

THREE-PHASE BRUSHLESS DC MOTOR DRIVER

PRELIMINARY DATA

- 3A OUTPUT CURRENT, CONTROLLED IN LINEAR MODE
- SUPPLY VOLTAGE UP TO 18 V
- COMPATIBLE WITH ANI f-TO-V CONVERTER AND PLL SPEED CONTROL SYSTEM
- INHIBIT FUNCTION
- SLEW RATE LIMITING FOR EMI REDUCTION
- CONNECTS DIRECTLY TO HALL EFFECT CELLS
- THERMAL SHUTDOWN WITH HYSTERESIS
- THREE-STATE OPERATION ALLOWS NEGLIGIBLE POWER DISSIPATION DURING 1/3 f CYCLE
- INTERNAL PROTECTION DIODES
- FEW EXTERNAL COMPONENTS

recirculation the output stage is switched to an off state, reducing dissipation to a very low value and minimizing torque ripple.

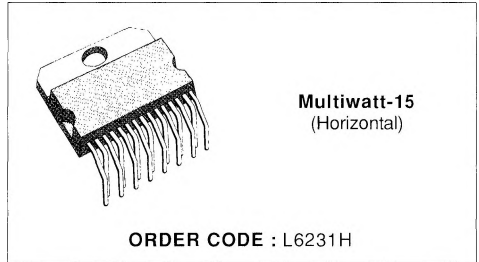
A speed control input controls the base current to the lower transistors to limit the motor current and hence control the speed. Any type of speed control system, including f to V and PLL systems, may be used with the L6231 by providing an analog signal at this input. The motor current may be sensed by an external resistor connected to a sensing pin on the device.

The power stage of the device is designed to eliminate the possibility of simultaneous conduction of the upper and lower power transistors of one output driver, when operating in the right loop.

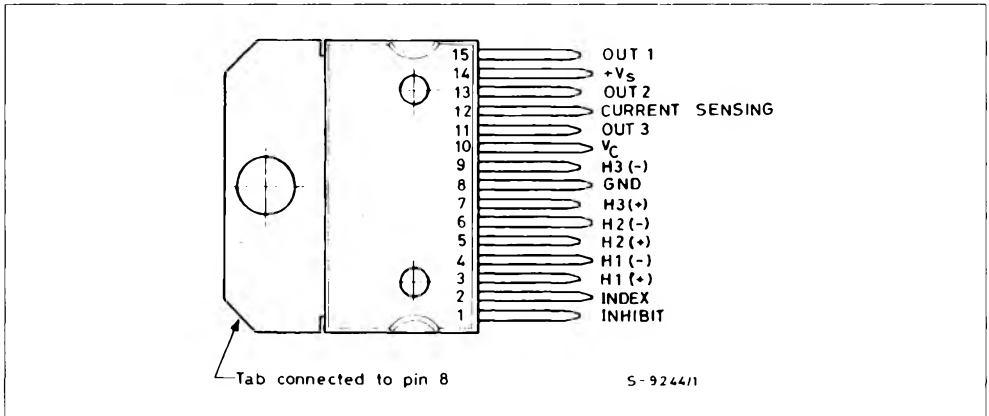
DESCRIPTION

The L6231 is a single-chip driver for three-phase brushless DC motors capable of delivering 3A output current with supply voltages to 18 V. Designed to accept differential input from the Hall effect sensors, the device drives the three phases of a brushless DC motor and includes all the commutation logic required for a three phase drive.

