

*ASSP For Power Supply Applications (Secondary battery)*

## DC/DC Converter IC for Charging

# MB3878

### ■ DESCRIPTION

The MB3878 is a DC/DC converter IC suitable for down-conversion, using pulse-width (PWM) charging and enabling output voltage to be set to any desired level from one cell to four cells.

These ICs can dynamically control the secondary battery's charge current by detecting a voltage drop in an AC adaptor in order to keep its power constant (dynamically-controlled charging).

The charging method enables quick charging, for example, with the AC adaptor during operation of a notebook PC. The MB3878 provides a broad power supply voltage range and low standby current as well as high efficiency, making it ideal for use as a built-in charging device in products such as notebook PC.

This product is covered by US Patent Number 6,147,477.

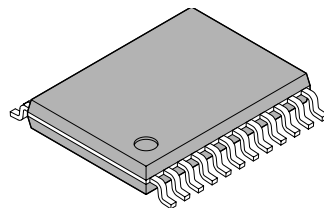
### ■ FEATURES

- Detecting a voltage drop in the AC adaptor and dynamically controlling the charge current (Dynamically-controlled charging)
- Output voltage setting using external resistor : 1 cell to 4 cells
- High efficiency : 94 %
- Wide range of operating supply voltages : 7 V to 25 V
- Output voltage setting accuracy :  $4.2V \pm 0.8%$  (per cell)
- Built-in frequency setting capacitor enables frequency setting using external resistor only
- Oscillator frequency range : 100kHz to 500kHz

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### ■ PACKAGE

24-pin plastic SSOP



(FPT-24P-M03)

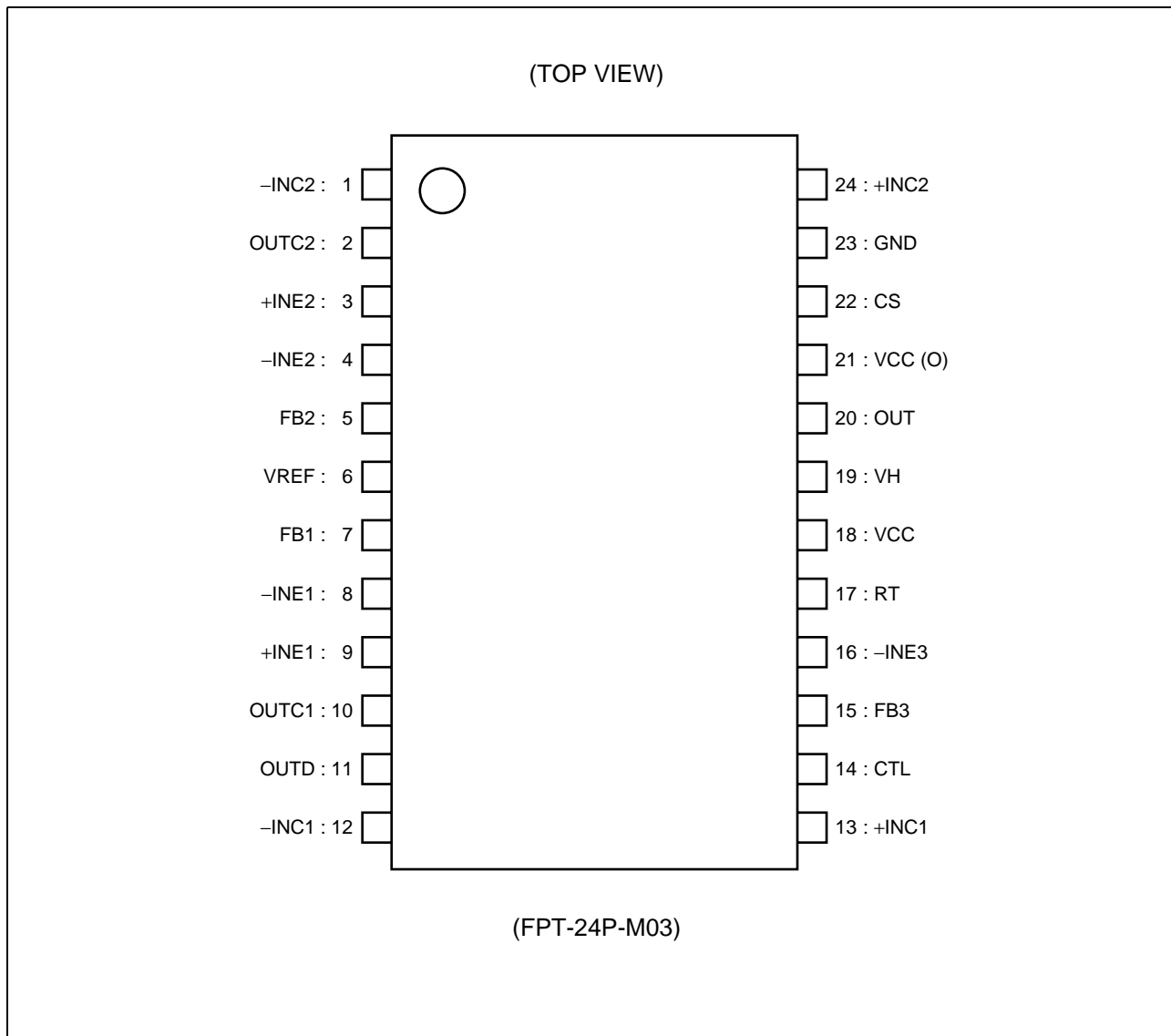
**FUJITSU**

# MB3878

(Continued)

- Built-in current detector amplifier with wide in-phase input voltage range : 0 V to V<sub>cc</sub>
- In standby mode, leave output voltage setting resistor open to prevent inefficient current loss
- Built-in standby current function : 0  $\mu$ A (standard)
- Built-in soft-start function
- Built-in totem-pole output stage supporting P-channel MOS FETs devices

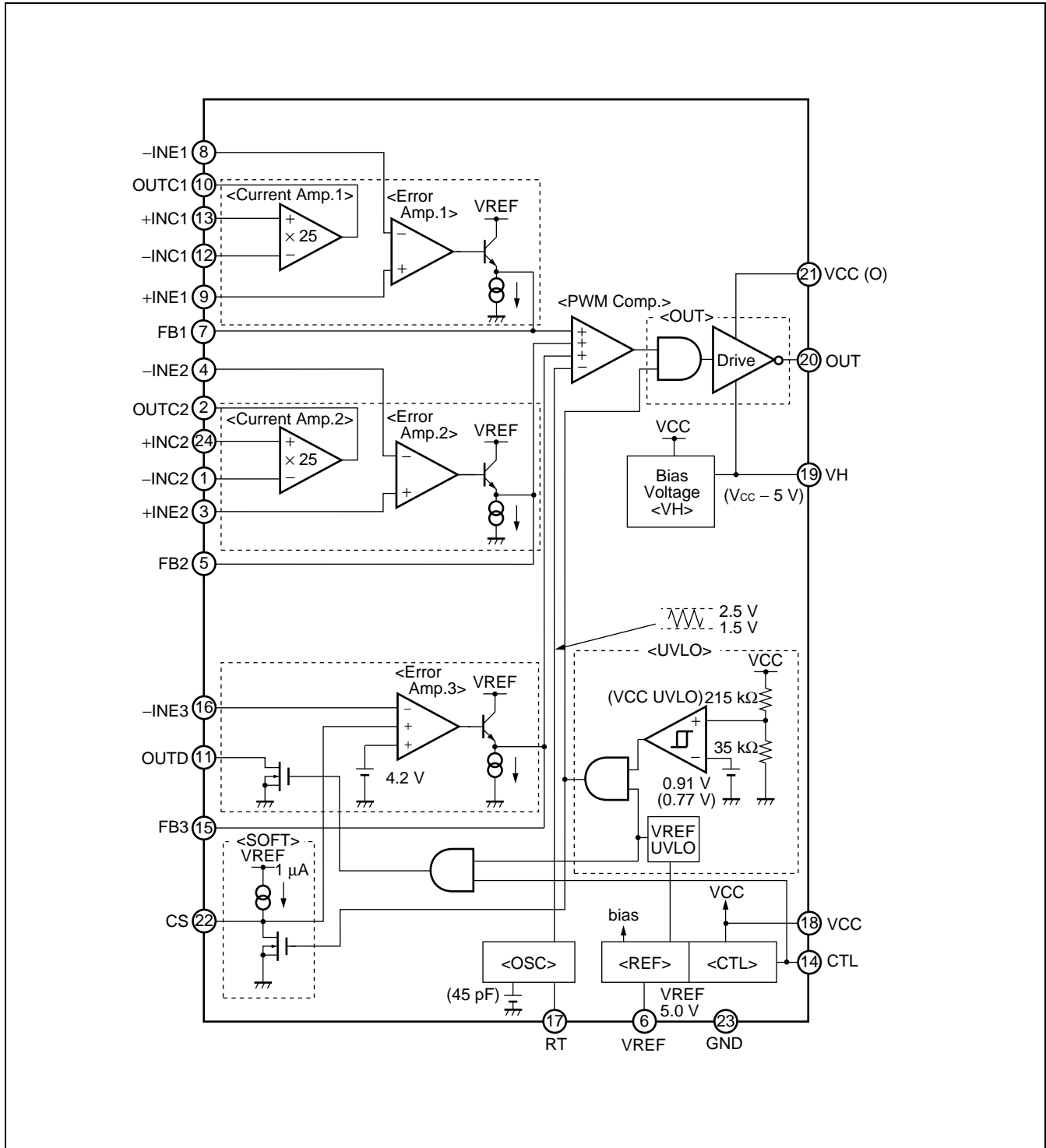
## ■ PIN ASSIGNMENT



## ■ PIN DESCRIPTION

| Pin No. | Symbol  | I/O | Descriptions   |
|---------|---------|-----|--|
| 1       | -INC2   | I   | Current detection amplifier (Current Amp. 2) input pin.  |
| 2       | OUTC2   | O   | Current detection amplifier (Current Amp. 2) output pin.   |
| 3       | +INE2   | I   | Error amplifier (Error Amp. 2) non-inverted input pin.   |
| 4       | -INE2   | I   | Error amplifier (Error Amp. 2) inverted input pin.   |
| 5       | FB2     | O   | Error amplifier (Error Amp. 2) output pin.   |
| 6       | VREF    | O   | Reference voltage output pin.  |
| 7       | FB1     | O   | Error amplifier (Error Amp. 1) output pin.   |
| 8       | -INE1   | I   | Error amplifier (Error Amp. 1) inverted input pin  |
| 9       | +INE1   | I   | Error amplifier (Error Amp. 3) non-inverted input pin.   |
| 10      | OUTC1   | O   | Current detection amplifier (Current Amp. 1) output pin.   |
| 11      | OUTD    | O   | With IC in standby mode, this pin is left open to prevent loss of current through output voltage setting resistance. Set CTL pin to "H" level and OUTD pin to "L" level. |
| 12      | -INC1   | I   | Current detector amplifier (Current Amp. 1) input pin.   |
| 13      | +INC1   | I   | Current detector amplifier (Current Amp. 1) input pin.   |
| 14      | CTL     | I   | Power supply control pin.<br>Setting the CTL pin low places the IC in the standby mode.  |
| 15      | FB3     | O   | Error amplifier (Error Amp. 3) output pin.   |
| 16      | -INE3   | I   | Error amplifier (Error Amp. 3) inverted input pin.   |
| 17      | RT      | —   | Triangular-wave oscillation frequency setting resistor connection pin.   |
| 18      | VCC     | —   | Power supply pin for reference power supply and control circuit.   |
| 19      | VH      | O   | Power supply pin for FET drive circuit (VH = Vcc - 5 V).   |
| 20      | OUT     | O   | High-side FET gate drive pin.  |
| 21      | VCC (O) | —   | Output circuit power supply pin.   |
| 22      | CS      | —   | Soft-start capacitor connection pin.   |
| 23      | GND     | —   | Ground pin.  |
| 24      | +INC2   | I   | Current detection amplifier (Current Amp. 2) input pin.  |

