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# HA16654A, HA16664A Series

## PWM Controlled Switching Regulator

# HITACHI

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The HA16654A and HA16664A are PWM control switching regulator ICs which drive a power MOSFET at high speed and high frequency. The standby current is limited to as small as 1.5 mA (typ). These devices incorporate totem pole circuits suited for high-speed push-pull operation at the output stage, accomplishing high-speed switching with rising time  $t_r = 80$  ns (typ) and falling time  $t_f = 40$  ns (typ) at 20 V swing.

### Functions

- Reference voltage circuit
- Triangular waveform oscillation circuit
- PWM comparator circuit
- Low-input malfunction protection circuit
- Output drive circuit
- Soft start and quick shut down

### Features

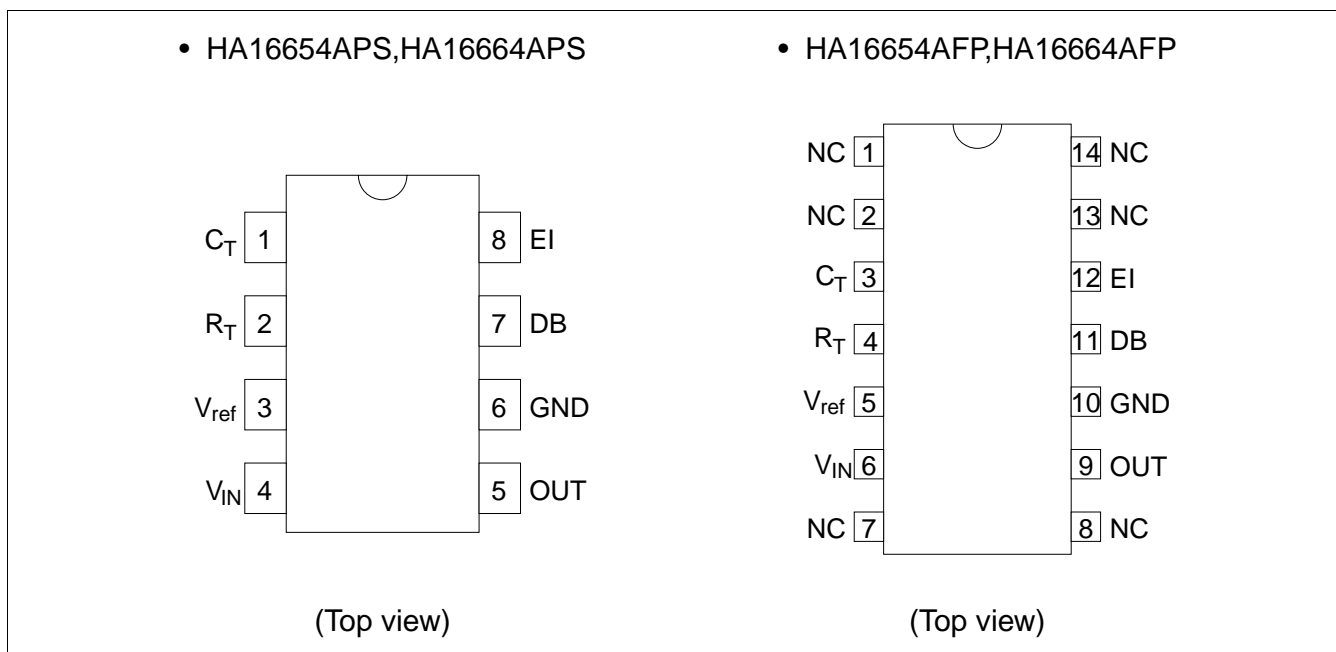
- High speed switching:  $t_r = 80$  ns,  $t_f = 40$  ns (typ) when use external driver circuit
- High frequency operation:  
HA16654A ( $f = 100$  kHz to 500 kHz)  
HA16664A ( $f = 100$  kHz to 200 kHz)  
Low power dissipation : 2 mA max in standby state
- 5 V reference voltage
- Low-input malfunction protection (High threshold voltage: 10 V Typ, Low threshold voltage: 8 V Typ)
- Adjustable dead band width
- Enlarged output pulse width control range (0 to 80%)
- Soft start and quick shut down functions
- Single output: totem pole

# HA16654A, HA16664A Series

## Ordering Information

Type No.	Operating Frequency	Package
HA16654APS	100 kHz to 500 kHz	DP-8
HA16654AFP		FP-14DA
HA16664APS	100 kHz to 200 kHz	DP-8
HA16664AFP		FP-14DA

## Pin Arrangement



**Table 1 Pin Function**

Symbol	Pin Name
$C_T$	Timing capacitor
$R_T$	Timing resistor
$V_{ref}$	Reference voltage
$V_{IN}$	Input voltage
EI	Error input
DB	Dead band
GND	Ground
OUT	Driver output

