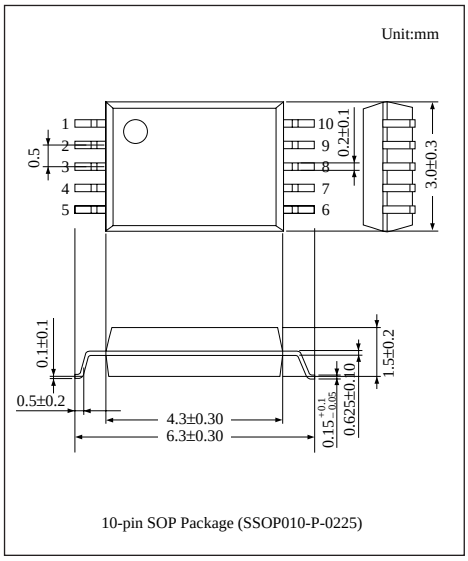
# AN8013SH

## 1-ch. Step-down/-up Supporting ICs for Control of DC-DC Converter




10-pin SOP Package (SSOP010-P-0225)

## ■ Overview

The AN8013SH is a 1-ch. IC for DC-DC converter using PWM method.

This IC can get the output voltage of any one type, step-up or inverting.

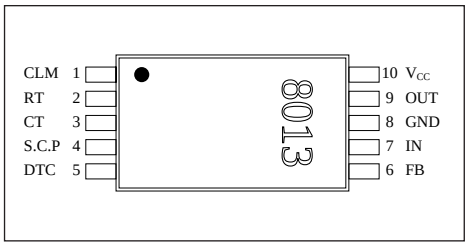
Also, its operating supply voltage range is wide and its consumption current is small. It incorporates overcurrent protective circuit, protecting the switching transistor from breakage or deterioration.

The package is 10-pin surface mounting type with 0.5mm pitch, and it is suitable for miniaturized highly efficient portable power supply.

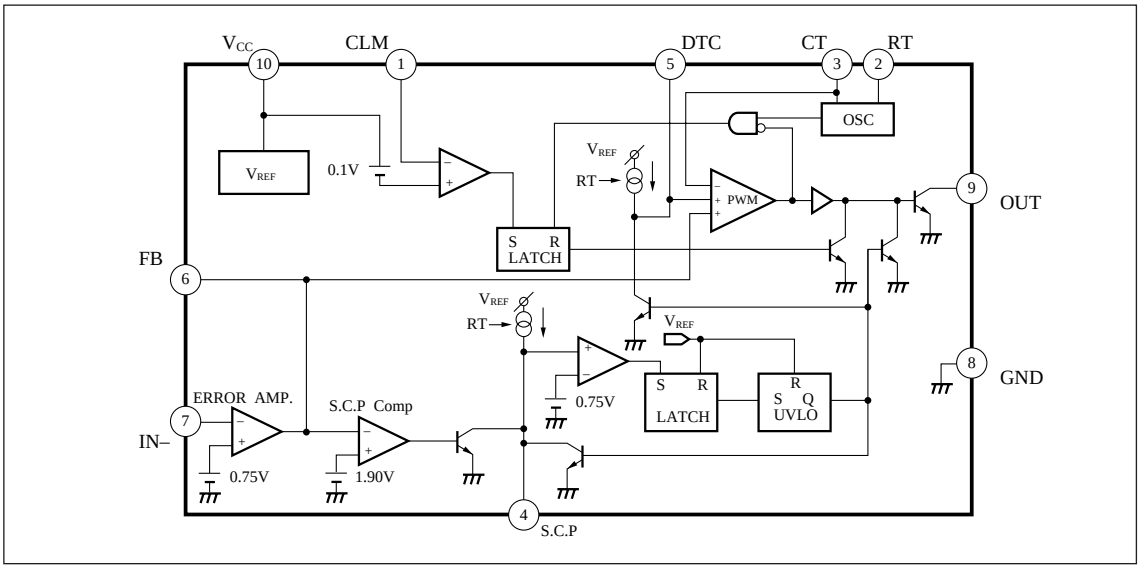
## ■ Features

- Wide operating supply voltage range (3.6 to 34V)
- Small consumption current (2.4mA typ)
- It can control converter in wide output frequency range (20k to 500kHz)
- Built-in pulse-by-pulse overcurrent protective circuit (detection voltage=$V_{CC}$–100mV)
- Built-in short-circuit protection circuit of timer latch type (Charging current:1.3µ A typ)
- Built-in circuit preventing malfunction under low input voltage
- Reference voltage circuit built-in (error amp. reference input:0.75V±4%)
- Output of open collector (Darlington)type
- High absolute maximum rating of output current(100mA)
- Small dispersion of duty ratio (55±5%)
- 10-pin SOP package of 0.5mm pitch

## ■ Pin Assignments




## ■ Block Diagram



## ■ Absolute Maximum Ratings (Ta=25˚C)

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Supply voltage | $V_{CC}$ | 35 | V |
| CLM terminal allowable applied voltage | $V_{CLM}$ | 35 | V |
| Error amplifier allowable input voltage | $V_{IN-}$ | – 0.3 to 2.5 | V |
| DTC terminal allowable input voltage | $V_{DTC}$ | 2.5 | V |
| OUT terminal allowable applied voltage | $V_{OUT}$ | 35 | V |
| Collector output current | $I_{OUT}$ | 100 | mA |
| Power dissipation (Ta=85˚C) | $P_D$ | 154 | mW |
| Operating ambient temperature | $T_{opr}$ | –30 to + 85 | ˚C |
| Storage temperature | $T_{stg}$ | –55 to + 150 | ˚C |

## ■ Recommended Operating Conditions (Ta=25˚C)

| Parameter | Symbol | min | max | Unit |
|---|---|---|---|---|
| Supply voltage (0 to 3.6V) rise time | tr ($V_{CC}$) | 10 | — | µs |
| Collector output voltage | $V_{OUT}$ | — | 34 | V |
| Collector output current | $I_{OUT}$ | — | 50 | mA |
| Timing capacitance | $C_T$ | 100 | 1800 | pF |
| Timing resistance | $R_T$ | 5.1 | 15 | kΩ |
| Oscillation frequency | $f_{OUT}$ | 20 | 500 | kHz |
| Time constant setting capacitance for short-circuit protection | $C_{SCP}$ | 1000 | — | pF |

