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Renesas Technology Corp.
Customer Support Dept.
April 1, 2003

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HA16107P/FP, HA16108P/FP

PWM Switching Regulator for High-performance Voltage Mode Control

ADE-204-012C (Z)

Rev.3
Jul. 2002

Description

The IC products in this series are primary control switching regulator control IC's appropriate for obtaining stabilized DC voltages from commercial AC power.

These IC's can directly drive power MOS FET's, they have a timer function built in to the secondary overcurrent protection, and they can perform intermittent operation or delayed latched shutdown as protection operations in unusual conditions. They can be used to implement switching power supplies with a high level of safety due to the wide range of built-in functionality.

Functions

- 6.45 V reference voltage
- Triangle wave generator
- Error amplifier
- Under voltage lockout protector
- PWM comparator
- Pulse-by-pulse current limitting
- Timer-latch current limitting (HA16107)
- ON/OFF timer function (HA16108)
- Soft start and quick shutdown
- Output circuit for power MOS FET driving

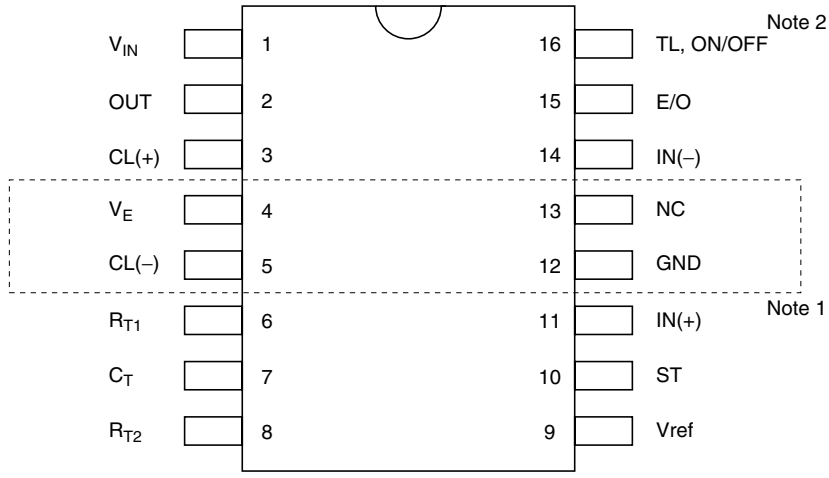
Features

- Operating frequencies up to a high 600 kHz
- Built-in pre-driver circuit for driving power MOS FET
- Built-in timer latch over-current protection function (HA16107)
- The OCL enables intermittent operation by an ON/OFF timer for prevention of secondary overcurrent. (HA16108)
- The UVL function (under voltage lockout) is applied to both Vin and Vref.
- ON/OFF reset: an auto-reset function which is based on the time constant of an external capacitor and observation of drops in Vin.
- Since the over-voltage protection function OVP (the TL pin) only observes voltage drops in Vin, it is possible to use the OVP and ON/OFF pin for independent purposes.
- Built-in 34 V Zener diode between Vin and ground.

Ordering Information

	Typical Threshold Voltage			
Product	**UVL1**	**OVP**	**Notes**	**Package**
HA16107P	Hi: 16.2 V	7.0 V	Timer latch protection	DP-16
HA16107FP	Lo: 9.5 V			FP-16DA
HA16108P	Hi: 16.2 V	Hi: 7.0 V	On-off timer protection	DP-16
HA16108FP	Lo: 9.5 V	Lo: 1.3 V	(intermittent operation possible)	FP-16DA

Pin Arrangement



(Top view)

Notes: 1. In the SOP package models (HA16107FP and HA16108FP) pins 4, 5, and 13 are connected inside the IC. However, all must be connected to the system ground.
2. Pin 16 is TL (HA16107), ON/OFF (HA16108).

Pin Functions

- HA16107P, HA16108P

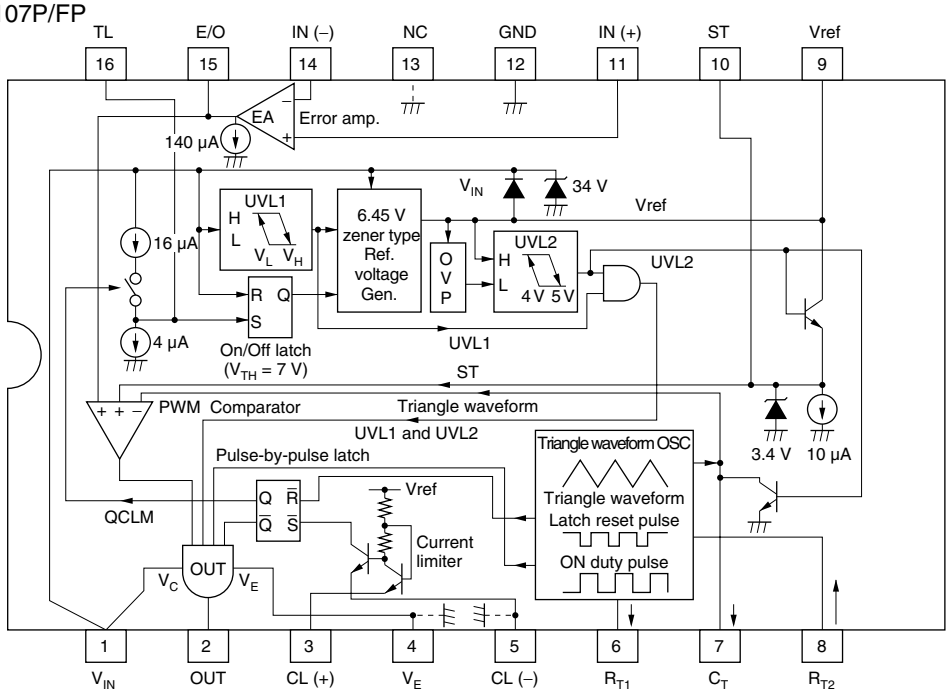
Pin No.	Symbol	Pin Functions
1	V_{IN}	Input voltage
2	OUT	Pulse output
3	CL (+)	Current limiter
4	V_E	Output ground
5	CL (–)	Current limiter
6	R_{T1}	Timing resistor (rising time)
7	C_T	Timing capacitor
8	R_{T2}	Timing resistor (falling time)
9	Vref	Reference voltage output
10	ST	Soft start
11	IN (+)	Error amp (+) input
12	GND	Ground
13	NC	NC
14	IN (–)	Error amp (–) input
15	E/O	Error output
16	TL, ON/OFF	Timer latch (HA16107), ON/OFF (HA16108)

- HA16107FP, HA16108FP

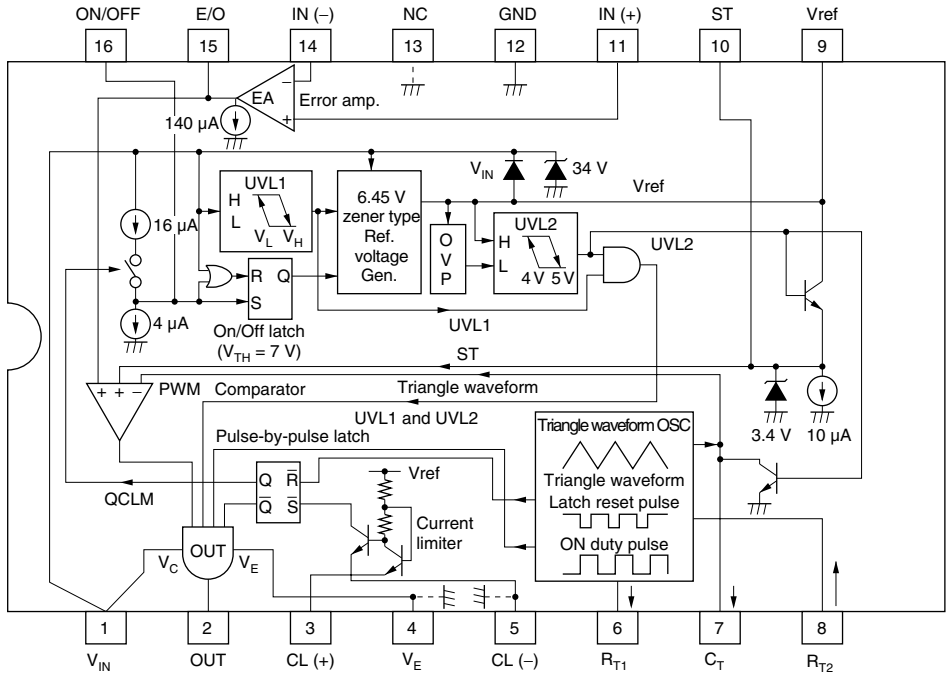
Pin No.	Symbol	Pin Functions
1	V_{IN}	Input voltage
2	OUT	Pulse output
3	CL (+)	Current limiter
4	GND	Ground
5	GND	Ground
6	R_{T1}	Timing resistor (rising time)
7	C_T	Timing capacitor
8	R_{T2}	Timing resistor (falling time)
9	Vref	Reference voltage output
10	ST	Soft start
11	IN (+)	Error amp (+) input
12	GND	Ground
13	GND	Ground
14	IN (–)	Error amp (–) input
15	E/O	Error output
16	TL, ON/OFF	Timer latch (HA16107), ON/OFF (HA16108)

Block Diagram

• HA16107P/FP



• HA16108P/FP

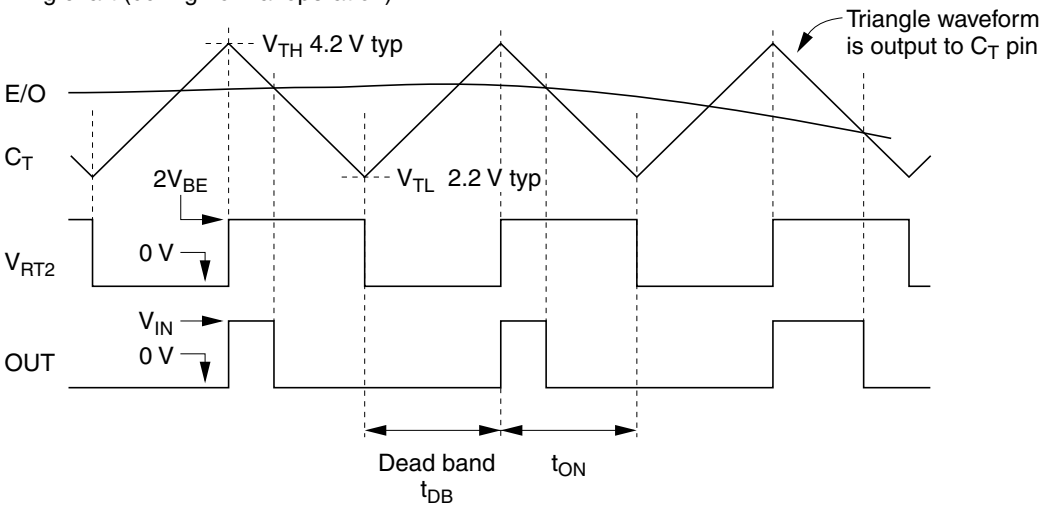


Note: Dotted lines apply to the SOP package model (pins 4, 5, and 13: ground)

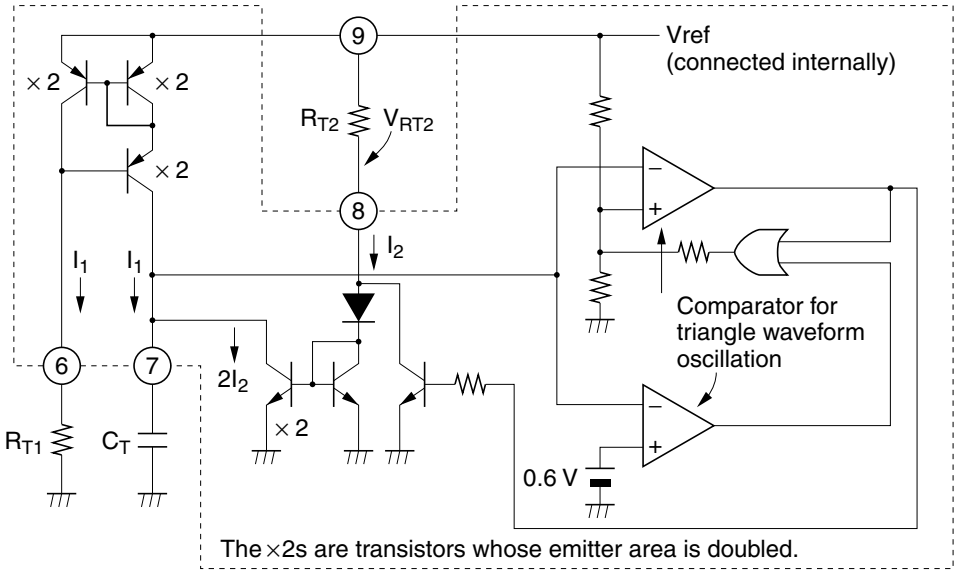
Function and Timing Chart

Triangle Waveform and PWM Output

• Timing chart (during normal operation)



• Oscillator equivalent circuit



$$I_1 = \frac{Vref - 2V_{BE}}{R_{T1}} \qquad t_{DB} = \frac{C_T \times R_{T1} \times 2V}{Vref - 2V_{BE}} \approx 0.4 \times C_T \times R_{T1}\ (s) \qquad Du\ max = \frac{R_{T2}}{2R_{T1}}$$

$$I_2 = \frac{Vref - 2V_{BE}}{R_{T2}} \qquad t_{ON} \approx t_{DB}\,\frac{R_{T2}}{2R_{T1} - R_{T2}}\ (s) \qquad f_{OSC} \approx \frac{1 - Du\ max}{t_{DB}}\ (Hz)$$

Note: When f_{OSC} is high, the actual value will differ from that given by the formula due to the delay time. Determine the correct constants after constructing a test circuit.

1. Timing in Normal Operation

Timing in these ICs is based on a triangular voltage waveform. The rising edge (leading edge) defines the deadband time t_{DB}. The falling edge (trailing edge) defines the ON-duty control band t_{ON}. PWM output is on in the area within t_{ON} that is bounded above by the triangle wave V_{CT} and error output $V_{E/O}$.

The following pin outputs are related to PWM control:

- C_T (pin 7): triangle-wave voltage output
- E/O (pin 15): error output voltage
- R_{T2} (pin 8): ON-duty pulse output voltage
- OUT (pin 2): PWM pulse output (for driving the gate of a power MOS FET)

2. Triangle Oscillator, Waveform and Frequency

The triangle oscillator in these ICs generates a triangular waveform by charging and discharging timing capacitor C_T with a constant current, as shown in the equivalent circuit. The C_T charge current is:

$$I(C_{Tchg}) = I_1 = \frac{V_{REF} - 2V_{BE}}{R_{T1}}$$

The discharge current is:

$$I(C_{Tdischg}) = 2I_2 - I_1, \text{ where } I_2 = \frac{V_{REF} - 2V_{BE}}{R_{T2}}$$

In these equations Vref (reference voltage) is typically 6.45 V, and V_{BE} (base-emitter voltage of internal transistors) is about 0.7 V.

The deadband time is:

$$t_{DB} = \frac{C_T \times R_{T1} \times 2V}{V_{REF} - 2V_{BE}} + 0.25\ \mu s$$
$$\approx 0.4 \times C_T \times R_{T1} + 0.25\ \mu s$$

The ON-duty time is:

$$t_{ON} = t_{DB} \times \frac{R_{T2}}{2R_{T1} - R_{T2}}$$

The 0.25 µs in these equations is a correction term for internal circuit delays.

