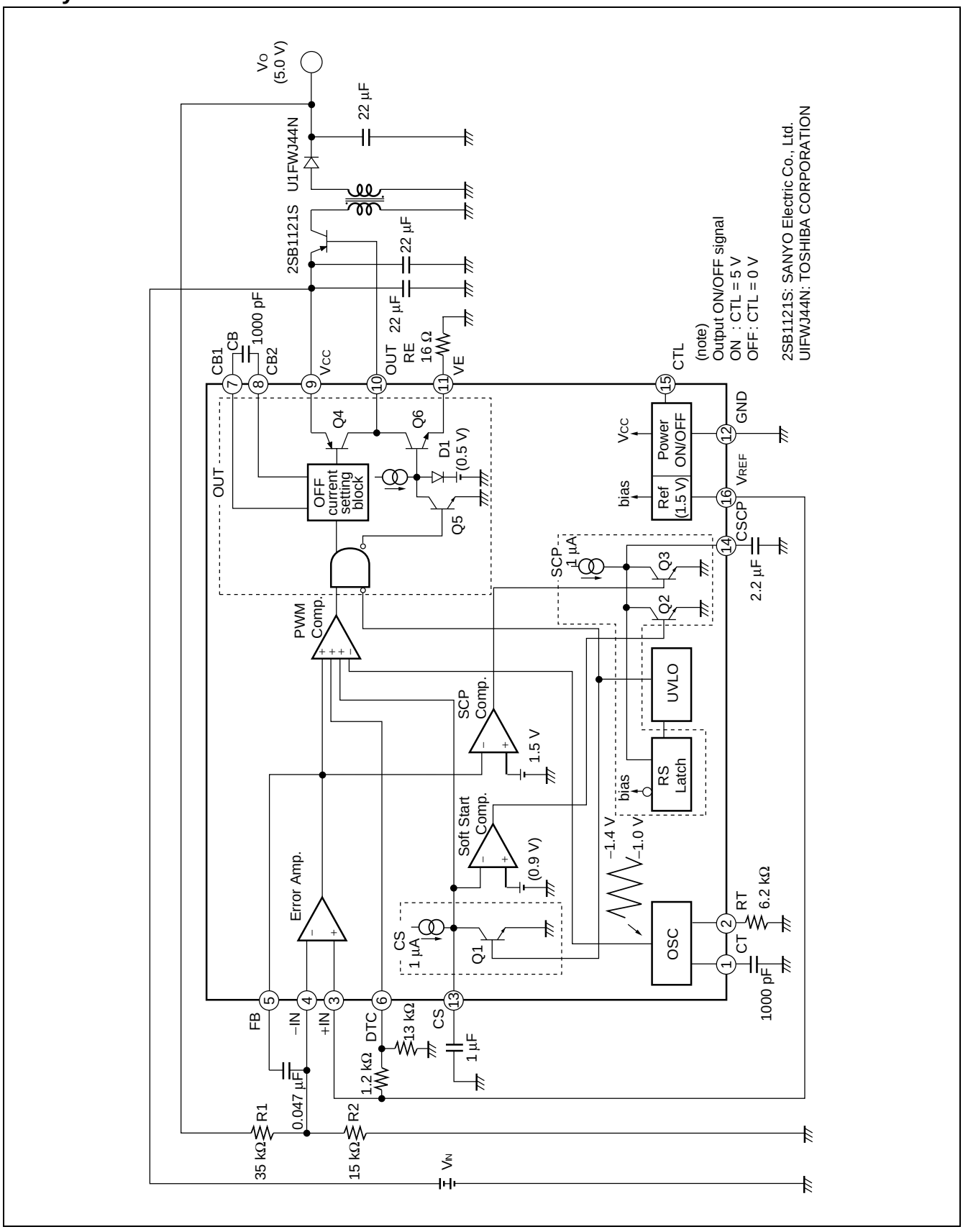
1. Step-down scheme



2. Zeta scheme



3. Flyback scheme



■ APPLICATION

1. Equivalent series resistance and stability of smoothing capacitor

The equivalent series resistance (ESR) of the smoothing capacitor in the DC/DC converter greatly affects the loop phase characteristic.

