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# HA16666P/FP

600kHz PWM Controlled Switching Regulator

# HITACHI

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## Description

The HA16666P/FP is a voltage mode PWM (pulse width modulation) control IC for switching regulator control. It can drive a power MOS FET efficiently on 600 kHz. Its standby current is 0.3 mA (max), and it is used as the primary control power supply.

## Functions

- +5 V reference voltage circuit
- Triangular waveform oscillator
- PWM comparator
- Output circuit (Totem pole output)
- Overcurrent protection circuit (with one-pulse latch mode)
- Undervoltage lockout protection circuit
- Soft start and quick shutdown function
- Remote control function
- Comparator with internal 1.3 V reference voltage

## Features

- High-speed switching;  
tr = 80 ns (15 V amplitude)  
tf = 40 ns (15 V amplitude)
- Low power dissipation;  
0.3 mA max in standby state  
12 mA max in operation state ( $V_{IN} = 15$  V)
- Dual-slope highly accurate dead-band duty setup circuit; Setup accuracy  $D_u = \pm 3\%$  (max)
- Wide output pulse width control range; 0 to 75%

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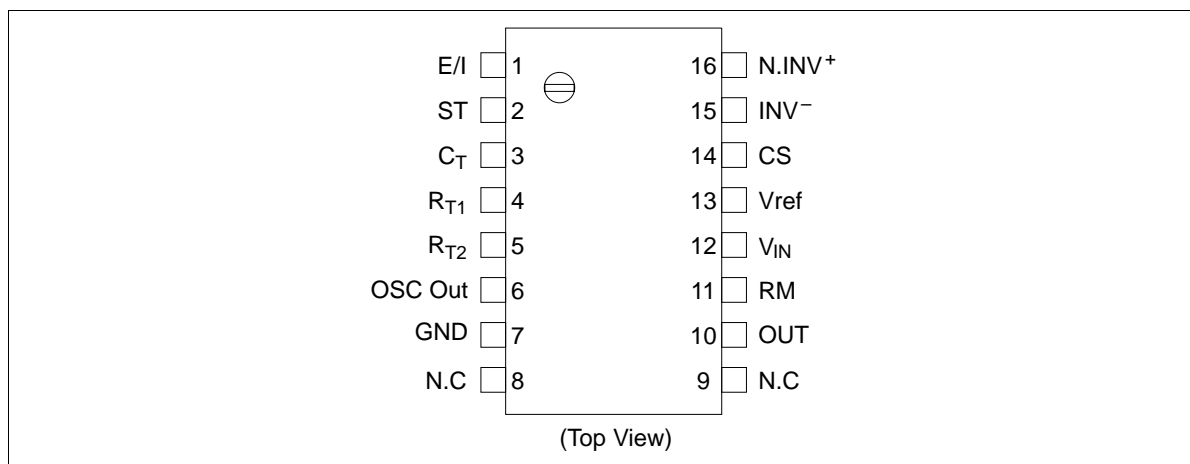
- Undervoltage lockout protection;  
     $V_{IN}$  high threshold voltage 10 V typ  
     $V_{IN}$  low threshold voltage 8 V typ
- Two input threshold voltage for overcurrent protection comparator;  
    fixed voltage (1.3 V)  
    variable voltage
- Double pulse output protection by overcurrent protection circuit with one-pulse latch mode
- Wide input supply voltage range;  $V_{CC} = 11$  to 40 V

## Ordering Information

| Type      | Package |
|-----------|---------|
| HA16666P  | DP-16   |
| HA16666FP | FP-16DA |

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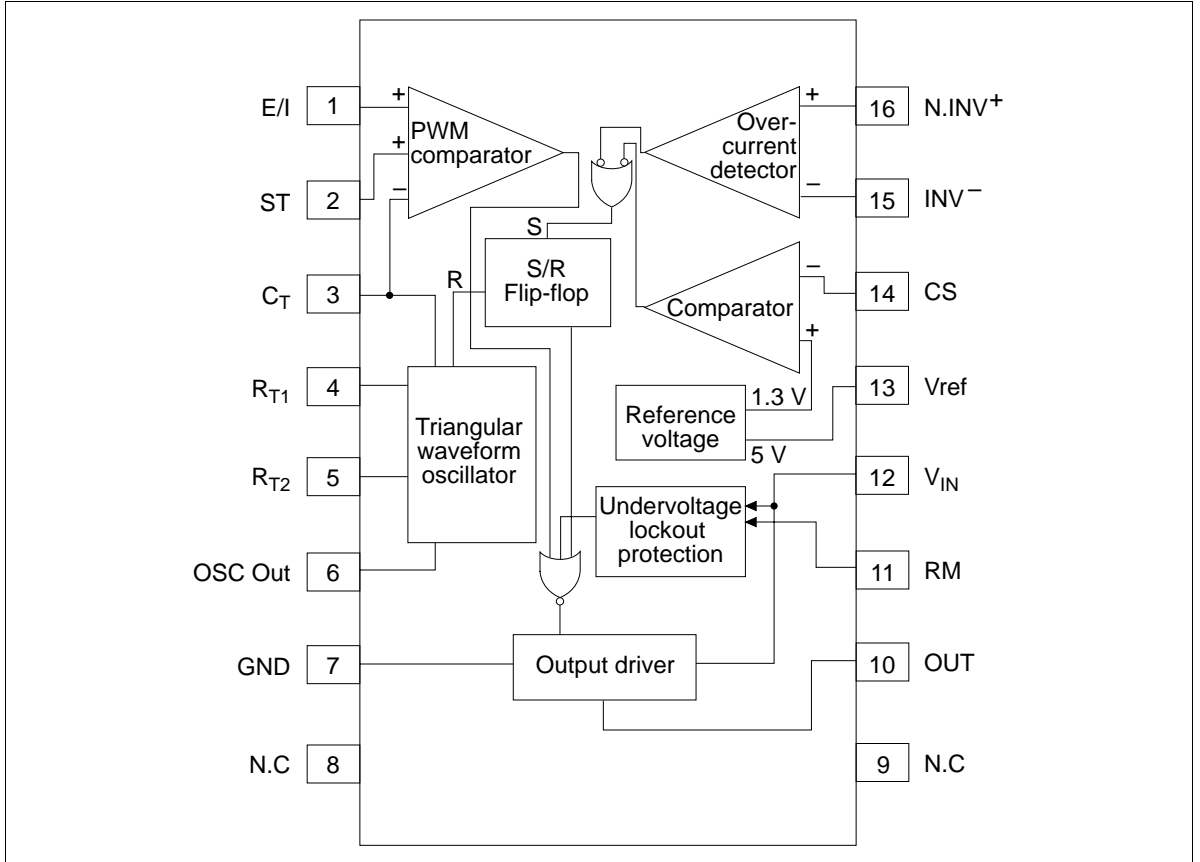
## Pin Arrangement