## ■ BLOCK DIAGRAM



## ■ ABSOLUTE MAXIMUM RATINGS

| Parameter            | Symbol           | Conditions                                   | Rating |      | Unit |
|----------------------|------------------|--|--------|------|------|
|                      |                  |  | Min    | Max  |      |
| Power supply voltage | V <sub>CC</sub>  | V <sub>CC</sub> , V <sub>CC</sub> (O)        | —      | 28   | V    |
| Output current       | I <sub>OUT</sub> | —  | —      | 60   | mA   |
| Peak output current  | I <sub>OUT</sub> | Duty ≤ 5 % (t = 1 / f <sub>osc</sub> × Duty) | —      | 500  | mA   |
| Power dissipation    | P <sub>D</sub>   | T <sub>a</sub> ≤ +25 °C                      | —      | 740* | mW   |
| Storage temperature  | T <sub>stg</sub> | —  | -55    | +125 | °C   |

\* : The package is mounted on the dual-sided 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            | Conditions                                   | Value |      |                       | Unit |
|------------------------------------|-------------------|--|-------|------|-----------------------|------|
|                                    |                   |  | Min   | Typ  | Max                   |      |
| Power supply voltage               | V <sub>CC</sub>   | V <sub>CC</sub> , V <sub>CC</sub> (O)        | 7     | —    | 25                    | V    |
| Reference voltage output current   | I <sub>REF</sub>  | —  | -1    | —    | 0                     | mA   |
| VH pin output current              | I <sub>VH</sub>   | —  | 0     | —    | 30                    | mA   |
| Input voltage                      | V <sub>INE</sub>  | -INE1 to -INE3, +INE1, +INE2                 | 0     | —    | V <sub>CC</sub> - 1.8 | V    |
|                                    | V <sub>INC</sub>  | +INC1, +INC2, -INC1, -INC2                   | 0     | —    | V <sub>CC</sub>       | V    |
| OUTD pin output voltage            | V <sub>OUTD</sub> | —  | 0     | —    | 17                    | V    |
| OUTD pin output current            | I <sub>OUTD</sub> | —  | 0     | —    | 2                     | mA   |
| CTL pin input voltage              | V <sub>CTL</sub>  | —  | 0     | —    | 25                    | V    |
| output current                     | I <sub>OUT</sub>  | —  | -45   | —    | 45                    | mA   |
| Peak output current                | I <sub>OUT</sub>  | Duty ≤ 5 % (t = 1 / f <sub>osc</sub> × Duty) | -450  | —    | 450                   | mA   |
| Oscillator frequency               | f <sub>osc</sub>  | —  | 100   | 290  | 500                   | kHz  |
| Timing resistor                    | R <sub>T</sub>    | —  | 33    | 47   | 130                   | kΩ   |
| Soft-start capacitor               | C <sub>S</sub>    | —  | —     | 2200 | 100000                | pF   |
| VH pin capacitor                   | C <sub>VH</sub>   | —  | —     | 0.1  | 1.0                   | μF   |
| Reference voltage output capacitor | C <sub>REF</sub>  | —  | —     | 0.1  | 1.0                   | μF   |
| Operating ambient temperature      | T <sub>a</sub>    | —  | -30   | +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

(Ta = +25 °C, VCC = 19 V, VCC (O) = 19 V, VREF = 0 mA)

| Parameter   | Symbol                          | Pin No.             | Conditions   | Value  |       |       | Unit                  |     |
|---|---------------------------------|---------------------|--|--|-------|-------|-----------------------|-----|
|   |                                 |                     |  | Min  | Typ   | Max   |                       |     |
| Reference voltage block (Ref)                         | Output voltage                  | V <sub>REF</sub>    | 6  | Ta = +25 °C                                      | 4.995 | 5.000 | 5.045                 | V   |
|   |                                 |                     |  | Ta = -30 °C to +85 °C                            | 4.945 | 5.000 | 5.055                 | V   |
|   | Input stability                 | Line                | 6  | VCC = 7 V to 25 V                                | —     | 3     | 10                    | mV  |
|   | Load stability                  | Load                | 6  | VREF = 0 mA to -1 mA                             | —     | 1     | 10                    | mV  |
|   | Short-circuit output current    | I <sub>OS</sub>     | 6  | VREF = 1 V                                       | -25   | -15   | -5                    | mA  |
| Under voltage lockout protection circuit block (UVLO) | Threshold voltage               | V <sub>TLH</sub>    | 18   | VCC = VCC (O) ,<br>VCC = $\overline{\downarrow}$ | 6.1   | 6.4   | 6.7                   | V   |
|   |                                 | V <sub>THL</sub>    | 18   | VCC = VCC (O) ,<br>VCC = $\overline{\uparrow}$   | 5.1   | 5.4   | 5.7                   | V   |
|   | Hysteresis width                | V <sub>H</sub>      | 18   | VCC = VCC (O)                                    | 0.7   | 1.0   | 1.3                   | V   |
|   | Threshold voltage               | V <sub>TLH</sub>    | 6  | VREF = $\overline{\downarrow}$                   | 2.6   | 2.8   | 3.0                   | V   |
|   |                                 | V <sub>THL</sub>    | 6  | VREF = $\overline{\uparrow}$                     | 2.4   | 2.6   | 2.8                   | V   |
| Hysteresis width                                      | V <sub>H</sub>                  | 6                   | V <sub>H</sub> = V <sub>TLH</sub> - V <sub>THL</sub> | 0.05   | 0.20  | 0.35  | V                     |     |
| Soft-start block (SOFT)                               | Charge current                  | I <sub>CS</sub>     | 22   | —  | -1.3  | -0.8  | -0.5                  | μA  |
| Triangular waveform oscillator circuit block (OSC)    | Oscillation frequency           | f <sub>OSC</sub>    | 20   | RT = 47 kΩ                                       | 260   | 290   | 320                   | kHz |
|   | Frequency temperature stability | Δf/fdt              | 20   | Ta = -30 °C to +85 °C                            | —     | 1*    | —                     | %   |
| Error amplifier block (Error Amp.1, Error Amp.2)      | Input offset voltage            | V <sub>IO</sub>     | 3, 4, 8, 9   | FB1 = FB2 = 2 V                                  | —     | 1     | 5                     | mV  |
|   | Input bias current              | I <sub>B</sub>      | 3, 4, 8, 9   | —  | -100  | -30   | —                     | nA  |
|   | Common mode input voltage range | V <sub>CM</sub>     | 3, 4, 8, 9   | —  | 0     | —     | V <sub>CC</sub> - 1.8 | V   |
|   | Voltage gain                    | A <sub>V</sub>      | 5, 7   | DC   | —     | 100*  | —                     | dB  |
|   | Frequency bandwidth             | B <sub>W</sub>      | 5, 7   | A <sub>V</sub> = 0 dB                            | —     | 2.0*  | —                     | MHz |
|   | Output voltage                  | V <sub>FBH</sub>    | 5, 7   | —  | 4.7   | 4.9   | —                     | V   |
|   |                                 | V <sub>FBL</sub>    | 5, 7   | —  | —     | 20    | 200                   | mV  |
|   | Output source current           | I <sub>SOURCE</sub> | 5, 7   | FB1 = FB2 = 2 V                                  | —     | -2.0  | -0.6                  | mA  |
| Output sink current                                   | I <sub>SINK</sub>               | 5, 7                | FB1 = FB2 = 2 V                                      | 150  | 300   | —     | μA                    |     |

\* : Standard design value.

