

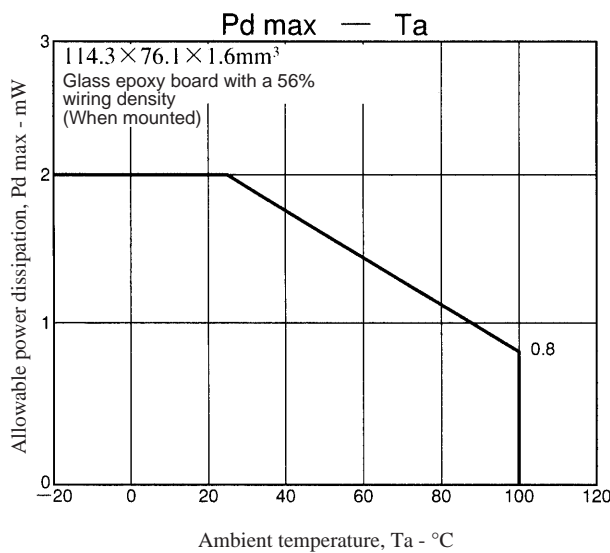


# LB1695M

## DC Fan Motor Driver

### Overview

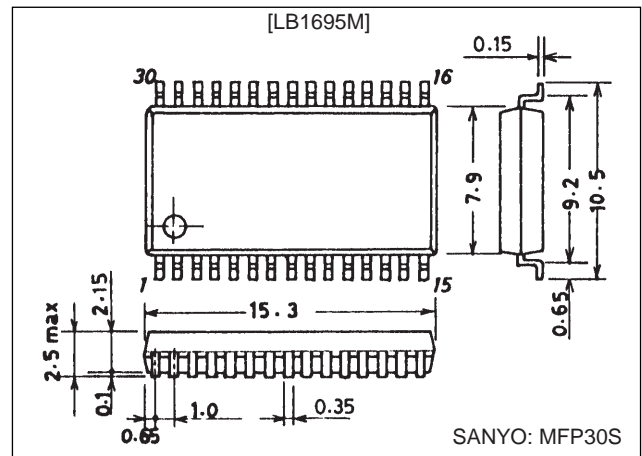
The LB1695M is a 3-phase brushless motor driver IC that is optimal for driving the DC fan motors used in home appliances such as water heaters.



### Package Dimensions

unit: mm

#### 3216A-MFP30S



### Specifications

#### Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	V <sub>CC</sub>		10	V
	V <sub>M</sub>		45	V
Output current	I <sub>O</sub>		2	A
Allowable power dissipation	Pd max	When mounted on a printed circuit board (114.3 × 76.1 × 1.6 mm, glass epoxy)	2	W
Operating temperature	T <sub>opr</sub>		-20 to +100	°C
Storage temperature	T <sub>stg</sub>		-55 to +150	°C

#### Allowable Operating Ranges at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Operating supply voltage range	V <sub>CC</sub>		4.5 to 5.5	V
	V <sub>M</sub>		5 to 42	V
Voltage slew rate at power on	ΔV <sub>CC</sub> /Δt	At the point V <sub>CC</sub> = V <sub>LVSD</sub> (OFF)*	Under 0.04	V/μs
	ΔV <sub>M</sub> /Δt	At the point V <sub>M</sub> = 0 V*	Under 0.16	V/μs

Note: For the items marked with asterisks (\*), through currents may flow in the outputs if the power supply voltage slew rate is excessive.

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### Electrical Characteristics at Ta = 25°C, VCC = 5 V, VM = 30 V