Block Diagram

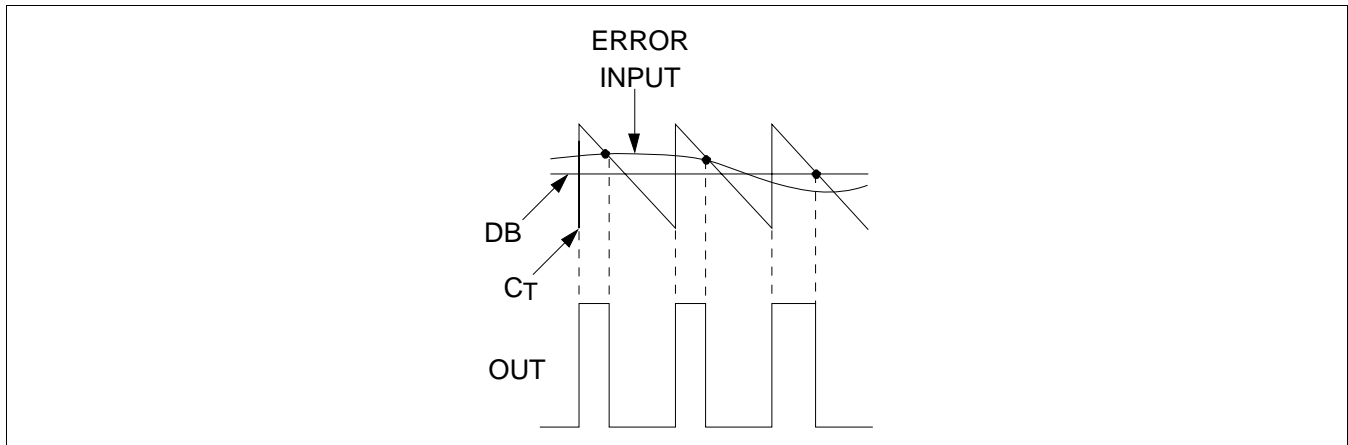
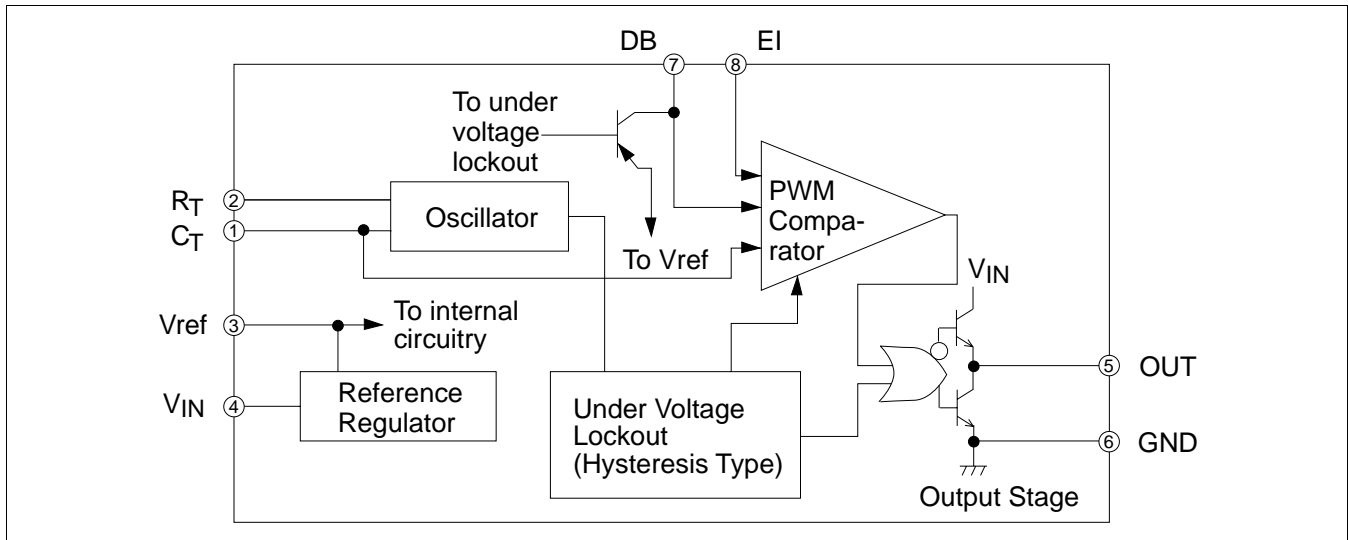


Figure 1 Waveform Timing

# HA16654A, HA16664A Series

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

Item	Symbol	Rating	Unit	Notes
Power supply voltage	V <sub>IN</sub>	+40	V	
Collector current (Push-pull)	I <sub>O</sub>	20	mA	
Comparator input voltage	V <sub>COM</sub>	V <sub>ref</sub> + 0.3	V	
R <sub>T</sub> input current	I <sub>RT</sub>	1	mA	
Power dissipation	P <sub>T</sub>	680	mW	1, 2
Operation temperature range	T <sub>opr</sub>	-20 to +85	°C	
Storage temperature range	T <sub>stg</sub>	-55 to 125	°C	

Notes: 1. Ta ≤ 45°C, if Ta > 45°C, derate by 8.3 mW/°C

2. T<sub>jmax</sub> = θ<sub>j-a</sub> • P<sub>cmax</sub> + Ta (θ<sub>j-a</sub>: Thermal resistance between junction and atmosphere at set board use)

The wiring density and the material of the set board must be chosen for thermal conductance of efficacy board.

## Electrical Characteristics

HA16654APS/AFP (Ta = 25°C, V<sub>IN</sub> = 20 V, C<sub>T</sub> = 220 pF, R<sub>T</sub> = 27 kΩ at f = 500 kHz)

### Voltage Reference

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Output voltage	V <sub>ref</sub>	4.75	5.00	5.25	V	
Line regulation	Line	—	—	100	mV	V <sub>IN</sub> = 7.3 to 11 V
		—	10	25	mV	V <sub>IN</sub> = 11 to 40 V
Load regulation	Load	—	5	16	mV	I <sub>O</sub> = 0 to 10 mA
Temperature stability	V <sub>RTC</sub>	—	-26	—	ppm/°C	
Short circuit current	I <sub>OS</sub>	10	35	—	mA	V <sub>ref</sub> = 0 V

**Oscillator**

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Maximum frequency	$f_{\max}$	500	—	—	kHz	$C_T = 220 \text{ pF}$
Minimum frequency	$f_{\min}$	—	—	100	kHz	$C_T = 560 \text{ pF}$
Initial accuracy	$f_{\text{dev}}$	—	—	$\pm 10$	%	
Voltage stability	$f_{\text{av}}$	—	-0.02	$\pm 1.0$	kHz/V	$V_{\text{IN}} = 11 \text{ to } 40 \text{ V}$

