Ordering number : EN5678

Monolithic Digital IC

LB1695

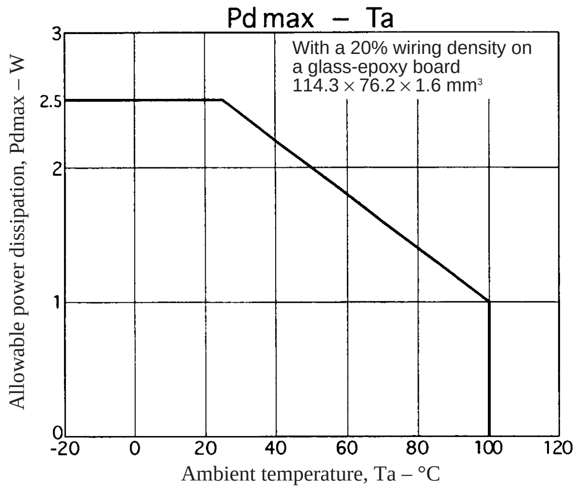
Three-Phase Brushless Motor Driver

Overview

The LB1695 is a three-phase brushless motor driver IC that is optimal for DC fan motor drive in home appliances such as on-demand water heaters.

Features

- Three-phase brushless motor drive
- 45-V voltage handling capacity, 2-A output current
- Current limiter circuit
- Low-voltage protection circuit
- Thermal shutdown protection circuit
- Hall amplifiers with hysteresis characteristics
- FG output function

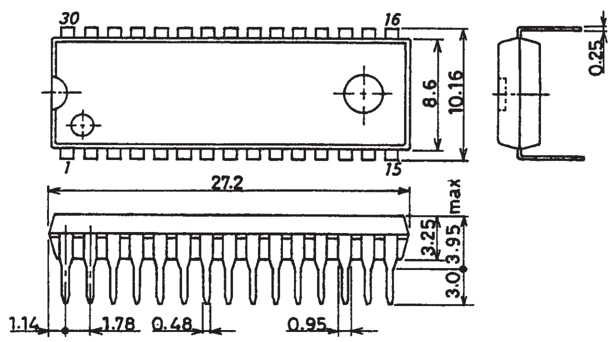


Package Dimensions

unit: mm

3196-DIP30SD

[LB1695]



SANYO: DIP30SD

Specifications

Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	V_{CC}		10	V
	V_M		45	V
Output current	I_O		2.0	A
Allowable power dissipation	Pd max	Mounted on a printed circuit board (114.3 × 76.2 × 1.6 mm³ glass-epoxy board)	2.5	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 5.5	V
	V_M		5 to 42	V
Maximum power-supply slew rate at power on	$\Delta V_{CC}/\Delta t$	At $V_{CC} = V_{LVSD}$(OFF)*	No more than 0.04	V/µs
	$\Delta V_M/\Delta t$	At V_M = 0 V*	No more than 0.16	V/µs

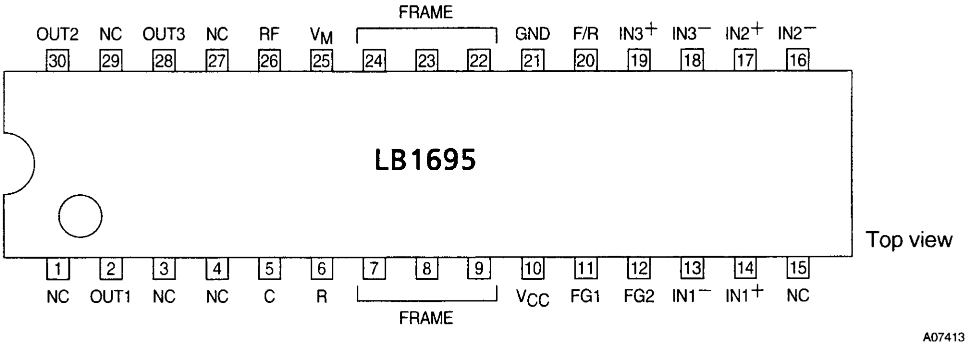
Note: *These items are stipulated because output through currents can occur if the speed with which the power-supply voltage rises is too fast when power is first applied.