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Current drain	$I_{CC}$	Forward rotation		13	19	mA
Output saturation voltage	$V_{O(sat)1}$	$I_O = 0.5 \text{ A } V_{O(sink)} + V_{O(source)}$		1.8	2.4	V
	$V_{O(sat)2}$	$I_O = 1.0 \text{ A } V_{O(sink)} + V_{O(source)}$		2.1	2.8	V
Output leakage current	$I_O \text{ leak}$				100	$\mu\text{A}$
[Hall Amplifier]						
Input bias current	$I_{HB}$			1	4	$\mu\text{A}$
Common-mode input voltage range	$V_{ICM}$		1.5		3.2	V
Hysteresis	$\Delta V_{IN}$		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	$V_{FGL}$	$I_{FG} = 5 \text{ mA}$			0.4	V
Pull-up resistance	$R_{FG}$		7.5	10.0	12.5	k $\Omega$
[Forward/Reverse Operation]						
Forward	$V_{FR1}$			0.0	0.8	V
Reverse	$V_{FR2}$		4.2	5.0		V
[Current Limiter Operation]						
Limiter	$V_{RF}$		0.42	0.50	0.60	V
[Thermal Protection Circuit]						
Operating temperature	TSD	*1	150	180		°C
Hysteresis	$\Delta TSD$	*1		40		°C
[Low Voltage Protection Circuit]						
Operating voltage	$V_{LVSD}$		3.5	3.8	4.1	V
Release voltage	$V_{LVSD(OFF)}$			4.3	4.5	V
Hysteresis	$\Delta V_{LVSD}$		0.4	0.5	0.6	V
[C Pin]						
Charge current	$I_{CL}$	$R = 33 \text{ k}\Omega$	30	40	50	$\mu\text{A}$
Discharge current	$I_{CH}$	$R = 33 \text{ k}\Omega$	90	120	150	$\mu\text{A}$
Charge start voltage	$V_{CL}$	$R = 33 \text{ k}\Omega$	0.3	0.4	0.5	V
Charge start voltage	$V_{CH}$	$R = 33 \text{ k}\Omega$	1.5	2.0	2.5	V
Output current ignored time	$t_{sm}$	$R = 33 \text{ k}\Omega, C = 4700 \text{ pF}$	58	68	78	$\mu\text{s}$
Output off time	$t_{so}$	$R = 33 \text{ k}\Omega, C = 4700 \text{ pF}$	164	193	222	$\mu\text{s}$

Note: Items marked with an asterisk are design target values and are not tested.

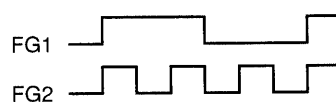
### Truth Table

	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

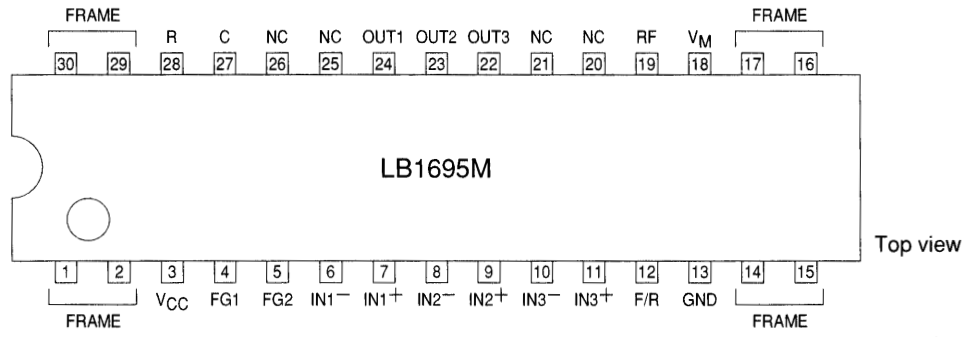
FG output



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## Pin Assignment



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## Pin Functions

Pin No.	Symbol	Pin voltage (V)	Equivalent circuit	Pin function
1, 2, 14, 15, 16, 17, 29, 30	FRAME			<ul style="list-style-type: none"> <li>Pins provided for heat dissipation. These pins must be electrically open.</li> </ul>
3	V <sub>CC</sub>			<ul style="list-style-type: none"> <li>Power supply for blocks other than the output block.</li> </ul>
4 5	FG1 FG2		<p style="text-align: right;">A09620</p>	<ul style="list-style-type: none"> <li>Speed pulse output 1 A pull-up resistor is built in.</li> <li>Speed pulse output 2 A pull-up resistor is built in.</li> </ul>
6 7 8 9 10 11	IN1 <sup>-</sup> IN1 <sup>+</sup> IN2 <sup>-</sup> IN2 <sup>+</sup> IN3 <sup>-</sup> IN3 <sup>+</sup>	1.5 V min V <sub>CC</sub> - 1.8 V max	<p style="text-align: right;">A09621</p>	<ul style="list-style-type: none"> <li>Hall inputs. The logic high state is when IN<sup>+</sup> &gt; IN<sup>-</sup>.</li> </ul>
12	F/R	0.0 V min V <sub>CC</sub> max	<p style="text-align: right;">A09622</p>	<ul style="list-style-type: none"> <li>Forward reverse control</li> </ul>
13	GND			<ul style="list-style-type: none"> <li>Ground for blocks other than the output block. The RF pin voltage will be the lowest potential taken on by the output transistors.</li> </ul>

Continued on next page.