(Continued)

(Ta = +25 °C, VCC = 19 V, VCC (O) = 19 V, VREF = 0 mA)

| Parameter   | Symbol                          | Pin No.             | Conditions            | Value  |       |       | Unit            |     |
|---|---------------------------------|---------------------|-----------------------|--|-------|-------|-----------------|-----|
|   |                                 |                     |                       | Min  | Typ   | Max   |                 |     |
| Error amplifier block<br>(Error Amp.3)                              | Threshold voltage               | V <sub>TH1</sub>    | 16                    | FB3 = 2 V, Ta = +25 °C                             | 4.167 | 4.200 | 4.233           | V   |
|   |                                 | V <sub>TH2</sub>    | 16                    | FB3 = 2 V,<br>Ta = -30 °C to +85 °C                | 4.158 | 4.200 | 4.242           | V   |
|   | Input current                   | I <sub>INE3</sub>   | 16                    | -INE3 = 0 V  | -100  | -30   | —               | nA  |
|   | Voltage gain                    | A <sub>v</sub>      | 15                    | DC   | —     | 100*  | —               | dB  |
|   | Frequency bandwidth             | B <sub>w</sub>      | 15                    | A <sub>v</sub> = 0 dB                              | —     | 2.0*  | —               | MHz |
|   | Output voltage                  | V <sub>FBH</sub>    | 15                    | —  | 4.7   | 4.9   | —               | V   |
|   |                                 | V <sub>FBL</sub>    | 15                    | —  | —     | 20    | 200             | mV  |
|   | Output source current           | I <sub>SOURCE</sub> | 15                    | FB3 = 2 V  | —     | -2.0  | -0.6            | mA  |
|   | Output sink current             | I <sub>SINK</sub>   | 15                    | FB3 = 2 V  | 150   | 300   | —               | μA  |
|   | OUTD pin output leak current    | I <sub>LEAK</sub>   | 11                    | OUTD = 16.8 V                                      | —     | 0     | 1               | μA  |
| OUTD pin output ON resistor   | R <sub>ON</sub>                 | 11                  | OUTD = 1 mA           | —  | 70    | 100   | Ω               |     |
| Current detection amplifier block<br>(Current Amp.1, Current Amp.2) | Input current                   | I <sub>-INCH</sub>  | 13, 24                | +INC1 = +INC2 = 12.7 V,<br>-INC1 = -INC2 = 12.6 V  | —     | 10    | 20              | μA  |
|   |                                 | I <sub>-INCH</sub>  | 1, 12                 | +INC1 = +INC2 = 12.7 V,<br>-INC1 = -INC2 = 12.6 V  | —     | 0.1   | 0.2             | μA  |
|   |                                 | I <sub>-INCL</sub>  | 13, 24                | +INC1 = +INC2 = 0.1 V,<br>-INC1 = -INC2 = 0 V      | -130  | -65   | —               | μA  |
|   |                                 | I <sub>-INCL</sub>  | 1, 12                 | +INC1 = +INC2 = 0.1 V,<br>-INC1 = -INC2 = 0 V      | -140  | -70   | —               | μA  |
|   | Current detection voltage       | V <sub>OUTC1</sub>  | 2, 10                 | +INC1 = +INC2 = 12.7 V,<br>-INC1 = -INC2 = 12.6 V  | 2.25  | 2.5   | 2.75            | V   |
|   |                                 | V <sub>OUTC2</sub>  | 2, 10                 | +INC1 = +INC2 = 12.63 V,<br>-INC1 = -INC2 = 12.6 V | 0.50  | 0.75  | 1.00            | V   |
|   |                                 | V <sub>OUTC3</sub>  | 2, 10                 | +INC1 = +INC2 = 0.1 V,<br>-INC1 = -INC2 = 0 V      | 1.25  | 2.50  | 3.75            | V   |
|   |                                 | V <sub>OUTC4</sub>  | 2, 10                 | +INC1 = +INC2 = 0.03 V,<br>-INC1 = -INC2 = 0 V     | 0.125 | 0.750 | 1.375           | V   |
|   | Common mode input voltage range | V <sub>CM</sub>     | 1, 12, 13, 24         | —  | 0     | —     | V <sub>CC</sub> | V   |
|   | Voltage gain                    | A <sub>v</sub>      | 2, 10                 | +INC1 = +INC2 = 12.7 V,<br>-INC1 = -INC2 = 12.6 V  | 22.5  | 25    | 27.5            | V/V |
| Frequency bandwidth   | B <sub>w</sub>                  | 2, 10               | A <sub>v</sub> = 0 dB | —  | 2.0*  | —     | MHz             |     |

\* : Standard design value.

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# MB3878

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( $T_a = +25\text{ }^\circ\text{C}$ ,  $V_{CC} = 19\text{ V}$ ,  $V_{CC(O)} = 19\text{ V}$ ,  $V_{REF} = 0\text{ mA}$ )

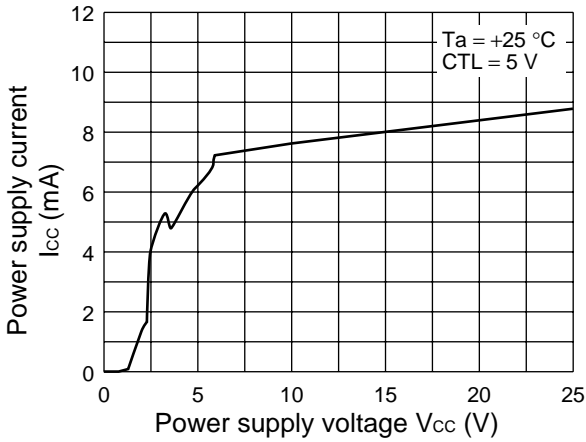
| Parameter  | Symbol                | Pin No.      | Conditions   | Value  |                |                | Unit           |               |
|--|-----------------------|--------------|--|--|----------------|----------------|----------------|---------------|
|  |                       |              |  | Min  | Typ            | Max            |                |               |
| Current detection amplifier block (Current Amp.1, Current Amp.2) | Output voltage        | $V_{OUTCH}$  | 2, 10  | —  | 4.7            | 4.9            | —              | V             |
|  |                       | $V_{OUTCL}$  | 2, 10  | —  | —              | 20             | 200            | mV            |
|  | Output source current | $I_{SOURCE}$ | 2, 10  | $OUTC1 = OUTC2 = 2\text{ V}$   | —              | -2.0           | -0.6           | mA            |
|  | Output sink current   | $I_{SINK}$   | 2, 10  | $OUTC1 = OUTC2 = 2\text{ V}$   | 150            | 300            | —              | $\mu\text{A}$ |
| PWM comparator block (PWM Comp.)                                 | Threshold voltage     | $V_{TL}$     | 5, 7, 15   | Duty cycle = 0 %   | 1.4            | 1.5            | —              | V             |
|  |                       | $V_{TH}$     | 5, 7, 15   | Duty cycle = 100 %   | —              | 2.5            | 2.6            | V             |
| Output block (OUT)   | Output source current | $I_{SOURCE}$ | 20   | $OUT = 11\text{ V}$ , Duty $\leq 5\%$<br>( $t = 1 / f_{osc} \times \text{Duty}$ )      | —              | -200*          | —              | mA            |
|  | Output sink current   | $I_{SINK}$   | 20   | $OUT = 16\text{ V}$ , Duty $\leq 5\%$<br>( $t = 1 / f_{osc} \times \text{Duty}$ )      | —              | 200*           | —              | mA            |
|  | Output ON resistor    | $R_{OH}$     | 20   | $OUT = -45\text{ mA}$  | —              | 8.0            | 12.0           | $\Omega$      |
|  |                       | $R_{OL}$     | 20   | $OUT = 45\text{ mA}$   | —              | 6.5            | 9.7            | $\Omega$      |
|  | Rise time             | $t_{r1}$     | 20   | $OUT = 3300\text{ pF}$<br>(equivalent to Si4435 $\times 1$ )                           | —              | 70*            | —              | ns            |
| Fall time  | $t_{f1}$              | 20           | $OUT = 3300\text{ pF}$<br>(equivalent to Si4435 $\times 1$ ) | —  | 60*            | —              | ns             |               |
| Control block (CTL)  | CTL input voltage     | $V_{ON}$     | 14   | Active mode  | 2              | —              | 25             | V             |
|  |                       | $V_{OFF}$    | 14   | Standby mode   | 0              | —              | 0.8            | V             |
|  | Input current         | $I_{CTLH}$   | 14   | $CTL = 5\text{ V}$   | —              | 100            | 200            | $\mu\text{A}$ |
|  |                       | $I_{CTL L}$  | 14   | $CTL = 0\text{ V}$   | —              | 0              | 1              | $\mu\text{A}$ |
| Bias voltage block (VH)  | Output voltage        | $V_H$        | 19   | $V_{CC} = V_{CC(O)} = 7\text{ V to }25\text{ V}$ ,<br>$V_H = 0\text{ to }30\text{ mA}$ | $V_{CC} - 5.5$ | $V_{CC} - 5.0$ | $V_{CC} - 4.5$ | V             |
| General  | Standby current       | $I_{CCS}$    | 18, 19   | $V_{CC} = V_{CC(O)}$ ,<br>$CTL = 0\text{ V}$   | —              | 0              | 10             | $\mu\text{A}$ |
|  | Power supply current  | $I_{CC}$     | 18, 19   | $V_{CC} = V_{CC(O)}$ ,<br>$CTL = 5\text{ V}$   | —              | 8.0            | 12.0           | mA            |

\* : Standard design value

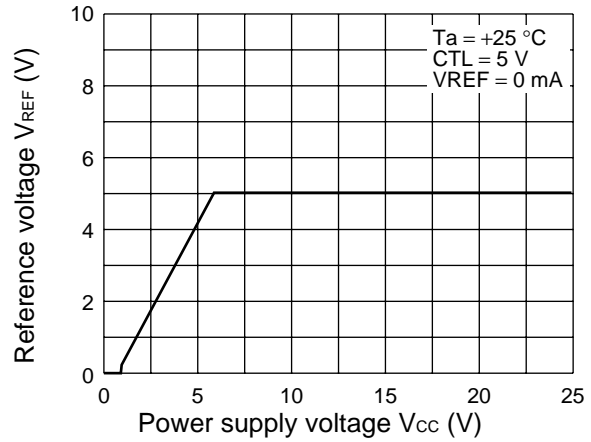


## TYPICAL CHARACTERISTICS

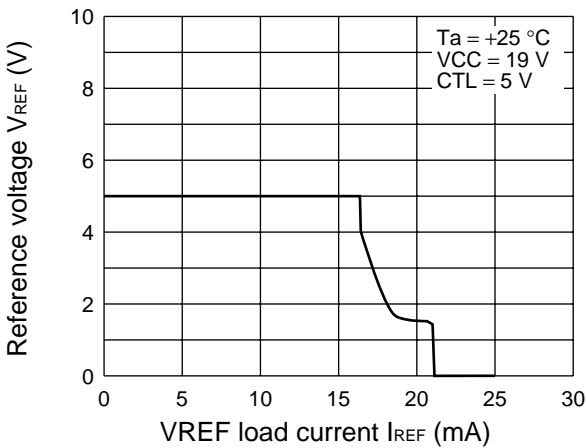
Power supply current vs. power supply voltage



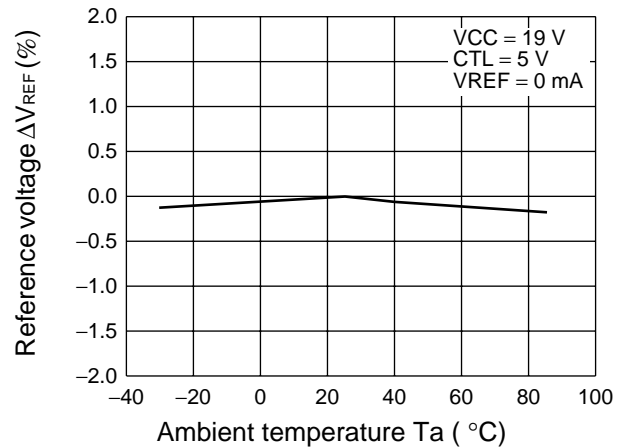
Reference voltage vs. power supply voltage