A smoothing capacitor with a high ESR improves system stability because the phase is advanced into the high-frequency range of an ideal capacitor (see Fig. 34 and 35) . A smoothing capacitor with a low ESR reduces system stability. Use care when using low ESR electrolytic capacitors (OS-CON™) and tantalum capacitors.

Note : OS-CON is the trademark of Sanyo Electric Co.,Ltd.

Figure 33 DC/DC Converter Basic Circuit

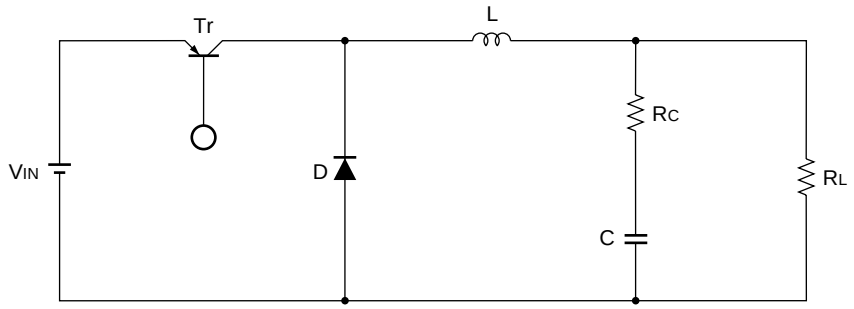


Figure 34 Gain vs. Frequency

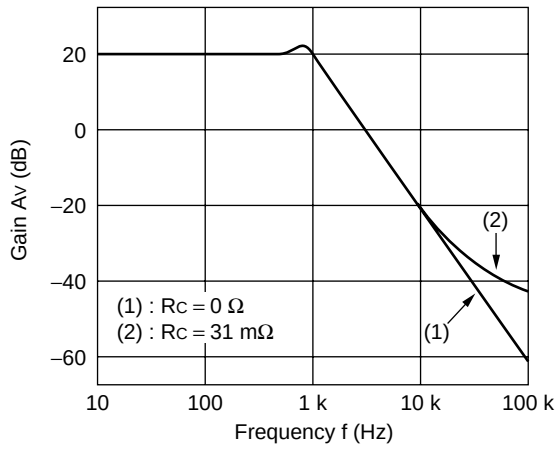
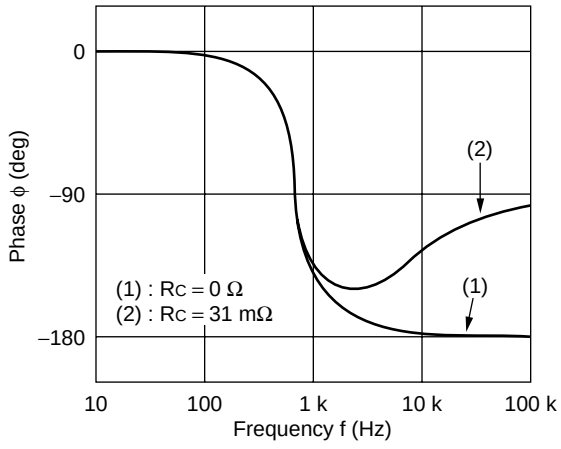


Figure 35 Phase vs. Frequency



Reference data

In an aluminum electrolytic smoothing capacitor (RC≒ 1.0 Ω) is replaced with a low ESR electrolytic capacitor (OS-CON™ : RC≒ 0.2 Ω) , the phase margin is reduced by half (see Fig. 37 and 38) .