## LB1695M Functional Description

### 1. Hall input circuit

The Hall input circuit is a differential amplifier with a hysteresis of 30 mV (typical). The operating DC level must fall within the common-mode input voltage range (1.5 V to  $V_{CC} - 1.8$  V). We recommend providing inputs with a swing of at least three times the hysteresis, i.e. 120 to 160 mV p-p, to prevent noise from interfering with circuit operation. Insert capacitors in the Hall amplifier  $IN^+$  and  $IN^-$  inputs if capacity is found to be problematic during noise evaluation.

### 2. Protection circuits

#### • Low voltage protection circuit

If the  $V_{CC}$  voltage falls below a stipulated level (VLVSD), the sink side output transistor is turned off. This circuit prevents incorrect operation at low  $V_{CC}$  voltages.

#### • Thermal protection circuit

If the junction temperature exceeds a stipulated temperature (TSD), the sink side output transistor is turned off. This circuit protects the IC from thermal damage. Applications must be designed so that this circuit only operates in abnormal conditions.

### 3. FG output circuit

This circuit outputs signals that are synthesized from the  $IN1$ ,  $IN2$ , and  $IN3$  Hall amplifier input signals and to which wave shaping has been applied. FG1 has the same frequency as the Hall inputs, and FG2 has a frequency three times that of the Hall inputs.

### 4. Forward/reverse control circuit

This IC is designed assuming that applications will not perform motor forward/reverse (F/R) control operations while the motor is turning. Through currents will flow in the output if the motor direction is switched while the motor is turning and ASO will become a problem. We recommend performing F/R control operations with the  $V_M$  power supply in the off state, i.e. when the motor is stopped.

### 5. $V_{CC}$ and $V_M$ power supplies

If the power supply slew rate at power on is excessive, through currents will flow in the output and ASO will become a problem. The power supply slew rates must not exceed  $\Delta V_{CC}/\Delta t = 0.04$  V/ $\mu$ s and  $\Delta V_M/\Delta t = 0.16$  V/ $\mu$ s. Also, at power on it is desirable to bring up the  $V_{CC}$  voltage first, and then bring up the  $V_M$  voltage. At power off, it is desirable to bring down  $V_M$  first, and then bring down  $V_{CC}$  only after the motor has stopped. If  $V_{CC}$  is turned off after  $V_M$  but while the motor is still turning due to inertia, the  $V_M$  voltage may rise beyond the voltage handling capacity of the IC.

### 6. Power supply stabilization capacitors

If large fluctuation occur in the  $V_{CC}$  line, the low-voltage protection circuit may operate incorrectly. Capacitors (with values of a few  $\mu$ F) must be inserted in the  $V_{CC}$  line (between  $V_{CC}$  and ground) to stabilize the power supply. Since large switching current flow in the  $V_M$  line, fluctuations in the IC  $V_M$  voltage may occur due to inductances in the wiring pattern. Capacitors must be inserted in the  $V_M$  line (between  $V_M$  and ground) so that incorrect operation and voltages in excess of the IC voltage handling capacity do not occur. In particular, if the application wiring lines ( $V_M$ ,  $V_{CC}$ , and ground) are long, capacitors adequate to stabilize the power supply lines must be used.

### 7. Current limiter circuit

When the output current reaches the current set as the output current (the limit value), the current limiter circuit turns off the sink side output transistor to limit the output current to the limit value. The RF pin is used to detect the output current. In particular, the output current is detected as a voltage using the Rf resistor, which is inserted between the RF pin and ground. The current limiter operates when the Rf pin reaches 0.5 V (typical) and thus the output current is limited to a value of  $0.5/R_f$ .

#### • Output off time

After the current limiter circuit operates and limits the current by turning off the sink side output transistor, it provides a fixed off period (referred to as the output off time), after which it turns the transistor back on. As opposed to current limiter techniques that operated the output in an unsaturated state, the use of an output switching system of this type for the current limiter has the advantage that ASO during current limiter operation is less likely to be a problem. The output off time is determined by the charging time of the capacitor connected to the C pin. When the current limiter operates, the circuit starts to charge the C pin capacitor, and the output off time is the time required to charge the capacitor to a voltage of 2 V (typical). When the capacitor voltage reaches 2 V, the sink side output is turned on again. The capacitor charge current is a fixed current determined by the resistor R connected to the R pin. The C charge

current  $I_{CL}$  and the output off time  $t_{OFF}$  are related as follows:

$$I_{CL} \approx 1.3/R \text{ (R must have a value in the range 13 k}\Omega \text{ to 100 k}\Omega)$$