## Pin Functions

| Pin No. | Symbol             | Description   |
|---------|--------------------|---|
| 1       | E/I                | Error input   |
| 2       | ST                 | Soft start  |
| 3       | C <sub>T</sub>     | Timing capacitance                                  |
| 4       | R <sub>T1</sub>    | Timing resistor (rise section)                      |
| 5       | R <sub>T2</sub>    | Timing resistor (fall section)                      |
| 6       | OSC Out            | Triangular waveform oscillator                      |
| 7       | GND                | Ground  |
| 8       | N.C                | No connect  |
| 9       | N.C                | No connect  |
| 10      | OUT                | Pulse output  |
| 11      | RM                 | Remote control                                      |
| 12      | V <sub>IN</sub>    | Power supply voltage                                |
| 13      | Vref               | Reference voltage (5 V) output                      |
| 14      | CS                 | Comparator input (-) with reference voltage (1.3 V) |
| 15      | INV <sup>-</sup>   | Comparator input (-) for overcurrent protection     |
| 16      | N.INV <sup>+</sup> | Comparator input (+) for overcurrent protection     |

## Block Diagram



## Absolute Maximum Ratings (Ta = 25°C)

| Item                          | Symbol           | Rating                             |                                    | Unit  |    |
|-------------------------------|------------------|------------------------------------|------------------------------------|-------|----|
|                               |                  | HA16666P                           | HA16666FP                          |       |    |
| Power supply voltage          | V <sub>IN</sub>  | +40                                | +40                                | V     |    |
| Output current<br>(Push-pull) | DC               | I <sub>O(DC)</sub>                 | 100                                | 100   | mA |
|                               | Peak             | I <sub>O(peak)</sub>               | 500*1                              | 500*1 | mA |
| Error input                   | V <sub>EI</sub>  | V <sub>ref</sub>                   | V <sub>ref</sub>                   | V     |    |
| OSC input voltage             | V <sub>OSC</sub> | V <sub>IN</sub> - 3V <sub>BE</sub> | V <sub>IN</sub> - 3V <sub>BE</sub> | V     |    |
| CS input voltage              | V <sub>CS</sub>  | V <sub>ref</sub>                   | V <sub>ref</sub>                   | V     |    |
| RM input voltage              | V <sub>RM</sub>  | V <sub>IN</sub>                    | V <sub>IN</sub>                    | V     |    |
| RT2 input current             | I <sub>R2</sub>  | 1                                  | 1                                  | mA    |    |
| RT1 input current             | I <sub>R1</sub>  | 1                                  | 1                                  | mA    |    |
| Power dissipation             | P <sub>T</sub>   | 680*2                              | 680*3                              | mW    |    |
| Operation temperature         | Topr             | -20 to +85                         | -20 to +85                         | °C    |    |
| Storage temperature           | Tstg             | -55 to +125                        | -55 to +125                        | °C    |    |

Notes: 1. Value at 300 ns of switching time

2. Value at Ta ≤ 45°C. If Ta &gt; 45°C, derated by 8.3 mW/°C

3. Value under the condition of 40 mm × 40 mm × 0.8 t ceramics board epoxy board

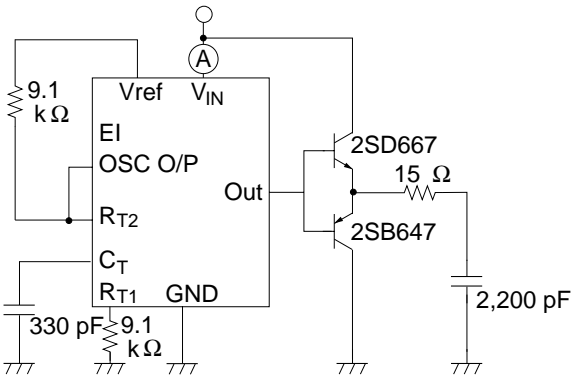
Electrical Characteristics (V<sub>IN</sub> = 15 V, Ta = 25°C, fosc = 300 kHz)

