Ordering number : EN6205

Monolithic Digital IC

LB1695D

Three-Phase Brushless Motor Driver for DC Fan

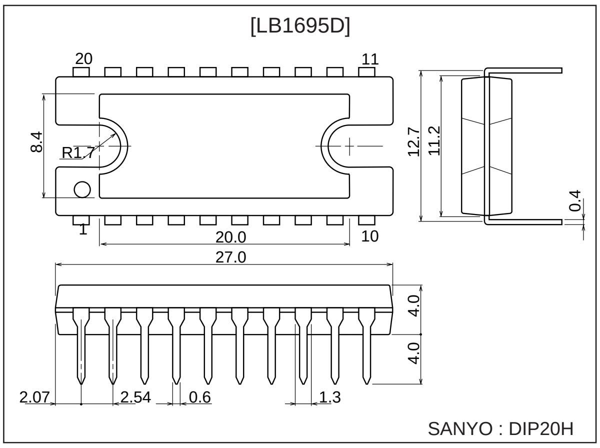
Overview

The LB1695D is a driver IC for 3-phase brushless DC fan motors such as used in water heaters and other domestic electrical appliances.

Package Dimensions

unit: mm

3037A-DIP20H



Features

- Three-phase brushless motor driver
- Withstand voltage 45V, output current 2A
- Built-in current limiter
- Built-in low-voltage protection circuit
- Built-in thermal shutdown circuit
- Built-in Hall amplifier with hysteresis
- FG output function

Specifications

Absolute Maximum Ratings at Ta = 25˚C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage	V_{CC} max		10	V
	V_M max		45	V
Maximum output current	I_O max		2.0	A
Allowable power dissipation	Pd max1	IC only	3	W
	Pd max2	With an arbitrary large heat sink	20	W
Operating temperature	Topr		–20 to +100	°C
Storage temperature	Tstg		–55 to +150	°C

Allowable Operating Ranges at Ta = 25˚C

Parameter	Symbol	Conditions	Ratings	Unit
Power supply voltage range	V_{CC}		4.5 to 9.0	V
	V_M		5 to 42	V
Power supply startup voltage slew rate	$\Delta V_{CC}/\Delta t$	$V_{CC} = V_{LVSD}$ (OFF) point *1	Up to 0.04	V / µs
	$\Delta V_M/\Delta t$	V_M = 0V point *1	Up to 0.16	V / µs

*1 After power-on, if the power supply voltage rise is fast, there may be some feedthrough current in the output.

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Electrical Characteristics at Ta = 25°C, V_{CC} = 5V, V_M = 30V

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Power supply current	I_{CC}	Forward		13	19	mA
Output saturation voltage	$V_O$sat1	I_O = 0.5A V_O (sink) + V_O (source)		1.8	2.4	V
	$V_O$sat2	I_O = 1.0A V_O (sink) + V_O (source)		2.1	2.8	V
Output leakage current	I_O leak				100	µA
[Hall amplifier]						
Input bias current	I HB			1	4	µA
Common mode input voltage range	V_{ICM}		1.5		V_{CC}–1.8	V
Hysteresis width	ΔV_{IN}		21	30	37	mV
Input voltage L -> H	V_{SLH}		5	15	25	mV
Input voltage H -> L	V_{SHL}		–25	–15	–5	mV
[FG pin (Speed pulse output)]						
Output Low level voltage	V_{FGL}	I_{FG} = 5 mA			0.4	V
Pull-up resistor value	R_{FG}		7.5	10	12.5	kΩ
[Forward/reverse operation]						
Forward	V_{FR1}		0		0.8	V
Reverse	V_{FR2}		4.2		V_{CC}	V
[Current limiter operation]						
Limiter	V_{RF}		0.42	0.5	0.6	V
[Thermal shutdown operation]						
Operating temperature	TSD	Design target value	150	180		°C
Hysteresis width	ΔTSD	Design target value		40		°C
[Low-voltage protection circuit operation]						
Operating voltage	V_{LVSD}		3.5	3.8	4.1	V
Release voltage	V_{LVSD}(OFF)			4.3	4.5	V
Hysteresis width	ΔV_{LVSD}		0.4	0.5	0.6	V
[C pin]						
Charge current	I_{CL}	R = 33 kΩ	30	40	50	µA
Discharge current	I_{CH}	R = 33 kΩ	90	120	150	µA
Charge start voltage	V_{CL}	R = 33 kΩ	0.3	0.4	0.5	V
Discharge start voltage	V_{CH}	R = 33 kΩ	1.5	2.0	2.5	V
Output current ignore time	t sm	R = 33 kΩ, C = 4700 pF	58	68	78	µs
Output off time	t so	R = 33 kΩ, C = 4700 pF	164	193	222	µs