The maximum ON-duty is

$$Du\ max = \frac{R_{T2}}{2R_{T1}}$$

The oscillating frequency is:

$$f_{OSC} = \frac{1}{\frac{0.4\ C_T\ R_{T1} + 0.25\ \mu}{1 - \frac{R_{T2}}{2R_{T1}}} + 0.25\ \mu}$$
$$= \frac{1}{\frac{0.8\ C_T\ R_{T1}^2 + 0.25\mu \times 2R_{T1}}{2R_{T1} - R_{T2}} + 0.25\ \mu}\ (Hz)$$

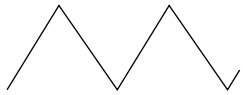
When $R_{T1} = R_{T2}$, the maximum ON-duty is 50%, and:

$$f_{OSC} \approx \frac{1}{0.8\ C_T\ R_{T1} + 0.25\ \mu \times 2 + 0.25\ \mu}$$
$$= \frac{1}{0.8\ C_T\ R_{T1} + 0.75\ \mu}\ (Hz)$$

This approximation is fairly close, but it should be checked in-circuit.

3. Programming of Maximum ON-Duty (Du Max)

   The preceding equations should be used to program the deadband or maximum ON-duty. The following table gives a summary.

Condition	$R_{T1} > R_{T2}$	$R_{T1} = R_{T2}$	$R_{T1} < R_{T2}$
Triangle waveform			
Du max	Less than 50%	50%	Greater than 50%*

Note: In a primary-control switching regulator, Du Max > 50% is dangerous because the transformer will saturate.

Soft Start and Quick Shutdown

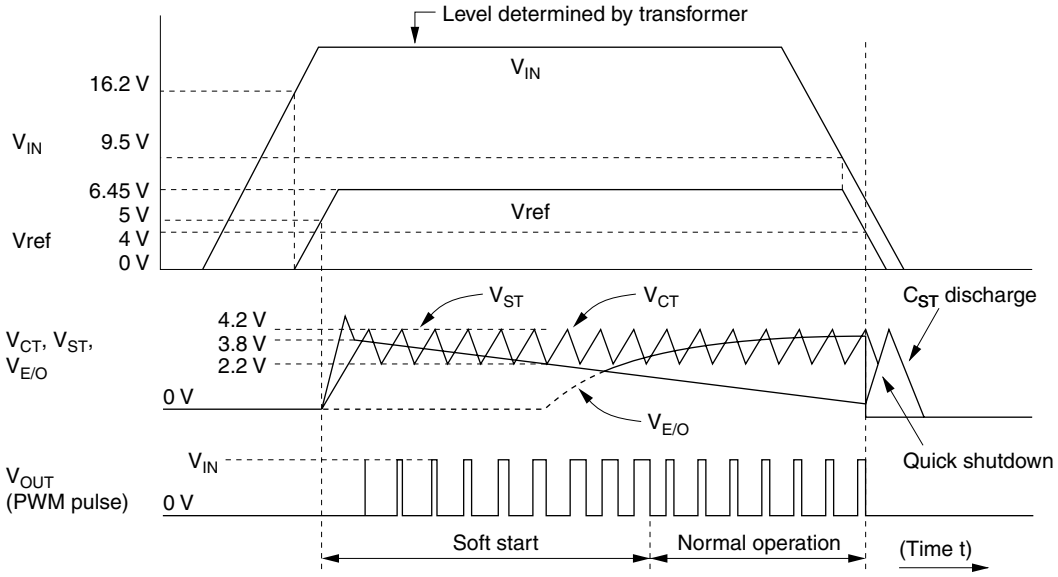
One purpose of the soft-start function is to protect the switching controller and power MOS FET from surges at power-up. Another purpose is to let the secondary-side DC voltage rise smoothly.

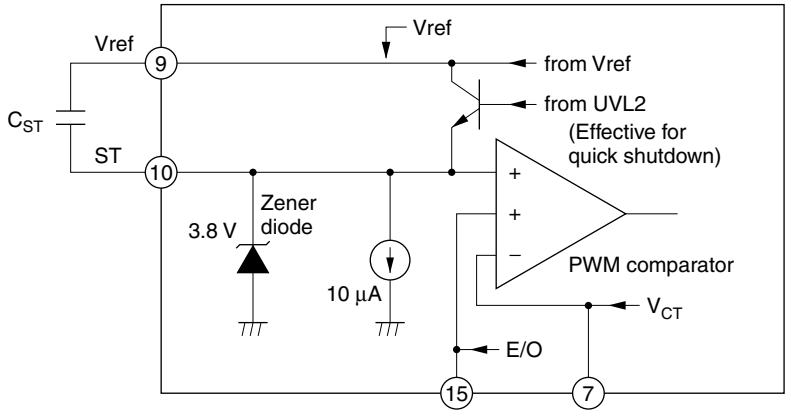
When power goes off, the quick-shutdown function rapidly discharges the capacitor in the soft-start circuit (and at the same time switches the PWM output off) to prepare for the next power-on.

The soft-start function in these ICs lets the PWM output develop smoothly from zero to the designated pulse width at power-up. The soft-start voltage is the 3.8 V voltage value of an internal Zener diode, so the PWM output is able to start widening gradually as soon as the soft-start function starts operating. The soft-start function will start promptly even if C_{ST} is large.

The soft-start and quick-shutdown modes are selected automatically in the IC, under control of the UVL signal.

• Timing waveforms



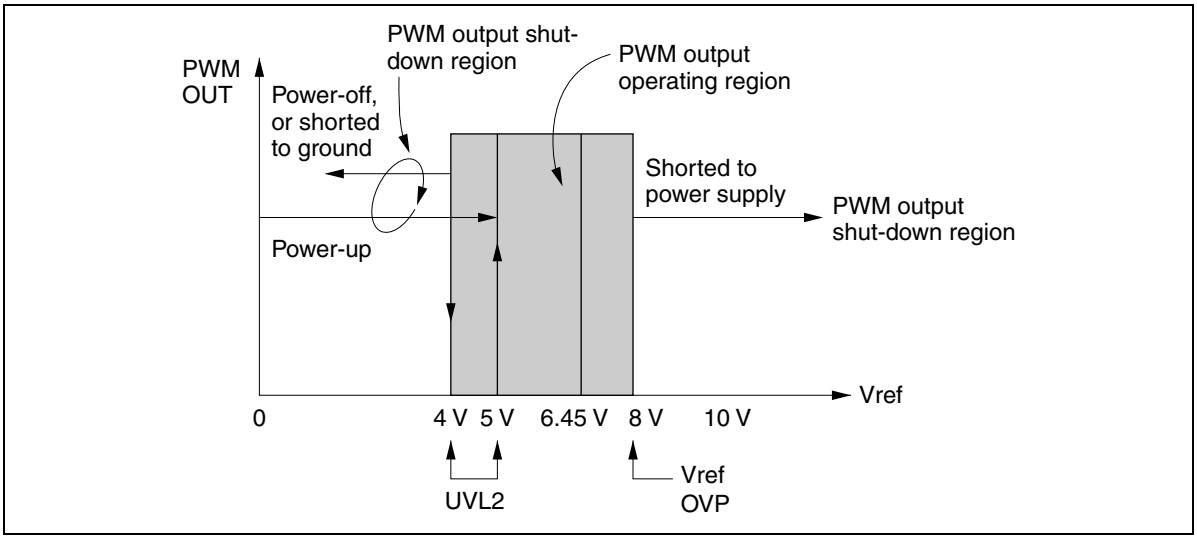


Note: The soft-start time constant is determined by C_{ST} and the constant-current value (typically 10 μA).

Vref Protection Functions: Overvoltage and Undervoltage

Vref overvoltage and undervoltage conditions are detected by the overvoltage detection circuit and UVL2 circuit. PWM output shuts down when Vref ≥ 8 V. UVL2 detects undervoltage with hysteresis between approximately 4 V and 5 V. PWM output also shuts down below these voltages. It follows that PWM output will shut off whenever the Vref pin is shorted to the power supply (V_{IN}) or ground (GND). PWM output also shuts off when V_{IN} is turned on or off.

The following diagram shows how these protection functions operate when power comes on and goes off (Vref < 6.45 V), and when a high external voltage is applied to the Vref pin (Vref > 6.45 V).



1. Current-Limiter Circuit

   The current limiter pin (CL) is connected to the emitter of an npn transistor, as shown in the block diagram. The threshold voltage is 240 mV typ. The switching speed of this circuit is approximately 100 ns from detection of overcurrent to shut-down of PWM output. Switching speed increases with the strength of the signal input to the CL pin.

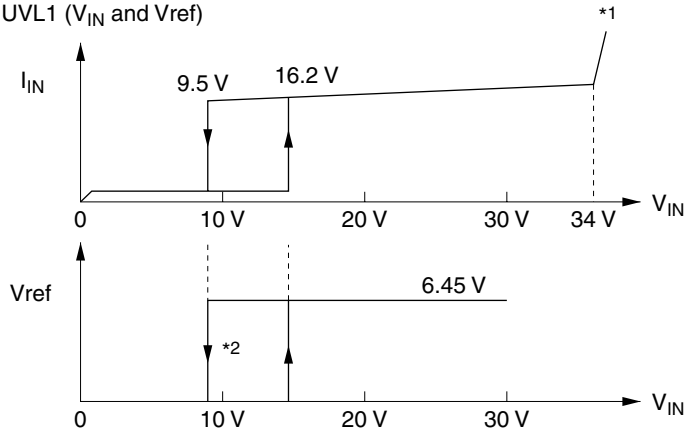
   Instead of simple pulse-by-pulse current limiting, in these ICs the current limiting circuit is linked to the timer-and-latch or ON/OFF timer circuit, and also detects the degree of overcurrent. The overcurrent value is determined from the point at which current limiting is triggered in the ON-duty cycle. With a large overcurrent (causing current limiting to operate even at a small ON-duty), the IC automatically shortens the timer time.

Undervoltage Lockout and PWM Output

The undervoltage lockout function turns off the PWM pulse output when the controller's supply voltage goes below a designated value. These ICs have two undervoltage lockout circuits. The UVL1 circuit senses the supply voltage V_{IN}. The UVL2 circuit senses the Vref voltage. A feature of these ICs is that PWM output is turned on only when both voltages are above designated values. Otherwise, the IC operates in standby mode.

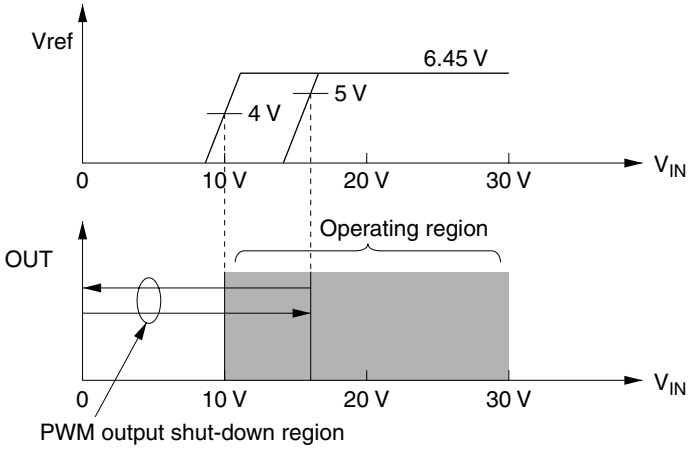
The two built-in undervoltage lockout circuits make it possible to configure an extremely safe power supply system. PWM output will shut down under a variety of abnormal conditions, such as if Vref is shorted to ground while V_{IN} is applied.

• UVL1 (V_{IN} and Vref)



Notes: 1. Breakdown voltage of the internal Zener diode (V_Z = 34 V typ).
2. Hysteresis characteristic.

• UVL2 (Vref and PWM output)



• UVL1 and UVL2

V_{IN} (UVL1)	L	H	H	L
Vref (UVL2)	L	L	H	H
PWM OUT	L	L	OUT	L
Standby mode	◎	◎	—	◎

Note: Double circles indicate standby mode.

Timer Latch and ON/OFF Timer

The HA16107 has a built-in timer-latch function. The HA16108 has a built-in ON/OFF timer function.

The timer-latch function is an overvoltage protection function that combines latched shutdown of PWM output with a timer function to vary the time until latched shutdown occurs according to the overcurrent value. A dedicated voltage detection pin is provided in addition to Vref overvoltage protection.

The ON/OFF timer function is equivalent to the above timer-latch function without the latch. If overcurrent is detected continuously, PWM output shuts down temporarily, then normal operation resumes. This process repeats, temporary shutdown alternating with normal operation.

Both the timer-latch function in the HA16107 and the ON/OFF function in the HA16108 wait for an interval after overcurrent detection before shutting down PWM output. The interval is determined by capacitor C_{TM} and the value of the charge/discharge current supplied internally from the IC. Normal operation therefore continues if a single overcurrent spike is detected, while if continuous overcurrent is detected, the current and voltage droop curves for the secondary-side output have sharp characteristics.

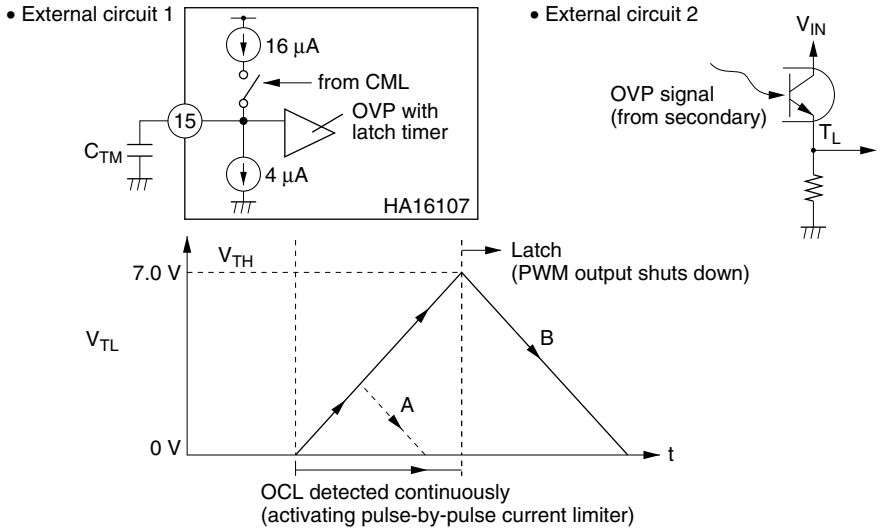
1. Use of Timer-Latch Pin (HA16107)

- Timer-Latch Usage

  See external circuit 1 in the following diagram. Under continuous overcurrent, the CML switch turns on, charging C_{TM} with 12 µA. PWM output shuts down when the voltage at pin 15 exceeds 7 V.

- Overvoltage Protection Usage

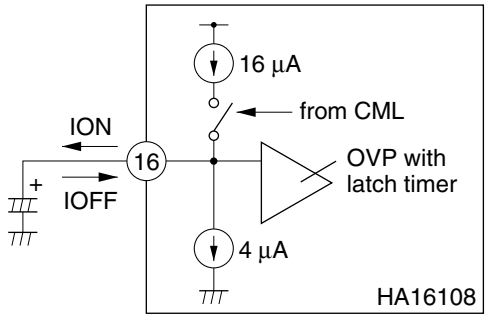
  See external circuit 2 in the diagram. This configuration is suitable when overvoltage is detected by an OVP signal received through an optocoupler from the DC output on the secondary side of an AC/DC converter. PWM output shuts down when the OVP signal allows the voltage at the TL pin to exceed 7 V. The shutdown is latched. V_{IN} must go below approximately 6.5 V (V_{INR2}) to release the latched state.