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

$$\approx 1.53 \times R \times C$$

- Output current ignored time

A regenerative current flows in the external diode provided to absorb regenerative currents in the upper side of the output that was turned off while the sink side of that output is turned off by the operation of the current limiter. When the output off time has elapsed and the sink side output has been turned on again a reverse current flows instantaneously in this diode, due to the reverse recovery period of the diode. This results in a current that may reach the current limit value instantaneously. If this current were to cause the current limiter circuit to operate again, the average current produced by the IC would be reduced, and the torque produced during motor drive could be reduced. Therefore, to assure that this current is not detected, the current limiter circuit provides a period (referred to as the output current ignored time) during which the output current is not detected for a fixed period after the sink side output is turned on again after being turned off. The output current ignored time is determined by the discharge time of the capacitor  $C$  connected to the  $C$  pin. Discharge starts at the point the capacitor has been charged to 2 V after the current limiter circuit operates, and the output current ignored time is the time until the capacitor is discharged to 0.4 V (typical). The capacitor discharge current is a fixed current set to be about three times the charge current  $I_{CL}$ . Accordingly, the output current ignored time is about 1/3 the output off time. The  $C$  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 in the on time at the point when the sink side output is turned back on, reverse currents will not increase significantly, even if a rectifying diode (that is, a diode whose reverse recovery time is relatively long) is used as the regenerative current absorbing diode.

- Output off time setting

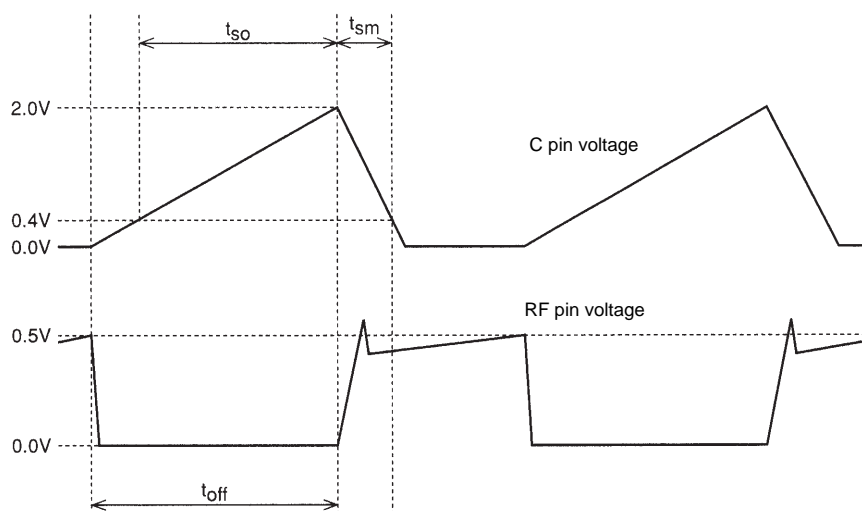
Applications must set up the output off time to be optimal for the type of motor used. (This time is set by the external resistor connected to the  $R$  pin and the external capacitor connected to the  $C$  pin.) Figure 1 shows the waveforms during current limiter operation.

— If the output off time is too short:

Since the ratio between the output off time and the output current ignored time is fixed at about 3:1 by IC internal circuits, it is not possible to set these parameters independently. This means that if a relatively short output off time is used, the output current ignored time may be insufficient. If the output current ignored time is insufficient, the current limiter circuit may operate due to the reverse current in the regenerative current absorption diode. (See section 7 above.) Also, if the output off time is too short, the reverse current may increase leading to ASO problems.

— If the output off time is too long:

Setting up a relatively long output off time can reduce the average current produced by the IC, which can result in reduced motor torque. For certain motor types, this may make it impossible to switch from the current limiter operating state to steady state operation at motor startup.



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**Figure 1 Current Limiter Circuit Operating Waveforms**

8. IC internal power dissipation calculation

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

9. Techniques for measuring IC temperature increases

Since it is not possible to measure the IC chip temperature directly, use one of the following techniques.

- Thermocouple measurement

When measuring the IC temperature using a thermocouple, attach the thermocouple to the heat sink. While this technique is simple, it suffers from large measurement errors when the thermal generation within the IC is not stable.

- Measurement using IC internal diode characteristics

We recommend using the parasitic diode between FG1 and ground to measure the operating temperature of this IC. To measure the temperature, set FG1 to the high (off) state, measure the  $V_F$  voltage of the parasitic diode, and calculate the temperature from the temperature characteristics of the  $V_F$  voltage.

According to Sanyo data:  $I_F = -1 \text{ mA}$ , and the  $V_F$  temperature characteristics are about  $-2 \text{ mV}/^\circ\text{C}$ .

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