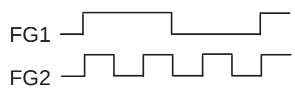
Truth Table

	Input			Forward/reverse control	Output	FG output	
	IN1	IN2	IN3	F/R	Source -> Sink	FG1	FG2
1	H	L	H	L	OUT2 -> OUT1	L	L
				H	OUT1 -> OUT2		
2	H	L	L	L	OUT3 -> OUT1	L	H
				H	OUT1 -> OUT3		
3	H	H	L	L	OUT3 -> OUT2	L	L
				H	OUT2 -> OUT3		
4	L	H	L	L	OUT1 -> OUT2	H	H
				H	OUT2 -> OUT1		
5	L	H	H	L	OUT1 -> OUT3	H	L
				H	OUT3 -> OUT1		
6	L	L	H	L	OUT2 -> OUT3	H	H
				H	OUT3 -> OUT2		

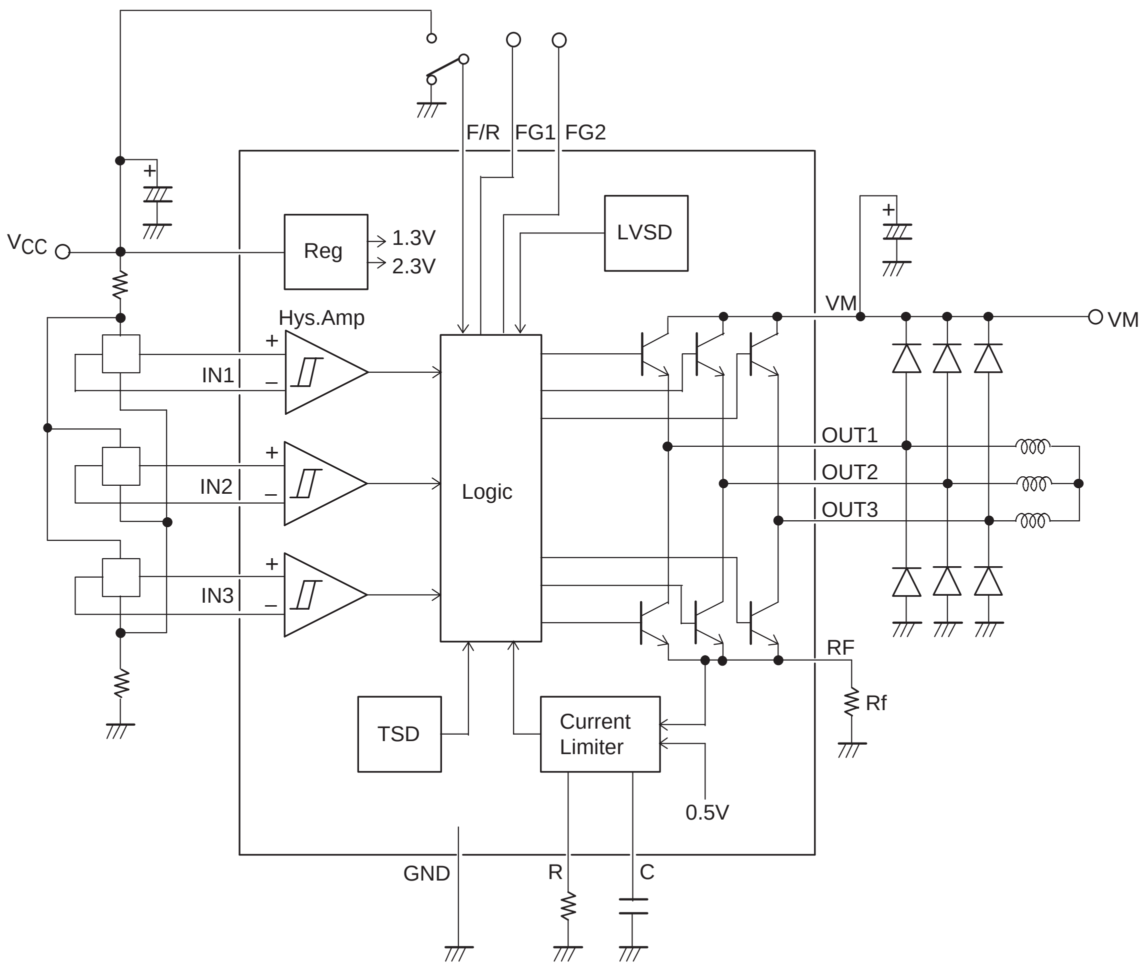
F/R

Forward	L	0.0 to 0.8V
Reverse	H	4.2 to 5.0V

FG output



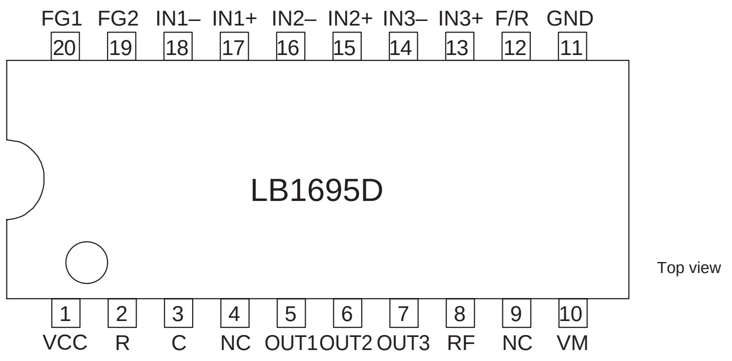
Block Diagram and Peripheral Circuitry

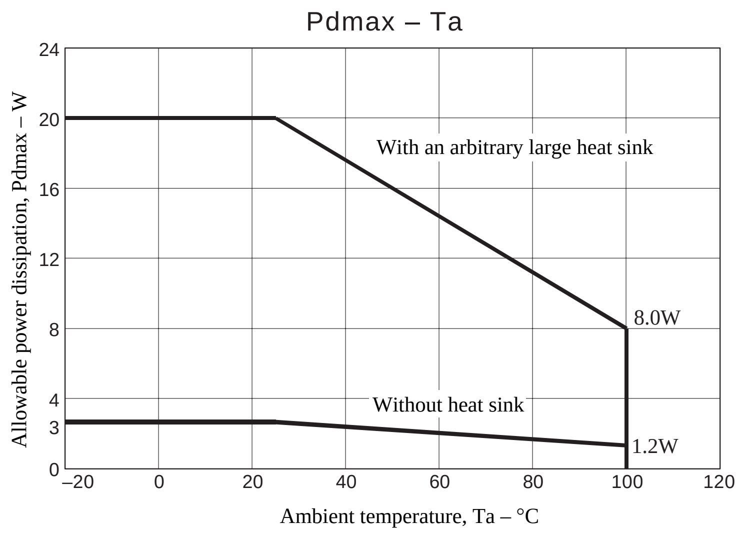


Pin Description

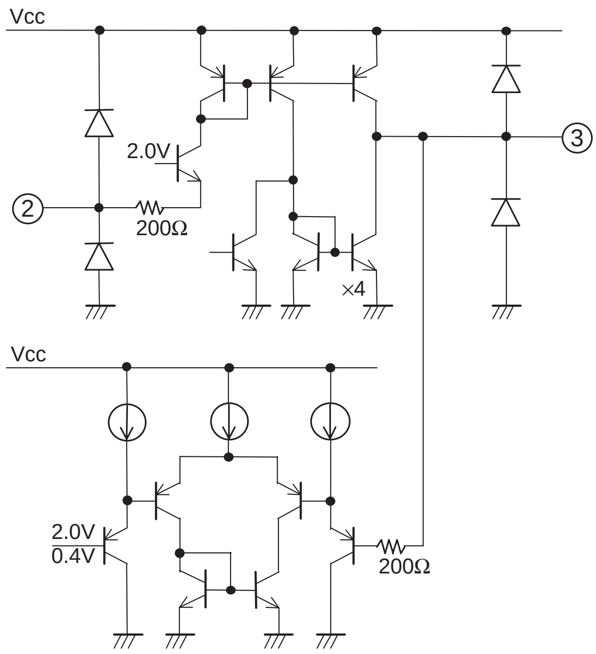
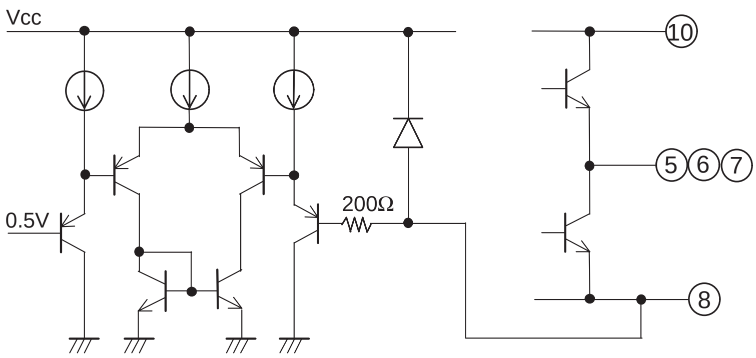
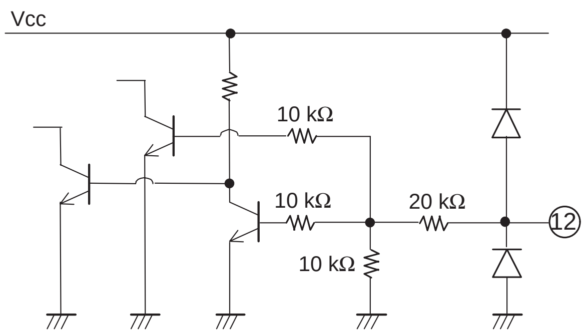
Pin name	Pin number	Function
VCC	1	Power supply pin for blocks except output
R	2	C pin charge/discharge current set pin