## ■ Electrical Characteristics (Ta=25±2˚C)

| Parameter | Symbol | Condition | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| U.V.L.O Block | | | | | | |
| Circuit operation starting voltage | $V_{UON}$ | | 2.8 | 3.1 | 3.4 | V |
| Hysteresis width | $V_{HYS}$ | | 100 | 200 | 300 | mV |
| Error Amplifier Block | | | | | | |
| Input threshold voltage | $V_{TH}$ | Voltage Follower | 0.72 | 0.75 | 0.78 | mV |
| Input stability | $V_{dv}$ | Voltage Follower $V_{CC}$=3.6 to 34V | — | 2 | 8 | mV |
| Input bias current | $I_B$ | | –500 | –25 | — | nA |
| 'H' level output voltage | $V_{EH}$ | | 2.0 | — | — | V |
| 'L' level output voltage | $V_{EL}$ | | — | — | 0.3 | V |
| Input threshold voltage fluctuation with temperature 1 | Vdt1 | Voltage Follower Ta=–30 to 25˚C | — | ±1 | — | % |
| Input threshold voltage fluctuation with temperature 2 | Vdt2 | Voltage Follower Ta=25 to 85˚C | — | ±1 | — | % |
| Output sink current | $I_{SINK}$ | $V_{FB}$=0.9V | — | 8 | — | mA |
| Output source current | $I_{SOURCE}$ | $V_{FB}$=0.9V | — | –120 | — | µA |
| Open loop gain | $A_V$ | | — | 70 | — | dB |

Note) $V_{CC}$=12V, $R_T$=15kΩ, $C_T$=150pF, unless otherwise specified.

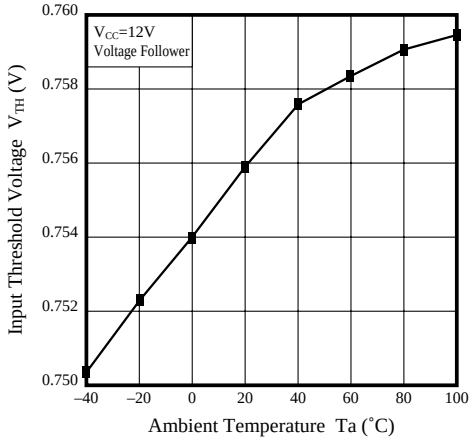
## ■ Electrical Characteristics (cont.) (Ta=25±2˚C)

| Parameter | Symbol | Condition | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| PWM Comparator Block | | | | | | |
| Input threshold voltage 'H' | $V_{DT-H}$ | Duty Ratio : 100% | 1.2 | — | — | V |
| Input threshold voltage 'L' | $V_{DT-H}$ | Duty Ratio : 0% | — | — | 0.6 | V |
| Input current | $I_{DTC}$ | | –12 | –11 | –10 | µA |
| Output Block | | | | | | |
| Output frequency | $f_{OUT}$ | $R_T$=15kΩ, $C_T$=150pF | 185 | 205 | 225 | kHz |
| Output duty ratio | $D_U$ | $R_{DTC}$=91kΩ | 50 | 55 | 60 | % |
| Output saturation voltage | $V_{OL}$ | $I_O$=50mA, $R_T$=15kΩ | — | 0.9 | 1.2 | V |
| Output leak current | $I_{LEAK}$ | $V_{CC}$=34V, when Output Tr is OFF | — | — | 10 | µA |
| RT terminal voltage | $V_{RT}$ | | — | 0.59 | — | V |
| Maximum oscillation frequency | $f_{OUT\,(MAX)}$ | $R_T$=5.1kΩ, $C_T$=120pF | — | 500 | — | kHz |
| Frequency fluctuation with supply voltage | $f_{dV}$ | $f_{OUT}$=200kHz $V_{CC}$=3.6 to 34V | — | ±1 | — | % |
| Frequency fluctuation with temperature 1 | $f_{dT1}$ | $f_{OUT}$=200kHz Ta=–30 to 25˚C | — | ±3 | — | % |
| Frequency fluctuation with temperature 2 | $f_{dT2}$ | $f_{OUT}$=200kHz Ta=25 to 85˚C | — | ±3 | — | % |
| Short-Circuit Protection Circuit Block | | | | | | |
| Input threshold voltage | $V_{THPC}$ | | 0.70 | 0.75 | 0.80 | V |
| Input stand-by voltage | $V_{STBY}$ | | — | — | 120 | mV |
| Input latch voltage | $V_{IN}$ | | — | — | 120 | mV |
| Charging current | $I_{CHG}$ | $V_{SCP}$ = 0V | –1.6 | –1.3 | –1.0 | µA |
| Comparator threshold voltage | $V_{THL}$ | | — | 1.90 | — | V |
| Overcurrent Protector Block | | | | | | |
| Input threshold voltage | $V_{CLM}$ | | $V_{CC}$–120 | $V_{CC}$–100 | $V_{CC}$–80 | mV |
| Delay time | $t_{DLY}$ | | — | 200 | — | ns |
| All Devices | | | | | | |
| Total consumption current 1 | $I_{CC1}$ | $R_T$=15kΩ | — | 2.4 | 3.5 | mA |
| Total consumption current 2 | $I_{CC2}$ | $R_T$=5.1kΩ, $C_T$=150pF | — | 3.4 | — | mA |

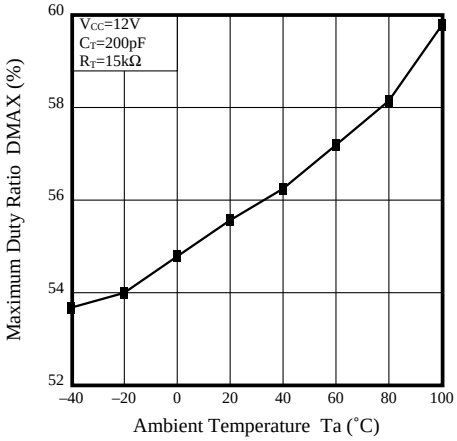
Note) $V_{CC}$=12V, $R_T$=15kΩ, $C_T$=150pF, unless otherwise specified.