**PWM**

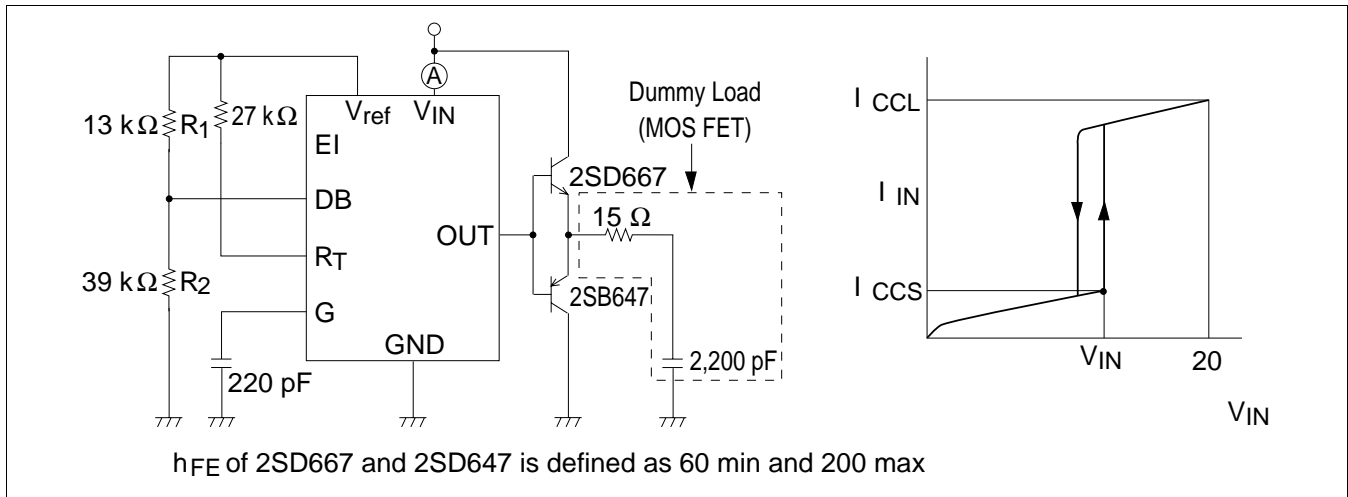
Item	Symbol	Min	Typ	Max	Unit	Test Condition
Maximum duty cycle	Du	80	—	—	%	
Duty cycle accuracy	Ddev	—	$\pm 1$	$\pm 6$	%	$R_1 = 13 \text{ k}\Omega, R_2 = 39 \text{ k}\Omega$
Input bias current	$I_B$	—	—	2.0	$\mu\text{A}$	$V_{E1} = 4 \text{ V}, V_{DB} = 0 \text{ V}$ or $V_{E1} = 0 \text{ V}, V_{DB} = 4 \text{ V}$

**Output Driver**

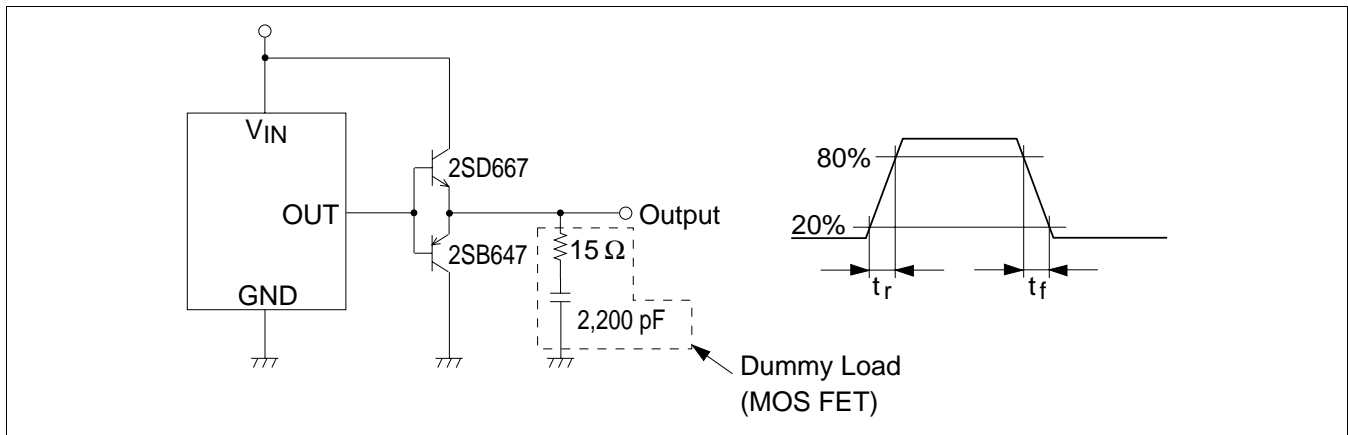
Item	Symbol	Min	Typ	Max	Unit	Test Condition
Sink current at Vin low	$I_{\text{OS(Low)}}$	0.6	1.5	—	mA	$V_{\text{IN}} = 6 \text{ V}, V_{\text{OUT}} = 0.4 \text{ V}$
Output low level	$V_{\text{OL}}$	—	0.86	1.4	V	$I_{\text{O(sink)}} = 10 \text{ mA}$
Output high level	$V_{\text{OH}}$	$V_{\text{IN}} - 2.2$	—	—	V	$I_{\text{O(source)}} = 10 \text{ mA}$
Output rising time	$t_r$	—	80	150	ns	Figure 3
Output falling time	$t_f$	—	40	100	ns	Figure 3
High level threshold	$V_{\text{THH}}$	9	10	11	V	UVL characteristics
Low level threshold	$V_{\text{THL}}$	7.3	8	9	V	UVL characteristics
Hysteresis width	$V_{\text{HRS}}$	1.5	2.0	2.5	V	UVL characteristics

**Total Current**

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Standby current	$I_{\text{CCS}}$	—	1.5	2.0	mA	Figure 2
Operation current	$V_{\text{CCL}}$	5.0	9.0	13.0	mA	$R_1 = 13 \text{ k}\Omega, R_2 = 29 \text{ k}\Omega,$ $V_{\text{IN}} = 20 \text{ V}$ Figure 2



**Figure 2**  $I_{CCS} \cdot I_{CCL}$  Measurement Circuit



**Figure 3**  $t_r, t_f$  Measurement Circuit

**HA16664APS/AFP** ( $T_a = 25^\circ\text{C}$ ,  $V_{IN} = 20\text{ V}$ ,  $C_T = 560\text{ pF}$ ,  $R_T = 82\text{ k}\Omega$  at  $f = 100\text{ kHz}$ )

## Voltage Reference

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Output voltage	Vref	4.75	5.00	5.25	V	
Line regulation	Line	—	—	100	mV	$V_{IN} = 7.3\text{ to }11\text{ V}$
		—	10	25	mV	$V_{IN} = 11\text{ to }40\text{ V}$
Load regulation	Load	—	5	16	mV	$I_O = 0\text{ to }10\text{ mA}$
Temperature stability	$V_{RTC}$	—	-26	—	ppm/ $^\circ\text{C}$	
Short circuit current	$I_{OS}$	10	35	—	mA	Vref = 0 V

## Oscillator

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Maximum frequency	$f_{\max}$	200	—	—	kHz	$C_T = 220 \text{ pF}$
Minimum frequency	$f_{\min}$	—	—	100	kHz	$C_T = 560 \text{ pF}$
Initial accuracy	$f_{\text{dev}}$	—	—	$\pm 10$	%	
Voltage stability	$f_{\text{av}}$	—	-0.02	$\pm 1.0$	kHz/V	$V_{\text{IN}} = 11 \text{ to } 40 \text{ V}$