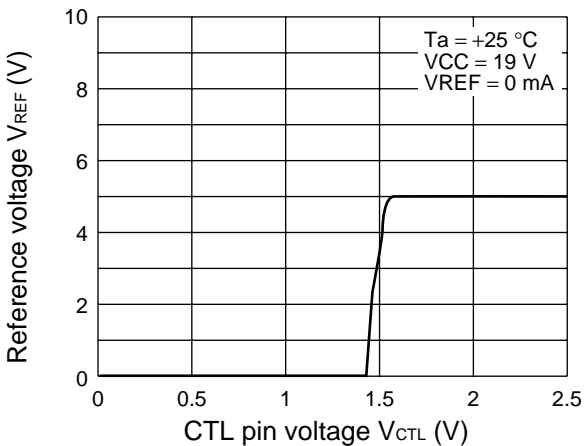
Reference voltage vs. V<sub>REF</sub> load current



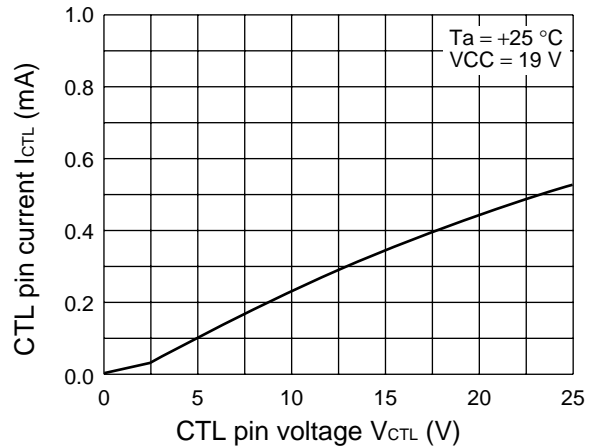
Reference voltage vs. ambient temperature



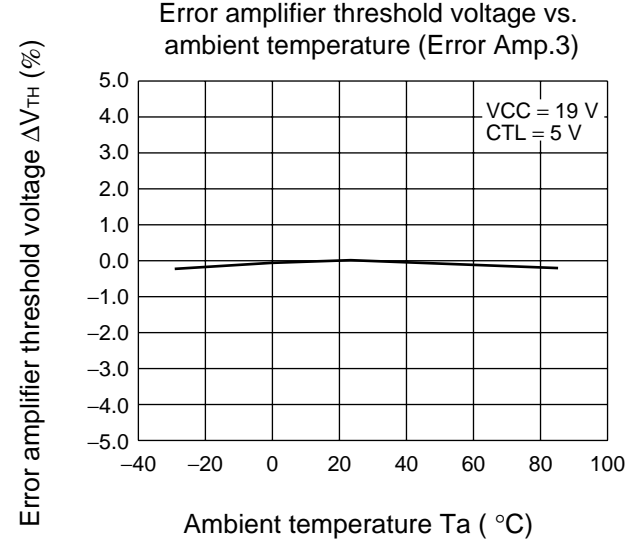
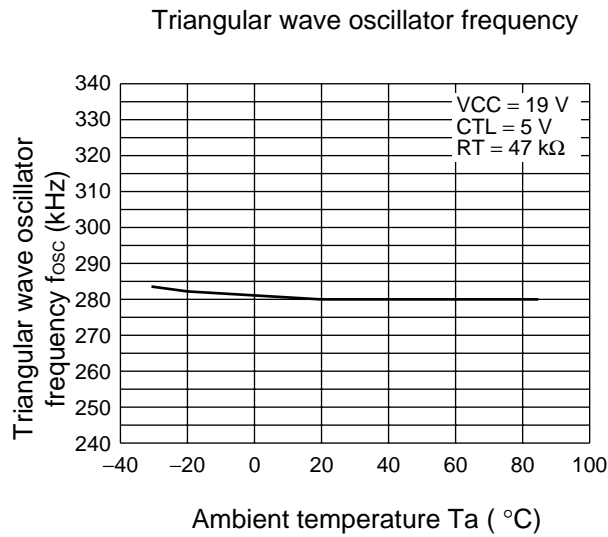
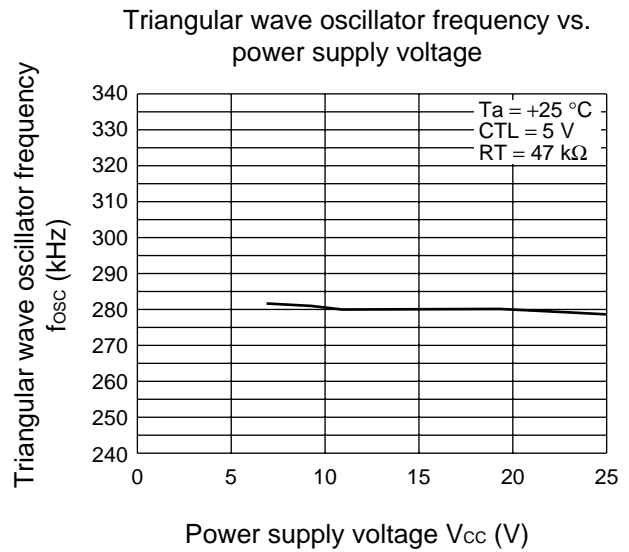
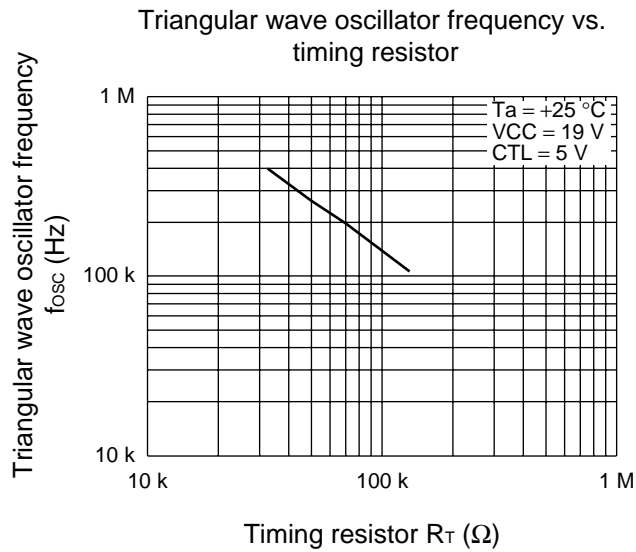
Reference voltage vs. CTL pin voltage



CTL pin current vs. CTL pin voltage



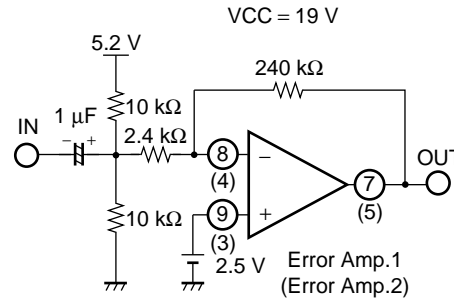
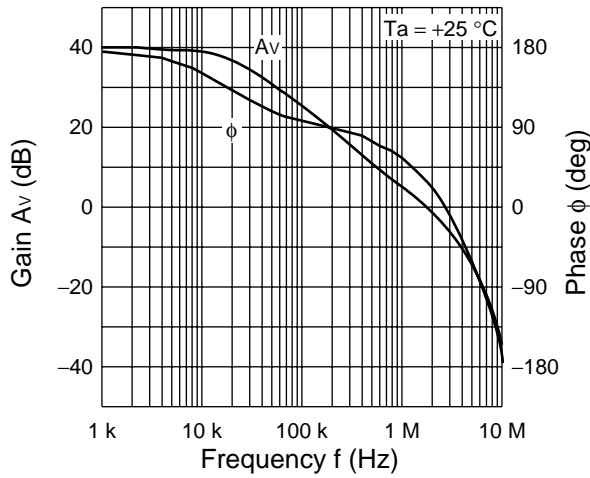
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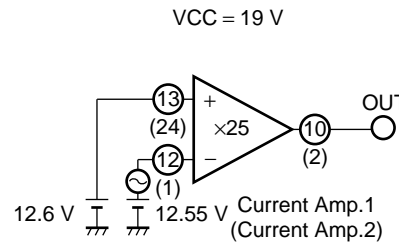
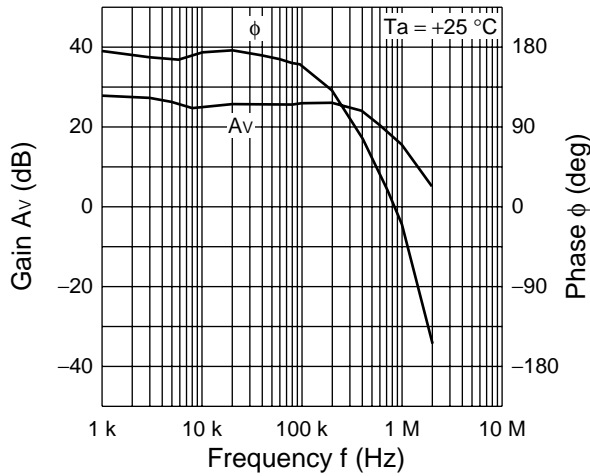
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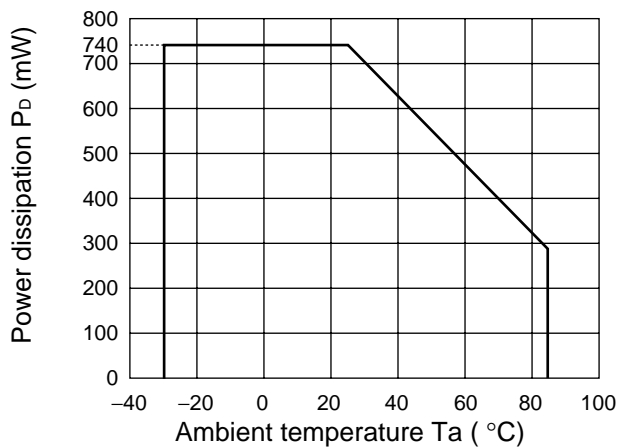
Error amplifier gain and phase vs. frequency



Current detection amplifier gain and phase vs. frequency



Power dissipation vs. ambient temperature



## ■ FUNCTIONAL DESCRIPTION

### 1. DC/DC Converter Unit

#### (1) Reference voltage block (Ref)

The reference voltage generator uses the voltage supplied from the VCC terminal (pin 18) to generate a temperature-compensated, stable voltage (5.0V Typ) used as the reference supply voltage for the IC's internal circuitry.