## ■ Characteristic Curve

Error Amp. Input Threshold Voltage Temperature Characteristics

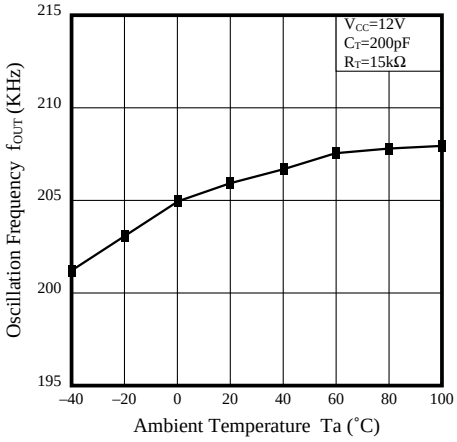



Maximum Duty Ratio Temperature Characteristics

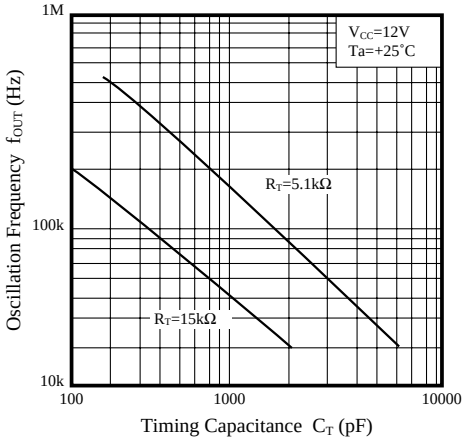


## ■ Characteristic Curve

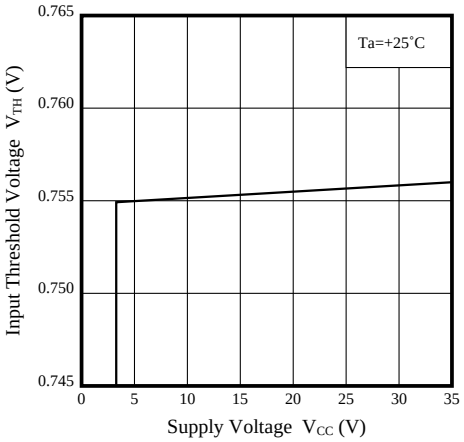
Oscillation Frequency Temperature Characteristics



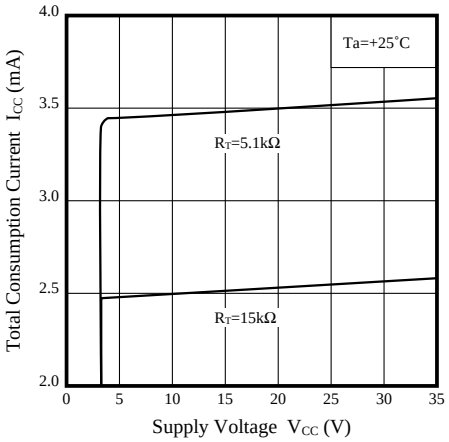

Timing Capacitance – Oscillation Frequency



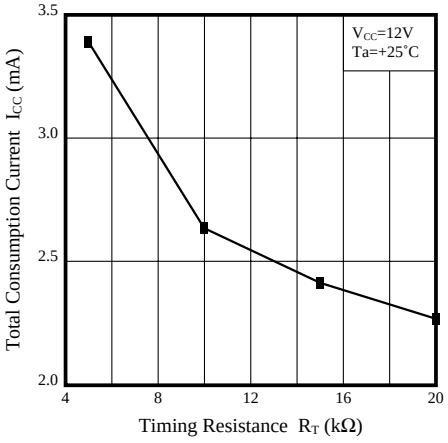

Input Threshold Voltage Input Fluctuation



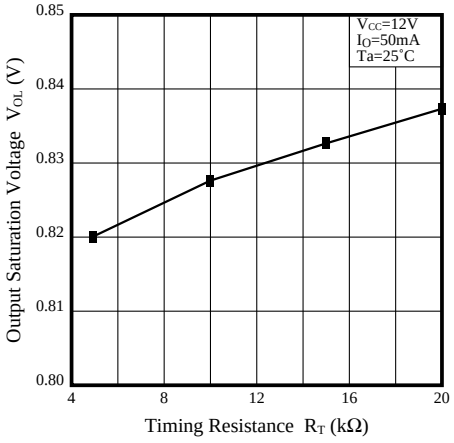

Total Consumption Current Input Fluctuation



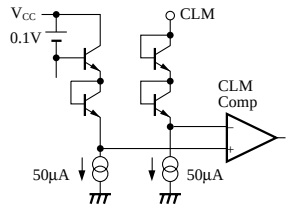
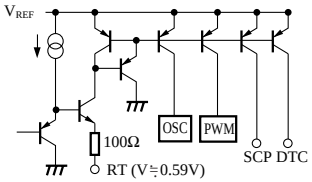
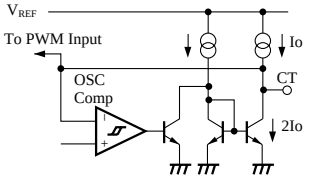
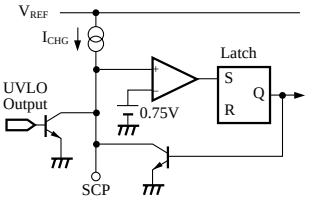
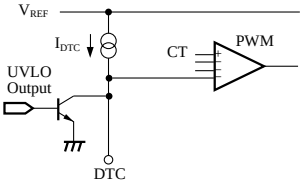

Timing Resistance – Total Consumption Current



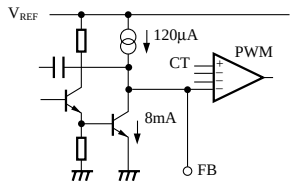
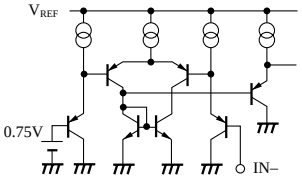
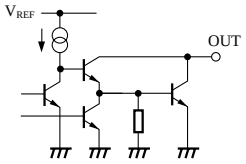

Timing Resistance – Output Saturation Voltage



## ■ Pin Descriptions

| Pin No. | Pin name | I/O | Description | Internal equivalent circuit |
|---|---|---|---|---|
| 1 | CLM | I | Terminal detecting the overcurrent condition of switching transistor.<br>Connect small resistance between this terminal and $V_{CC}$ terminal to detect the overcurrent. When its voltage decreases 100mV from $V_{CC}$, PWM output is turned off to narrow the ON width during its cycle (Overcurrent protection of pulse-by-pulse type). |  |
| 2 | RT | I | Connector terminal of timing resistance setting the frequency of oscillator.<br>Use the resistance value between 5.1k to 15kΩ.<br>Terminal Voltage is approx. 0.59V. |  |
| 3 | CT | O | Connector terminal of timing capacitance setting the frequency of oscillator.<br>Set the capacitance value between 100 to 1800pF.<br>For frequency setting, refer to the"Function Description" in attached sheets.<br>Use it with oscillation frequency falling in the range of 20 to 500 kHz. |  |
| 4 | S.C.P | O | Capacitive connector terminal for setting the time constant of short-circuit protection circuit of soft start and timer latch type.<br>The capacitance value should fall in the range over 1000pF.<br>The charging current $I_{CHG}$ depends on the timing resistance RT. Thus dispersion and temperature fluctuation can be suppressed. It is approx. –1.3µA, when $R_T$=15kΩ :<br>$I_{CHG} = \frac{V_{RT}}{RT} \times \frac{1}{30}$ [A] |  |
| 5 | DTC | I | Connector terminal of resistance and capacitance for setting the dead time and soft start period of PWM output.<br>Input current $I_{DTC}$ depends on the timing resistance $R_T$. Thus dispersion and temperature fluctuation can be suppressed. It is approx. –11µA, when $R_T$=15kΩ :<br>$I_{DTC} = \frac{V_{RT}}{R_T} \times \frac{1}{3.6}$ [A] |  |