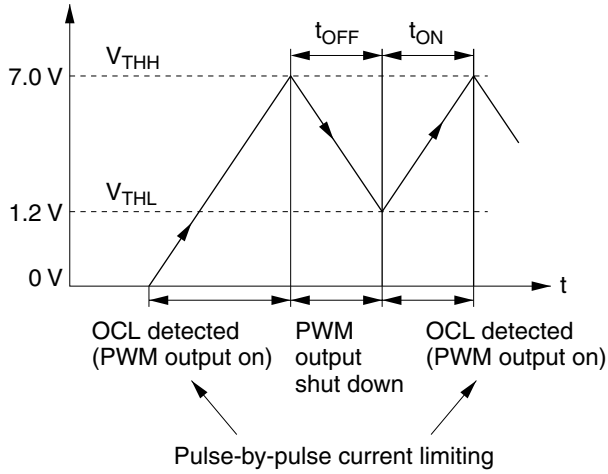
Notes: 1. Path A is followed if the OCL input stops before V_{TH} is reached.
2. Path B is followed if OCL is detected continuously until the latch point is reached.
3. The latch function is cleared when V_{IN} goes below approximately 7.0 V.

2. Use of ON/OFF Timer Pin (HA16108)

- External Circuit



- ON/OFF Timer Operation



$$t_{ON} \approx \frac{C \times 5.8\ V}{(0.9 - Du) \times 16\ \mu A - 4\ \mu A}$$

$$t_{OFF} \approx \frac{C \times 5.8\ V}{4\ \mu A}$$

Notes: 1. C is the capacitance of an external timing capacitor connected between this pin and ground.
2. Du is the ON-duty of the PWM output when overcurrent limiting is triggered.
3. The values of t_{ON} and t_{OFF} for TL can be determined by the same equations as given for the ON/OFF timer, except that 5.8 V ($V_{THH} - V_{THL}$) becomes V_{THH} = 7 V.
4. If the timer goes off during soft start or in the undervoltage lockout region, after recovery, output will come on after the soft-start time or after the rise time to the undervoltage lockout release point, which is determined by the time constant.

Absolute Maximum Ratings

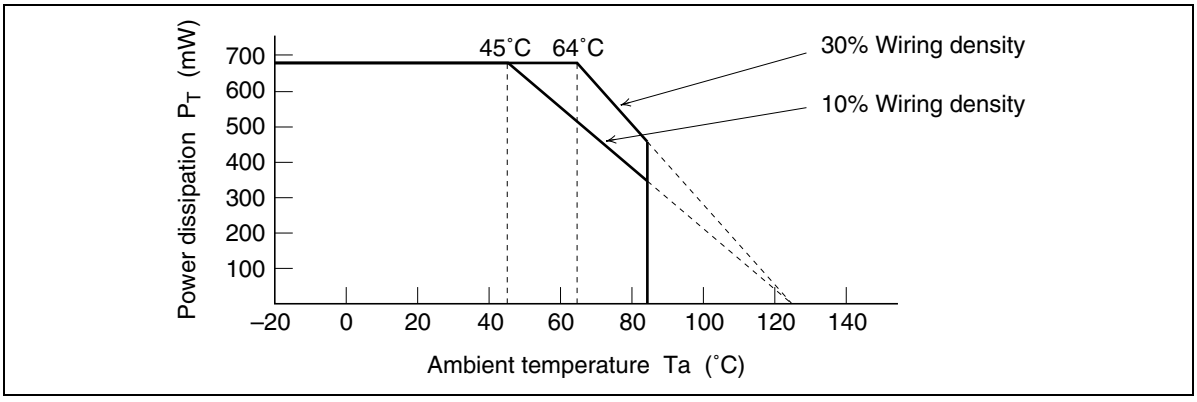
(Ta = 25°C)

Item	Symbol	Rating Value	Units	Notes
Supply voltage	V_{IN}	30	V	
Output current (DC)	I_O	±0.2	A	
Output current (peak)	Iopeak	±2	A	
Current limiter voltage	V_{CL}	+4, –1	V	
Error amp input voltage	V_{IEA}	Vref	V	
E/O output voltage	$V_{IE/O}$	Vref	V	
R_{T1} pin current	I_{RT1}	500	µA	
R_{T2} pin current	I_{RT2}	5	mA	
Power dissipation	P_T	680	mW	1, 2
Operating temperature range	Topr	–20 to +85	°C	
Storage temperature range	Tstg	–55 to +125	°C	

Notes: 1. For the “FP” products (SOP package), this value is when mounted on a 40 by 40 by 1.6 mm glass epoxy substrate. However, this value must be derated by 8.3 mW/°C from Ta = 45°C. When the wiring density is 10%, and 11.1 mW/°C from Ta = 64°C when the wiring density is 30%.

2. For the “P” products (DIP package), this value is valid up to 45°C, and must be derated by 8.3 mW/°C above 45°C.

3. In the case of SOP, use center 4 pins, (4), (5), (12), (13) for solder-mounting and connect the wide ground pattern, because these pins are available for heat sink of this IC.



Electrical Characteristics

(Ta = 25°C, V_{IN} = 18 V, f_{OSC} = 100 kHz)

Section	Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Note
Reference voltage	Output voltage	Vref	6.10	6.45	6.80	V		
	Line regulation	Line	—	30	60	mV	12 V ≤ V_{IN} ≤ 30 V	
	Load regulation	Load	—	30	60	mV	0 mA ≤ I_O ≤ 10 mA	
	Temperature stability	ΔVref/ ΔTa	—	40	—	ppm/ °C		
	Short circuit current	I_{OS}	30	50	—	mA	Vref = 0 V	
	Over voltage protection (Vref OVP voltage)	Vrovp	7.4	8.0	9.0	V		
Triangle wave generator	Maximum frequency	fmax	600	—	—	kHz		
	Minimum frequency	fmin	—	—	1	kHz		
	Voltage stability	$\Delta f/fo_1$	—	±1	±3	%	12 V ≤ V_{IN} ≤ 30 V fo_1 = (fmax + fmin)/2	
	Temperature stability	$\Delta f/fo_2$	—	±1	—	%	–20°C ≤ Ta ≤ +85°C fo_2 = (fmax + fmin)/2	
	Frequency accuracy	f_{OSC}	270	300	330	kHz	R_{T1} = R_{T2} = 27 kΩ C_T = 120 pF	
PWM comparator	Minimum deadband pulse width	t_{DB}	—	—	1.0	µs		
	Low level threshold voltage	V_{TL}	1.9	2.2	2.5	V		
	High level threshold	V_{TH}	3.8	4.2	4.6	V		
	Differential threshold	ΔV_{TH}	1.7	2.0	2.3	V		
	Deadband width initial accuracy	ΔDB1	—	±1	±3	%	R_{T1} = R_{T2} = 27 kΩ C_T = 470 pF	
	Deadband width voltage stability	ΔDB2	—	±0.2	±2.0	%	12 V ≤ V_{IN} ≤ 30 V (Dmax – Dmin)/2	
	Deadband width temperature stability	ΔDB3	—	±1	—	%	–20°C ≤ Ta ≤ +85°C (Dmax – Dmin)/2	
Error amp	Input offset voltage	V_{IO}	—	2	10	mV		
	Input bias current	I_{IB}	—	0.8	2.0	µA		
	Input sink current	Iosink	80	140	—	µA	V_O = 2 V	
	Output source current	Iosource	80	140	—	µA	V_O = 5 V	

Electrical Characteristics (cont.)

(Ta = 25°C, V_{IN} = 18 V, f_{OSC} = 100 kHz)

Section	Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Note
Error amp (cont.)	High level output voltage	V_{OH}	Vref – 1.5	—	—	V	I_O = 10 µA	
	Low level output voltage	V_{OL}	—	—	0.5	V	I_O = 10 µA	
	Voltage gain	G_V	—	55	—	dB	f = 10 kHz	
	Band width	BW	—	15	—	MHz		
	(–) Common mode voltage	V_{CM}–	1.2	—	—	V		
	(+) Common mode voltage	V_{CM}+	—	—	Vref – 1.5	V		
Over-current detector	(+) Threshold voltage	V_{TH}+	0.216	0.240	0.264	V		
	(+) Bias current	I_B+	—	180	250	µA	V_{CL}+ = 0 V	
	(–) Threshold voltage	V_{TH}–	–0.264	–0.240	–0.216	V		1, 2
	(–) Bias current	I_B–	—	950	1350	µA	V_{CL} = –0.3 V	1, 2
	Response time	t_{off}	—	100	—	ns	CL; open V_{CL} = +0.35 V	
Soft start	High level voltage	V_{STH}	3.2	3.8	4.4	V	Isink = 1 mA	
	Sink current	Isink	7	10	13	µA	V_{ST} = 2.0 V	
Under voltage lockout 1	V_{IN} high level threshold voltage	V_{INTH}	14.7	16.2	17.7	V		
	V_{IN} low level threshold voltage	V_{INTL}	8.5	9.5	10.5	V		
	Threshold differential voltage	ΔV_{TH}	5.2	6.2	7.2	V	(V_{INTH} – V_{INTL})	
Under voltage lockout 2	Vref high level threshold voltage	V_{rTH}	4.5	5.0	5.5	V		
	Vref low level threshold voltage	V_{rTL}	3.5	4.0	4.5	V		

Notes: 1. Only applies to the HA16107P, HA16108P
2. The terminal should not be applied under –1.0 V.

Electrical Characteristics (cont.)

(Ta = 25°C, V_{IN} = 18 V, f_{OSC} = 100 kHz)

Section	Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Note
Timer latch, ON/OFF timer*2	Latch threshold voltage	V_{THH}	6.5	7.0	7.5	V		
	V_{IN} reset voltage	V_{INR2}	6.0	6.5	7.0	V		
	Reset voltage	V_{THL2}	1.0	1.3	1.6	V		1
	Differential threshold to UVL low voltage	ΔV	2.0	3.0	—	V	(V_{INTL} – V_{INR2})	
	Source current (OCL mode)	Isource	8	12	16	µA	Over current detection mode	
	Sink current (latch mode)	Isink	2.5	4	5.5	µA	TL(ON/OFF) terminal = 4 V	
Output	Low voltage	V_{OL1}	—	1.7	2.2	V	Iosink = 0.2 A	
	High voltage	V_{OH}	V_{IN} – 2.2	—	—	V	Iosource = 0.2 A	
	Low voltage (standby mode)	V_{OL2}	—	—	0.5	V	Iosink = 1 mA	
	Rising time	t_r	—	40	—	ns	C_L = 1000 pF	
	Falling time	t_f	—	60	—	ns	C_L = 1000 pF	
Total	Standby current	Ist	—	160	250	µA	V_{IN} = 14 V	
	Operation current	I_{IN1}	—	16	20	mA	V_{IN} = 30 V, C_L = 1000 pF, f = 100 kHz	
	Operation current	I_{IN2}	—	12	16	mA	V_{IN} = 30 V, f = 100 kHz, Output open	
	ON/OFF latch current	I_{IN3}	—	350	460	µA	V_{IN} = 14 V	
	V_{IN} – GND Zener voltage	V_Z	30	34	—	V		

Notes: 1. Only applies to the HA16108P/FP.
2. Timer latch: HA16107P/FP.
ON/OFF timer: HA16108P/FP.

Note on Standby Current

In the test circuit shown in figure 1, the operating current at the start of PWM pulse output is the standby current.

If the resistance connected externally to the Vref pin (including R_{T2}) is smaller than that of the test circuit, the apparent standby current will increase.

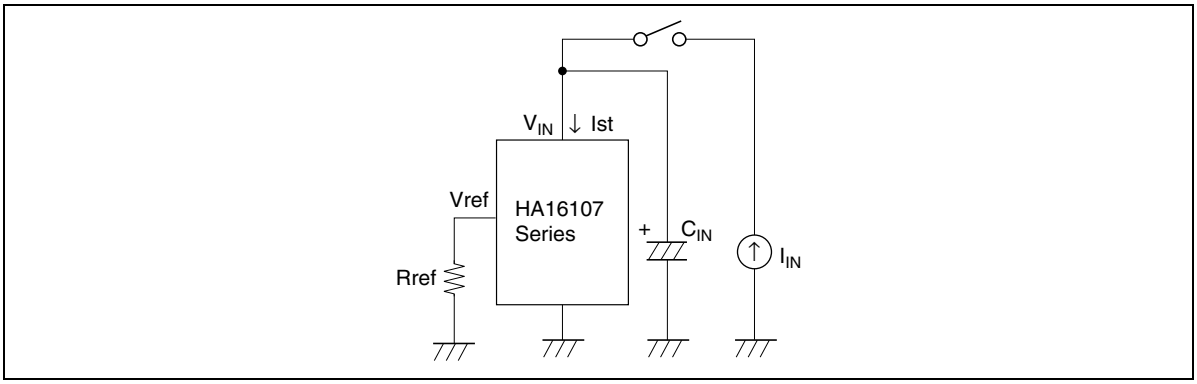


Figure 1 Standby Current Test Circuit

Application Note

- Case:

  When DC power is applied directly as the power supply of the HA16107/HA16108, without using the transformer backup coil.
- Phenomenon:

  The IC may not be activated in the case of a circuit in which V_{IN} rises quickly (10 V/100 µs or faster), such as that shown in figure 2.
- Reason:

  Because of the IC circuit configuration, the timer latch block operates first.
- Remedy (counter measure):

  Take remedial action such as configuring a time constant circuit as shown in figure 3, to keep the V_{IN} rise speed below 10 V/100 µs.

If the IC power supply consists of an activation resistance and backup coil, as in an AC/DC converter, The V_{IN} rise speed is usually around 1 V/100 µs, and there is no risk of this phenomenon occurring.