## PWM Comparator

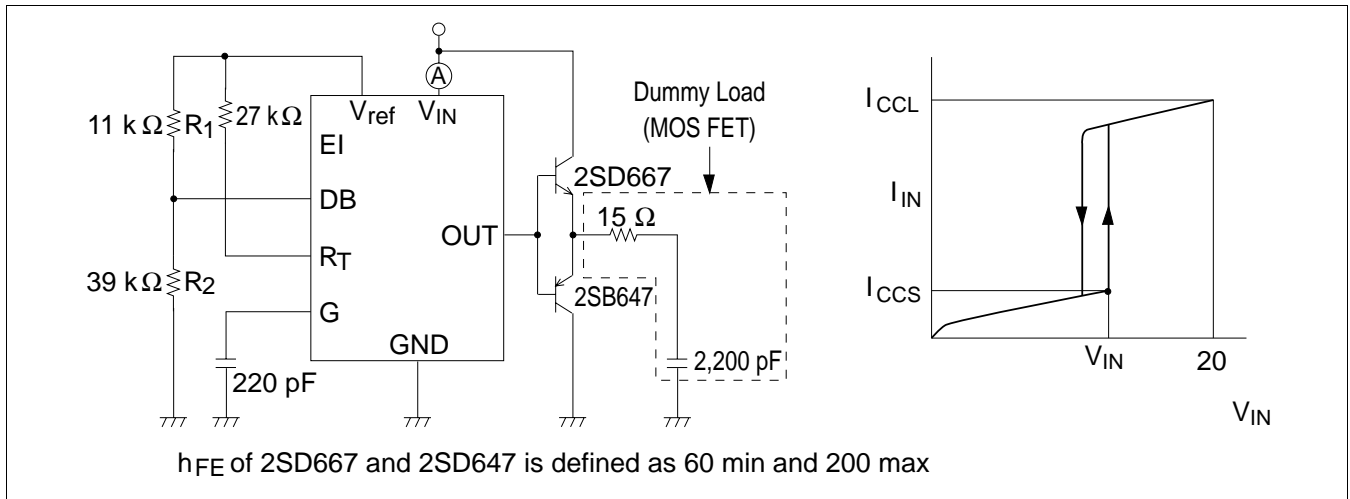
Item	Symbol	Min	Typ	Max	Unit	Test Condition
Maximum duty cycle	Du	80	—	—	%	
Duty cycle accuracy	Ddev	—	$\pm 1.0$	$\pm 6$	%	$R_1 = 11 \text{ k}\Omega, R_2 = 39 \text{ k}\Omega$
Input bias current	$I_B$	—	—	2.0	$\mu\text{A}$	$V_{\text{EI}} = 4 \text{ V}, V_{\text{DB}} = 0 \text{ V}$ or $V_{\text{EI}} = 0 \text{ V}, V_{\text{DB}} = 4 \text{ V}$

## Output Driver

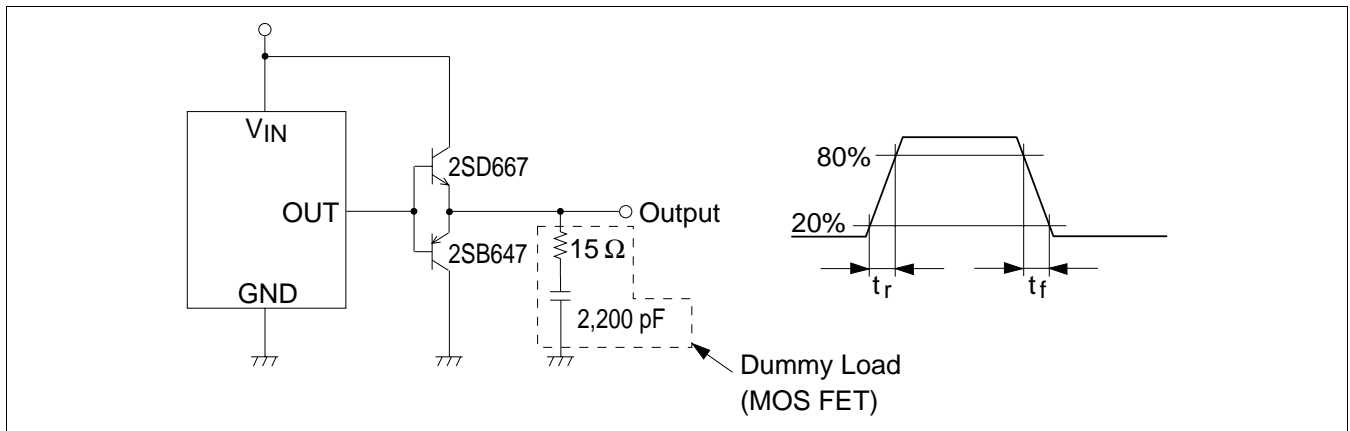
Item	Symbol	Min	Typ	Max	Unit	Test Condition
Sink current at Vin low	$I_{\text{OS(Low)}}$	1.0	1.5	—	mA	$V_{\text{IN}} = 6 \text{ V}, V_{\text{OUT}} = 0.4 \text{ V}$
Output low level	$V_{\text{OL}}$	—	0.86	1.4	V	$I_{\text{O(sink)}} = 10 \text{ mA}$
Output high level	$V_{\text{OH}}$	$V_{\text{IN}} - 2.2$	—	—	V	$I_{\text{O(source)}} = 10 \text{ mA}$
Output rising time	$t_r$	—	80	300	ns	Figure 5
Output falling time	$t_f$	—	40	200	ns	Figure 5
High level threshold	$V_{\text{THH}}$	9	10	11	V	UVL characteristics
Low level threshold	$V_{\text{THL}}$	7.3	8	9	V	UVL characteristics
Hysteresis width	$V_{\text{HRS}}$	1.5	2.0	2.5	V	UVL characteristics

## Total Current

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Standby current	$I_{\text{CCS}}$	—	1.5	2.0	mA	Figure 4
Operation current	$V_{\text{CCL}}$	3.0	5.0	7.0	mA	$R_1 = 11 \text{ k}\Omega, R_2 = 39 \text{ k}\Omega,$ $V_{\text{IN}} = 20 \text{ V}$ Figure 4