■ Pin Descriptions (cont.)

| Pin No. | Pin name | I/O | Description | Internal equivalent circuit |
|---|---|---|---|---|
| 6 | FB | O | Output terminal of error amplifier.<br>Source current is approx. –120µA and sink current is approx. 8 mA.<br>Connect resistance and capacitance between this terminal and IN Terminal to compensate the frequency characteristics of gain and phase. |  |
| 7 | IN– | I | Reverse input terminal of error amplifier<br>For common-mode input, use the range between – 0.1 and 0.8V. |  |
| 8 | GND | — | Ground terminal |  |
| 9 | OUT | O | Output terminal of open collector type (Darlington).<br>The absolute maximum rating of output current is 100mA.<br>Set the constant output current to 50mA or less. |  |
| 10 | $V_{CC}$ | — | Supply voltage application terminal<br>The operating supply voltage should fall in the range from 3.6 to 34V. |  |

## ■ Timing Chart

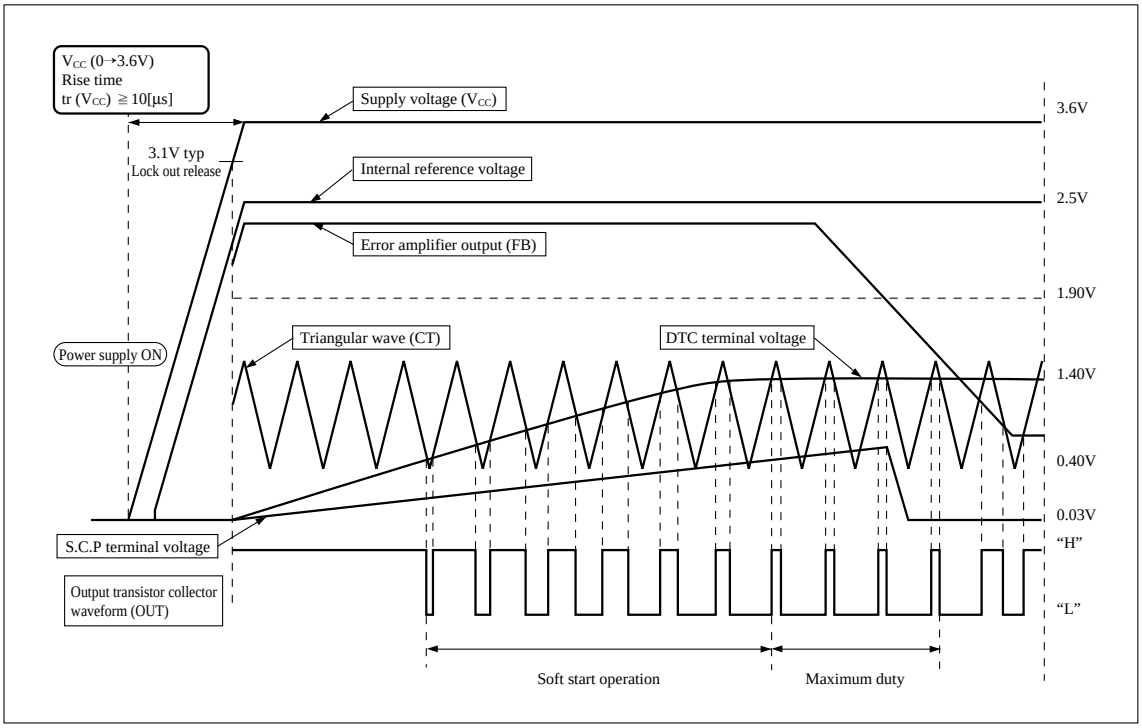



Fig.1 PWM Comparator Operation Waveform

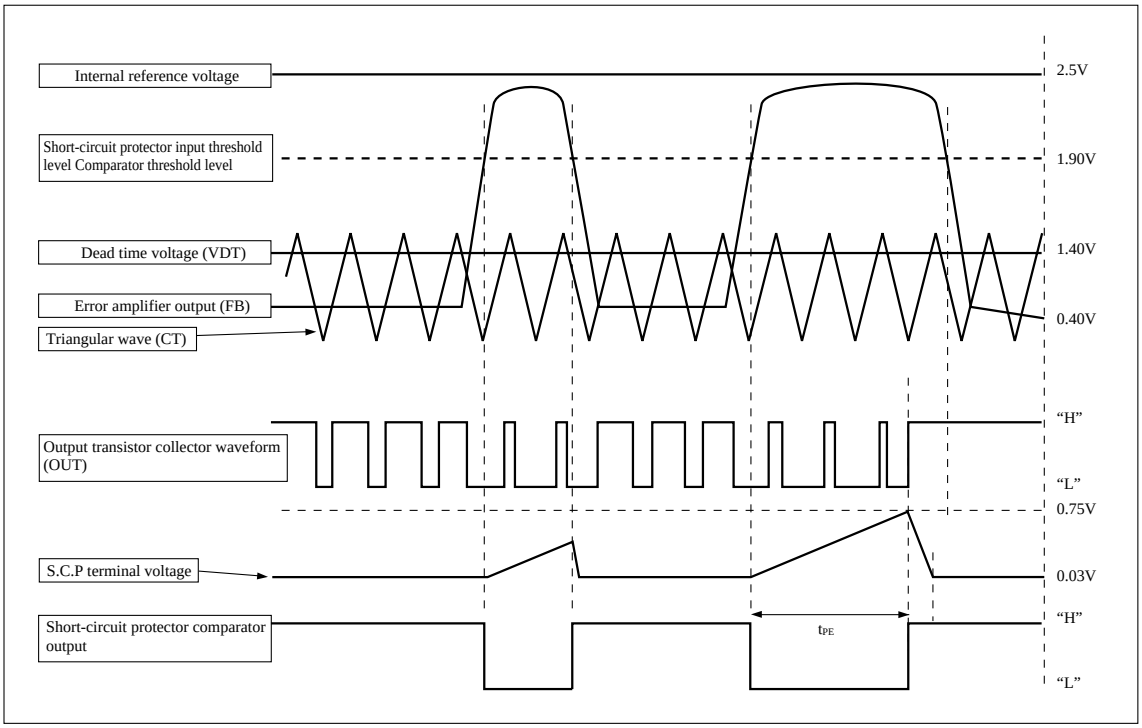



Fig.2 Short-circuit Protector Operation Waveform

## ■ Function Descriptions of Each Block

1) Reference voltage block

This block consists of band-gap circuits and outputs the reference voltage temperature-compensated to 2.5V. When the power supply voltage is 3.6V or more, the reference voltage is stabilized and used as the operation power supply inside IC.