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

Parameter	Symbol	Conditions	Ratings min	Ratings typ	Ratings max	Unit
Current drain	I_{CC}	Forward rotation		13	19	mA
Output saturation voltage	V_O(sat)1	I_O = 0.5 A, V_O (sink) + V_O (source)		1.8	2.4	V
	V_O(sat)2	I_O = 1.0 A, 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		3.2	V
Hysteresis	ΔV_{IN}		21	30	37	mV
Input voltage (low → high)	V_{SLH}		5	15	25	mV
Input voltage (high → low)	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 resistance	R_{FG}		7.5	10.0	12.5	kΩ
[Forward/Reverse Operation]						
Forward	V_{FR1}			0	0.8	V
Reverse	V_{FR2}		4.2	5.0		V
[Current Limiter Operation]						
Limiter	V_{RF}		0.42	0.5	0.6	V
[Thermal Shutdown Operation]						
Operating temperature	TSD	*	150	180		°C
Hysteresis	ΔTSD	*		40		°C
[Low-Voltage Protection Operation]						
Operating voltage	V_{LVSD}		3.5	3.8	4.1	V
Release voltage	$V_{LVSD(OFF)}$			4.3	4.5	V
Hysteresis	ΔV_{LVSD}		0.4	0.5	0.6	V
[Pin C]						
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 ignored 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

Note: *The items marked with an asterisk are design target values and are not tested.

Pin Assignment



Truth Table

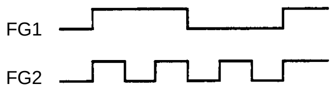
	Input			Forward/reverse control	Output	FG output	
	IN1	IN2	IN3	F/R	Source → sink	FG1	FG2
1	H	L	H	L	OUT2 → OUT1	L	L
				H	OUT1 → OUT2		
2	H	L	L	L	OUT3 → OUT1	L	H
				H	OUT1 → OUT3		
3	H	H	L	L	OUT3 → OUT2	L	L
				H	OUT2 → OUT3		
4	L	H	L	L	OUT1 → OUT2	H	H
				H	OUT2 → OUT1		
5	L	H	H	L	OUT1 → OUT3	H	L
	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

F/R

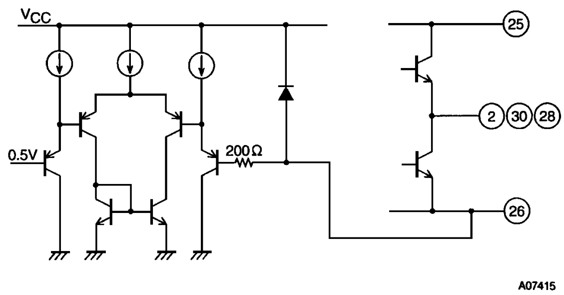
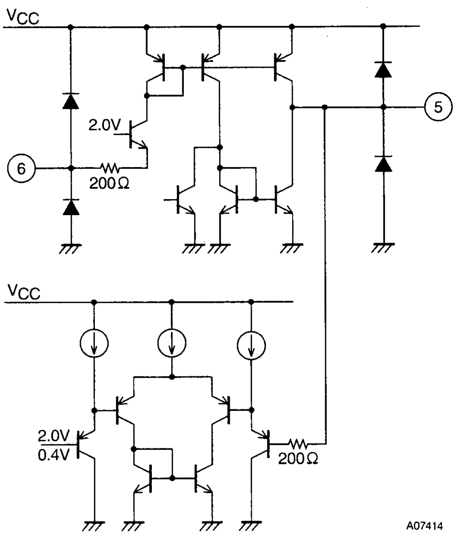
Forward (low): 0.0 to 0.8 V

Reverse (high): 4.2 to 5.0 V

FG Output

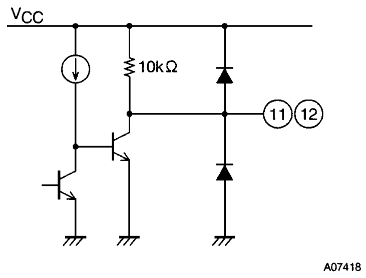
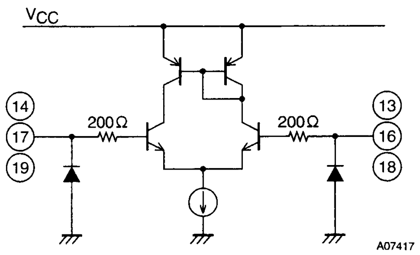
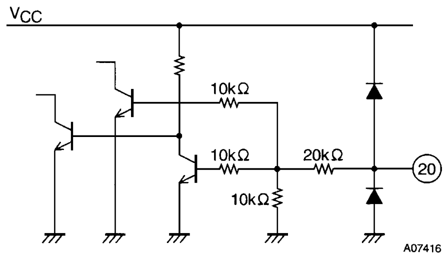