| Item                           | Symbol                               | Min              | Typ  | Max  | Unit | Test Condition |                               |
|--------------------------------|--------------------------------------|------------------|------|------|------|----------------|-------------------------------|
| Voltage reference              | Output voltage                       | V <sub>ref</sub> | 4.75 | 5.00 | 5.25 | V              | no load                       |
|                                | Line regulation                      | Line             | —    | 50   | 100  | mV             | V <sub>IN</sub> = 11 to 40 V  |
|                                | Load regulation                      | Load             | —    | 9    | 20   | mV             | I <sub>O</sub> = 0 to 10 mA   |
|                                | Temperature stability                | V <sub>RTC</sub> | —    | +60  | —    | ppm/°C         | no load                       |
|                                | Short circuit current                | I <sub>OS</sub>  | 10   | 35   | —    | mA             | V <sub>ref</sub> = 0 V        |
| Triangular waveform oscillator | Maximum frequency                    | f <sub>max</sub> | 600  | —    | —    | kHz            | C <sub>T</sub> = 150 pF       |
|                                | Minimum frequency                    | f <sub>min</sub> | —    | —    | 1    | kHz            | C <sub>T</sub> = 0.15 μF      |
|                                | Frequency accuracy                   | f <sub>der</sub> | -10  | 0    | +10  | %              |                               |
|                                | Voltage stability                    | f <sub>T</sub>   | —    | 1    | —    | %              | 11 V ≤ V <sub>IN</sub> ≤ 40 V |
|                                | Temperature coefficient of frequency | f <sub>i</sub>   | —    | 2    | —    | %              | -20°C ≤ Ta ≤ +85°C            |

**Electrical Characteristics** ( $V_{IN} = 15\text{ V}$ ,  $T_a = 25^\circ\text{C}$ ,  $f_{osc} = 300\text{ kHz}$ ) (cont)

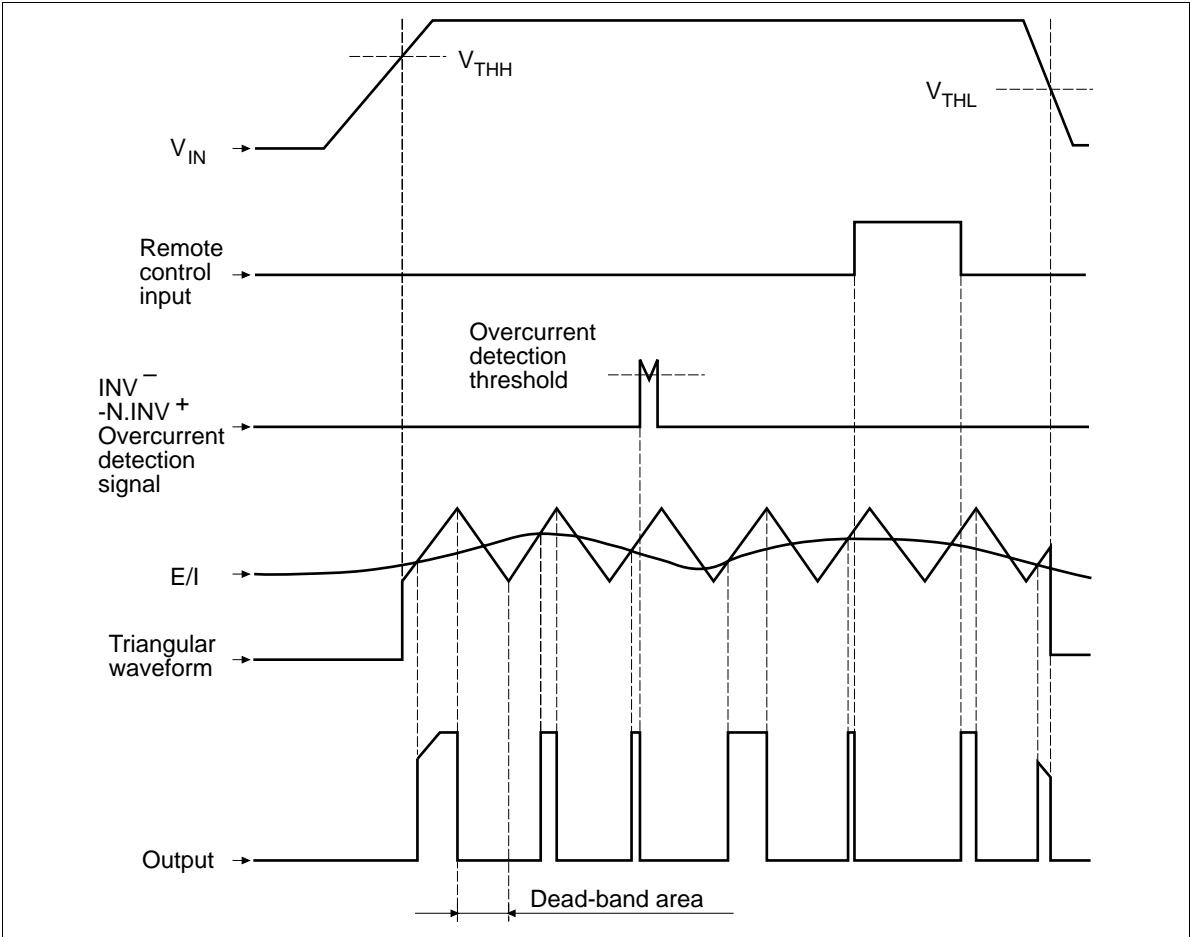
| Item                           |   | Symbol            | Min               | Typ     | Max       | Unit          | Test Condition                                      |
|--------------------------------|---|-------------------|-------------------|---------|-----------|---------------|---|
| PWM comparator                 | Maximum duty cycle                        | Du                | 75                | —       | —         | %             |   |
|                                | Input bias current                        | $I_b$             | -2                | —       | —         | $\mu\text{A}$ | Pin 1   |
|                                | Low-level threshold voltage               | $V_{OSCL}$        | —                 | 1.5     | —         | V             | Pin 1   |
|                                | High-level threshold voltage              | $V_{OSCH}$        | —                 | 2.5     | —         | V             | Pin 1   |
|                                | Dead-band duty accuracy                   | $\Delta\text{Du}$ | —                 | $\pm 1$ | $\pm 3$   | %             |   |
|                                | Dead-band duty input voltage stability    | $D_T$             | —                 | 1       | —         | %             | $11\text{ V} \leq V_{IN} \leq 40\text{ V}$          |
|                                | Temperature coefficient of dead-band duty | $D_{UT}$          | —                 | 1       | —         | %             | $-20^\circ\text{C} \leq T_a \leq +85^\circ\text{C}$ |
| Overcurrent detector           | Input bias current                        | $I_{B1}$          | -2                | —       | —         | $\mu\text{A}$ | Pin 15, 16  |
|                                | Common-mode input voltage range           | $V_{CM1}$         | 0 to $V_{IN} - 3$ | —       | —         | V             | Pin 15, 16  |
| Comparator                     | Input bias current                        | $I_{B2}$          | —                 | 5       | 13        | $\mu\text{A}$ | $V_{CS} = 5\text{ V}$                               |
|                                | Input threshold voltage                   | $V_{th}$          | 1.2               | 1.3     | 1.4       | V             |   |
|                                | Input voltage range                       | $V_{CS}$          | 0                 | —       | $V_{ref}$ | V             |   |
| Remote controller              | Input current to remote control pin       | $I_{RM}$          | —                 | —       | 1.5       | mA            | $V_{RM} = 5\text{ V}$                               |
|                                | Input high-voltage                        | $V_{INH}$         | 1                 | —       | —         | V             |   |
|                                | Input low-voltage                         | $V_{INL}$         | —                 | —       | 0.4       | V             |   |
| Undervoltage lockout protector | High-level threshold voltage              | $V_{THH}$         | 9                 | 10      | 11        | V             |   |
|                                | Low-level threshold voltage               | $V_{THL}$         | 7                 | 8       | 9         | V             |   |
|                                | Hysteresis width                          | Hys               | 1.5               | 2.0     | 2.8       | V             |   |
| Output driver                  | Output low-level                          | $V_L$             | —                 | 0.7     | 1.4       | V             | $I_{O(SINK)} = 10\text{ mA}$                        |
|                                | Output high-level                         | $V_H$             | $V_{IN} - 2.2$    | —       | —         | V             | $I_{O(SOURCE)} = 10\text{ mA}$                      |
|                                | Output rise time                          | $t_r$             | —                 | 80      | 150       | ns            | Note 1  |
|                                | Output fall time                          | $t_f$             | —                 | 40      | 100       | ns            | Note 1  |
| Total current                  | Standby current                           | $I_{CS}$          | —                 | 0.15    | 0.3       | mA            | Note 1  |
|                                | Operation current                         | $I_{CL}$          | —                 | 8       | 12        | mA            | Note 1  |