C	3	Setting pin for current limiter output off time and output current ignore time
NC	4, 9	May be used for wiring
OUT1 OUT2 OUT3	5 6 7	Output pin 1 Output pin 2 Output pin 3
RF	8	Output current detection pin. Insert a resistor (Rf) between this pin and ground. The output current will be limited to the value determined by VRF/Rf (output current limiter).
VM	10	Power supply pin for output
GND	11	Ground for blocks except output Lowest electrical potential of output transistors is voltage at RF pin.
F/R	12	Forward/reverse control pin
IN1+, IN1– IN2+, IN2– IN3+, IN3–	17, 18 15, 16 13, 14	Hall input pin Logic High refers to IN+ > IN– Hall input pin Logic High refers to IN+ > IN– Hall input pin Logic High refers to IN+ > IN–
FG1 FG2	20 19	Speed pulse output pin 1 with built-in pull-up resistor Speed pulse output pin 2 with built-in pull-up resistor

Pin Assignment





Pin Equivalent Circuit

Pin number	Pin name	Pin voltage	Equivalent circuit
3 2	C R		
5 6 7 8 10	OUT1 OUT2 OUT3 RF VM		
12	F/R	0.0V min V_{CC} max	

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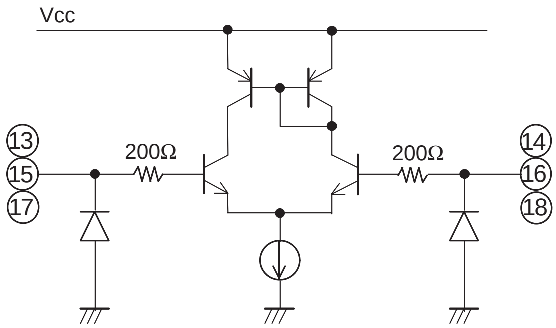
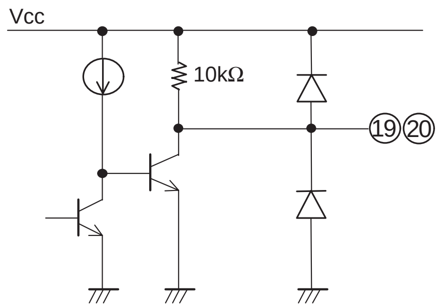
Pin number	Pin name	Pin voltage	Equivalent circuit
17 18 15 16 13 14	IN1+ IN1– IN2+ IN2– IN3+ IN3–	1.5V min V_{CC}–1.8V max	
20 19	FG1 FG2		

Description of the LB1695D

1. Hall input circuit

   The Hall input circuit is a differential amplifier with a hysteresis of 30 mV (typ.). The operating DC level must be within the common mode input voltage range (1.5V to V_{CC} – 1.8V). To prevent noise and other adverse influences, the input level should be at least 3 times the hysteresis (120 to 160 mVp-p). If noise evaluation at the Hall input shows a problem, a noise-canceling capacitor (about 0.01 μF) should be connected across the Hall input IN+ and IN– pins.