Pin Functions

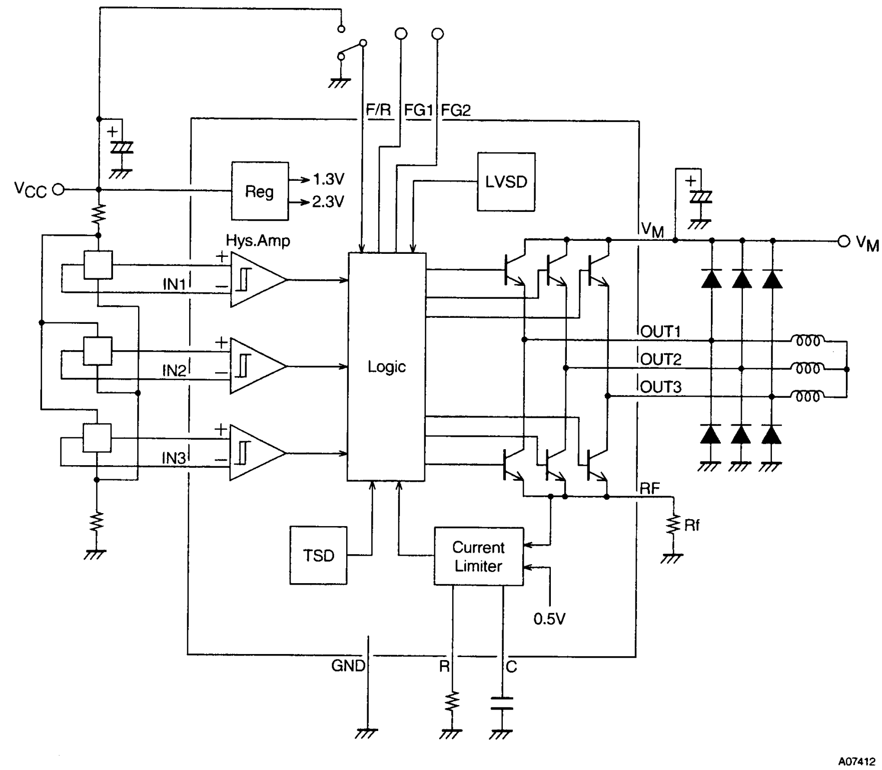
Pin No.	Pin	Pin voltage(V)	Pin function	Equivalent circuit
2 30 28	OUT1 OUT2 OUT3		• Output pin 1 • Output pin 2 • Output pin 3	
25	V_M		• Power supply pin that provides the output	
26	RF		• Output current detection Connect the resistor Rf between this pin and ground. • The current limiter limits the output current to the value set by V_{RF}/Rf (current limiter operation).	
5	C		• The capacitor connected to this pin determines both the time the output is turned off when the current limiter operates and the time the output current is ignored.	
6	R		• The resistor connected to this pin determines the charge current for the pin C capacitor.	

Continued on next page.

Continued from preceding page.

Pin No.	Pin	Pin voltage(V)	Pin function	Equivalent circuit
7, 8, 9, 22, 23, 24	FRAME		• This pin is used for heat dissipation. Electrically, it must be left open.	
10	V_{CC}		• Power for all circuits other than the output block.	
11 12	FG1 FG2		• First speed pulse output. A pull-up resistor is built in. • Second speed pulse output. A pull-up resistor is built in.	
13 14 16 17 18 19	IN1– IN1+ IN2– IN2+ IN3– IN3+	1.5 V min V_{CC}–1.8V max	• Hall element input Logic high is defined as IN+ > IN–. • Hall element input Logic high is defined as IN+ > IN–. • Hall element input Logic high is defined as IN+ > IN–.	
20	F/R	0.0 V min V_{CC} max	• Forward/reverse control	
21	GND		• Ground for all circuits other than the output block. The lowest potential of the output transistors will be the potential of the Rf pin.	