Note: 1. Measurement conditions of  $I_{CS}$ ,  $I_{CL}$ ,  $t_r$ ,  $t_f$  are defined as following diagram.

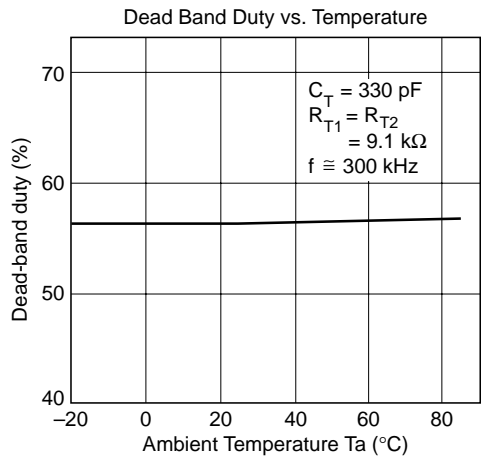
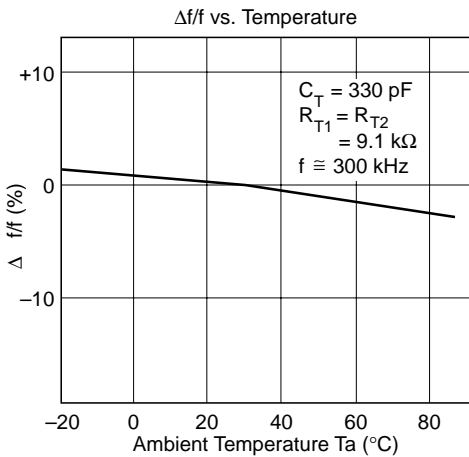
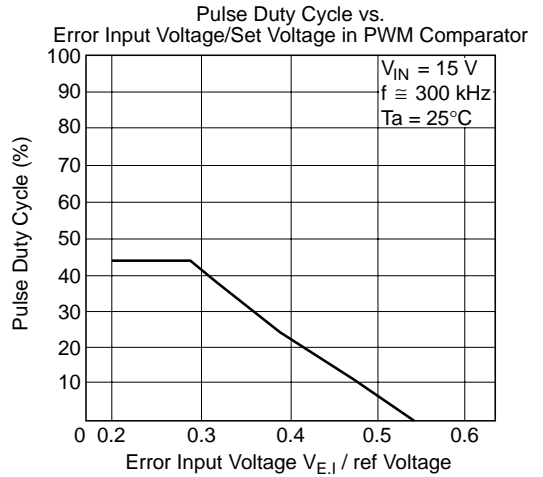
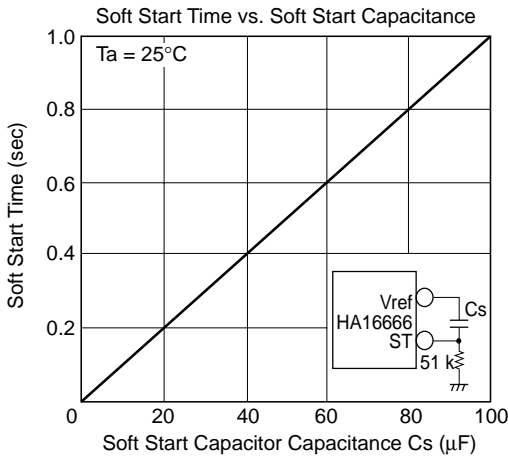
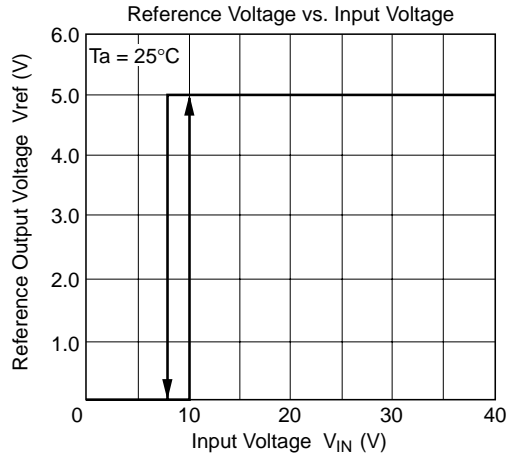
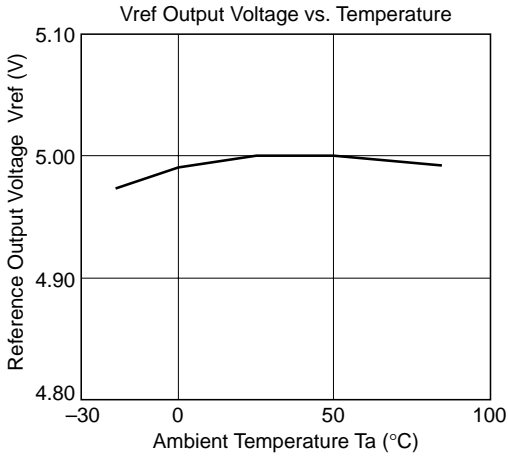


$h_{FE}$  of 2SD667 is defined as 60 min and 200 max.