Figure 36 DC/DC Converter A_V vs. ϕ characteristic Test Circuit

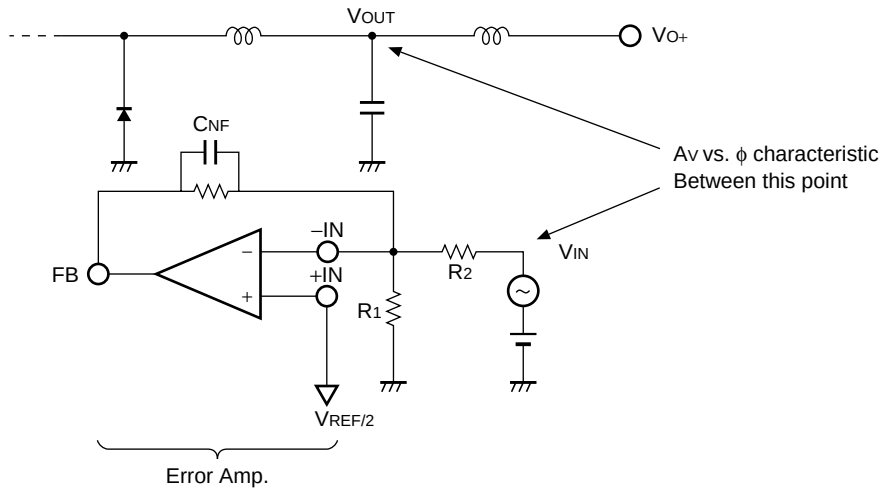


Figure 37 DC/DC Converter +5 V output Gain vs. Phase

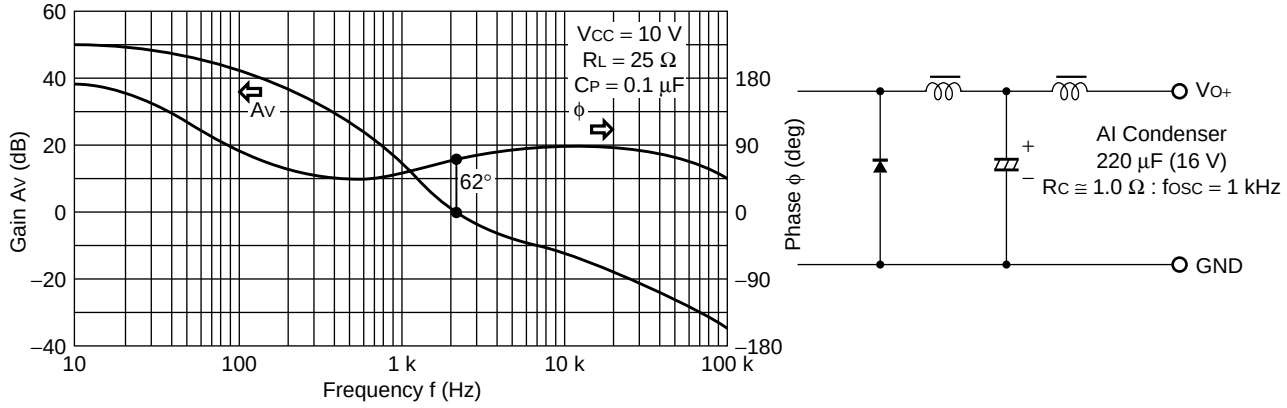
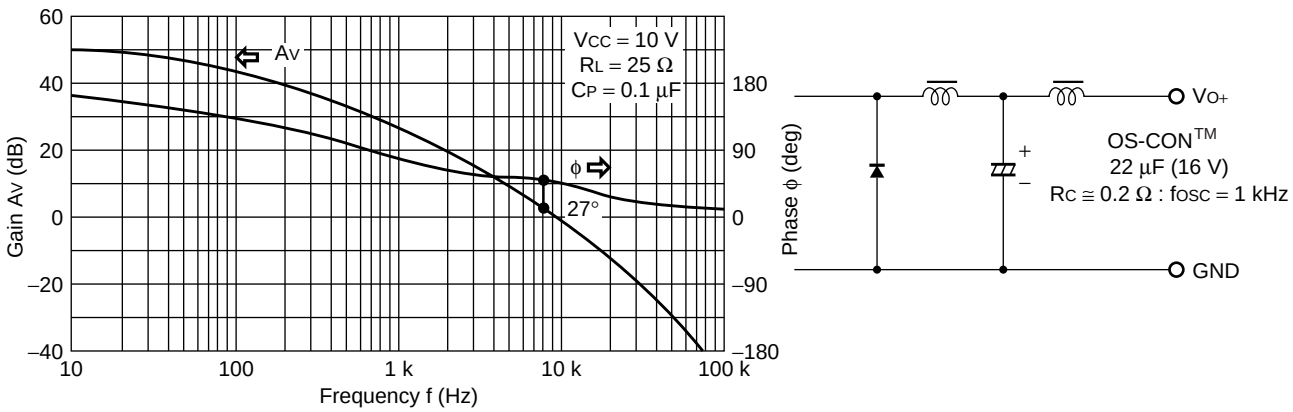


Figure 38 DC/DC Converter +5 V output Gain vs. Phase



■ NOTES ON USE

- Take account of common impedance when designing the earth line on a printed wiring board.