This pin can also be used to obtain a load current to a maximum of 1mA from the reference voltage VREF terminal (pin 6).

#### (2) Triangular wave oscillator block (OSC)

The triangular wave oscillator builds the capacitor for frequency setting into, and generates the triangular wave oscillator waveform by connecting the frequency setting resistor with the RT terminal (pin 17).

The triangular wave is input to the PWM comparator on the IC.

#### (3) Error amplifier block (Error Amp.1)

This amplifier detects the output signal from the current detector amplifier (Current amp .1), compares this to the +INE1 terminal (pin 9), and outputs a PWM control signal to be used in controlling the charging current.

In addition, an arbitrary loop gain can be set up by connecting a feedback resistor and capacitor between the FB1 terminal (pin 7) and -INE terminal (pin 8), providing stable phase compensation to the system.

#### (4) Error amplifier block (Error Amp.2)

This amplifier (Error Amp.2) detects voltage dependency of the AC adaptor and outputs a PWM control signal.

In addition, an arbitrary loop gain can be set by connecting a feedback resistor and capacitor from the FB2 terminal (pin 5) to the -INE2 terminal (pin 4) of the error amplifier, enabling stable phase compensation to the system.

#### (5) Error amplifier block (Error Amp.3)

This error amplifier (Error Amp. 3) detects the output voltage from the DC/DC converter and outputs the PWM control signal. External output voltage setting resistors can be connected to the error amplifier inverse input pin to set the desired level of output voltage from 1 cell to 4 cells.

In addition, an arbitrary loop gain can be set by connecting a feedback resistor and capacitor from the FB3 terminal (pin 15) to the -INE3 terminal (pin 16) of the error amplifier, enabling stable phase compensation to the system.

Connecting a soft-start capacitor to the CS terminal (pin 22) prevents surge currents when the IC is turned on. Using an error amplifier for soft-start detection makes the soft-start time constant, independent of the output load.

#### (6) Current detector amplifier block (Current Amp.1)

The current detection amplifier (Current Amp.1) detects a voltage drop which occurs between both ends of the output sense resistor ( $R_s$ ) due to the flow of the charge current, using the +INC1 terminal (pin 13) and -INC1 terminal (pin 12). Then it outputs the signal amplified by 25 times to the error amplifier (Error Amp.1) at the next stage.

## (7) PWM comparator block (PWM Comp.)

The PWM comparator circuit is a voltage-pulse width converter for controlling the output duty of the error amplifiers (Error Amp. 1 to Error Amp. 3) depending on their output voltage.

The PWM comparator circuit compares the triangular wave generated by the triangular wave oscillator to the error amplifier output voltage and turns on the external output transistor during the interval in which the triangular wave voltage is lower than the error amplifier output voltage.

## (8) Output block (OUT)

The output circuit uses a totem-pole configuration capable of driving an external P-channel MOS FET.

The output "L" level sets the output amplitude to 5 V (Typ) using the voltage generated by the bias voltage block (VH).

This results in increasing conversion efficiency and suppressing the withstand voltage of the connected external transistor in a wide range of input voltages.

## (9) Control block (CTL)

Setting the CTL terminal (pin 14) low places the IC in the standby mode. (The supply current is 10  $\mu$ A at maximum in the standby mode.)

## (10) Bias voltage block (VH)

The bias voltage circuit outputs  $V_{cc} - 5$  V (Typ) as the minimum potential of the output circuit. In the standby mode, this circuit outputs the potential equal to  $V_{cc}$ .

## 2. Protection Functions

### Under voltage lockout protection circuit (UVLO)

The transient state or a momentary decrease in supply voltage or internal reference voltage (VREF), which occurs when the power supply is turned on, may cause malfunctions in the control IC, resulting in breakdown or degradation of the system. To prevent such malfunction, the under voltage lockout protection circuit detects a supply voltage or internal reference voltage drop and fixes the OUT terminal (pin 20) to the "H" level. The system restores voltage supply when the supply voltage or internal reference voltage reaches the threshold voltage of the under voltage lockout protection circuit.

## 3. Soft-start Function

### Soft-start block (SOFT)

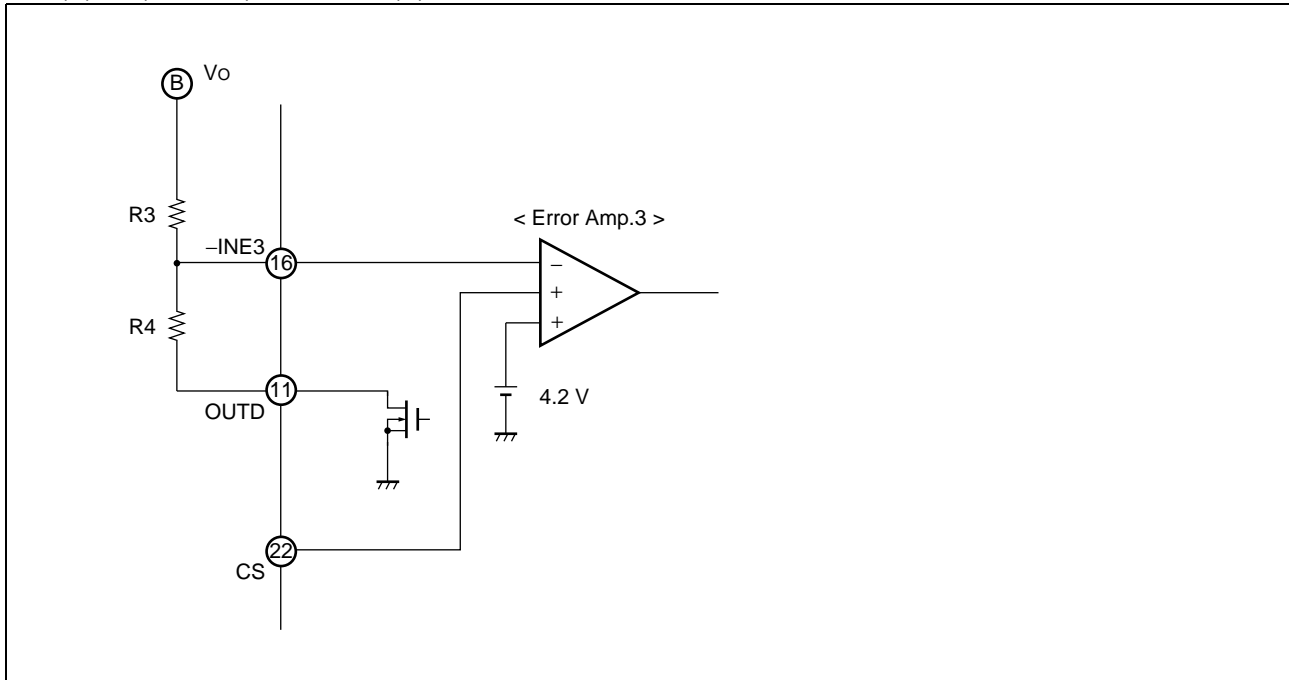
Connecting a capacitor to the CS terminal (pin 22) prevents surge currents when the IC is turned on. Using an error amplifier for soft-start detection makes the soft-start time constant, independent of the output load of the DC/DC converter.

## ■ SETTING THE CHARGING VOLTAGE

The charging voltage (DC/DC output voltage) can be set by connecting external voltage setting resistors (R3, R4) to the -INE3 terminal. Be sure to select a resistor value that allows you to ignore the on resistor (70 Ω, 1 mA) of the internal FET connected to the OUTD terminal (pin 11).

Battery charging voltage:  $V_o$

$$V_o (V) = (R3 + R4) / R4 \times 4.2 (V)$$



## ■ METHOD OF SETTING THE CHARGING CURRENT

The charge current (output control current) value can be set with the voltage at the +INE1 terminal (pin 9).

If a current exceeding the set value attempts to flow, the charge voltage drops according to the set current value.

Battery charge current setting voltage : +INE1

$$+INE1 (V) = 25 \times I1 (A) \times R_s (\Omega)$$

## ■ METHOD OF SETTING THE SOFT-START TIME

Upon activation, the IC starts charging the capacitor (Cs) connected to the CS terminal (pin 22).

The error amplifier causes soft-start operation to be performed with the output voltage in proportion to the CS terminal voltage regardless of the load current of the DC/DC converter.

Soft-start time:  $t_s$  (Time taken for the output voltage to reach 100 %)

$$t_s (s) \cong 4.2 \times C_s (\mu F)$$

## ■ METHOD OF SETTING THE TRIANGULAR WAVE OSCILLATOR FREQUENCY

The triangular wave oscillator frequency can be set by the timing resistor ( $R_T$ ) connected the RT terminal (pin 17).

Triangular wave oscillator frequency:  $f_{osc}$

$$f_{osc} (kHz) \cong 13630 / R_T (k\Omega)$$

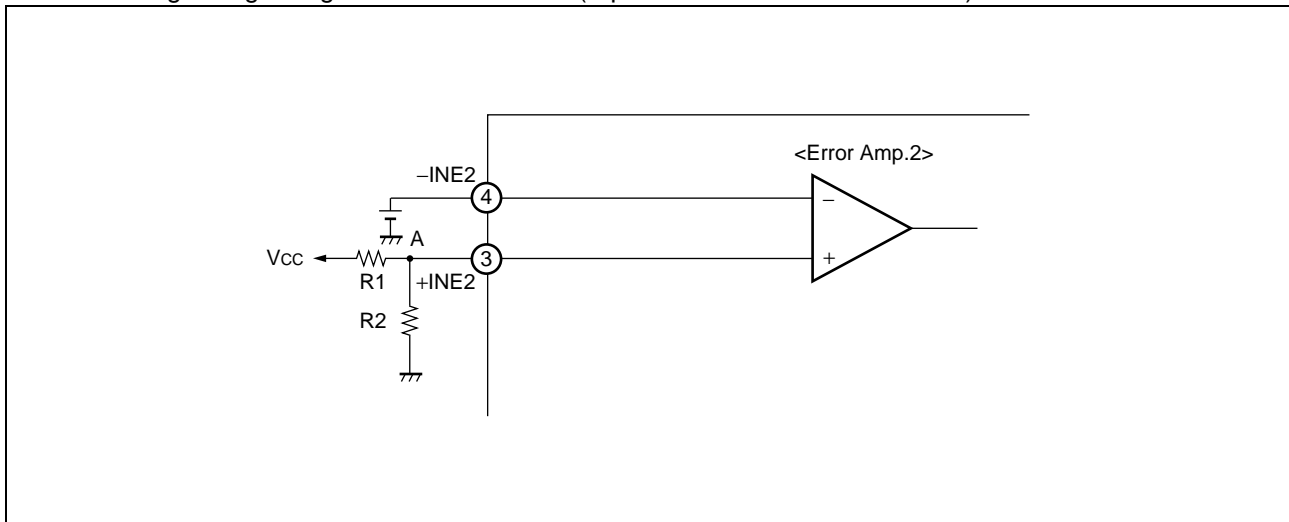
## ■ AC ADAPTOR VOLTAGE DETECTION

With an external resistor connected to the +INE2 terminal(pin 3), the IC enters the dynamically-controlled charging mode to reduce the charge current to keep AC adaptor power constant when the partial potential point A of the AC adaptor voltage (Vcc) becomes lower than the voltage at the -INE2 terminal.