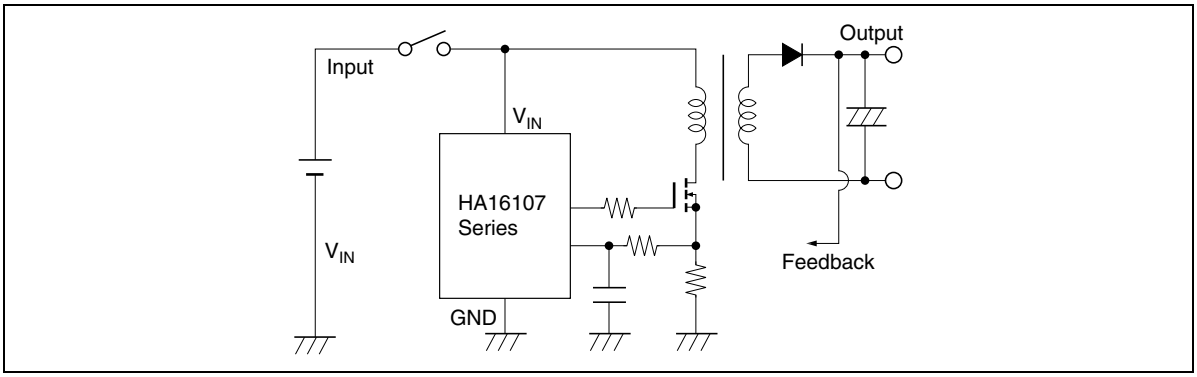


Figure 2 Example of Circuit with Fast V_{IN} Rise Time

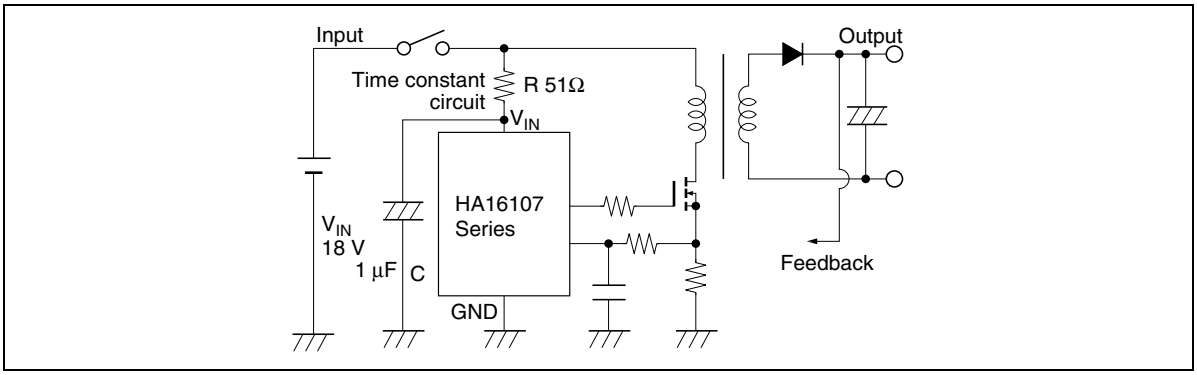
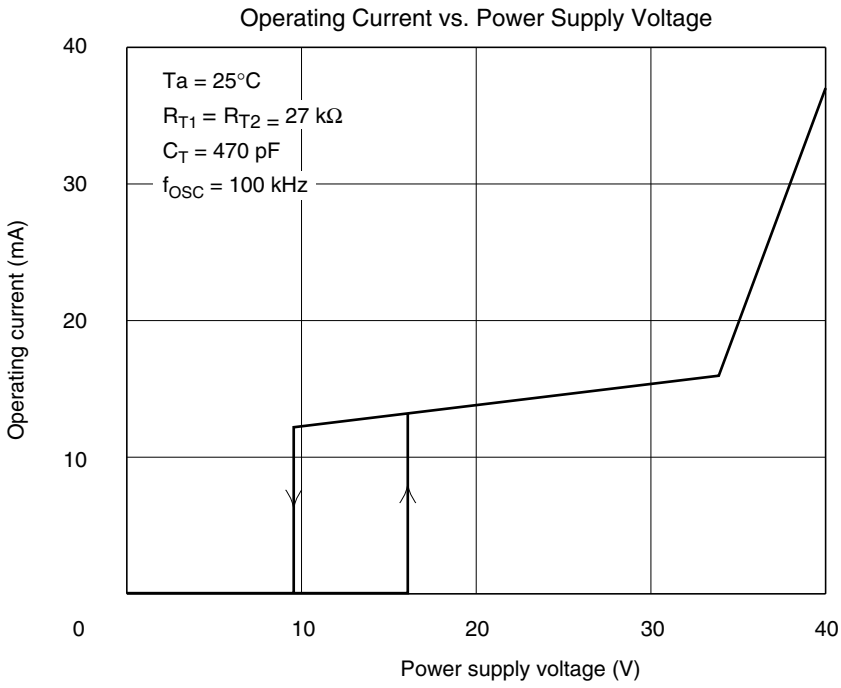
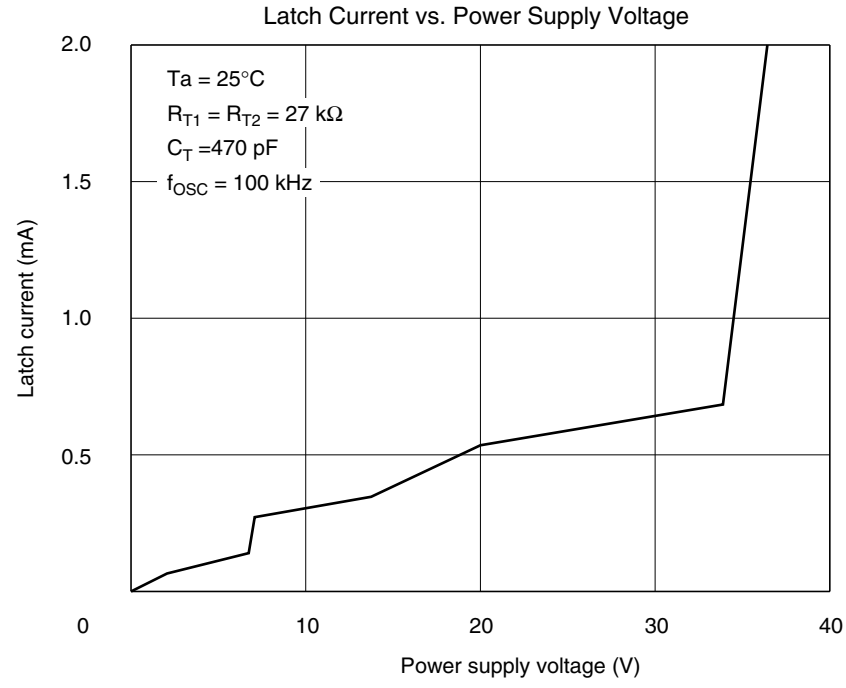


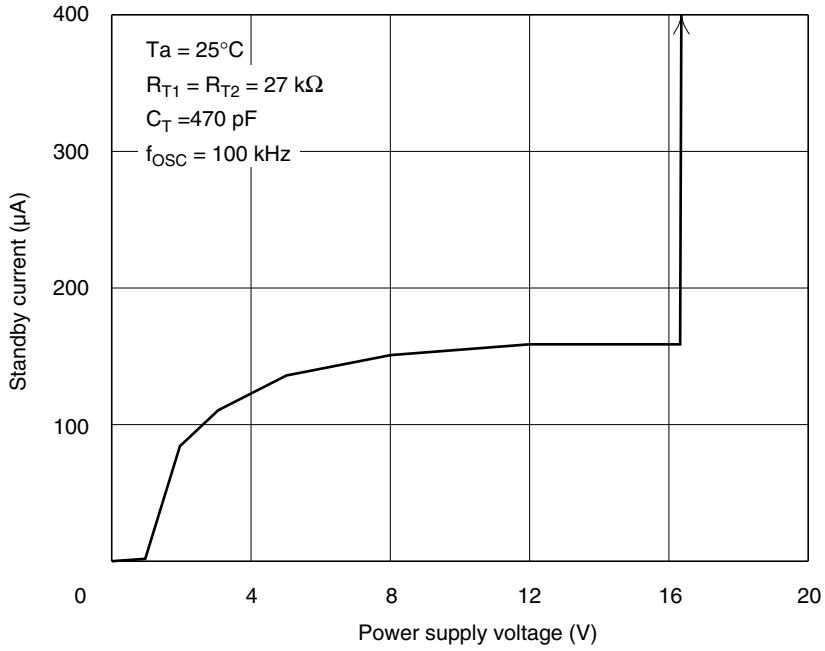
Figure 3 Sample Remedial Circuit

Characteristic Curves

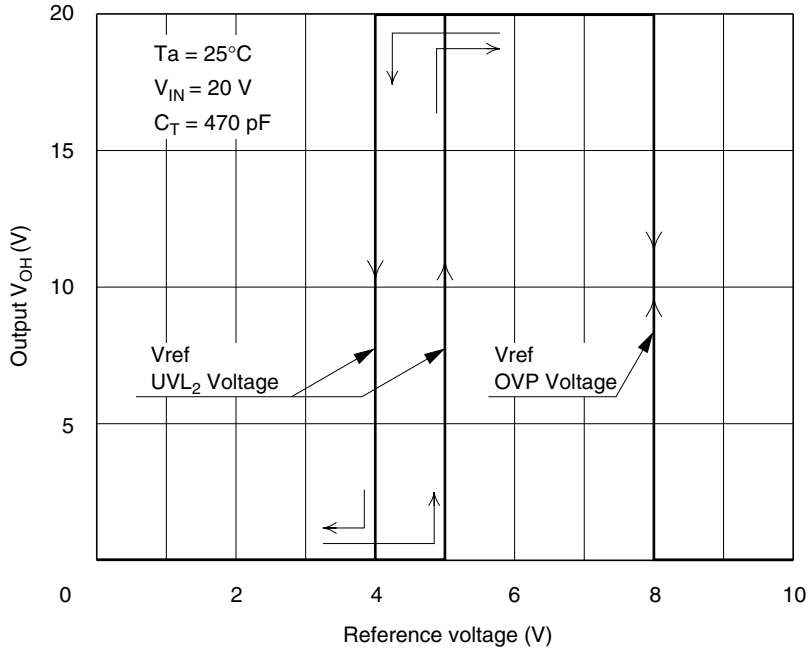


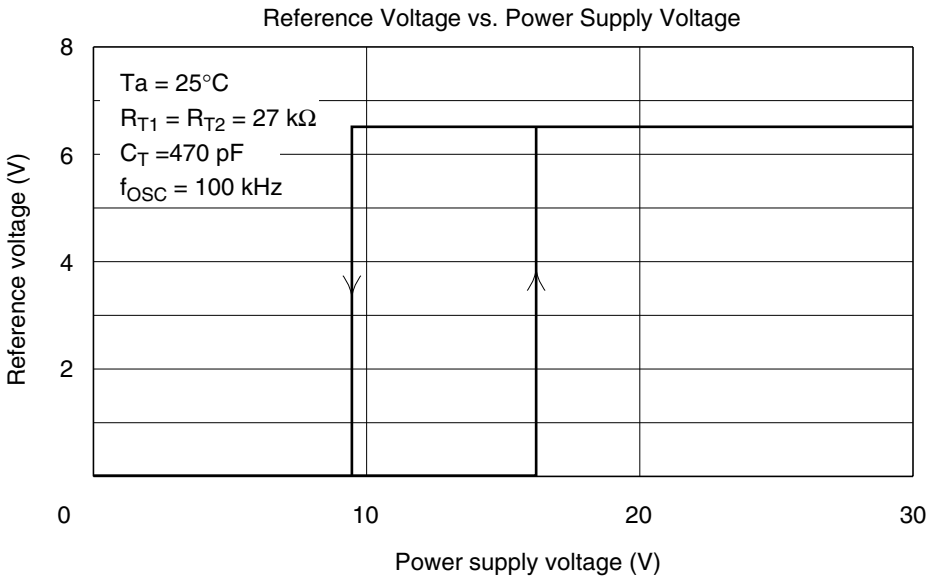


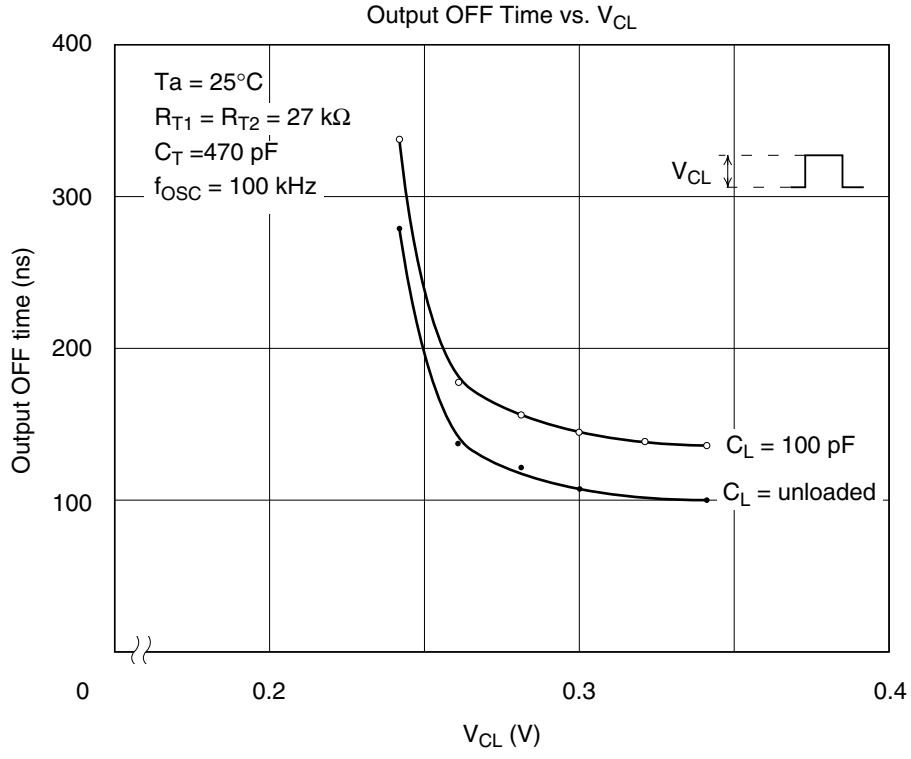
Standby Current vs. Power Supply Voltage