- Take measures against static electricity.
  - For semiconductors, use antistatic or conductive containers.
  - When storing or carrying a printed circuit board after chip mounting, put it in a conductive bag or container.
  - The work table, tools and measuring instruments must be grounded.
  - The worker must put on a grounding device containing 250 kΩ to 1 MΩ resistors in series.

- Do not apply a negative voltage
  - Applying a negative voltage of –0.3 V or less to an LSI may generate a parasitic transistor, resulting in malfunction.

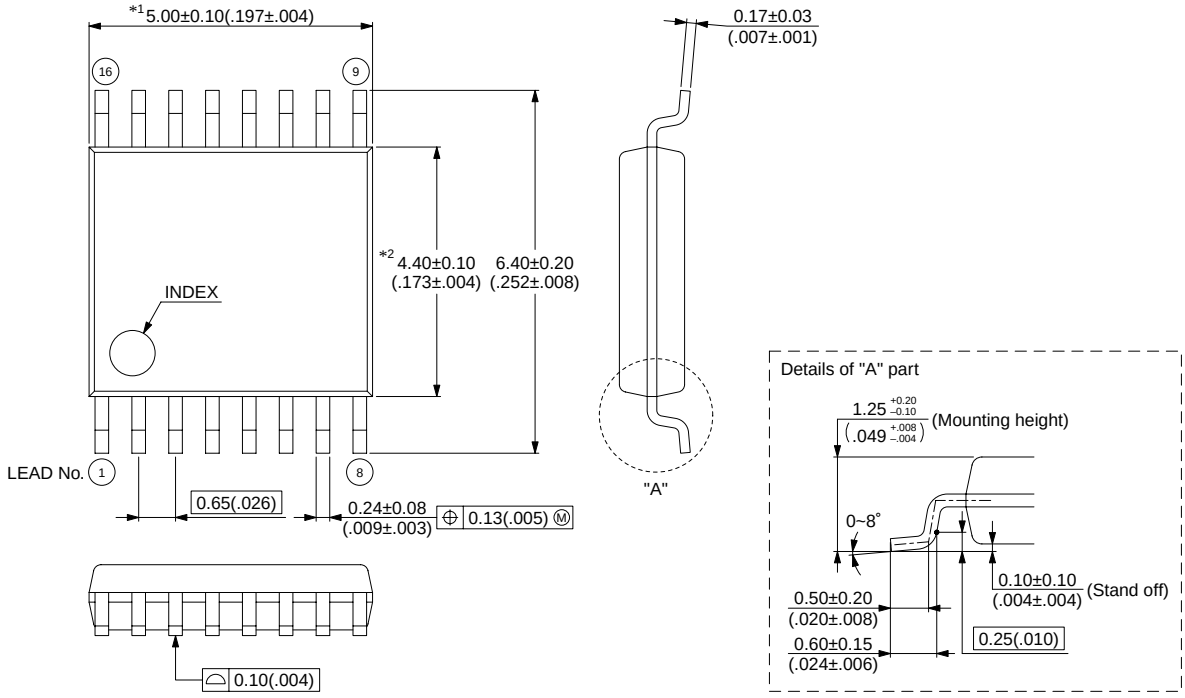
■ ORDERING INFORMATION

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

■ PACKAGE DIMENSION

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

Note 1) *1 : Resin protrusion. (Each side : +0.15 (.006) Max) .
Note 2) *2 : These dimensions do not include resin protrusion.
Note 3) Pins width and pins thickness include plating thickness.
Note 4) Pins width do not include tie bar cutting remainder.



Dimensions in mm (inches)
Note : The values in parentheses are reference values.

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