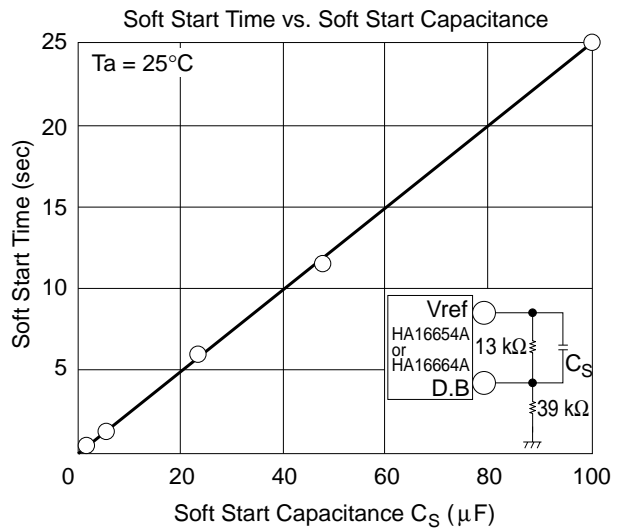
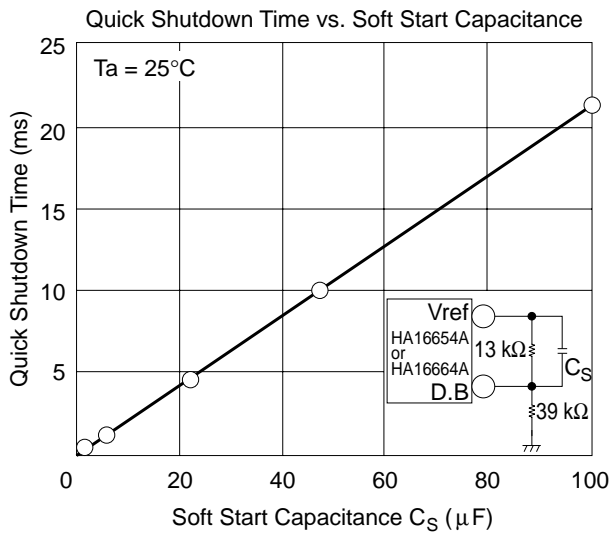
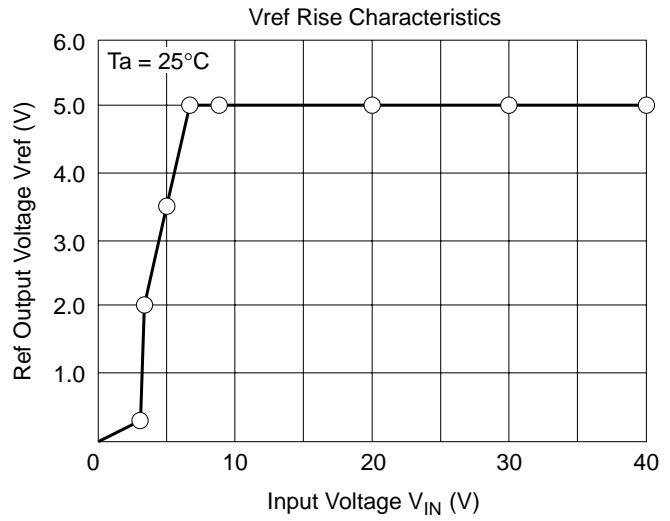
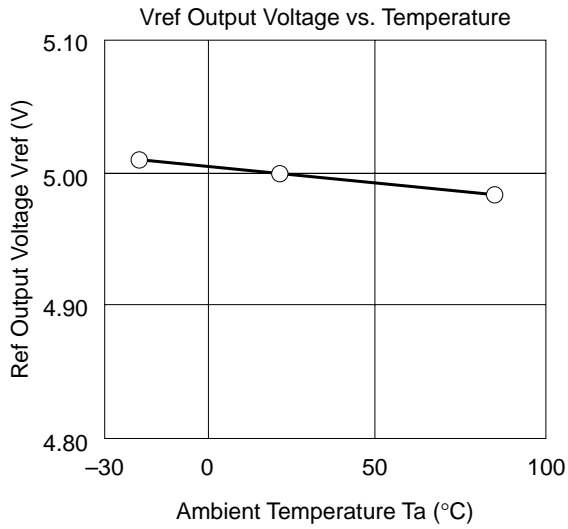
**Figure 4**  $I_{CCS} \cdot I_{CCL}$  Measurement Circuit

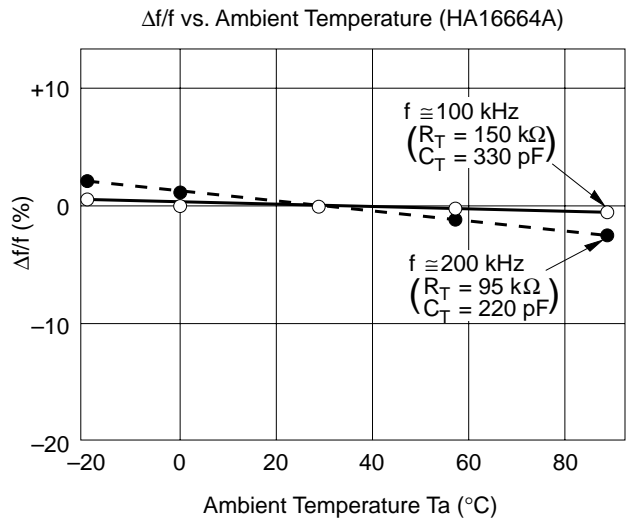
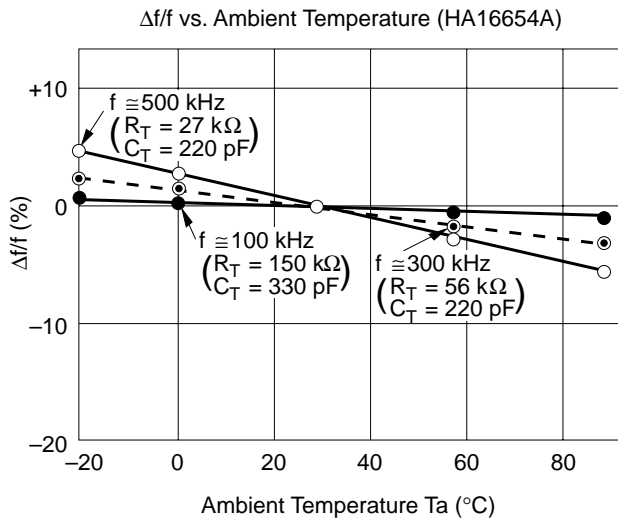
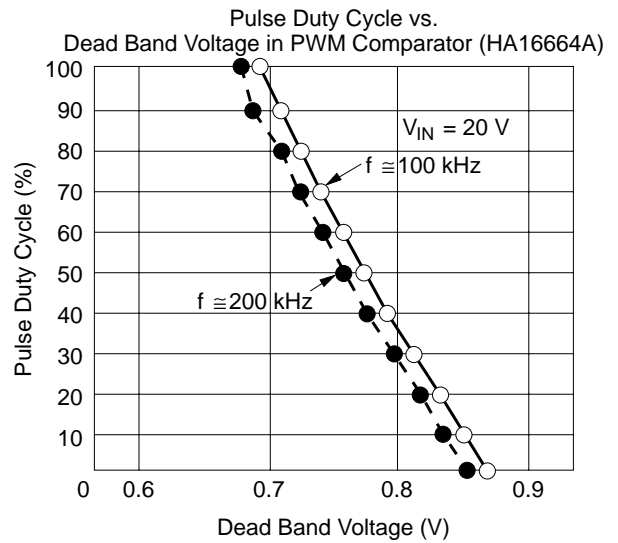
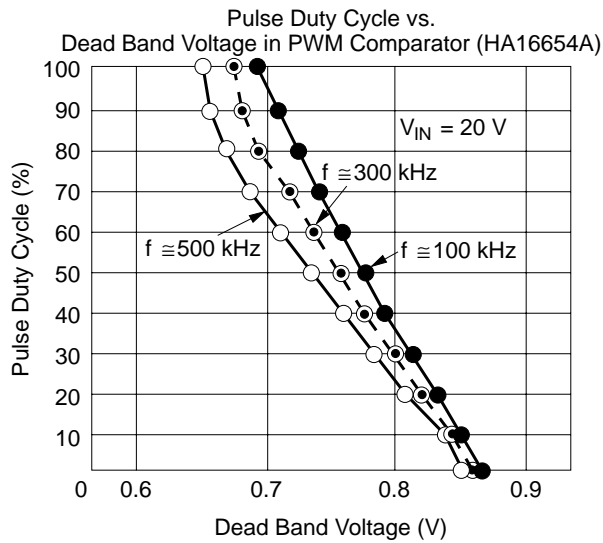