2) Triangular oscillator block

The triangular wave with peak value of approx. 1.45V of and bottom value of approx. 0.35V is generated from this block, by connecting the resistor and capacitor for timing to CT terminal (Pin3) and RT terminal (Pin2) respectively. The oscillation frequency can be set to any desired value by the value of external CT, RT. The triangular wave is connected to the reverse input of PWM comparator inside IC.

3) Error amplifier block

This block inputs the signal which is amplified through detection of output voltage of DC-DC converter by the error amplifier of PNP transistor input, to the PWM comparator.

Non-reverse input is given 0.75V, which is resistance-divided from the internal reference voltage.

Any desired gain setting and phase compensation can be obtained, by connecting the feedback resistance and capacitance from the output terminal of error amplifier (Pin6) to the reverse input terminal (Pin7).

By connecting the resistive divider as shown in Fig.3, the output voltage $V_{OUT}$ is given in the following :

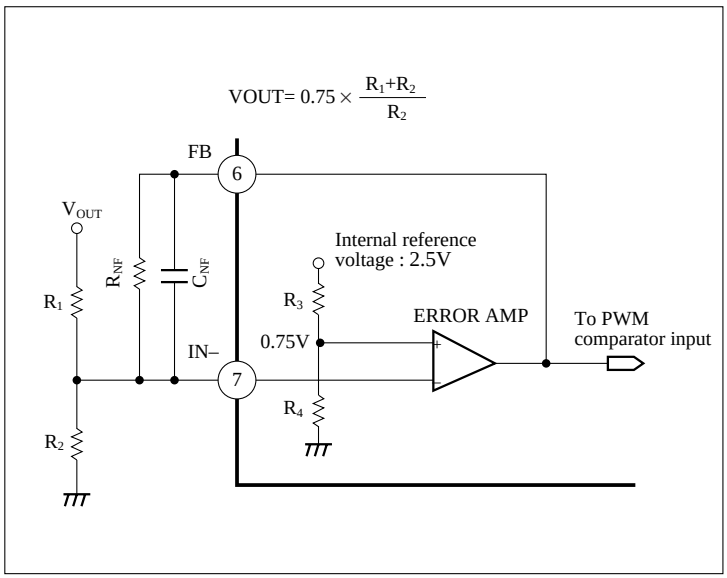



Fig.3 Connection of Error Amplifier

4) Short-circuit protection circuit of timer latch type

When short-circuit or overload of power supply output continues for a certain period, this short-circuit protection circuit of timer latch type protects the external main switch device, fly-wheel diode, and choke coil from breakage or deterioration.

It detects the output level of error amplifier. When the output voltage of DC-DC converter decreases and the output level of error amplifier becomes 1.90V or higher, it outputs “LOW” level, the timer circuit starts to operate and the external capacitor for enabling protection starts charging,

If the output of error amplifier can not return to the normal voltage range until the voltage of the above capacitor reaches 0.75V, it sets the latch circuit, shut off the output drive transistor and sets the dead time to 100%.

5) Circuit preventing malfunction under low input voltage

When the power supply voltage is low under transient condition at power on/off, this circuit protects the system from breakdown or deterioration due to malfunction of control.

This circuit preventing malfunction under low input voltage detects the internal reference voltage which varies with the power supply voltage level. Until the power supply voltage reaches 3.1V during rise time, it shuts off the output drive transistor, set the dead time to 100% and holds the S.C.P terminal (Pin4) at “LOW” . During fall time of the power supply voltage, it has hysteresis width of 200mV and operates at 2.9V or less.

6) PWM comparator block

The PWM comparator block controls the “ON” time of output pulse according to the input voltage. It turns on the output transistor during the period when the triangular wave of CT terminal (Pin3) is lower than each voltage of the error amplifier output (Pin6) and DTC terminal (Pin5).

Dead time setting is performed by adding the resistance between the DTC terminal and GND.

The soft start is activated, which gradually extends “ON” time according to the RC time constant at power on, by adding the capacitor in parallel with external resistance $R_{DTC}$.

7) Overcurrent protection block

The overcurrent of the power supply output is proportional to the value of current which flows in the main switch (bipolar transistor). By limiting the upper limit of the current flowing in the main switch, it prevents the breakage of the main switch device, flywheel diode and choke coil, which are easy to be damaged due to overcurrent.

It detects the current, through monitoring the voltage decrease at the CLM terminal (Pin1) due to low resistance, which is connected between the main switch device and $V_{CC}$ terminal. When the main switch device (bipolar transistor) turns on and the voltage of CLM terminal reaches $V_{CC}$–100mV, the threshold for the overcurrent detection, it shuts off the output drive transistor so that the current can not further flow in the main switch device. This control is repeated for each cycle. Once the overcurrent is detected, shut-off is continued during that cycle and it is not turned on until the next cycle starts. The overcurrent detection described in the above is called “pulse-by-pulse overcurrent detection.”

8) Output block

The output drive transistor uses the output of open-collector type, which is Darlington-connected, for emitter-common GND. The collector output terminal (Pin5), which has withstand voltage of 34V, allows up to the output current of 100mA to be taken out.