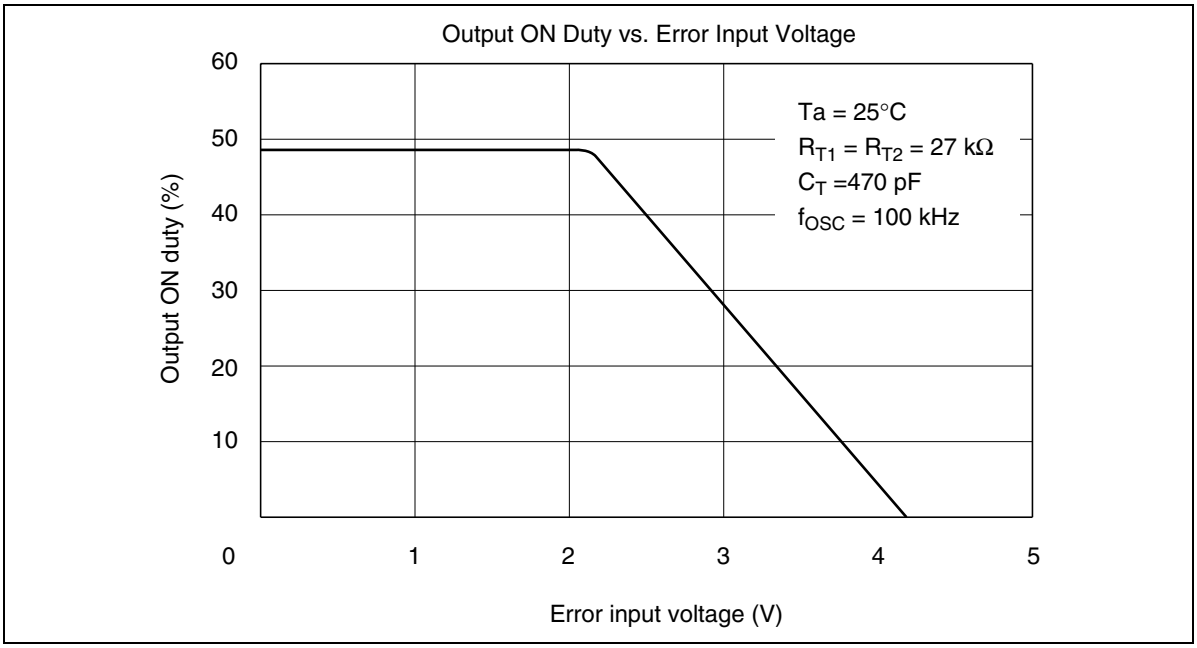


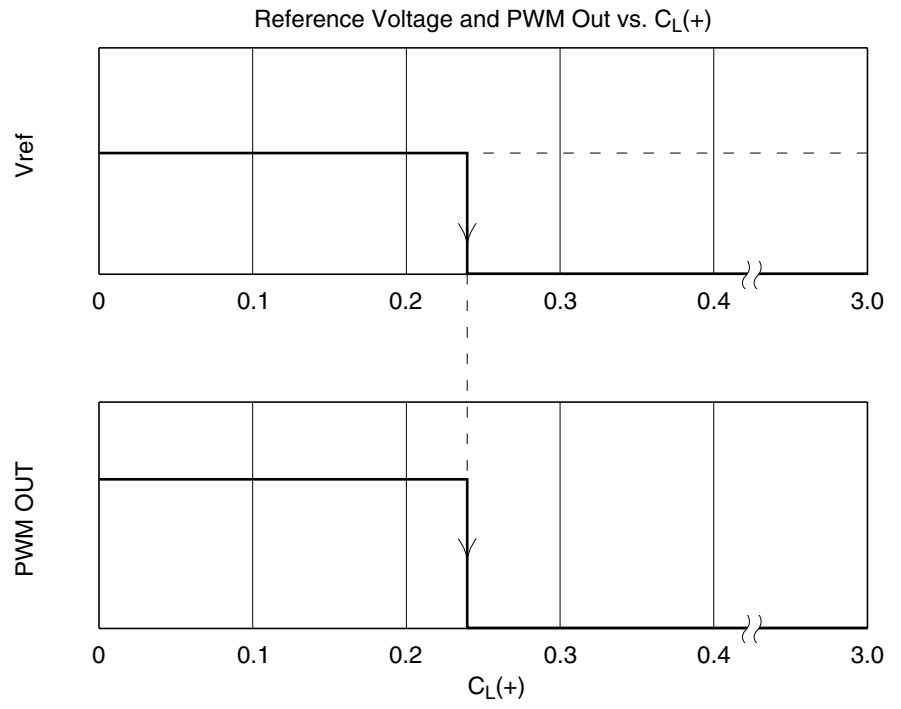
Output V_{OH} vs. Reference Voltage

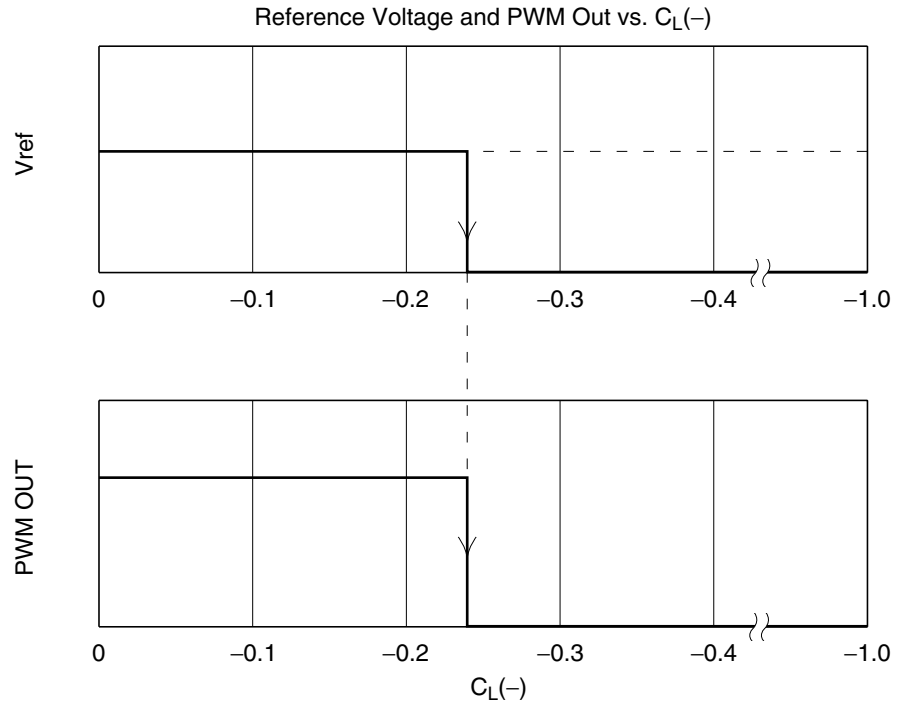



Reference Voltage vs. Power Supply Voltage
Ta = 25°C
R_{T1} = R_{T2} = 27 kΩ
C_T =470 pF
f_{OSC} = 100 kHz
Reference voltage (V)
8
6
4
2
0
10
20
30
Power supply voltage (V)

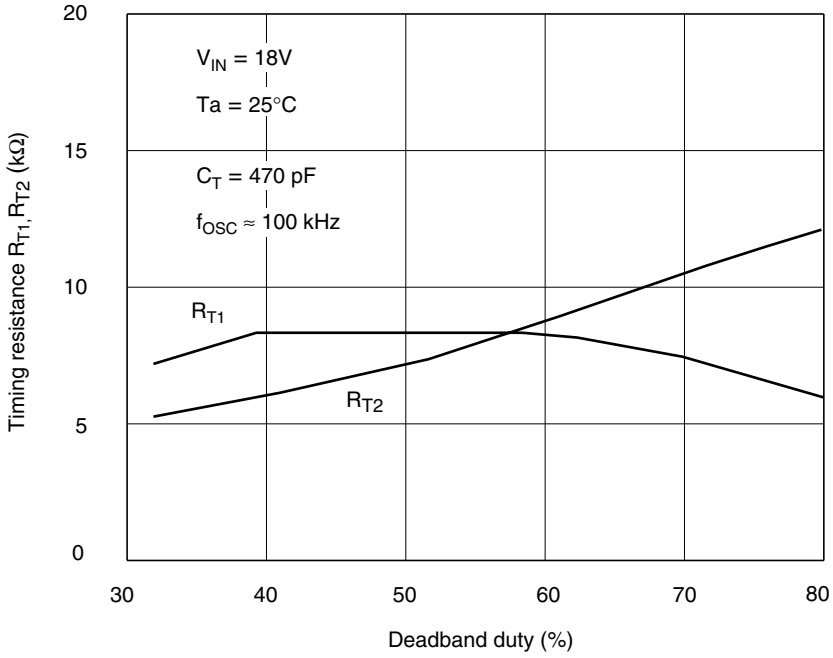

Output OFF Time vs. V_{CL}
Ta = 25°C
R_{T1} = R_{T2} = 27 kΩ
C_T =470 pF
f_{OSC} = 100 kHz
V_{CL}
C_L = 100 pF
C_L = unloaded
Output OFF time (ns)
400
300
200
100
0
0.2
0.3
0.4
V_{CL} (V)


Output ON Duty vs. Error Input Voltage
Output ON duty (%)
60
50
40
30
20
10
0
1
2
3
4
5
Error input voltage (V)
Ta = 25°C
R_{T1} = R_{T2} = 27 kΩ
C_T =470 pF
f_{OSC} = 100 kHz

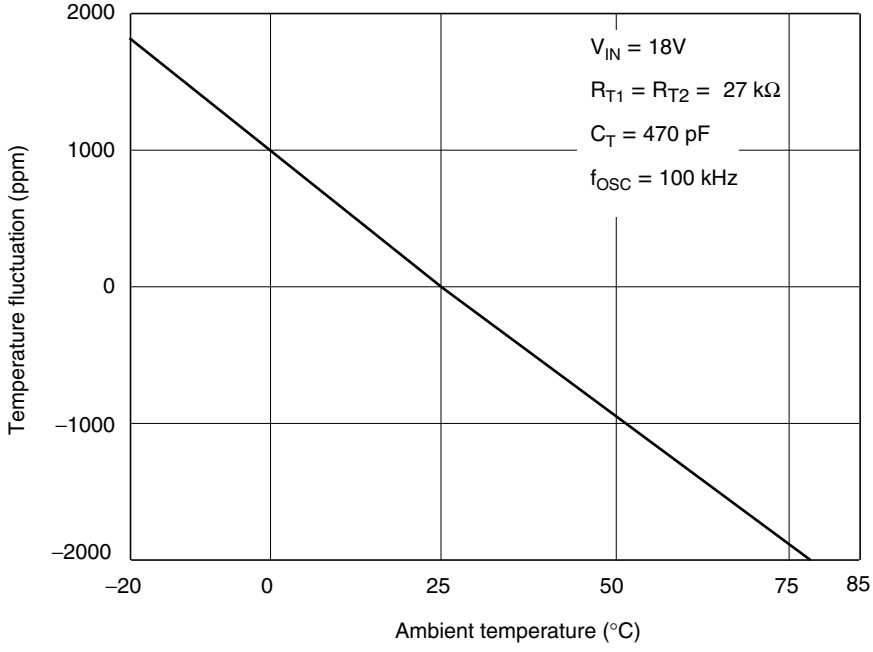

Reference Voltage and PWM Out vs. C_L(+)
Vref
0
0.1
0.2
0.3
0.4
3.0
PWM OUT
0
0.1
0.2
0.3
0.4
3.0
C_L(+)


Reference Voltage and PWM Out vs. C_L(–)
Vref
0
–0.1
–0.2
–0.3
–0.4
–1.0
PWM OUT
0
–0.1
–0.2
–0.3
–0.4
–1.0
C_L(–)

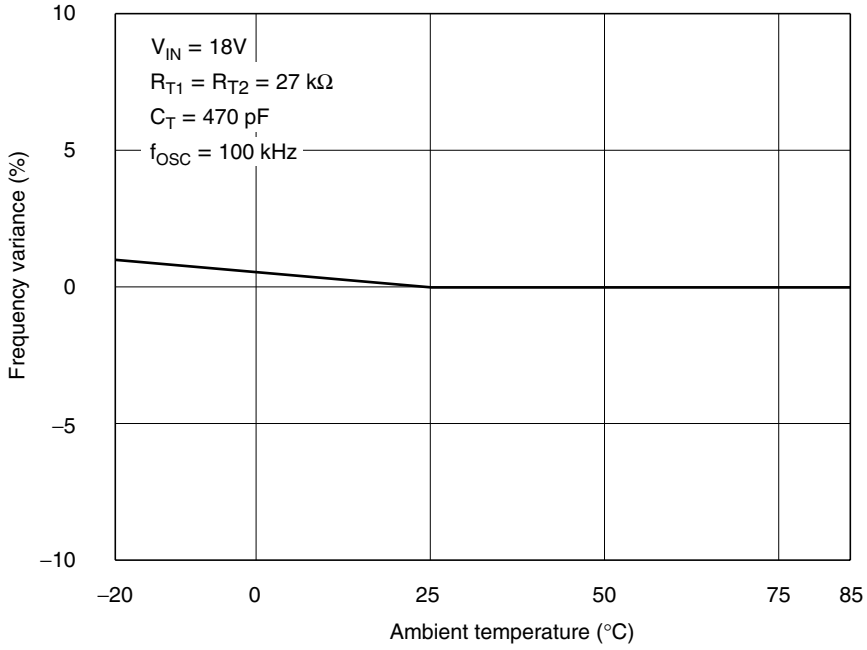
Timing Resistance vs. Deadband Duty



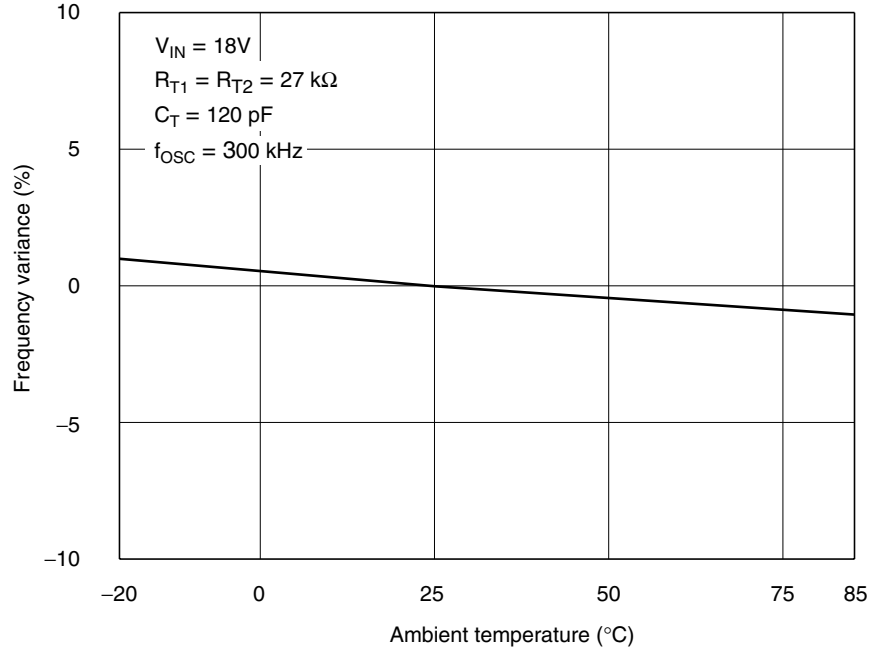
Temperature Fluctuation vs. Ambient Temperature



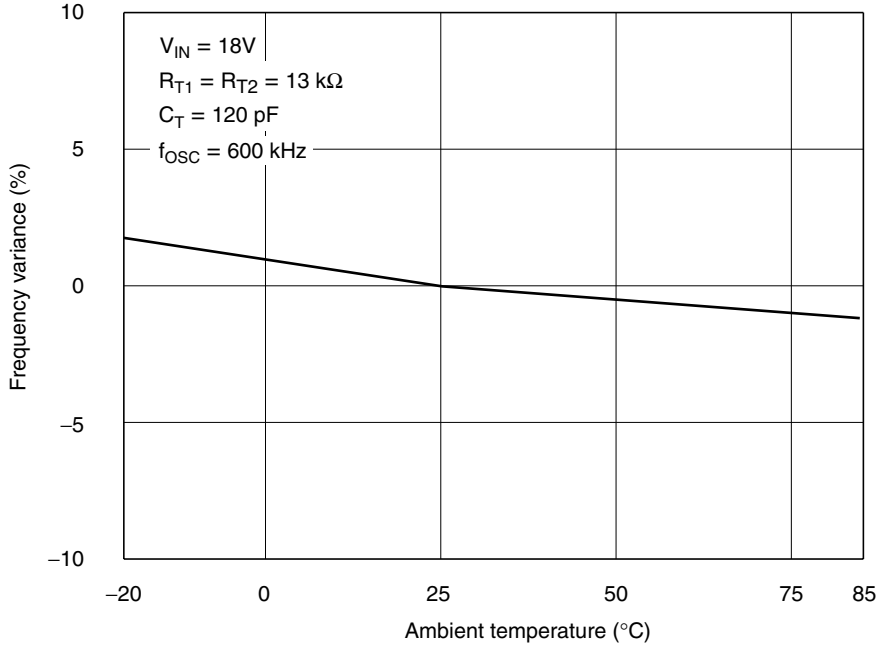
Frequency Variance vs. Ambient Temperature



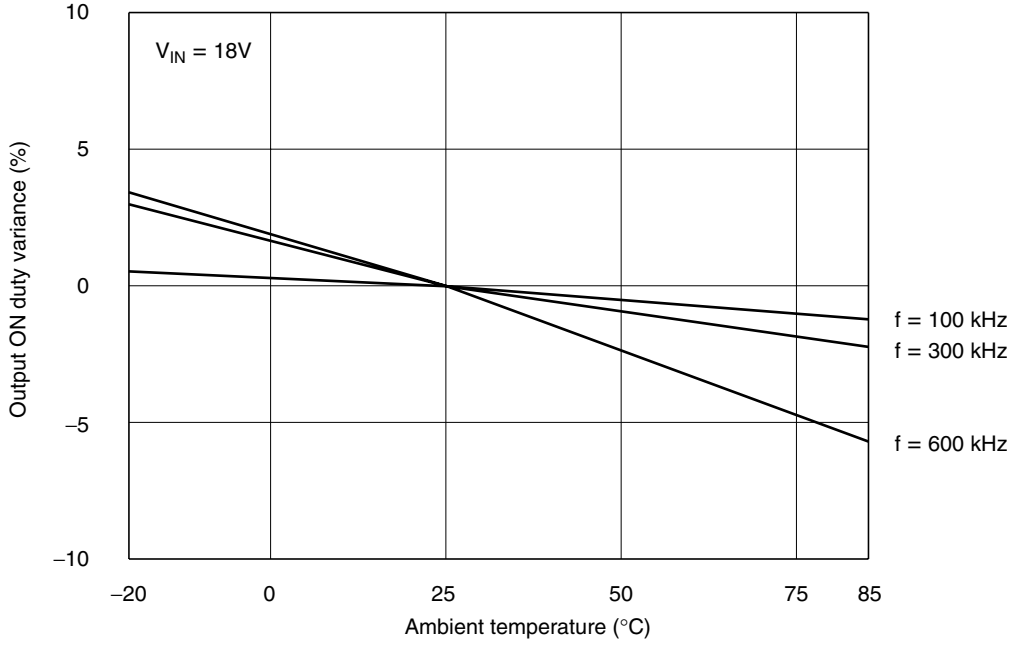
Frequency Variance vs. Ambient Temperature