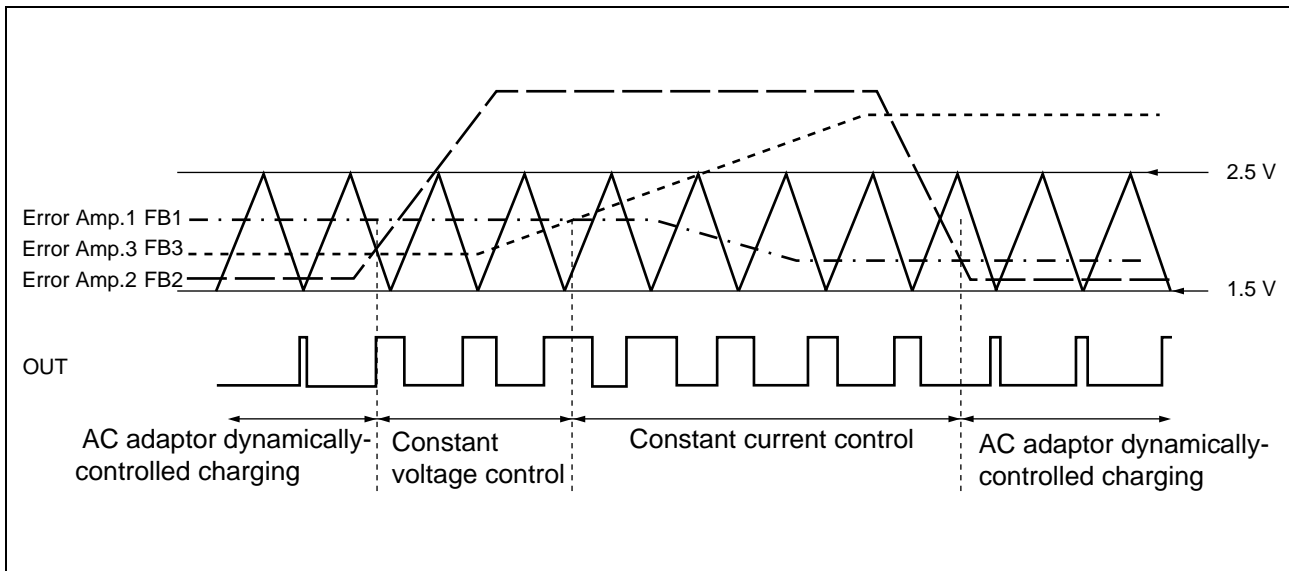
AC adaptor detected voltage setting: Vth

$$V_{th} (V) = (R1 + R2) / R2 \times -INE2$$

-INE2 setting voltage range : 1.176 V to 4.2 V (equivalent to 7 V to 25 V for Vcc)

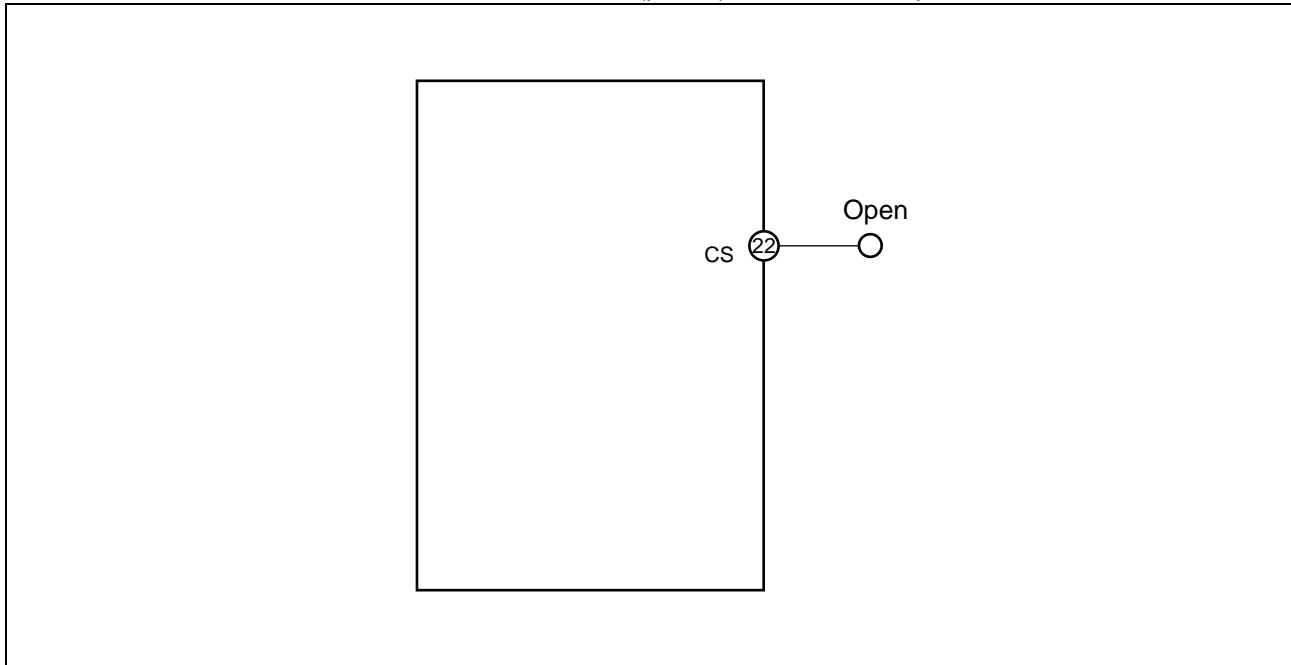


## ■ OPERATION TIMING DIAGRAM



## ■ PROCESSING WITHOUT USE OF THE CS PIN

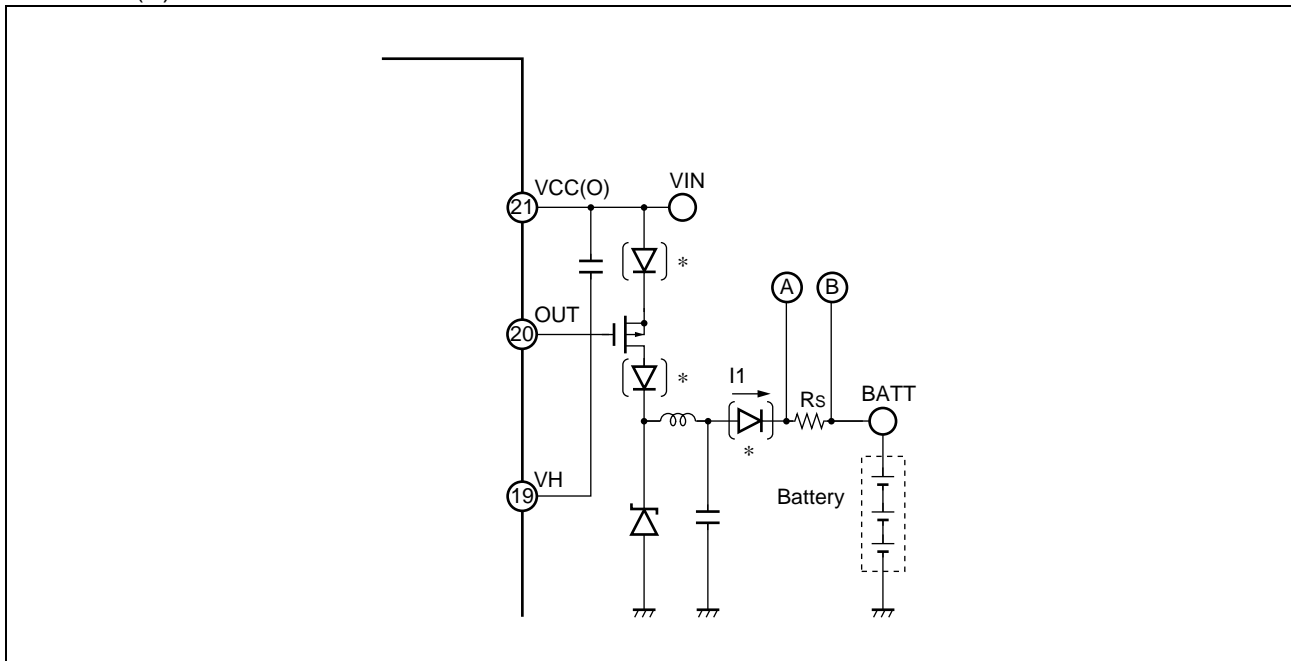
If the soft-start function is not used, the CS terminal (pin 22) should be left open.



When no soft-start time is specified.