2. Protection circuits

   2-1. Low voltage protection circuit

   When the V_{CC} voltage falls below a certain level (V_{LVSD}), the low voltage protection circuit cuts off the sink-side output transistors to prevent malfunction caused by a V_{CC} voltage drop.

   2-2. Thermal shutdown circuit

   When the junction temperature rises above a certain value (TSD), the thermal shutdown circuit cuts off the sink-side output transistors to prevent IC damage due to overheating. Design the application heat characteristics so that the protection circuit will not be triggered under normal circumstances.

3. FG output circuit

   The Hall input signal at IN1, IN2, and IN3 is synthesized and subject to waveform shaping before appearing at this output. The signal at FG1 has the same frequency as the Hall input, and the signal at FG2 has a frequency that is three times higher than the Hall input.

4. Forward/Reverse control circuit

   This IC is designed under the assumption that forward/reverse (F/R) switching will not be carried out while the motor is running. If switching is carried out while the motor is running, a feedthrough current flows in the output and a problem will be caused regarding ASO. F/R switching should be carried out while the V_M power supply is off (motor is stopped).

5. V_{CC}, V_M power supply

   When the power supply voltage (V_{CC}, VM) rises very quickly at power-on, a feedthrough current may flow in the output and a problem will be caused regarding ASO. The power supply rise speed should be kept below $\Delta V_{CC}/\Delta t$ = 0.04V/μS and $\Delta V_M/\Delta t$ = 0.16V/μS. For the power-up sequence, V_{CC} should be turned on before V_M.
   The sequence at power-down should be V_M first, and then motor stop, and then V_{CC}. With some motors, if V_{CC} is switched off immediately after V_M, while the motor is still rotating due to inertia, the V_M voltage may rise and exceed the withstand voltage.

6. Power supply stabilizing capacitors

   If the V_{CC} line fluctuates drastically, the low-voltage protection circuit may be activated by mistake, or other malfunctions may occur. The V_{CC} line should therefore be stabilized by connecting a capacitor of at least several μF between V_{CC} and ground. Because a large switching current flows in the V_M line, wiring inductance and other factors can lead to VM voltage fluctuations. As the GND line also fluctuates, the V_M line must be stabilized by connecting a capacitor of at least several μF between V_M and ground, to prevent malfunction or exceeding the withstand voltage. Especially when long wiring runs (V_M, V_{CC}, GND) are used, sufficient capacitance should be provided to ensure power supply stability.

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7. Current limiter circuit

The current limiter circuit cuts off the sink-side output transistors when the output current reaches a preset value (limiter value). This limits the output current peak value.
For detection of output current, the RF pin is used. By connecting the resistance Rf between the RF pin and ground, the output current can be detected as a voltage. When the RF pin voltage reaches 0.5V (typ.), the current limiter is activated. This limits the output current to the value determined by 0.5/Rf.

7-1. Output off time

When the current limiter circuit was triggered and has switched off the sink-side output transistors, it will turn them on again after a preset interval (power off time). By switching the output in this way, the current limiter circuit of the LB1695D reduces the likelihood of ASO problems as compared to current limiters using the non-saturation output principle.
The output off time is determined by the charge time for the capacitance C connected to the C pin. When the limiter is triggered, C starts to charge, and the time required for the C voltage to reach 2V (typ.) is the output off time. When C was charged to 2V, the sink-side output is turned on again. The charge current for C is constant-current and is determined by the resistance R connected to the R pin. The C charge current I_{CL} and the output off time toff are calculated according to the following equations.

$$I_{CL} \doteqdot 1.3/R \quad \text{(R should be between 13 k}\Omega\text{ to 100 k}\Omega\text{)}$$
$$\mathrm{toff} \doteqdot C/I_{CL} \times 2.0$$
$$\doteqdot 1.53 \times R \times C$$