Block Diagram and Peripheral Circuits



LB1695 Functional Description

1. Hall element input circuits

The Hall element input circuits are differential amplifiers with a hysteresis of about 30 mV (typical). The operating DC level must be within the common-mode input voltage range (1.5 V to V_{CC} – 1.8 V). We recommend providing input levels that exceed the hysteresis by at least a factor of three (120 to 160 mVp-p) to assure that circuit operation is not affected by noise. If the ability to withstand noise is determined to be a problem during noise evaluation or other testing, insert capacitors (of about 0.01 µF) between the Hall input IN^+ and IN^- pins.

2. Protection circuit

2.1 Low-voltage protection circuit

The sink side output transistors are turned off if the V_{CC} voltage falls below the stipulated voltage (V_{LVSD}). This circuit prevents incorrect operation when the V_{CC} voltage is reduced.

2.2 Thermal shutdown circuit

The sink side output transistors are turned off if the junction temperature exceeds the stipulated temperature (TSD). This circuit prevents the IC from being destroyed by overheating. Applications must be designed so that this circuit does not operate except in unusual situations.

3. FG output circuit

The LB1695 combines the IN1, IN2, and IN3 inputs and then wave shapes the combined signal. The FG1 output has the same frequency as the Hall inputs, and the FG2 output has a frequency three times that of the Hall inputs.

4. Forward/reverse control circuit

This circuit was designed with the assumption that the direction will not be switched from the F/R pin while the motor is turning. If the direction is switched while the motor is turning, through currents will flow in the output and ASO will become a problem. We recommend only using F/R switching when the V_M power supply is in the off state, i.e. with the motor in the stopped state.

5. V_{CC} and V_M power supplies

If the speed with which the power-supply voltages (V_{CC} and V_M) rise when power is first applied is too fast, through currents will flow in the output and ASO will become a problem. Applications must assure that the power supply rise speeds do not exceed 0.04 V/µs ($\Delta V_{CC}/\Delta t$) and 0.16 V/µs ($\Delta V_M/\Delta t$). When applying power, it is desirable to apply V_{CC} first and then apply V_M. When turning the power off, it is desirable to first turn off V_M, then to wait for the motor to stop, and only then turn off V_{CC}. If V_{CC} is turned off after V_M is turned off but while the motor is still turning due to inertia, certain motor types may cause the V_M voltage at the IC to rise and generate voltages that exceed the voltage handling capacity of the IC.

6. Power supply stabilization capacitor

The low-voltage protection circuit may operate or other problems may occur if large fluctuations occur in the V_{CC} line voltage. The V_{CC} line must be stabilized by a capacitor (of a few µF) inserted between V_{CC} and ground. Also, the large switching currents that flow in the V_M line can cause fluctuations in the IC V_M voltage due to inductive components in the circuit wiring. The V_M line must also be stabilized by a capacitor inserted between V_M and ground to prevent fluctuations in the ground line potential, incorrect operation, and voltages that exceed the voltage handling capacity of the IC. In particular, applications that have long circuit lines for V_M, V_{CC}, and ground must have adequate stabilization capacitors inserted in the power lines.

7. Current limiter circuit

The current limiter circuit turns off the sink side output transistors when the output current reaches the set limit value (the limit current). The RF pin is used for current detection, and the output current is detected as a voltage by inserting the resistor R_f between the RF pin and ground. The current limiter circuit operates when the RF pin reaches 0.5 V (typical), and thus the output current is limited to the current limit set by the term $0.5/R_f$.

7.1 Output off time

After the current limiter circuit operates and turns off the sink side output transistors, it then turns the output on again after a fixed period (the output off time) has elapsed. This current limiter circuit output switching technique adopted in the LB1695 is much less susceptible to problems with ASO than are output limitation techniques in which the output is not operated at the saturated level. The output off time it determined by the charge time for the capacitor connected to the C pin. When the current limiter circuit operates, the C pin capacitor begins to charge, and the time required to charge this capacitor to the C voltage, which is 2 volts (typical), is the output off time. When the capacitor is charged to the C voltage of 2 volts, the sink side output transistors are turned on again. The C pin charge current is a fixed current determined by the resistor R connected to the R pin. The capacitor charge current I_{CL} and the output off time t_{off} are related as follows.