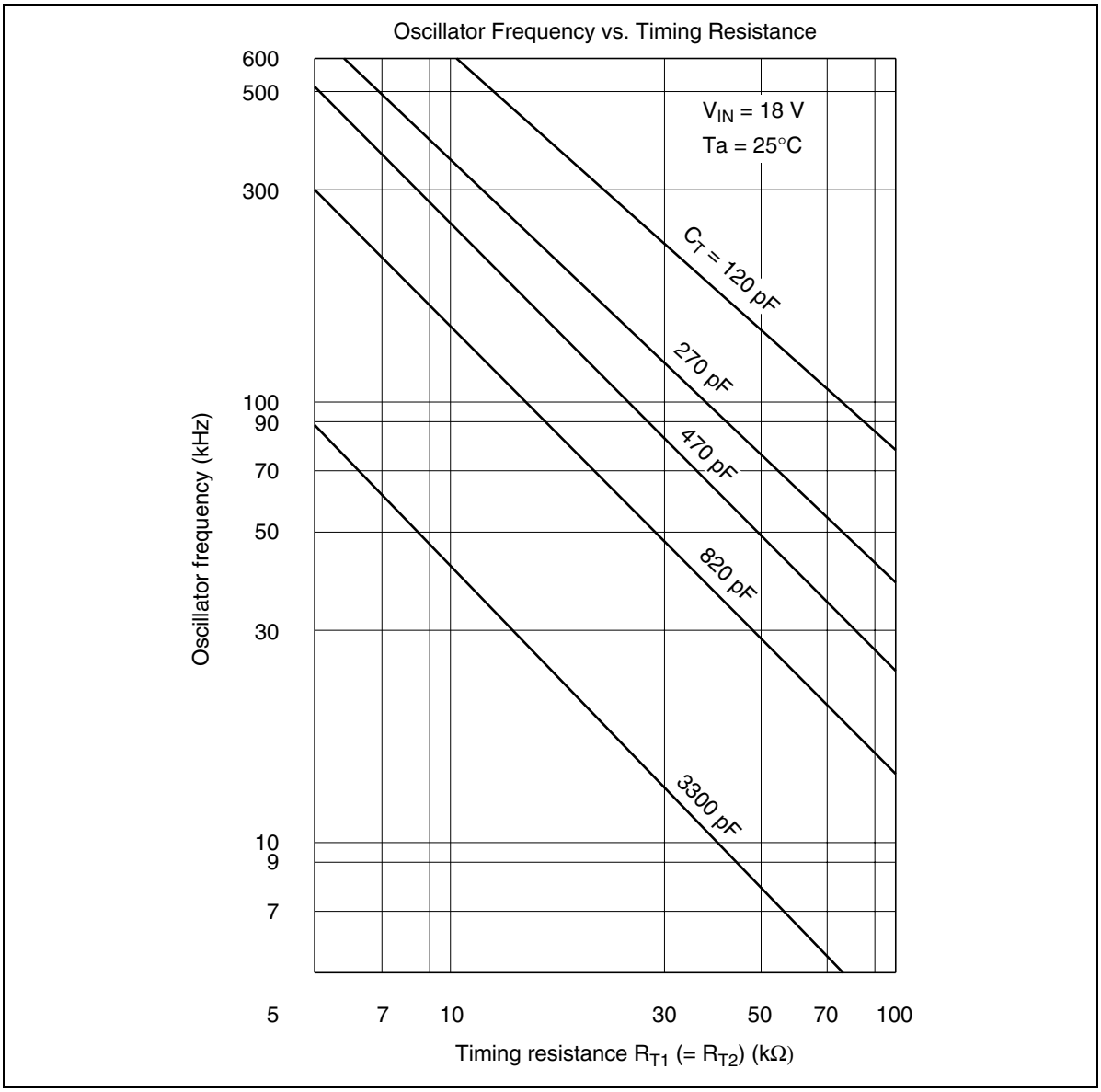


Frequency Variance vs. Ambient Temperature

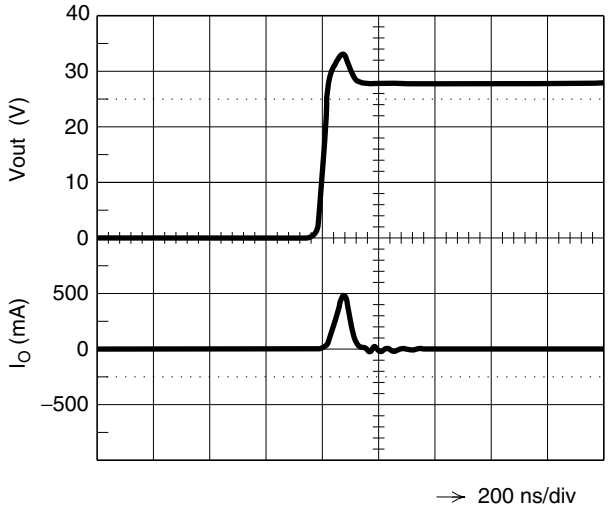


Output ON Duty Variance vs. Ambient Temperature



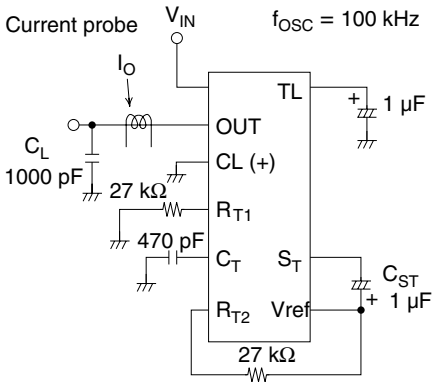

Oscillator Frequency vs. Timing Resistance
V_{IN} = 18 V
Ta = 25°C
C_T = 120 pF
270 pF
470 pF
820 pF
3300 pF
Oscillator frequency (kHz)
600
500
300
100
90
70
50
30
10
9
7
5
7
10
30
50
70
100
Timing resistance R_{T1} (= R_{T2}) (kΩ)

Vout Output Rising Waveform



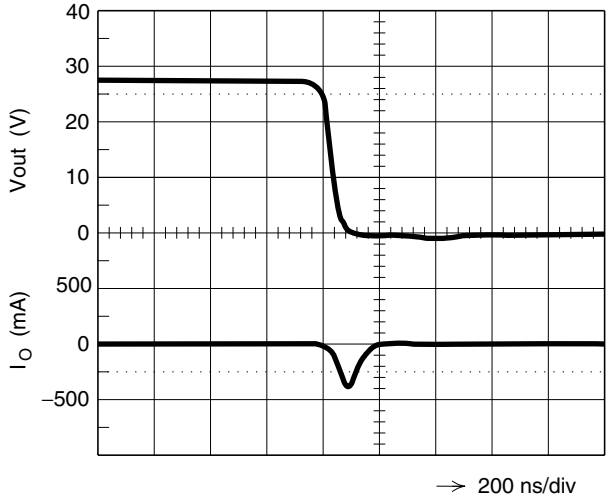
Test circuit

Ta = 25°C
$R_{T1} = R_{T2} = 27\ k\Omega$
$C_T = 470\ pF$
$f_{OSC} = 100\ kHz$



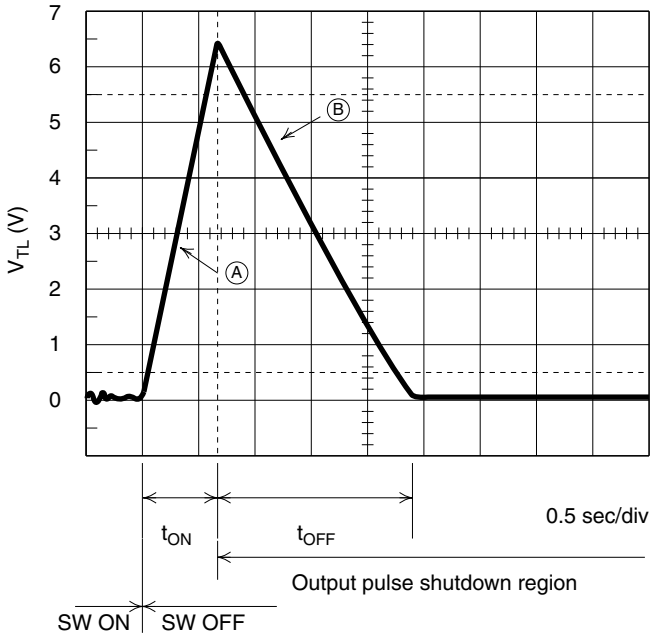
* Current probe: Tektronix AM503

Vout Output Falling Waveform

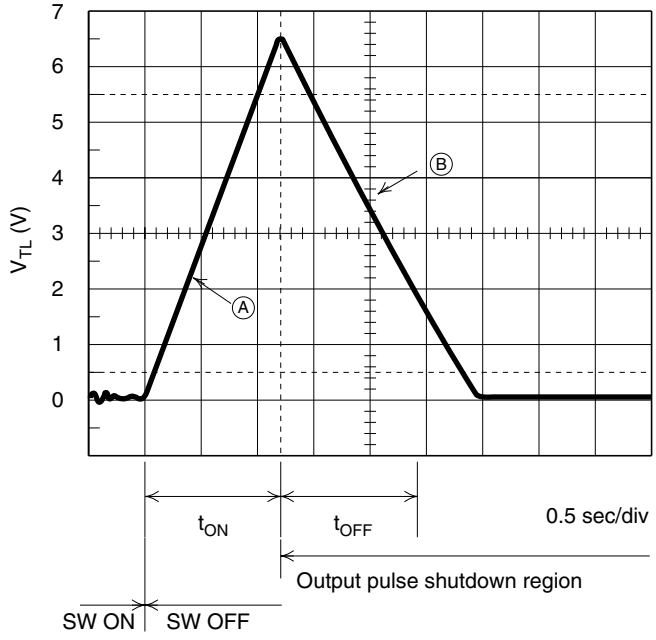


Operating waveform at the TL pin

When overcurrent is input at the point where the duty cycle is 0%.



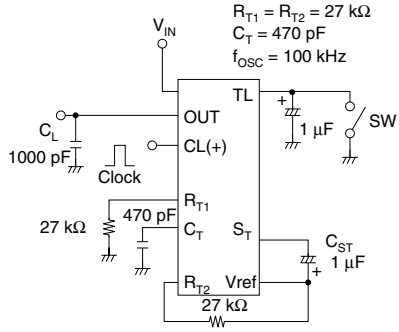
When overcurrent is input at the point where the duty cycle is 30%.

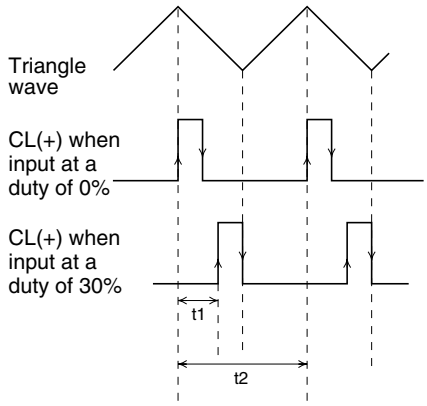


HA16107

Test circuit

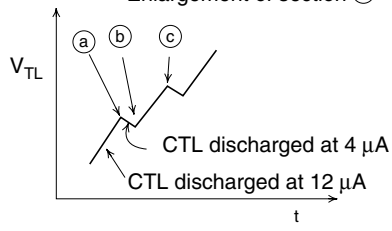
V_{IN} = 18V
$R_{T1} = R_{T2}$ = 27 kΩ
C_T = 470 pF
f_{OSC} = 100 kHz



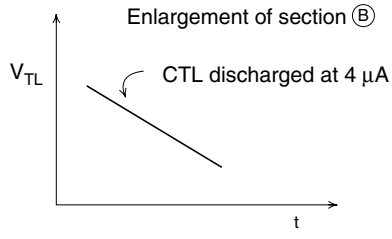


$$Du = \frac{t1}{t2} \times 100\ (\%)$$

Enlargement of section Ⓐ



Enlargement of section Ⓑ



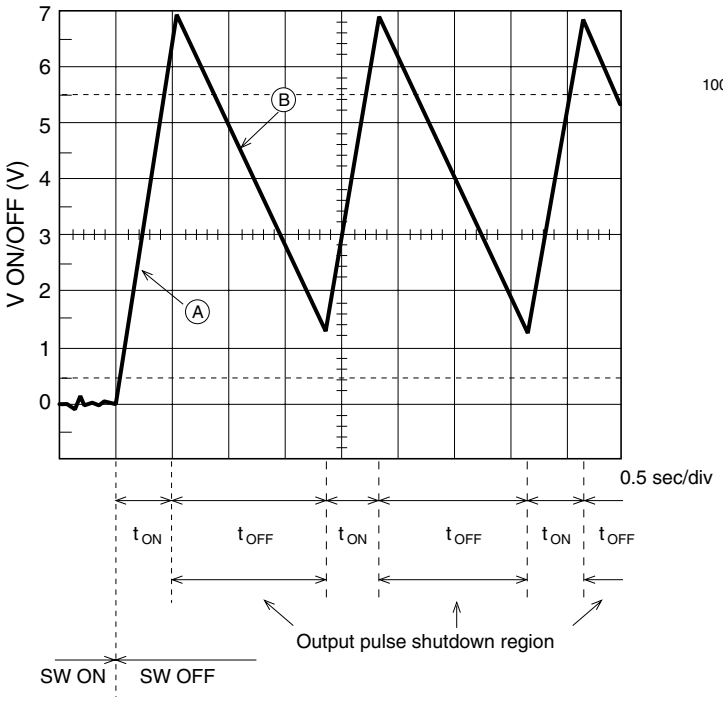
ⓐ to ⓑ : PWM pulse output is High

ⓑ : The point where overcurrent is detected

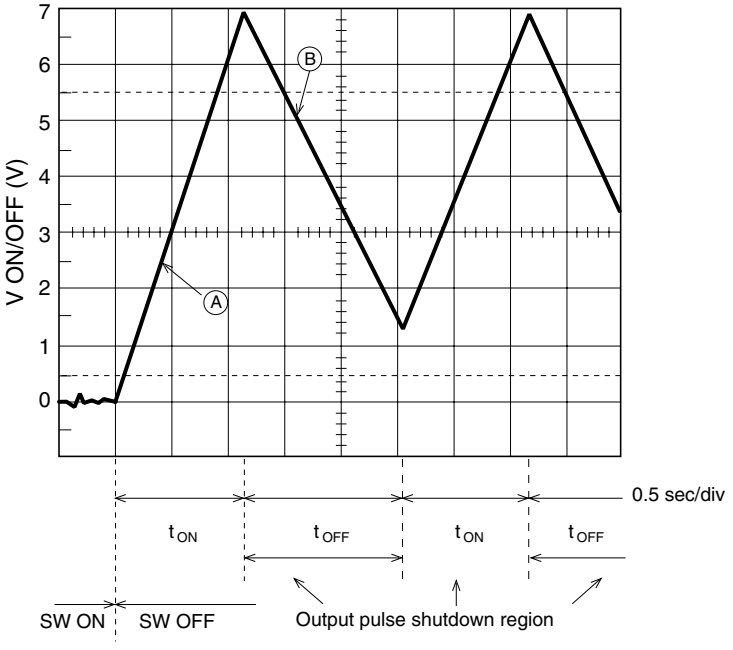
ⓑ to ⓒ : PWM pulse output is Low.