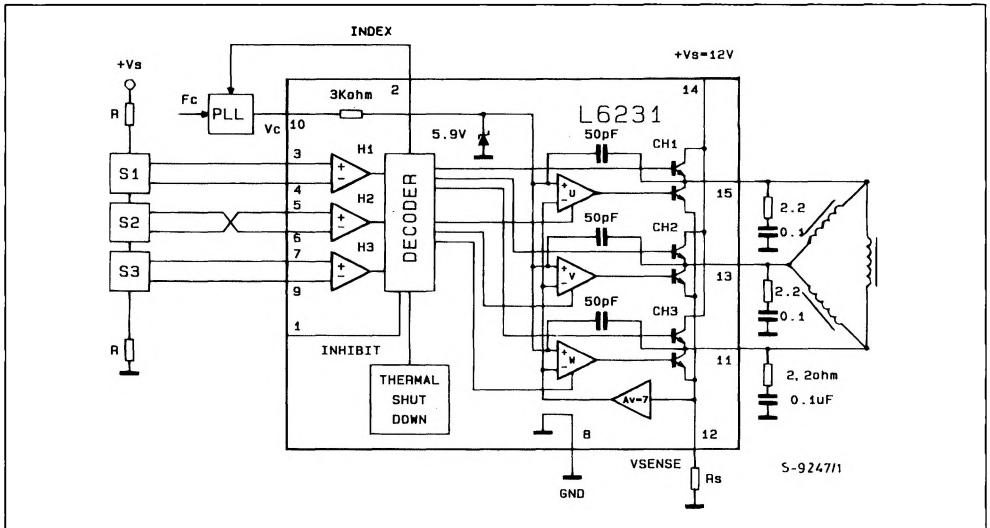
To limit EMI emission the L6231 controls the rise and fall times of the output stage. In addition the device is designed to limit power dissipation : during



PIN CONNECTION (top view)



BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_s	Supply Voltage	20	V
I_o	Peak Output Current Each Channel		
	- Non Repetitive (100 μ s)	4	A
	- Repetitive (t = 10 ms)	3.5	A
	- DC Operation	3	A
V_I	Logic and Analogic Inputs	V_s	
P_{Tot}	Total Power Dissipation $T_{case} = 75^\circ C$	25	W
T_{Op}	Operating Temperature Range	0 to 70	$^\circ C$
T_{j}, T_{sgt}	Storage and Junction Temperature	- 40 to 150	$^\circ C$

THERMAL DATA

$R_{th\ j-case}$	Thermal Resistance Junction-case	Max	3	$^\circ C/W$
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PIN FUNCTIONS

N°	Name	I/O	Function
1	INHIBIT	I	Output Stage Inhibit. When this pin is high all three output stages are in a high impedance state.
2	INDEX	O	Signal Pulse Proportional to the Motor Speed. In PPL speed control applications, this is the feedback to the PLL. One pulse per electrical rotation. This is an open collector output.
3	H1 (+)	I	Positive Input of Differential Amplifier on Channel 1. Interfaces with Hall Effect sensor, S1, from motor.
4	H1 (-)	I	Negative Input of Differential Amplifier on Channel 1. Interfaces with Hall Effect sensor, S1, from motor.
5	H2 (+)	I	Same as Pin 3 for Channel 2.
6	H2 (-)	I	Same as Pin 4 for Channel 2.
7	H3 (+)	I	Same as Pin 3 for Channel 3.
8	GND		Ground Connection.
9	H3 (-)	I	Same as Pin 4 for Channel 3.
10	V _C	I	Speed Control Input. Connected to output of PLL in PLL speed control applications.
11	Out 3.	O	Output Motor Drive for Phase 3.
12	Sense	I	Current Sensing. Input for load current sense voltage for output stage.
13	Out 2	O	Output Motor Drive for Phase 2.
14	V _S		Motor Supply Voltage.
15	Out 1	O	Output Motor Drive for Phase 1.