### Waveform Timing

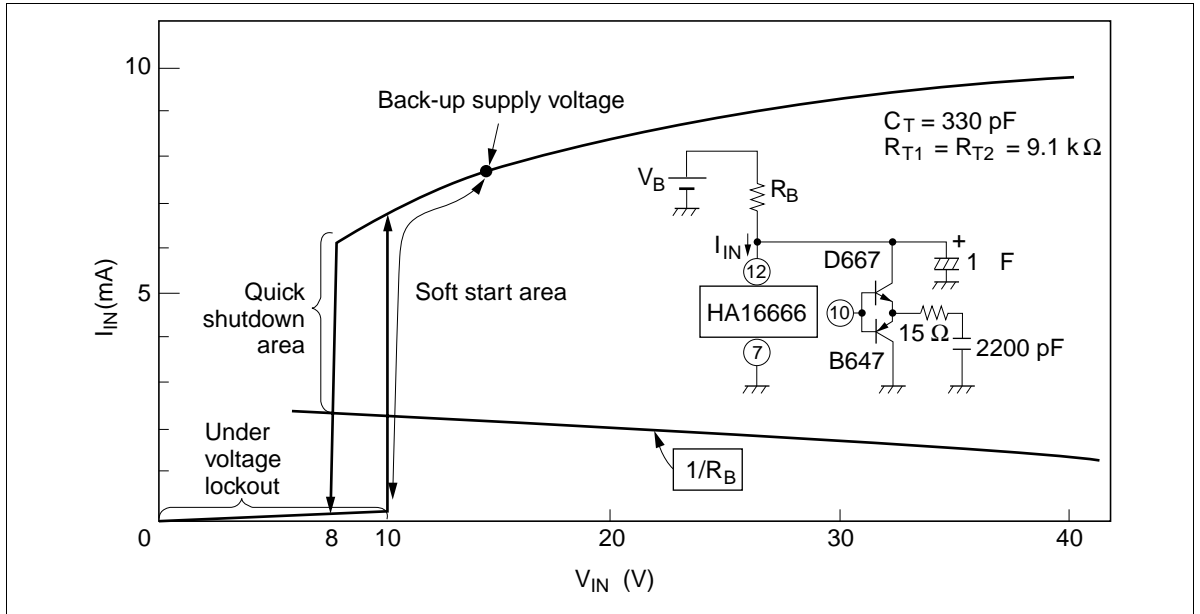


## Characteristic Curves

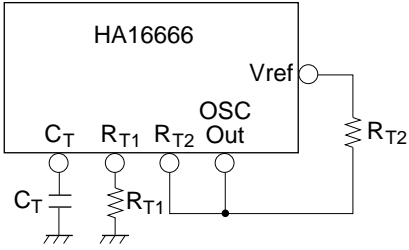




$V_{IN}$  Bias Point



Formula for the oscillation frequency



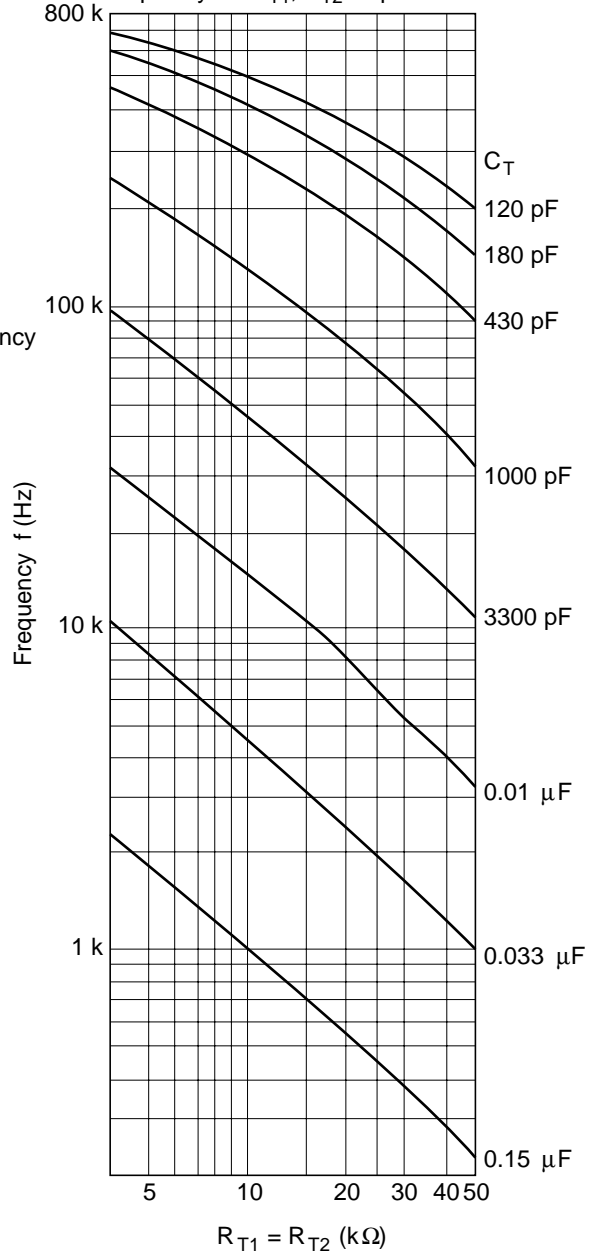
HA16666 summary formula of the oscillation frequency  
 $\log(f) \approx a \times \log\left(\frac{R_{T1}}{R_{T2}}\right) + b$

↑  