Operating waveform at the ON/OFF pin

When overcurrent is input at the point where the duty cycle is 0%.



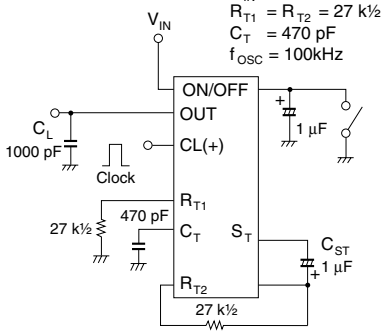
When overcurrent is input at the point where the duty cycle is 30%.

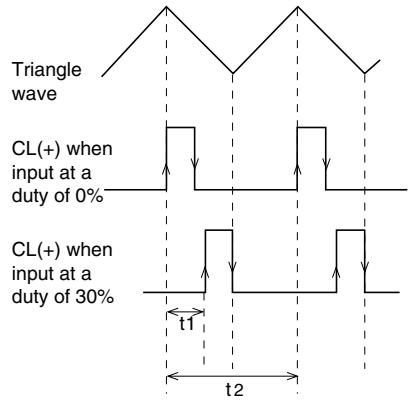


HA16108

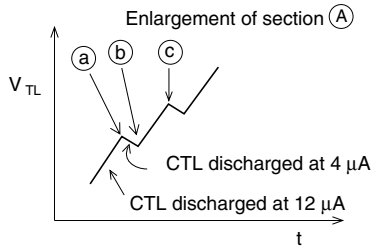
Test circuit

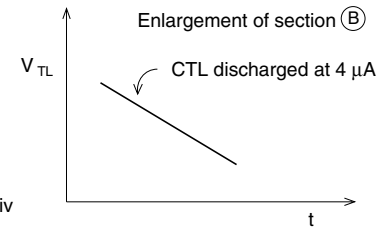
V_{IN} = 18V
R_{T1} = R_{T2} = 27 kΩ
C_T = 470 pF
f_{OSC} = 100kHz





$$Du = \frac{t1}{t2} \times 100\ (\%)$$



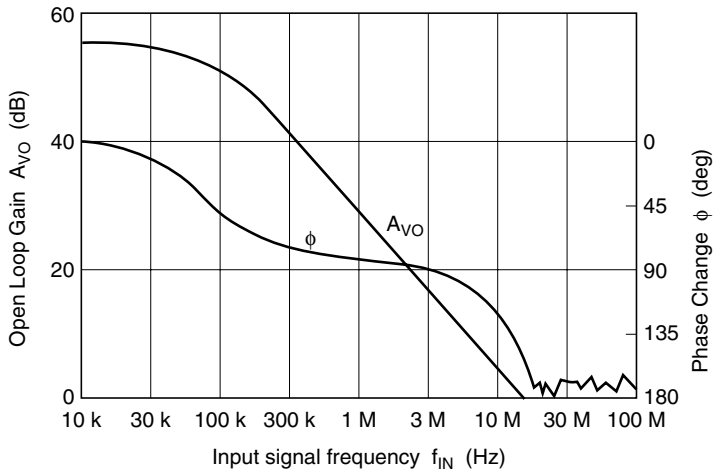


(a) to (b): PWM pulse output is High.

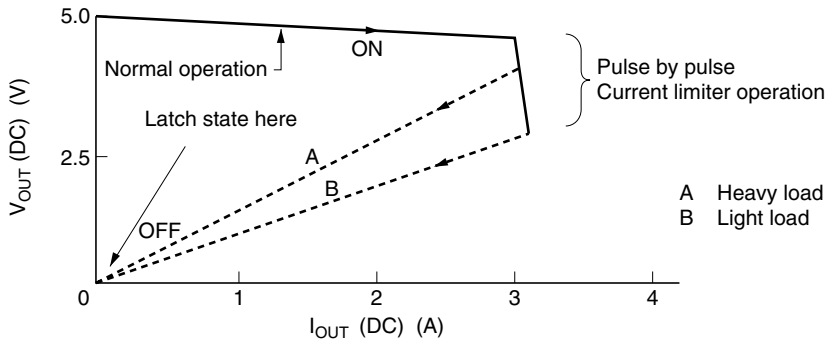
(b) : The point where overcurrent is detected.

(b) to (c): PWM pulse output is Low.

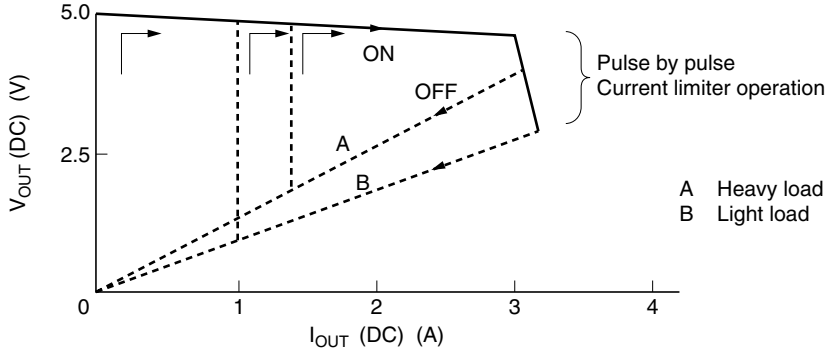
Error Amplifier Characteristic



Examples of Drooping Characteristics of Power Supplies Using these ICs

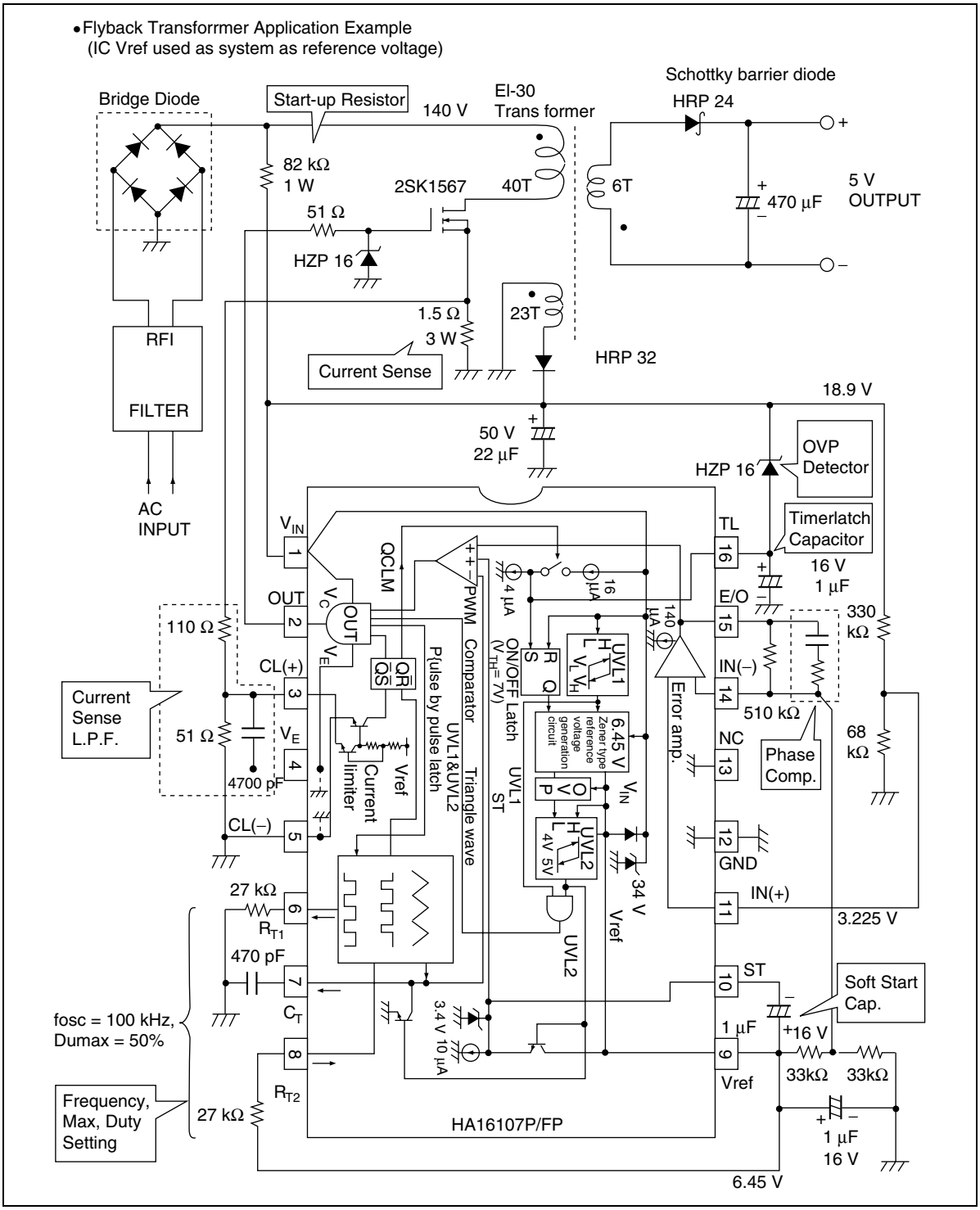


HA16107 (Latch shut-down)

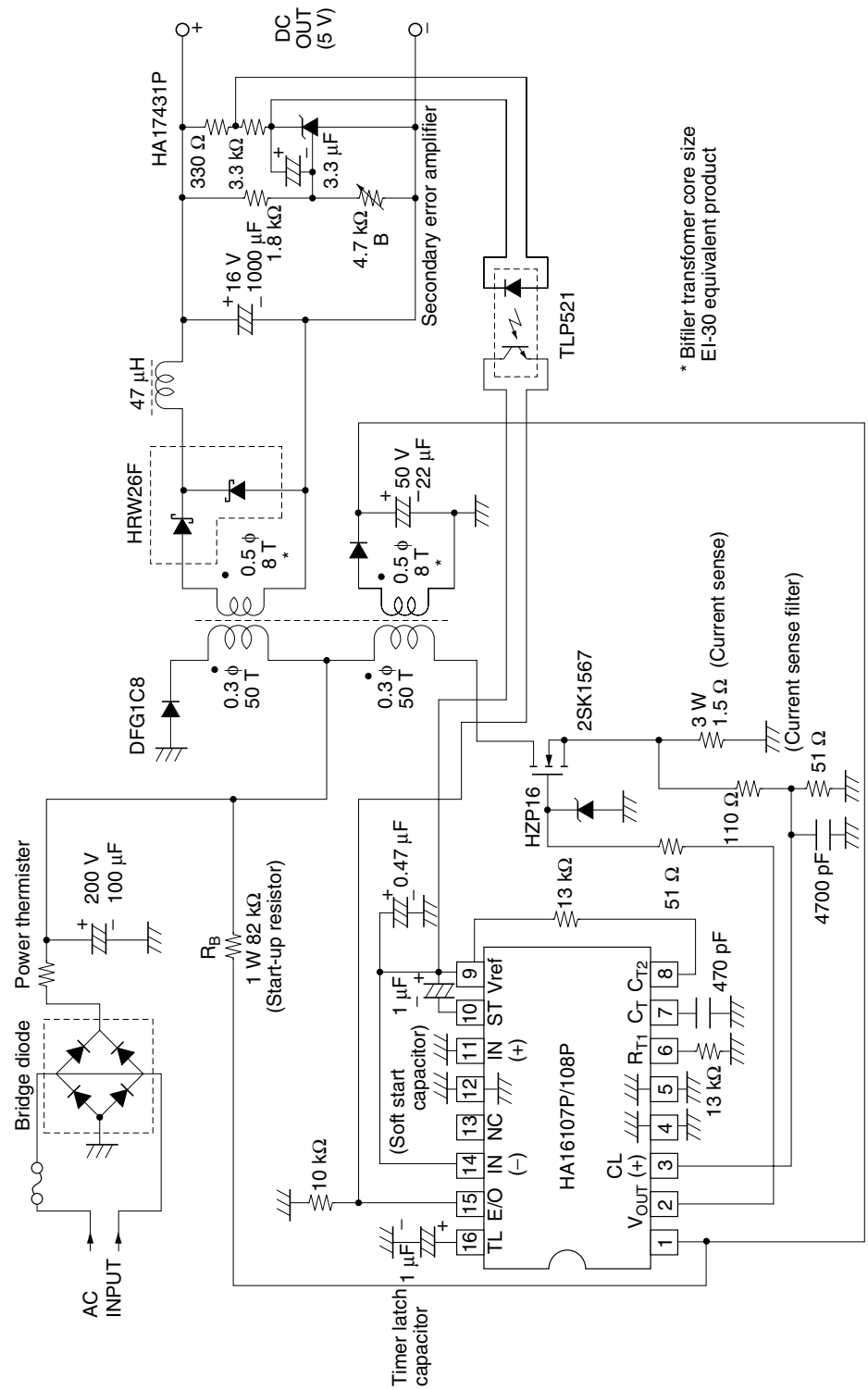


HA16108 (Intermittent operation by means of ON/OFF timer)

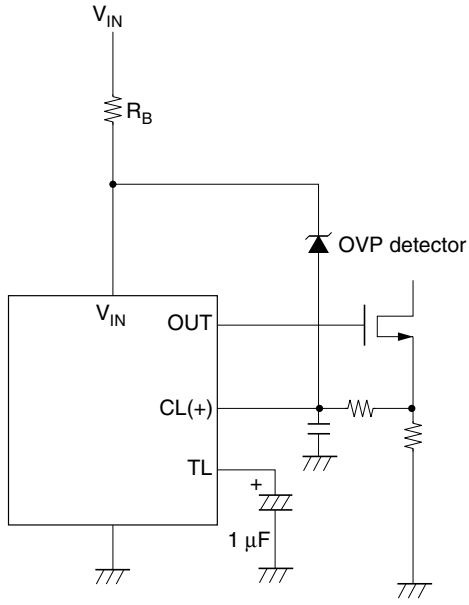
Operating Circuit Example



• Forward Transformer Application Example



• When OVP signal is inserted at CL(+) pin



When the OVP detection Zener diode turns on, latch shutdown of the output is performed after the elapse of the time determined by the capacitance connected the TL pin.

Application

1. Use of Error Amplifier for Flyback Transformer Primary-Side Control

In this example, the fact that the transformer winding ratio and voltage ratio in Figure 1.1 are mutually proportional is made use of in a flyback transformer type AC-DC converter. As fluctuation of output voltage V_2 also appears in IC power supply voltage V_3, this is divided by a resistance and amplified by an error amplifier. An advantage of this method is that a photocoupler need not be used, making it possible to configure a power supply with a small number of parts (this example cannot be applied to a forward transformer).

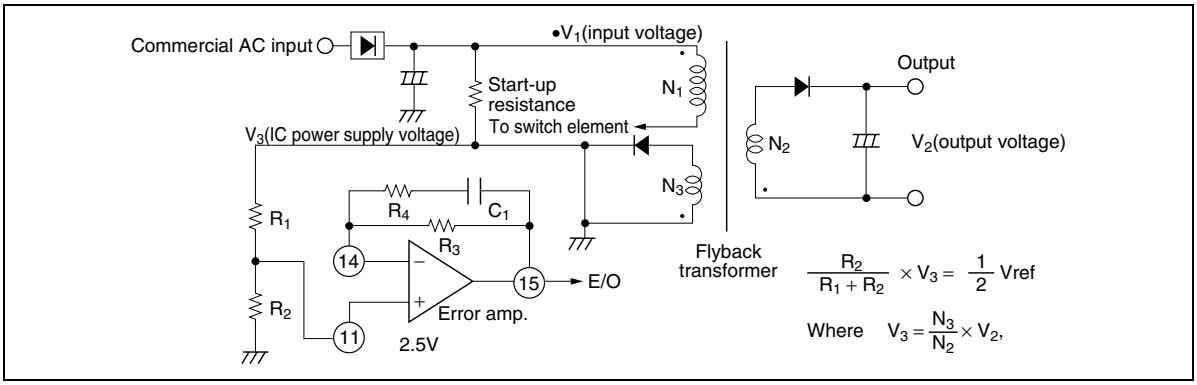


Figure 1.1 Error Amplifier Peripheral Circuitry Diagram

<Determining External Constants around Error Amplifier>

1. Detrrrmining DC Characteristics

   In Figure 1.1, the relational expression in the box is satisfied, and therefore parameters are determined based on this. The absolute value of the number of transformer windings is determined based on the equation $N_1:N_2:N_3 = V_1:V_2:V_3$, taking primary inductance into consideration.
   Next, IC operating voltage V_3 is made around 11V to 18V, taking the UVL voltage into consideration. If V_3 is too large, the power consumption of the IC will increase, causing heat emission problems. If V_3 is too small, on the other hand, there will be problems with defective power supply start-up.