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C ; V_S = 12V unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V _S	Supply Voltage		10	12	18	V
I _S	Quiescent Supply Current			60	100	mA

HALL AMPLIFIERS

V _{CM}	Common Mode Voltage Range		0		10	V
V _{io}	Input Offset Voltage	V _I = 6 V		2	10	mV
V _{Ib}	Input Bias Current	V _I = 6 V		2	10	μA
I _{io}	Input Offset Current	V _I = 6 V		0.1		μA

SPEED CONTROL INPUT (V_C)

V _I	Input Voltage Range		0		5	V
I _{Ib}	Input Bias Current	V _C < V _{Sens}		1	5	μA
V _{Ic}	Input Clamping Voltage			5.9		V

ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
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INHIBIT INPUT

V_{IH}	Input High Voltage		2		V_S	V
V_{IL}	Input Low Voltage		0		0.8	V
I_{IH}	Input High Current				10	μA
I_{IL}	Input Low Current			-5	-50	μA

HALL LOGIC OUTPUT

V_{LO}	Low Output Voltage	$I = 5 \text{ mA}$			0.8	V
I_L	Leakage Current	$V_{CE} = 12 \text{ V}$			10	μA

OUTPUT POWER STAGE

V_{sat}	Total Saturation Voltage	$I_o = 1A$ $I_o = 2A$ $I_o = 3A$		2.7 3.6 4.2	3.7 4.5	V
V_{OSR}	Output Voltage Slew-rate			100		V/ms
V_{sens}	Sens Voltage Range		0		0.7	V

THERMAL SHUTDOWN

T_J	Junction Temperature		150			$^{\circ}C$
T_H	Hysteresis				30	$^{\circ}C$

DESCRIPTION

The L6231 is a three-phase brushless motor driver IC containing all the power stages and commutation logic required for a three-phase drive. When the INHIBIT INPUT is high all three OUTPUT ARE PLACED in a high - IMPEDANCE STATE.

Logic signals from the motor's Hall effect sensors are decoded to generate the correct driving sequence according to the truth-table of Fig. 1.

When one of the push-pull output drivers is activated the upper transistor is always in saturation while the lower transistor is controlled in linear mode to set the desired speed in steady state conditions.

In PLL speed control applications the device provides a signal proportional to the motor speed at pin 2 (it is buffered H1 input). The output of the PLL is connected to the speed control input on the device at pin 10, V_C .

In addition, a 1 V offset is added to the speed demand voltage to match the minimum output of the PLL.

An external resistor, R_S , senses the output stage current. The sensing voltage across this resistor is amplified in the device by a factor of 7 to allow a reduction in the voltage drop the resistor.

The amplified sensing voltage is then compared with the speed demand signal from the PLL and the resulting error signal sets the amplifier output accordingly.

The output current is related to the speed control voltage by :

$$I_o = \frac{(V_C - 1)}{7 R_S}$$

The value of the sensing resistor is given by :

$$R_S = (V_X - 1) / (7 I_{max})$$

where V_X is the full scale voltage of V_C (see fig.2).

In this way the V_C / I_{out} characteristics can be modified as shown in Fig. 2. Note that V_X max is clamped at 5.9 V.

The most important feature of the L6231 is slow rate control. With this device a typical value of 0.1 V/ μ s is achieved, reducing EMI to a very low value.

Another key feature is three-state operation ; when the current is recirculating the corresponding phase driver is switched off and power dissipation in negligible. Current recirculates through the free-wheeling diodes in the acceleration phase and through the motor in steady-state conditions. Torque ripple is also minimized.

The L6231 can also operate with a brushless motor connected in a star configuration, leaving the center floating.

The Hall inputs are ground compatible comparators and can work with direct active digital Hall signals on three terminals (of the same polarity) and a TTL level on the other three terminals.

Figure 1 : Truth Table.

Hall Effect Diff. Input			Upper Driver Status			Lower Driver Status		
1 = Positive 0 = Negative			1 = On 0 = Off			1 = On 0 = Off		
H1	H2	H3	UD1	UD2	UD3	LD1	LD2	LD3
1	0	0	0	0	1	1	0	0
1	1	0	0	0	1	0	1	0
1	1	1	1	0	0	0	1	0
0	1	1	1	0	0	0	0	1
0	0	1	0	1	0	0	0	1
0	0	0	0	1	0	1	0	0

Figure 2 : Output Current vs. Input Voltage.