(=  $R_{T2}$ )

The following table show empirical values of a and b for different values of  $C_T$ .

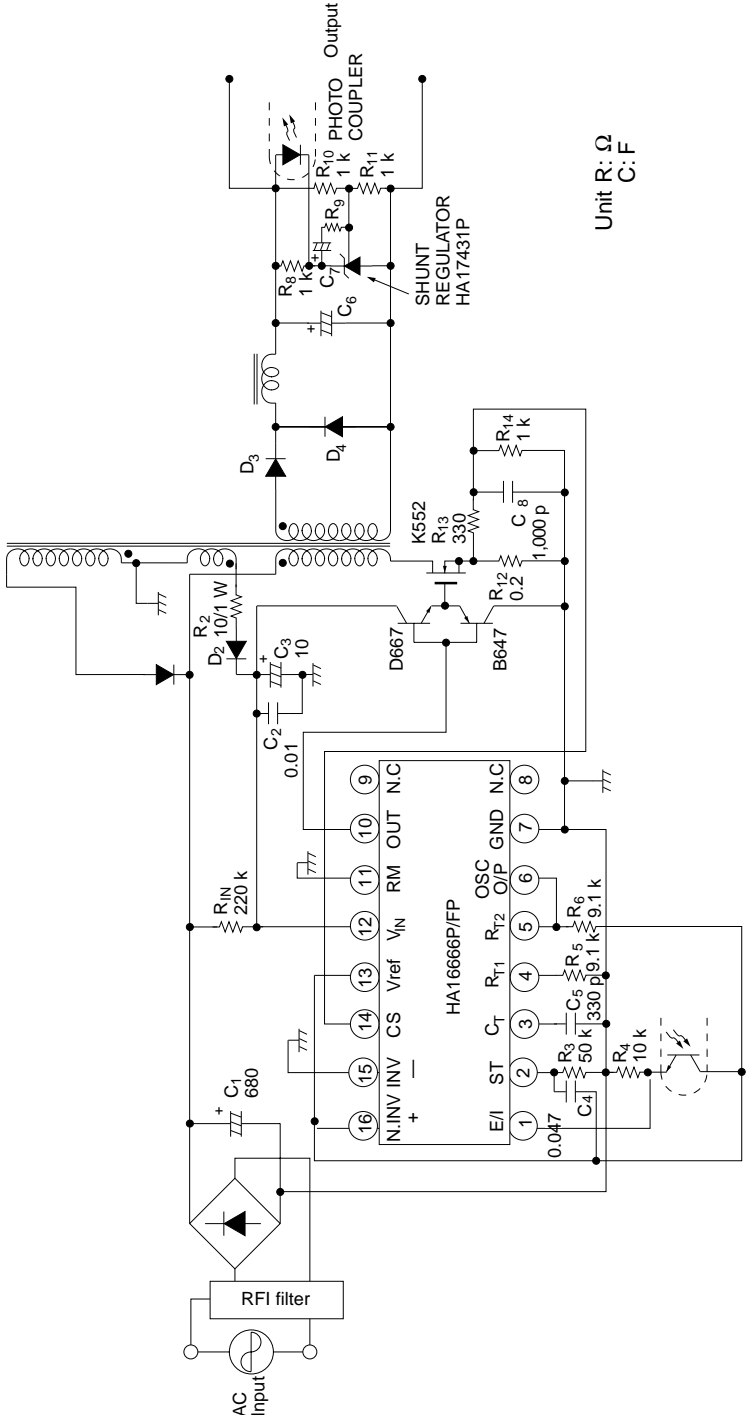
| $C_T$        | a     | b    |
|--------------|-------|------|
| 180pF        | -0.50 | 7.58 |
| 330pF        | -0.61 | 7.86 |
| 1000pF       | -0.75 | 8.09 |
| 0.01 $\mu$ F | -0.86 | 7.57 |
| 0.15 $\mu$ F | -0.86 | 6.45 |