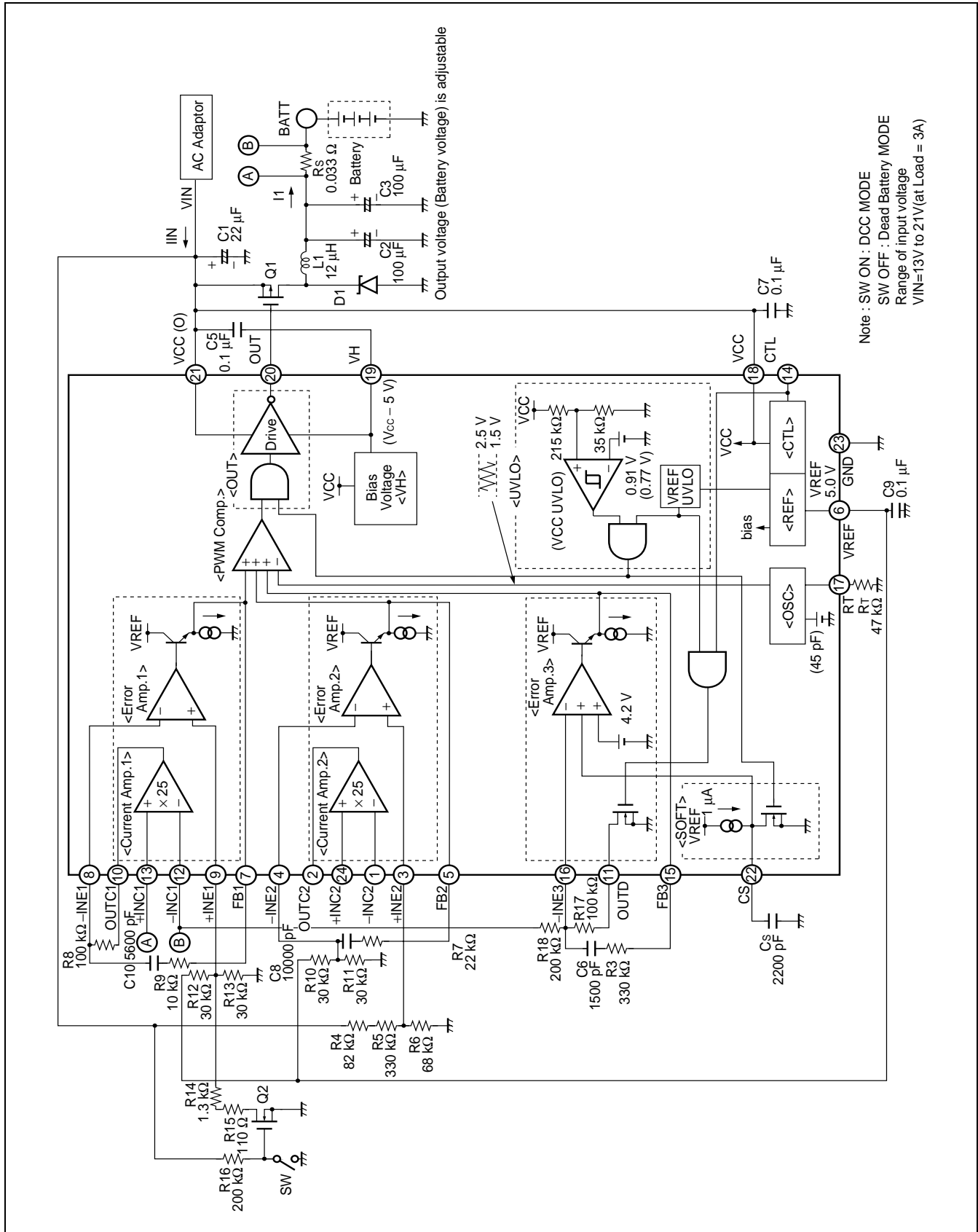
## ■ NOTE ON AN EXTERNAL REVERSE-CURRENT PREVENTIVE DIODE

- Insert a reverse-current preventive diode at one of the three locations marked \* to prevent reverse current from the battery.
- When selecting the reverse current prevention diode, be sure to consider the reverse voltage ( $V_R$ ) and reverse current ( $I_R$ ) of the diode.





## APPLICATION EXAMPLE 1



# MB3878

## ■ PARTS LIST (for APPLICATION EXAMPLE 1)

| COMPONENT   | ITEM   | SPECIFICATION  |   | VENDOR                                     | PARTS No.          |
|---|--|--|---|--|--------------------|
| Q1<br>Q2  | FET<br>FET   | Si4435DY<br>2N7002   |   | VISHAY<br>SILICONIX<br>VISHAY<br>SILICONIX | Si4435DY<br>2N7002 |
| D1  | Diode  | MBRS130LT3   |   | MOTOROLA                                   | MBRS130LT3         |
| L1  | Coil   | 12 $\mu$ H   | 4.0 A, 38 m $\Omega$  | SUMIDA                                     | CDRH124-12 $\mu$ H |
| C1<br>C2, C3<br>Cs<br>C5<br>C6<br>C7<br>C8<br>C9<br>C10   | OS Condenser<br>OS Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser | 22 $\mu$ F<br>100 $\mu$ F<br>2200 pF<br>0.1 $\mu$ F<br>1500 pF<br>0.1 $\mu$ F<br>10000 pF<br>0.1 $\mu$ F<br>5600 pF  | 25 V (10 %)<br>25 V (10 %)<br>10 %<br>16 V<br>10 %<br>25 V<br>10 %<br>16 V<br>10 %  | —  | —                  |
| Rs<br>Rr<br>R3<br>R4<br>R5<br>R6<br>R7<br>R8<br>R9<br>R10 to R13<br>R14<br>R15<br>R16<br>R17<br>R18 | Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor                 | 0.033 $\Omega$<br>47 k $\Omega$<br>330 k $\Omega$<br>82 k $\Omega$<br>330 k $\Omega$<br>68 k $\Omega$<br>22 k $\Omega$<br>100 k $\Omega$<br>10 k $\Omega$<br>30 k $\Omega$<br>1.3 k $\Omega$<br>110 $\Omega$<br>200 k $\Omega$<br>100 k $\Omega$<br>200 k $\Omega$ | 1.0 %<br>1.0 %<br>1.0 %<br>0.5 %<br>0.5 %<br>0.5 %<br>1.0 %<br>1.0 %<br>1.0 %<br>0.5 %<br>0.5 %<br>0.5 %<br>5 %<br>0.5 %<br>0.5 % | —  | —                  |

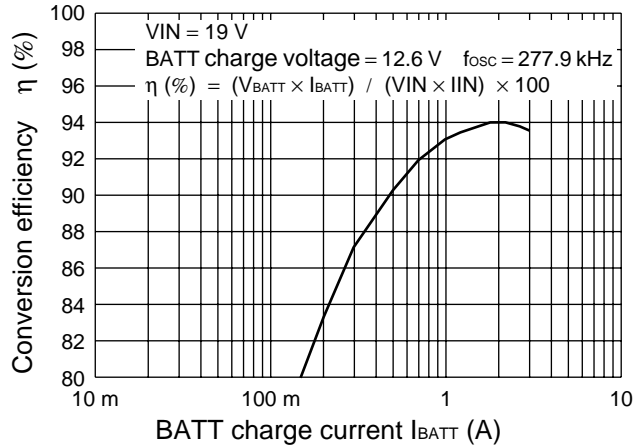
Note VISHAY SILICONIX : VISHAY Intertechnology, Inc.

MOTOROLA : Motorola Japan Ltd.

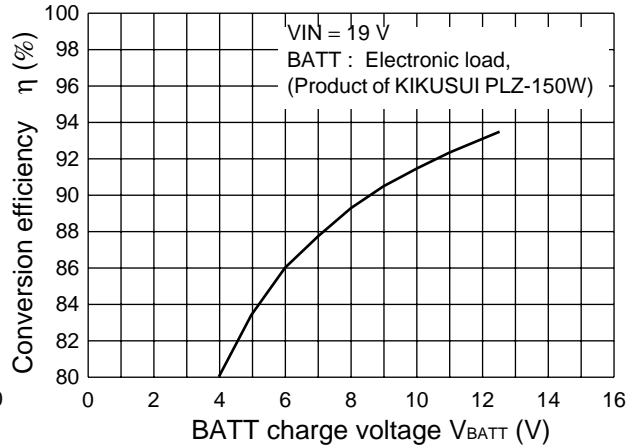
SUMIDA : SUMIDA ELECTRIC CO., Ltd.

## REFERENCE DATA

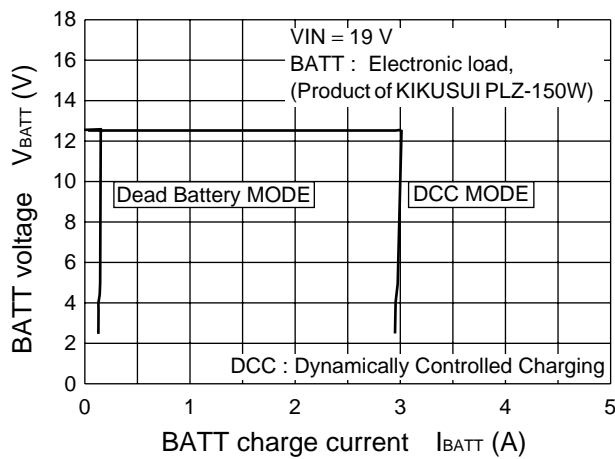
Conversion efficiency vs. charge current  
(Fixed voltage mode)



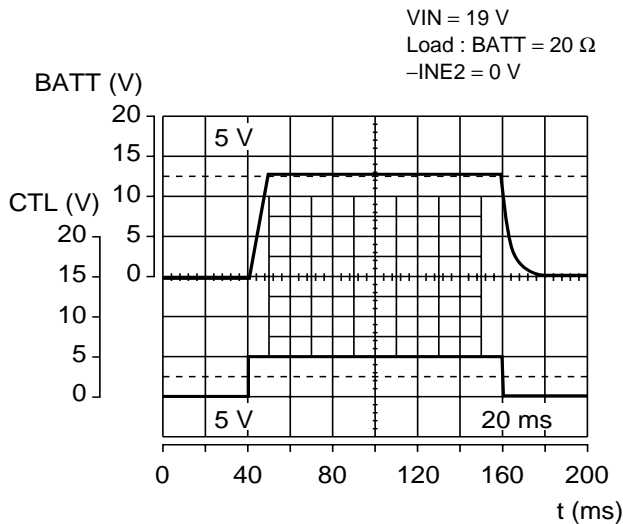
Conversion efficiency vs. charge voltage  
(Fixed current mode)