2. Determining Error Amplifier Gain vs. Frequency Characteristic

   Taking the configuration in Figure 1.1, the error amplifier gain characteristic with respect to fluctuation of output voltage V_2 is as shown in Figure 1.2.

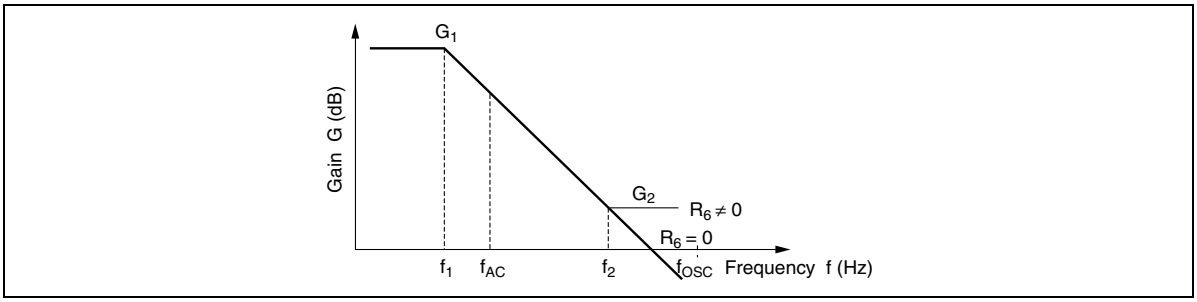


Figure 1.2 Error Amplifier Characteristic

In Figure 1.2, the parameters are given by the following equations.

Gain

$G_1 = V_3/V_2 \times R_3/R_1$

$G_2 = V_3/V_2 \times R_4/R_1$

Corner frequencies

$f_1 = 1/(2\pi C_1 R_3)$

$f_2 = 1/(2\pi C_1 R_4)$

Where R3>>R4 (10:1 or above)

G_1 is made around 30 to 50 dB, taking both regulation and stability into consideration.
f_1 is made a lower value than commercial frequency ripple f_{AC}, thus preventing hunting (a system instability phenomenon).
Next, G_2 is set to 0 dB or less as a guideline, so that there is no gain in IC operating frequency f_{OSC} (several tens to several hundreds of kHz). f_2 should be set to a value that is substantially smaller than f_{OSC}, and that is appropriate for the power supply response speed (several kHz). In the case of a bridge type rectification circuit, the commercial frequency ripple is twice the input frequency (with a 50 Hz commercial frequency, f_{AC} = 100 Hz).

2. External Constant Design for Current Detection Section (HA16107, HA16108, HA16666)

In the above IC models, which incorporate a current detection function, a low-pass filter such as shown in Figure 2.1 must be inserted between switch element current detection resistance R_{CS} and the current detection pin of the IC.

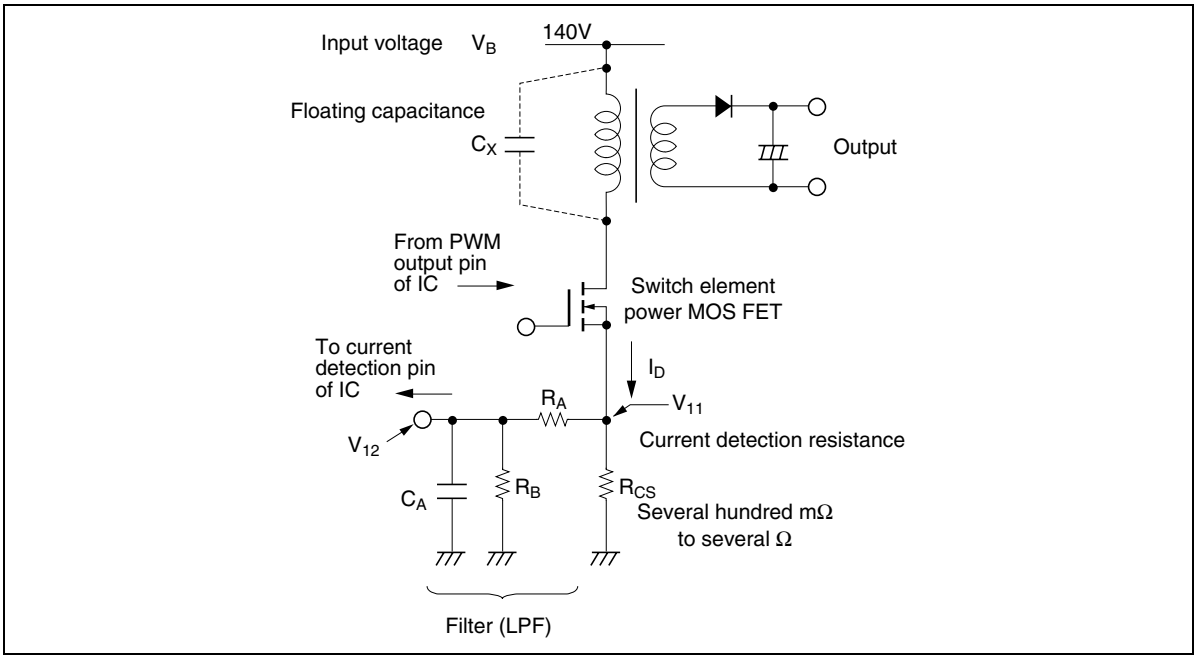


Figure 2.1 Current Detection Circuit

The reason for this is that, when the switch element is on in each cycle, there is an impulse current associated with charging of transformer floating capacitance C_X, and IC current detection malfunctions (see Figure 2.2).

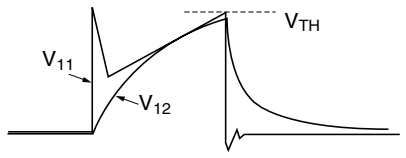


Figure 2.2 Current Detection Waveform

<Setting Numeric Values>

If the switch element current to be detected is designated I_D, and the current detection resistance R_{CS}, then the following equation is satisfied using the parameters in Figure 2.1.

$$I_D \times R_{CS} = ((R_A + R_B)/R_B)\ V_{TH}$$

V_{TH} is the detection level voltage of the IC (240 mV in the case of the HA16107, for example). R_A and R_B are set to values on the order of several hundred Ω to several kΩ, so that R_{CS} is not affected.
Next, the filter cutoff frequency is set according to the following equation.

$$f_C = 1/(2\pi\ C_A\ (R_A/R_B))$$

f_C can be found with the following guideline, using IC operating frequency f_{OSC}, power supply rating on-duty D, and power MOS element turn-on time t_{ON}.

$$fosc/D \le f_C \le 1/(100 \times t_{ON})$$

Value 100 in the above equation provides a margin for noise, ringing, and so forth.

<Actual Example>

In an SW power supply using an HA16107, with a 100 kHz operating frequency and a D value of 30%, the relevant values were as follows: V_B = 140 V, C_X = 80 pF, t_{ON} = 10 ns. Thus, when R_{CS} = 1 Ω, the V_{11} level peak value reaches the following figure.

$$\begin{aligned} V_{11}\ (peak) &= R_{CS} \times I_D\ peak \\ &= R_{CS} \times (V_B \times C_X)/t_{ON} \\ &= 1\Omega \times (140\ V \times 80\ pF)/10\ ns \\ &= 1.12\ (V) \end{aligned}$$

A filter with the following constants was then inserted.

$$R_A = R_B = 1\ k\Omega,\ \ C_A = 1000\ pF$$

At this time, the detectable drain current is 0.48 (A), and the filter cutoff frequency is 318 (kHz). Note that increasing a filter time constant is effective against noise, but if the value is too large, error will arise in the switch element current detection level.

3. IC Heat Emission Problem and Countermeasures (HA16107 Series, HA16114 Series)

While the above ICs can directly drive a power MOS FET gate, if the method of use is not thoroughly investigated, there will be a tendency for the gate drive power to increase and a problem of heat emission by the IC may occur.
This section should therefore be noted and appropriate measures taken to prevent this kind of problem.

1. Power MOS FET Drive Characteristics

   When power MOS FET drive is performed, in order to lower the on-resistance sufficiently, overdrive is normally performed with a voltage considerably higher than 5 V, for example, such as the 15 V power supply voltage of the IC.

   At this time, the power that should be supplied from the IC to the power MOS FET is determined by gate load Qg in Figure 4.2.

2. IC Heat-Emission Power Calculation (Figure 4.2)

   The power that contributes to IC heat emission is calculated by means of the following equation.

   $$Pd = V_{IN} I_Q + 2Qg V_{IN} f$$

   Where V_{IN} : Power supply voltage of IC
   I_Q : Operating current of IC (unloaded)
   Qg : Above-mentioned gate load
   f : Operating frequency of IC

   The coefficient, 2, indicates that gate discharging also contributes to heat emission.

4. Power MOS FET Gate Resistance Design (HA16107 Series, HA16114 Series)

There are the following three purposes in connecting a gate resistance, and the circuit is generally of the kind shown in Figure 4.1.

(1) To suppress peak current due to gate charging
(2) To protect IC output pins
(3) To provide drive appropriate to power MOS FET input characteristics

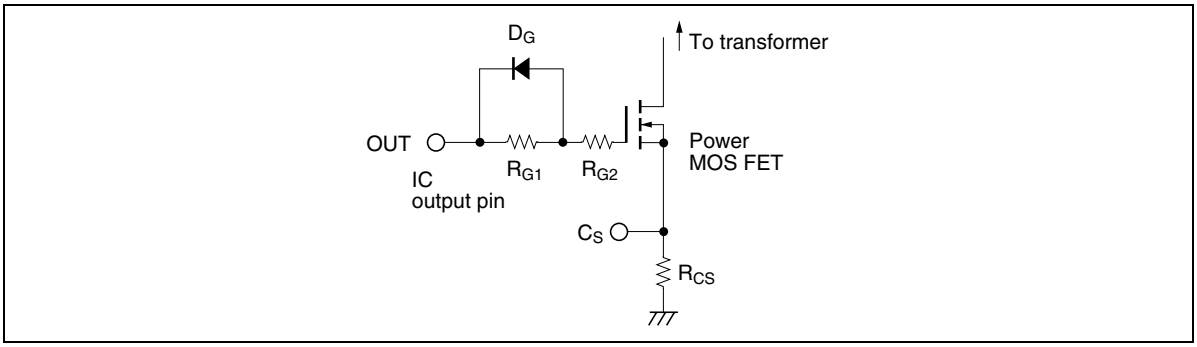


Figure 4.1 Gate Drive Circuit

This gate resistance R_G is given by the following equation.

$$R_G = (V_G/I_G) - (V_G \times t_{ON})/Qg, \quad R_G = R_{G1} + R_{G2}$$

I_G : Gate input peak current

V_G : Gate drive voltage wave high value (equal to power supply voltage of IC)

t_{ON} : Power MOS FET turn-on time

t_{OFF} : Power MOS FET turn-off time

Qg : Gate charge according to Figure 4.2

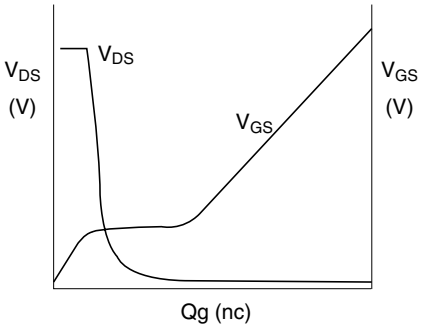


Figure 4.2 Power MOS FET Dynamic Input Characteristics

Refer to the power MOS FET catalog for information on t_{ON} and Qg.

By dividing R_G into R_{G1} and R_{G2}, it is possible for speed to be slowed when the power MOS FET is on, and increased when off.

Power MOS FET on and off times when mounted, t_{ON}' and t_{OFF}', are as follows.

$$t_{ON}' = t_{ON} + Qg(R_{G1} + R_{G2})/V_G$$
$$t_{OFF}' = t_{OFF} + Qg \cdot R_{G2}/V_G$$

<Actual Example>

When driving a power MOS FET and 2SK1567 with an HA16107, etc.

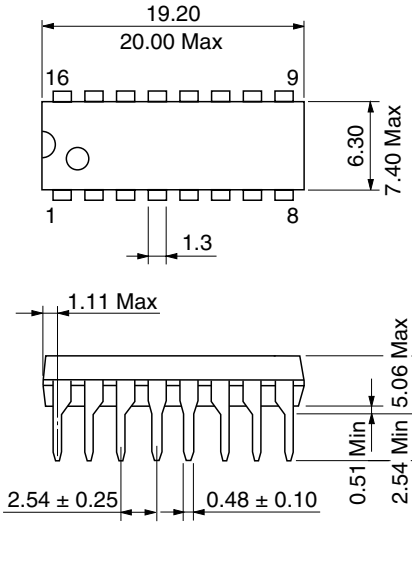
(R_{G1} = 100 Ω, R_{G2} = 20 Ω, V_G = 15 V)

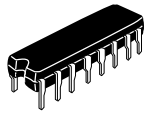
$$t_{ON}' = 70 \text{ ns} + 36 \text{ nc} \cdot (100\ \Omega + 20\ \Omega)/(15 \text{ V}) = 360 \text{ (ns)}$$
$$t_{OFF}' = 135 \text{ ns} + 36 \text{ nc} \cdot (20\ \Omega)/(15 \text{ V}) = 183 \text{ (ns)}$$

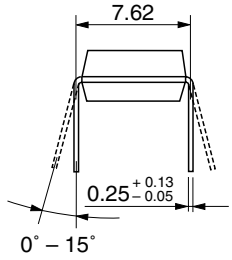
Generally, the gate resistance values in the case of this circuit configuration are on the order of 100 to 470 Ω for R_{G1} and 10 to 47 Ω for R_{G2}.

Package Dimensions

As of January, 2002
Unit: mm

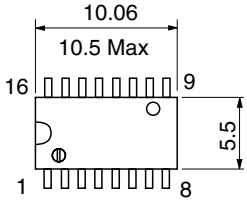


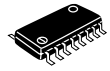


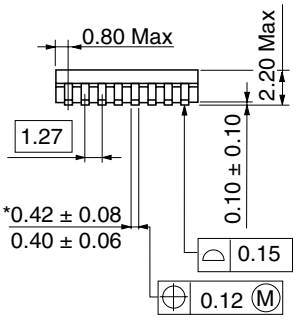


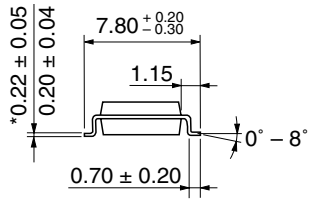
Hitachi Code	DP-16
JEDEC	Conforms
JEITA	Conforms
Mass (reference value)	1.07 g

As of January, 2002
Unit: mm









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

*Dimension including the plating thickness
Base material dimension

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