**Figure 5**  $t_r \cdot t_f$  Measurement Circuit

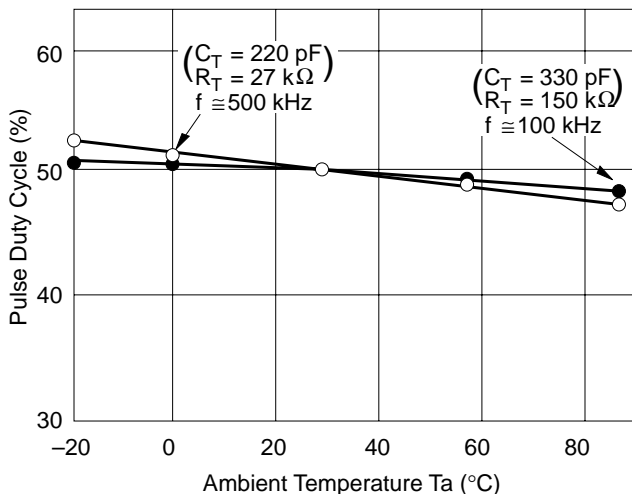


Characteristic Curves

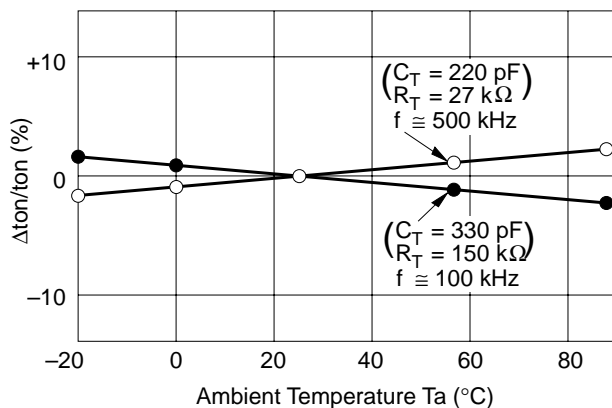




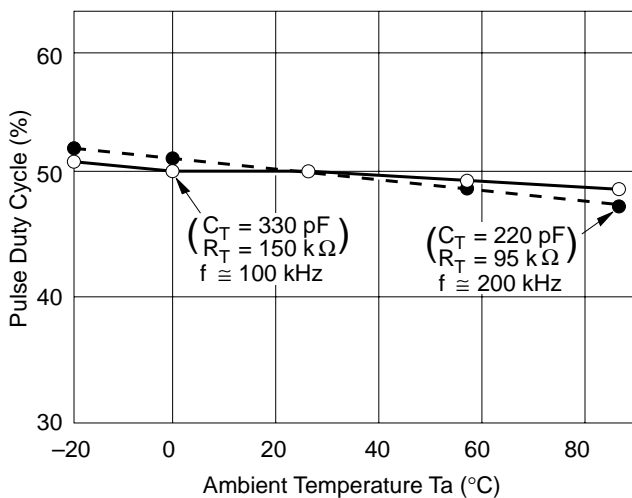
Pulse Duty Cycle vs. Ambient Temperature (HA16654A)



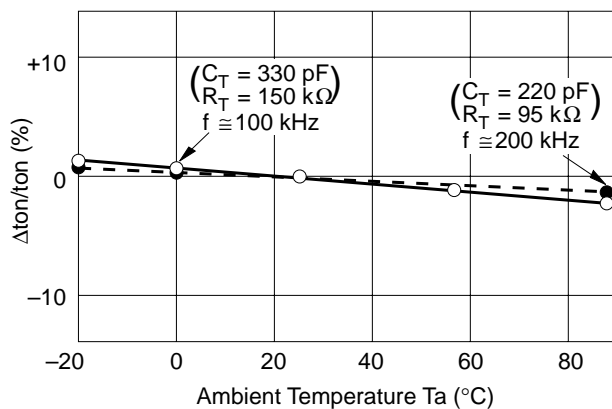
$\Delta$ ton/ton vs. Ambient Temperature (HA16654A)