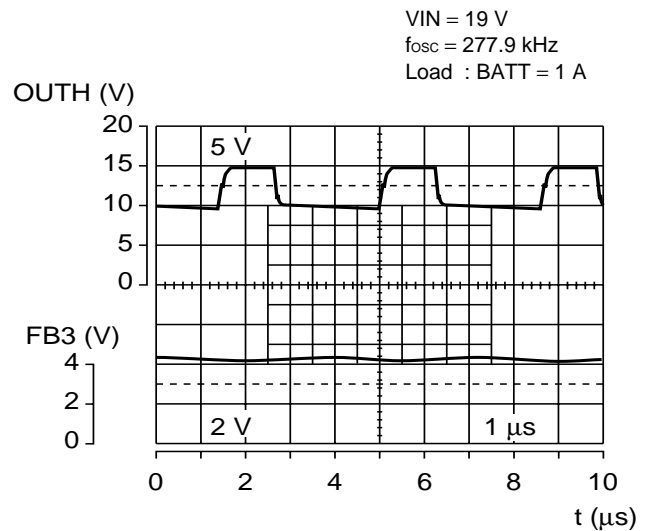
BATT voltage vs. BATT charge current



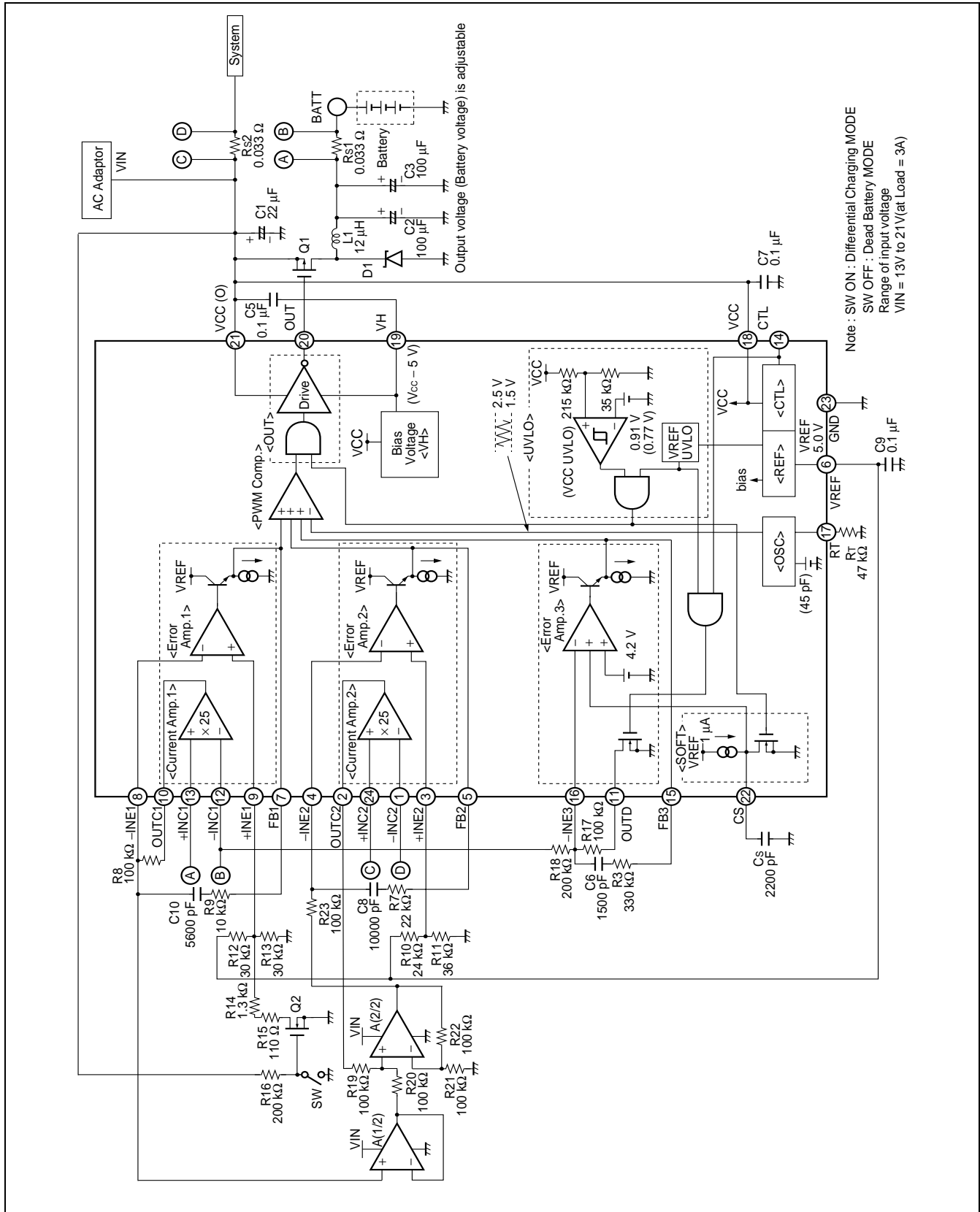
Soft-start operating waveforms



DC/DC converter switching waveforms



## APPLICATION EXAMPLE 2



## ■ PARTS LIST (for APPLICATION EXAMPLE 2)

| COMPONENT   | ITEM   | SPECIFICATION  |   | VENDOR                               | PARTS No.          |
|---|--|--|---|--------------------------------------|--------------------|
| Q1<br>Q2  | FET<br>FET   | Si4435DY<br>2N7002   |   | VISHAY SILICONIX<br>VISHAY SILICONIX | Si4435DY<br>2N7002 |
| D1  | Diode  | MBRS130LT3   |   | MOTOROLA                             | MBRS130LT3         |
| A   | Dual Op-amp  | MB47358  |   | Our Company                          | MB47358            |
| L1  | Coil   | 12 $\mu$ H   | 4.0 A,<br>38 m $\Omega$   | SUMIDA                               | CDRH124-12 $\mu$ H |
| C1<br>C2, C3<br>Cs<br>C5<br>C6<br>C7<br>C8<br>C9<br>C10   | OS Condenser<br>OS Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser<br>Ceramics Condenser   | 22 $\mu$ F<br>100 $\mu$ F<br>2200 pF<br>0.1 $\mu$ F<br>1500 pF<br>0.1 $\mu$ F<br>10000 pF<br>0.1 $\mu$ F<br>5600 pF  | 25 V (10 %)<br>25 V (10 %)<br>10 %<br>16 V<br>10 %<br>25 V<br>10 %<br>16 V<br>10 %  | —                                    | —                  |
| R <sub>S1</sub> , R <sub>S2</sub><br>R <sub>T</sub><br>R3<br>R7<br>R8<br>R9<br>R10<br>R11<br>R12, R13<br>R14<br>R15<br>R16<br>R17<br>R18<br>R19, R20<br>R21, R22<br>R23 | Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor<br>Resistor | 0.033 $\Omega$<br>47 k $\Omega$<br>330 k $\Omega$<br>22 k $\Omega$<br>100 k $\Omega$<br>10 k $\Omega$<br>36 k $\Omega$<br>27 k $\Omega$<br>30 k $\Omega$<br>1.3 k $\Omega$<br>110 $\Omega$<br>200 k $\Omega$<br>100 k $\Omega$<br>200 k $\Omega$<br>100 k $\Omega$<br>100 k $\Omega$<br>100 k $\Omega$ | 1.0 %<br>1.0 %<br>1.0 %<br>1.0 %<br>1.0 %<br>1.0 %<br>0.5 %<br>0.5 %<br>0.5 %<br>0.5 %<br>0.5 %<br>5 %<br>1.0 %<br>0.5 %<br>1.0 %<br>0.5 %<br>1.0 % | —                                    | —                  |

Note VISHAY SILICONIX : VISHAY Intertechnology, Inc.  
MOTOROLA : Motorola Japan Ltd.  
SUMIDA : SUMIDA ELECTRIC CO., Ltd.

# MB3878

## ■ USAGE PRECAUTIONS

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

• 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 k $\Omega$  to 1 M $\Omega$  between body and ground.

• Do not apply negative voltages.

The use of negative voltages below  $-0.3$  V may create parasitic transistors on LSI lines, which can cause abnormal operation

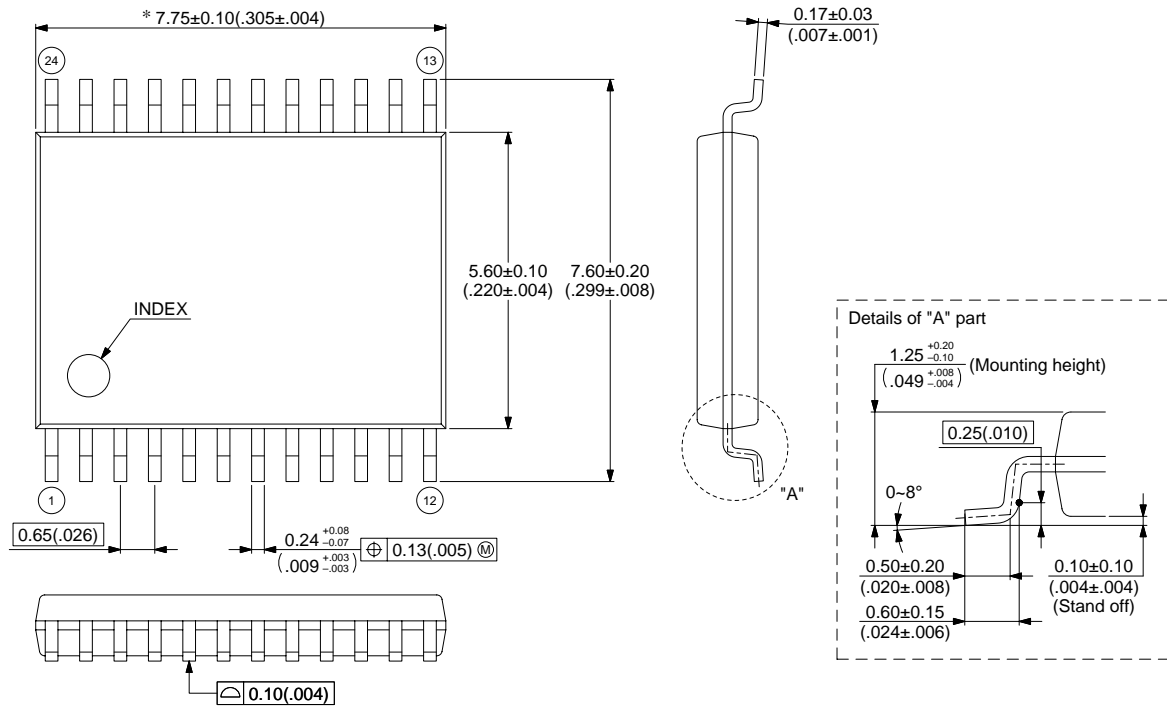
## ■ ORDERING INFORMATION

| Part number | Package                              | Remarks |
|-------------|--------------------------------------|---------|
| MB3878PFV   | 24-pin plastic SSOP<br>(FPT-24P-M03) |         |

## PACKAGE DIMENSION

24-pin plastic SSOP  
(FPT-24P-M03)

Note1: Pins width and pins thickness include plating thickness.  
Note2: \* This dimension does not include resin protrusion.



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Dimensions in mm (inches)

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