$I_{CL} \approx 1.3/R$ (R must be set to a value in the range 13 to 100 kΩ)

$t_{off} \approx C/I_{CL} \times 2.0$

$\approx 1.53 \times R \times C$

7.2 Output current ignored time

While the current limiter circuit is operating and the sink side output is off, a regenerative current flows in the external diode provided to absorb regenerative currents in the upper side of the output circuit that was turned off. When the sink side output is turned off after the output off time has elapsed, a reverse current flows instantaneously in this diode due to the diode’s reverse recovery time. Due to this phenomenon, a current that may reach the current limit value flows instantaneously in the output. If the current limiter operated again due to this current, the output would be turned off and the average current level would fall. This could result in significantly lower torque during, for example, motor startup. Therefore, to prevent this current from being detected, the current limiter circuit also provides a fixed period (the output current ignored time) during which the output current is not detected at the point where the sink side output is turned on again after being turned off. The output current ignored time is determined by the discharge time for the capacitor connected to the C pin. This discharge starts at the point where the capacitor is charged to 2 volts following operation of the current limiter circuit. The output current ignored time is the time for the capacitor to discharge to 0.4 volts (typical). The capacitor discharge current is a fixed current and is set to be a current about three times the charge current. Therefore, the output current ignored time is about 1/3 the output off time. The capacitor discharge current I_{CH} and the output current ignored time t_{sm} are related as follows.

$I_{CH} \approx 1.3/R \times 3$

$t_{sm} \approx C/I_{CH} \times 1.6$

$\approx 0.41 \times R \times C$

Since the current limiter circuit provides a slope to the on time when the sink side output is turned on again, the reverse circuit never becomes significantly large, even if a rectifying diode (i.e. a diode whose reverse recovery time is not particularly short) is used as the regenerative current absorption external diode.

7.3 Output off time setting

The output off time must be set to a period optimal for the type of motor used. This time is set by the values of the external resistor attached to the R pin and the external capacitor attached to the C pin. Figure 1 shows the waveforms during current limiter operation.

(1) If a shorter output off time is used:
Since the output off time and the output current ignored time are set to have a ratio of about 3:1 by IC internal circuits, it is not possible to set these periods independently. Thus the output current ignored period may become insufficient if the output off time is set to an excessively short period. If the output current ignored period is too short, the reverse current in the regenerative current absorption external diode may cause the current limiter circuit to operate. (See Section 7.2.) Also, if the output off time is decreased, the diode reverse current will increase and ASO may become a problem.

(2) If a longer output off time is used:
If an excessively long output off time is used, the average current will decrease resulting in reduced torque during motor startup. For some motor types, this may make it impossible to switch from the current limiter operating state to steady state operation.

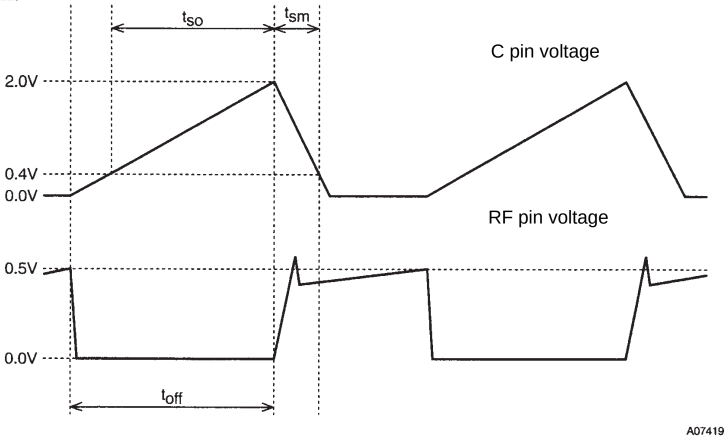


Figure 1. Current Limiter Operating Waveforms

8. IC internal power dissipation calculation

$$Pd = (V_{CC} \times I_{CC}) + (V_M \times I_M) - \text{(power dissipated in the motor coils)}$$

9. Techniques for measuring IC internal temperature increases

Since it is not possible to measure the IC internal temperature directly, one of the following techniques is normally used for temperature measurement.

9.1 Thermocouple measurement

When using a thermocouple for temperature measurement, the thermocouple is attached to a fin on the heat sink. While this measurement technique is simple, it suffers from large measurement errors when the thermal generation process is not at steady state.

9.2 Measurement using IC internal diode properties

We recommend using the properties of the parasitic diode that exists between FG1 and ground for measuring the temperature of this IC. Set FG1 to the high (off) state and measure the V_F voltage of the parasitic diode. Then calculate the temperature from the temperature characteristics of the V_F voltage.