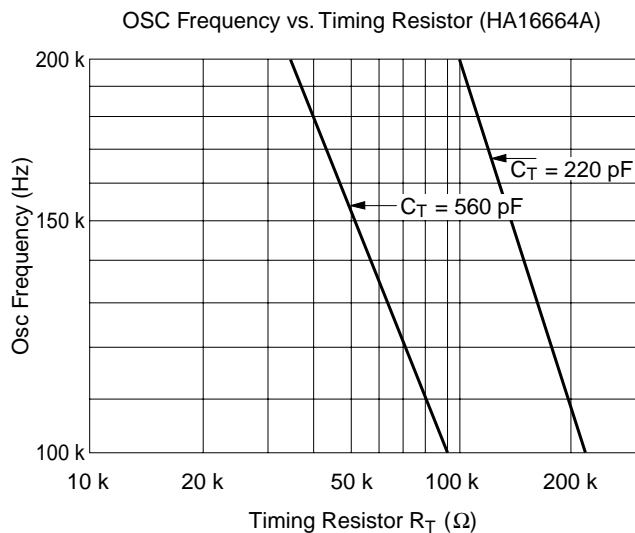
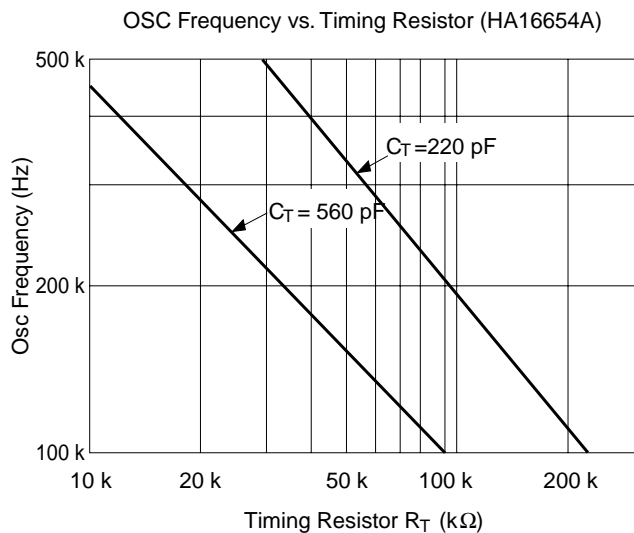


Pulse Duty Cycle vs. Ambient Temperature (HA16664A)



$\Delta$ ton/ton vs. Ambient Temperature (HA16664A)





Formula for the oscillation frequency  $f$

$$f = 1 / [ \{ C_T (R_T + 1 \times 10^3)(a \cdot R_T + b) / (V_{ref} - V_{BE}) \} + 100 \times 10^{-9} ]$$

$C_T$  : Timing capacitor (F)

$R_T$  : Timing resistor ( $\Omega$ )

$V_{ref}$  : Reference voltage 5.0 (V) (Typ)

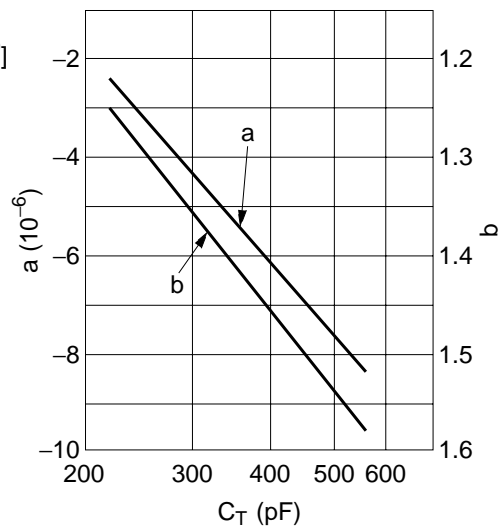
$V_{BE}$  : Base-emitter voltage 0.65 (V) (Typ)

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

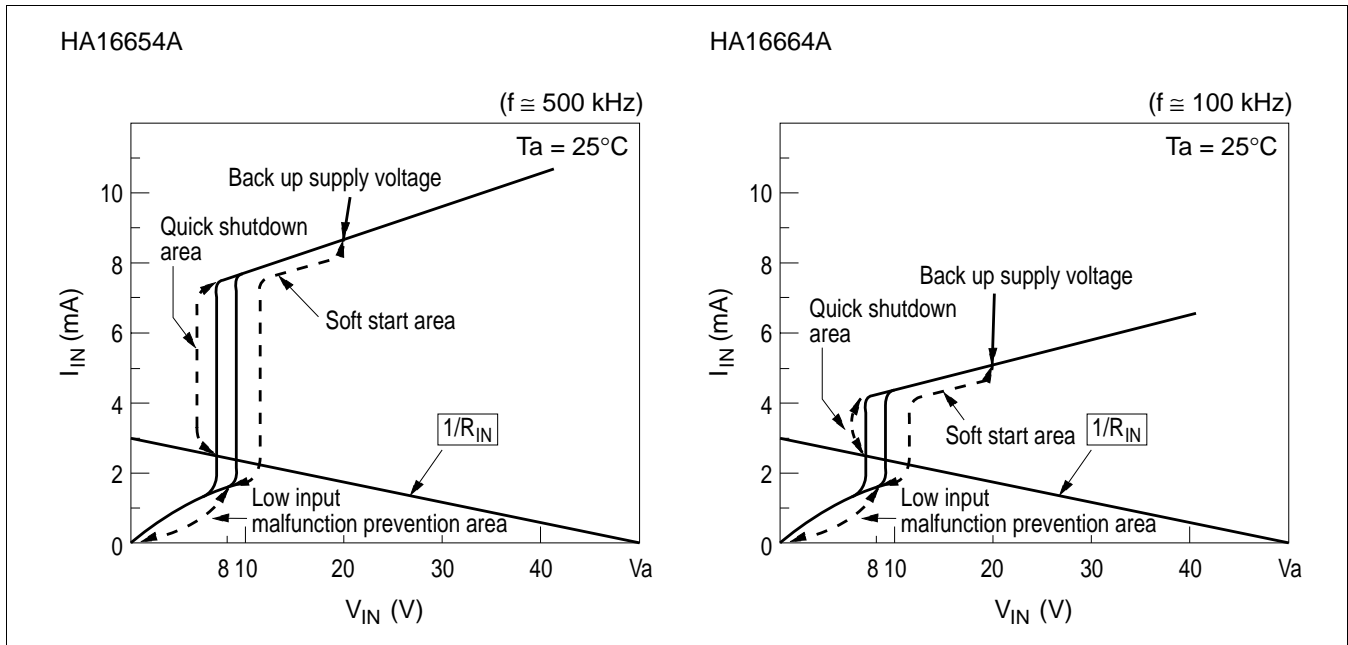
$C_T$ (pF)	$a$	$b$
220	$-2.30 \times 10^{-6}$	1.247
560	$-8.37 \times 10^{-6}$	1.575