Frequency vs.  $R_{T1}$ ,  $R_{T2}$  Dependence



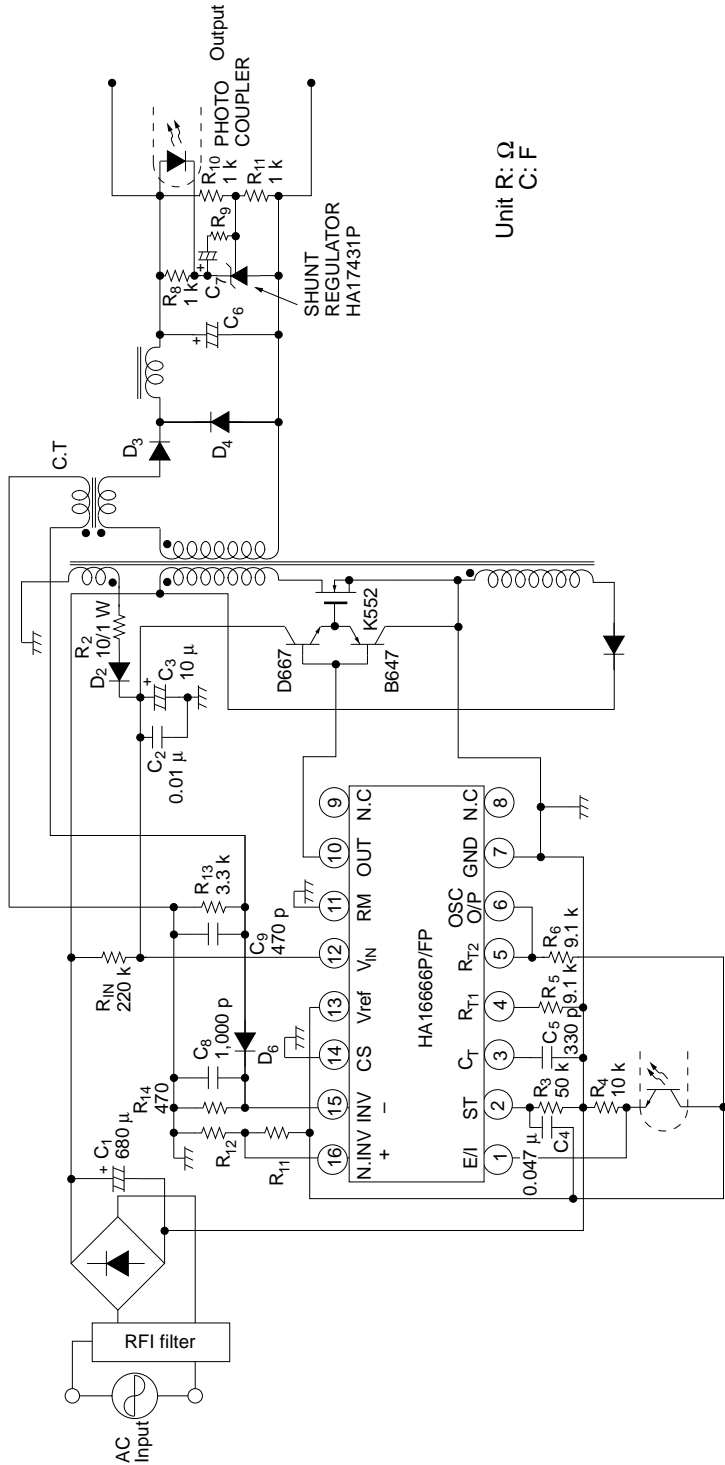
System Connection Example

Over current protection; Resistance sensing method

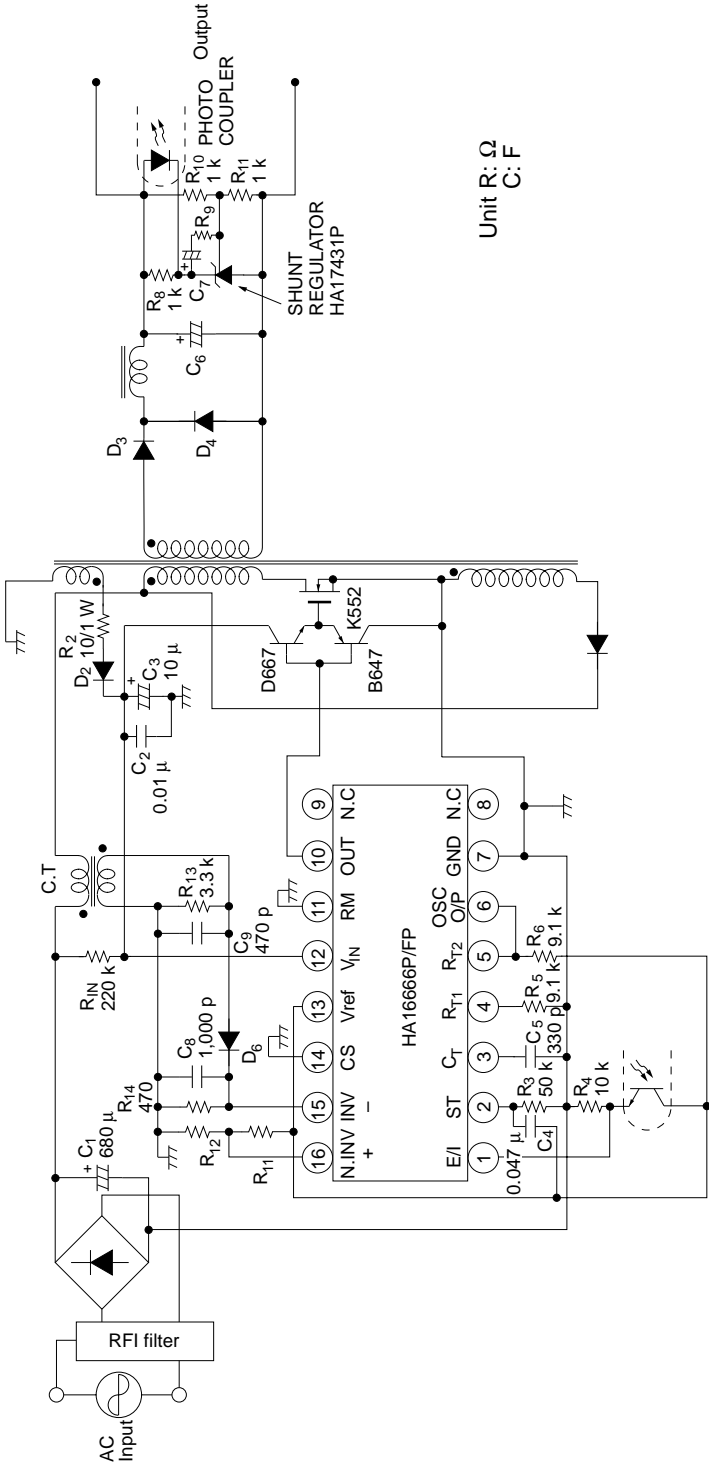


Unit R: Ω  
C: F

Over current protection; Current transformer method



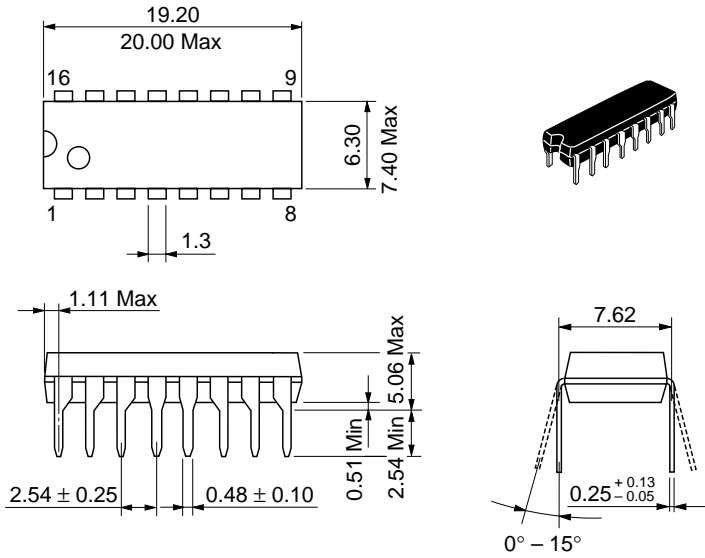
Over current protection; Current transformer method



Unit R: Ω  
C: F

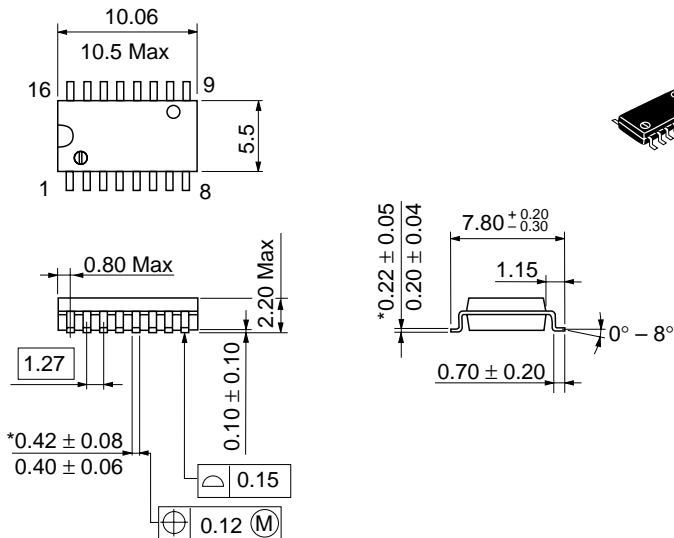
## Package Dimensions

Unit: mm



|                        |          |
|------------------------|----------|
| Hitachi Code           | DP-16    |
| JEDEC                  | Conforms |
| EIAJ                   | Conforms |
| Mass (reference value) | 1.07 g   |

Unit: mm



|                        |          |
|------------------------|----------|
| Hitachi Code           | FP-16DA  |
| JEDEC                  | —        |
| EIAJ                   | Conforms |
| Mass (reference value) | 0.24 g   |

\*Dimension including the plating thickness  
Base material dimension

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