7-2. Output current ignore time

While the sink-side output is turned off by the current limiter, a regenerative current flows in the upper side regenerative current absorption diode connected externally. When the output off time has elapsed and the sink-side output is turned on again, a momentary reverse current flows in the external diode (due to the reverse recovery time of the diode), which causes a limiter-value current to flow momentarily in the output. If this triggers the current limiter again, the output will be turned off, which lowers the average current and causes a reduction in motor torque for example during startup. To prevent this, the circuit is designed not to monitor the output current for a certain period after the sink-side output were turned off and on again. This is called the output current ignore time.
The output current ignore time is determined by the discharge time of the capacitance C connected to the C pin. After the current limiter was triggered and C was charged to 2V, the discharge process starts. The time required to discharge to a voltage of 0.4V (typ.) is the output ignore time. The discharge current for C is constant-current and is about 3 times the charge current (I_{CL}). Therefore the output current ignore time is about 1/3 of the output off time.
The C discharge current I_{CH} and the output current ignore time tsm are calculated according to the following equations.

$$I_{CH} \doteqdot 1.3/R \times 3$$
$$\mathrm{tsm} \doteqdot C/I_{CH} \times 1.6$$
$$\doteqdot 0.41 \times R \times C$$

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Because the current limiter circuit is slanted towards the ON time for turning the sink-side output on again, the reverse current will not be so large even if a rectifying diode (without a short reverse recovery time) is used as regenerative current absorption diode connected externally.

7-3. Output off time setting

The output off time must be optimized for the type of motor that is being controlled. The output off time setting is controlled by the external resistance connected to the R pin and the external capacitance connected to the C pin. Figure 1 shows the current limiter operating waveform.

(1) Short output off time setting

Because the IC is designed internally to give a ratio of about 3:1 for the output off time and output current ignore time, the two values cannot be set independently. If the output off time is set to a very small value, the output current ignore time may be too short. In such a case, the external regenerative current absorption diode acts to limit current flow by its reverse current (see section 7-2). If the output off time is small, the diode reverse current will increase, which can lead to ASO problems.

(2) Long output off time setting

If the output off time is set to a very high value, the average current will be reduced, resulting in lower motor startup torque. Depending on the motor type, the circuit may not change from the current limiter operating state to the normal rotation state.

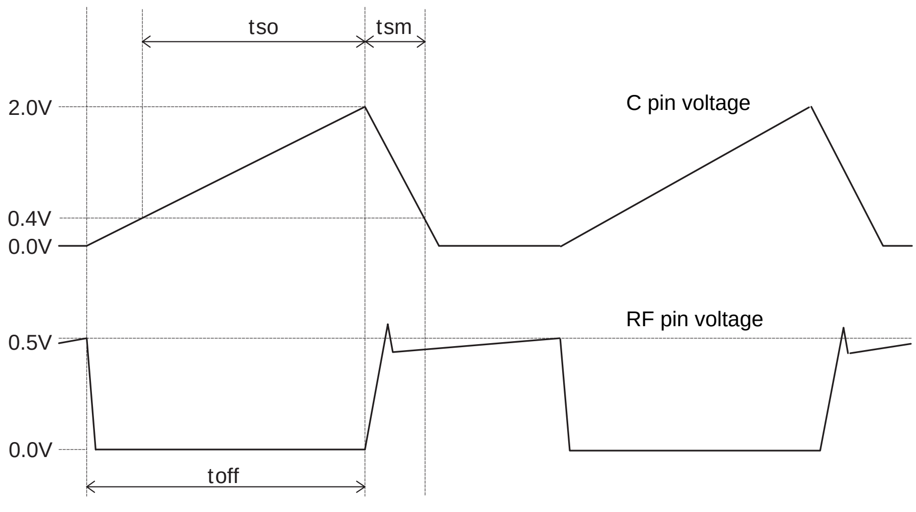

Figure. 1 Current limiter operating waveform

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8. Internal power dissipation calculation
   $Pd = (V_{CC} \times I_{CC}) + (V_M \times I_M)$ – (motor coil power dissipation)

9. IC temperature rise measurement
   Because the chip temperature of the IC cannot be measured directly, measurement should be carried out according to one of the following procedures.

   9-1. Thermocouple measurement method
   A thermocouple element is mounted to the IC heat dissipation fin. This measurement method is easy to implement, but it will be subject to measurement errors if the temperature is not stable.

   9-2. Measurement using internal diode characteristics of IC
   This is the recommended measurement method. It makes use of the parasitic diode incorporated in the IC between FG1 and GND. Set FG1 to High (off) and measure the voltage VF of the parasitic diode to calculate the temperature.
   (Sanyo data: for I_F = –1 mA, V_F temperature characteristics are about –2 mV/°C)