Also,

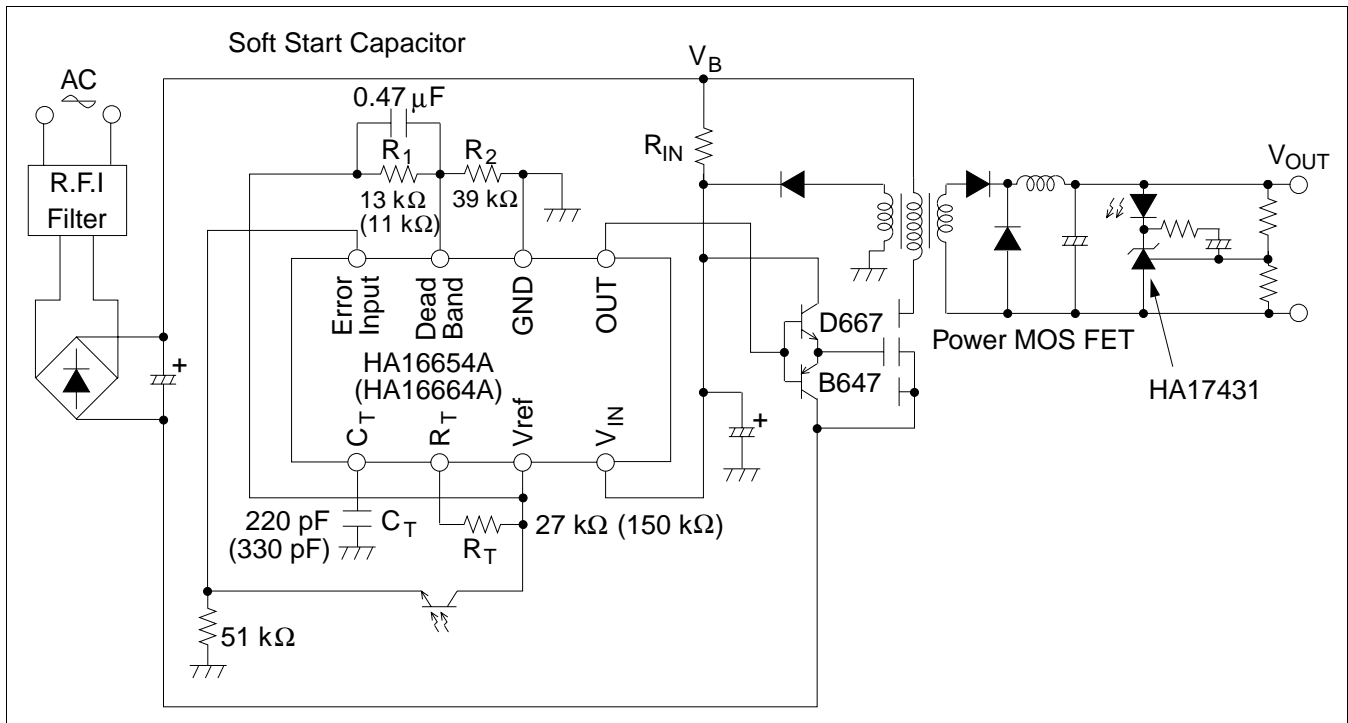
$$f \approx 4.35 / (C_T \cdot R_T)$$



**$V_{IN}$  Bias Point**

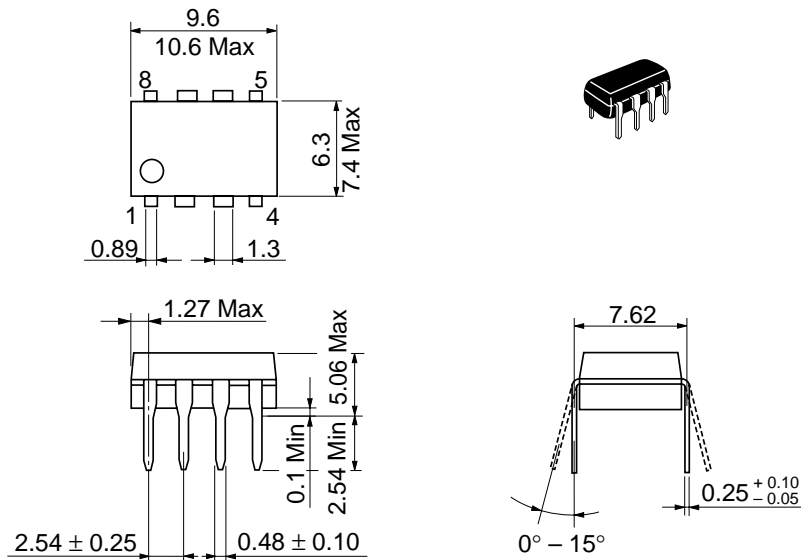


**Primary Control Forward Converter System**



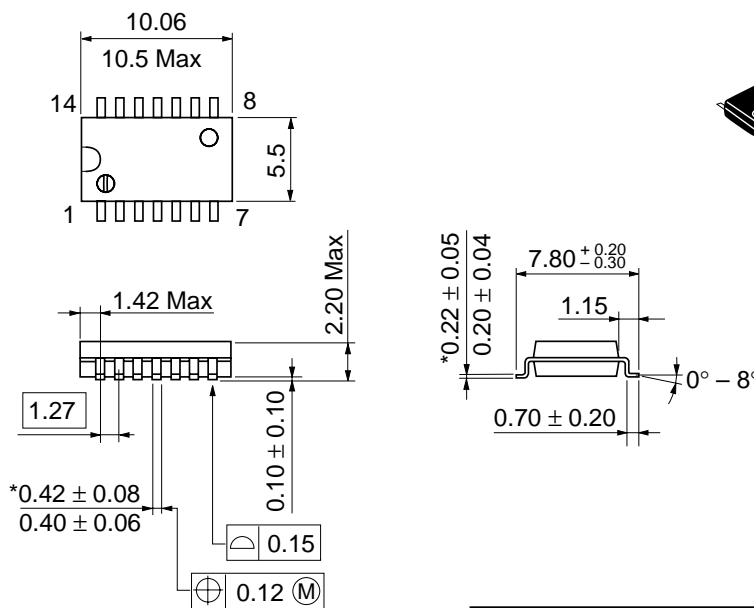
## Package Dimensions

Unit: mm



Hitachi Code	DP-8
JEDEC	Conforms
EIAJ	Conforms
Mass (reference value)	0.54 g

Unit: mm



\*Dimension including the plating thickness  
Base material dimension

Hitachi Code	FP-14DA
JEDEC	—
EIAJ	Conforms
Mass (reference value)	0.23 g

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