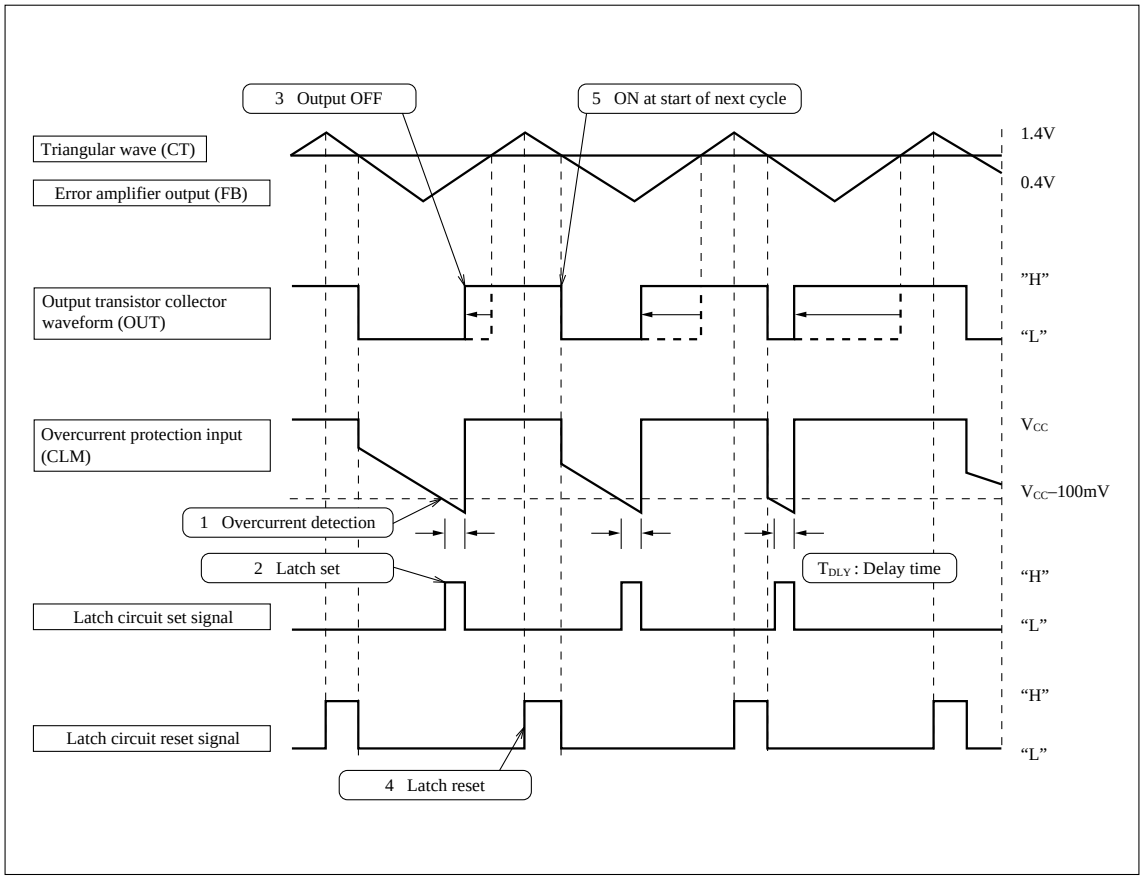



Fig.4 Pulse-by-pulse Overcurrent Protector Operation Waveform

## ■ Triangular Oscillation Circuit

### 1) Setting the oscillation frequency

The triangular oscillation waveform is obtained through the process, in which the external timing capacitor $C_T$ connected to CT terminal (Pin3) charges and discharges the constant current $I_O$. The constant current is set by the external timing resistor $R_T$.

The peak value of the triangular wave, $V_{CTH}$ is fixed to approx. 1.45V, and its bottom value, $V_{CTL}$ to approx. 0.35V.

The oscillation frequency $f_{OSC}$ is obtained as follows :

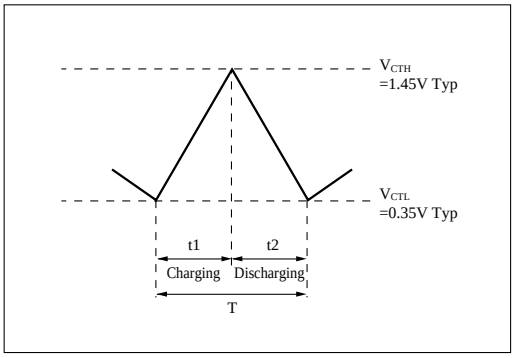



Fig.5 Triangular Wave Oscillation Waveform

$$f_{OSC} = \frac{1}{t1 + t2} = \frac{I_O}{2 \times C_T \times (V_{CTH} - V_{CHL})}$$

$$\text{Howerer, } I_O = 1.8 \times \frac{V_{RT}}{R_T} = 1.8 \times \frac{0.59}{R_T}$$

and $V_{CTH} - V_{CTL} = 1.1V$

$$\text{Therefore } f_{OSC} \fallingdotseq \frac{1}{2.07 \times C_T \times R_T} \text{ [Hz]}$$

The output frequency $f_{OUT}$ is the same as $f_{OSC}$, owing to the PWM control.

### 2) Precautions on use

The AN8013SH uses the constant current given by the timing resistance $R_T$ as the bias current of the triangular oscillation block and PWM comparator, so that only low consumption current is required. The total consumption current is approx. 2.4mA (typ.) when $R_T$ is 15kΩ, and increases to approx. 3.4mA (typ.) when $R_T$ becomes 5.1kΩ. In order to get the constant output current of open collector output, 100mA, $R_T$ should be set under 15kΩ.

The recommended operation range of the oscillation frequency is from 20 to 50kHz.

For the high frequency, the overshoot amount and undershoot amount increase due to operation delay of the triangular oscillation comparator, and the actually measured value may deviate from the above calculated value. Refer to the timing capacitance versus oscillation frequency in Fig.10.

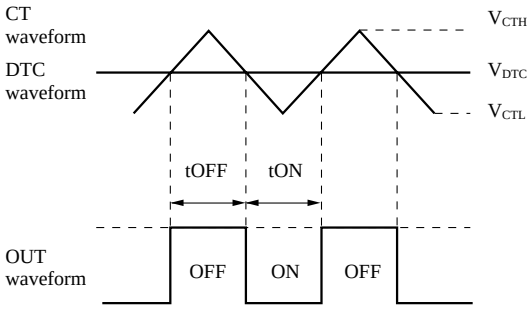
The AN8013SH can not be used as an IC for slave, when the several ICs operate in parallel synchronously.

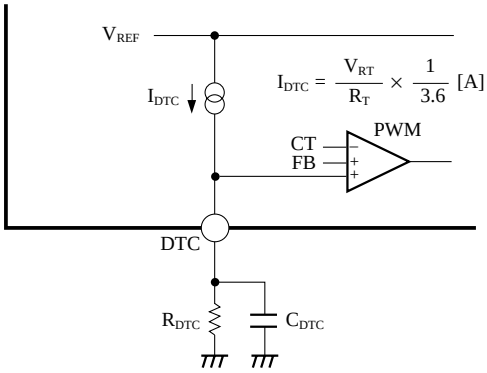
## ■ Dead Time (Max. Duty) Setting

The dead time is set by regulating the voltage of DTC terminal (Pin5), $V_{DTC}$, as shown in Fig.6. Since the DTC terminal uses the output of constant current given by resistance RT, $V_{DTC}$ is regulated by adding external resistor $R_{DTC}$.

The output duty ratio DU, and the voltage of DTC terminal, $V_{DTC}$ are given in the following figure. Under the condition where the oscillation frequency $f_{OSC}$ is 200kHz, when $V_{DTC}$ is 0.45V, the output duty ratio is 0%, and when $V_{DTC}$ is 1.45V, the output duty ratio is 100%.

However, for the peak value and bottom one of the triangular wave, the overshoot amount and undershoot one vary according to the oscillation frequency.




$$Du = \frac{t_{ON}}{t_{ON}+t_{OFF}} \times 100 \ [\%]$$

$$= \frac{V_{CTH}-V_{DTC}}{V_{CTH}-V_{CTL}} \times 100 \ [\%]$$

$$V_{DTC} = I_{DTC} \times R_{DTC}$$

$$= V_{RT} \times \frac{R_{DTC}}{R_T} \times \frac{1}{3.6} \ [V]$$

Example) When $f_{OSC}$=200kHz (RT=15kΩ. CT=150pF)

$V_{CTH} \fallingdotseq 1.45V$ (typ.) $V_{RT} \fallingdotseq 0.59V$ (typ.)

$V_{CTL} \fallingdotseq 0.35V$ (typ.) $I_{DTC} \fallingdotseq 11\mu A$ (typ.)

Fig.6 Dead Time Setting

When capacitor CDTC is additionally connected with the external resistance RDTC in parallel, the soft start works, which gradually broadens “ON” width of the output pulse, when the power supply starts. Such operation can prevent the overshoot of the DC-DC converter output.

## ■ Setting Time Constant for Short-circuit Protective Circuit of Timer Latch Type

The construction of protection latch circuit is shown in Fig.7. The comparator for short-circuit protection always compares the reference voltage of 1.90V and the output of error amplifier $V_{FB}$.

Under the stable load condition of DC-DC comparator output, since the output of error amplifier does not fluctuate, the short-circuit protective comparator keeps the balance. In such a condition, the output transistor Q1 remains in the conductive condition and the S.C.P terminal is held to approx. 30mV.

However, when the load condition changes dramatically and the “H” level signal (1.90V or more) is inputted from the error amplifier to the non-reverse input of short-circuit protective comparator, the short-circuit protective comparator outputs “L” level signal. And by shutting off the output transistor Q1, the voltage of S.C.P terminal, $V_{PE}$ is released and the external capacitor $C_S$ starts charging according to the expression shown below. Then, the external capacitor $C_S$, which is charged up to approx. 0.75V, sets the latch circuit. Moreover, by enabling the malfunction prevention circuit which acts under low input, it shuts off the output drive transistor and sets the dead time to 100%.

$$V_{PE} = V_{STBY} + I_{CHG} \times \frac{t_{PE}}{C_S} \text{ [V]}$$

$$0.75V = 0.03V + I_{CHG} \times \frac{t_{PE}}{C_S}$$

$$C_S = I_{CHG} \times \frac{t_{PE}}{0.72} \text{ [F]}$$

$I_{CHG}$, constant current, which depends on the oscillator timing resistance $R_T$, has small dispersion and temperature fluctuation as given in the following :

$$I_{CHG} = \frac{V_{RT}}{R_T} \times \frac{1}{30} \text{ [A]}$$

In addition, $V_{RT}$ is approx. 0.5V. When $R_T$=15kΩ, $I_{CHG}$ becomes approx. 1.1μA.

Once the malfunction prevention circuit which acts under low input is enabled, the voltage of SCP terminal is discharged to approx. 30mV, however, the latch circuit is not reset unless the power supply turns off.

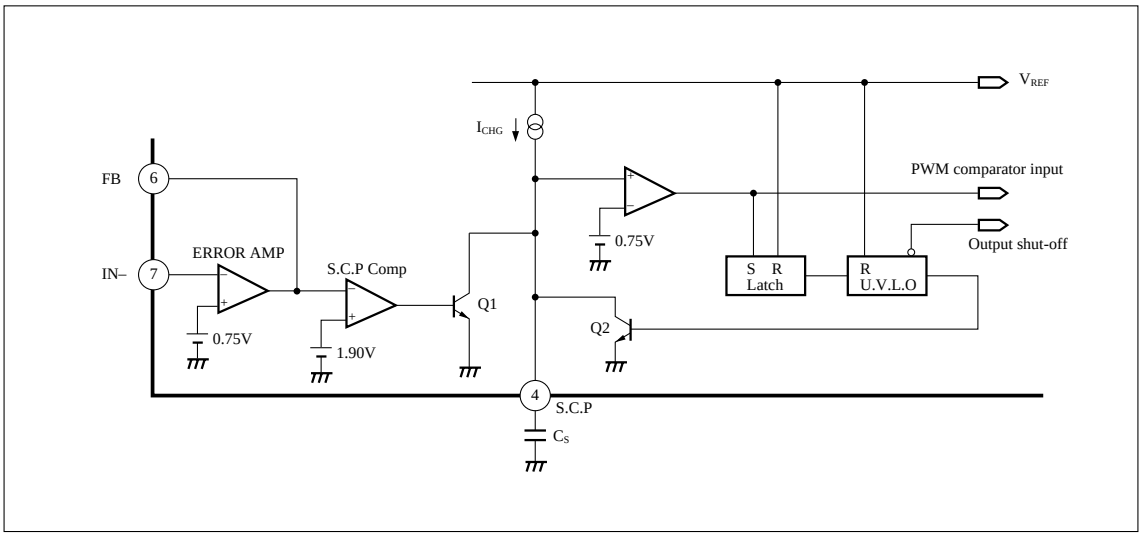
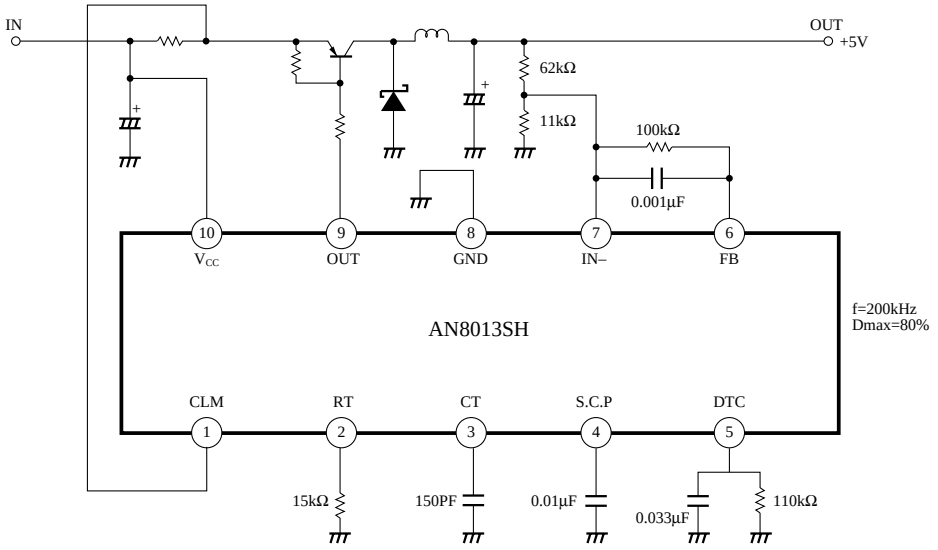



Fig.7 Short-circuit Protective Circuit

At start of the power supply, when the output short-circuit condition is presumed, the output of the error amplifier becomes “H” level, and the voltage of SCP terminal $V_{PE}$ is released to start charging. The external capacitor should be set so that the output voltage of DC-DC converter can be activated before setting the latch circuit in the poststage. Especially for soft start, particular care should be taken because the start time is extended.

## ■ Application Circuit

(Voltage decrease)




(Voltage increase)

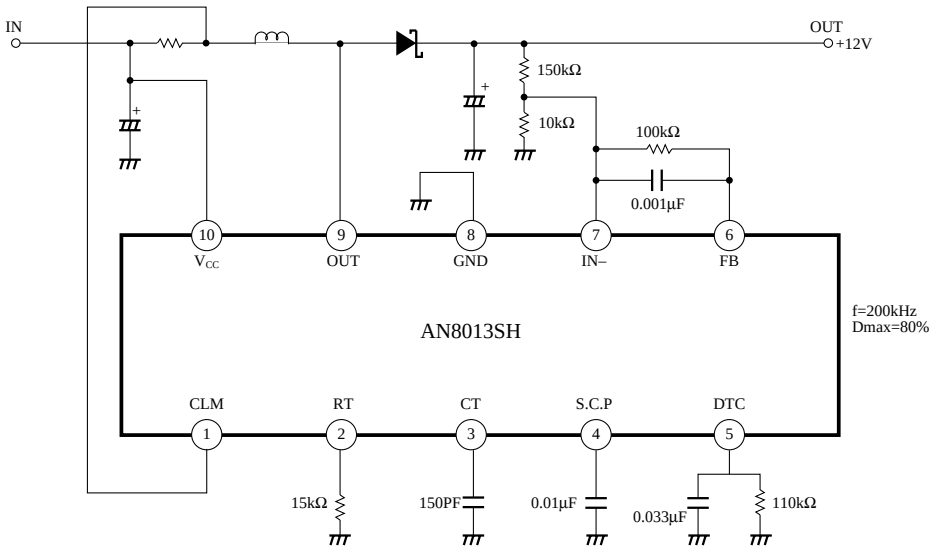
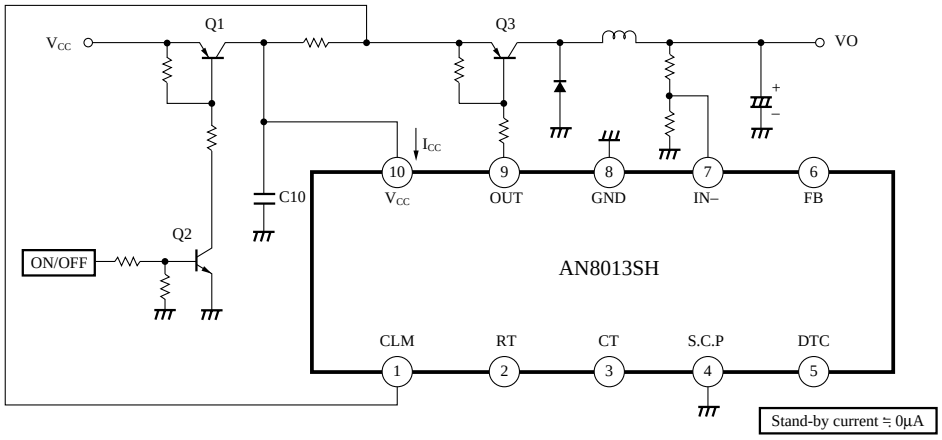
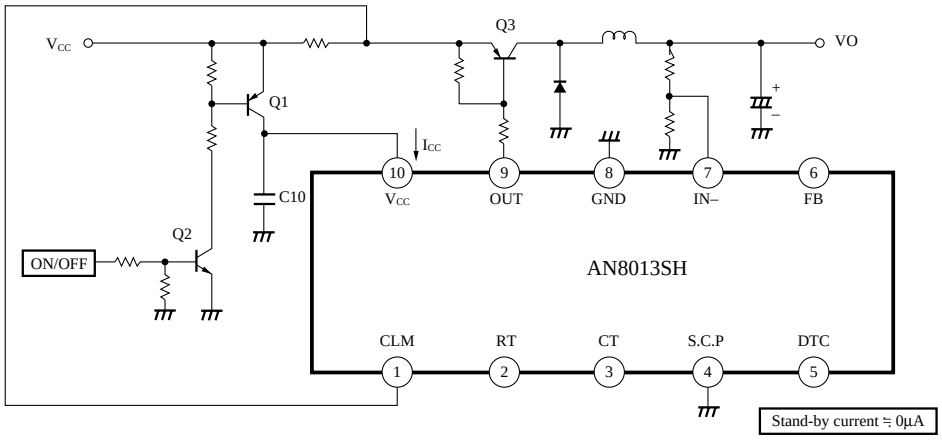



Fig.8 Application Circuit

## ■ ON/OFF Circuit




a) The power supply line cut




b) The $V_{CC}$ line of IC cut

Fig.9 ON/OFF circuit

### 1) Application

Since the AN8013SH does not incorporate the ON/OFF circuit, external parts should be added to give it the stand-by function.

When the switch (Q1) is inserted in the power supply line, the stand-by current is suppressed to 0. In this case, the transistor equivalent to the main switch device (Q3) is required.

When the switch (Q1) is inserted between the power supply line and $V_{CC}$ terminal (Pin10) of the IC as shown in Fig.9b), the switch device (Q1) can be miniaturized, however, the dispersion of Q1 saturation voltage may result in dispersion of threshold of overcurrent protection.

### 2) Precautions on use

When the ON/OFF circuit is added outside, $V_{CC}$ rise time becomes very short. In this case, the latch circuit inside the IC is set, which may cause the start failure. Use C10 for setting so that the rise time of $V_{CC}$ terminal (Pin10) can not be less than 10µs.