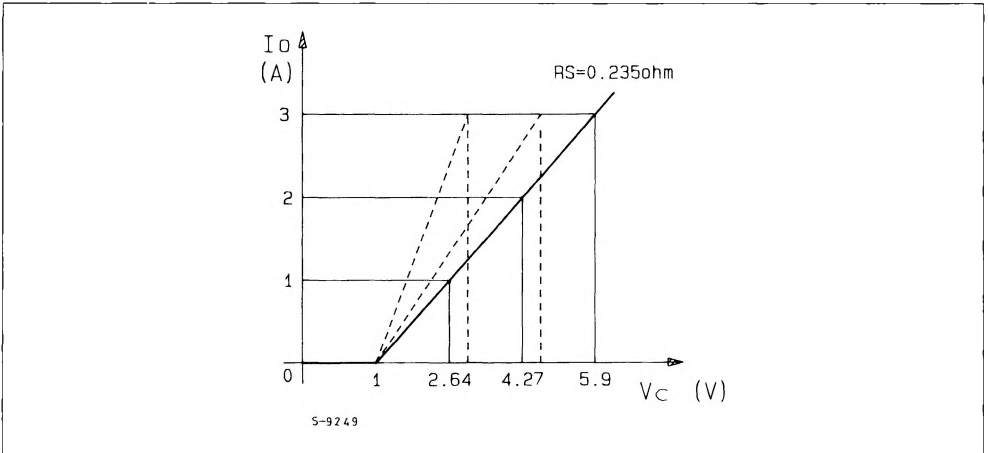
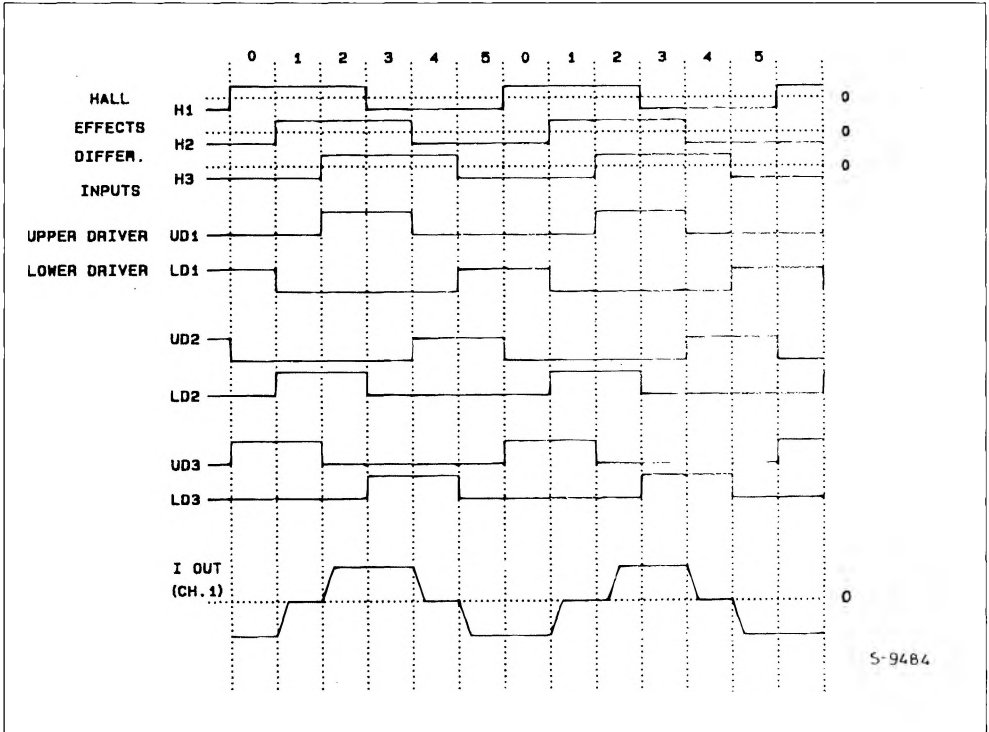


Figure 3 : Timing Diagram.



DETERMINING HALL EFFECT SENSOR CODING

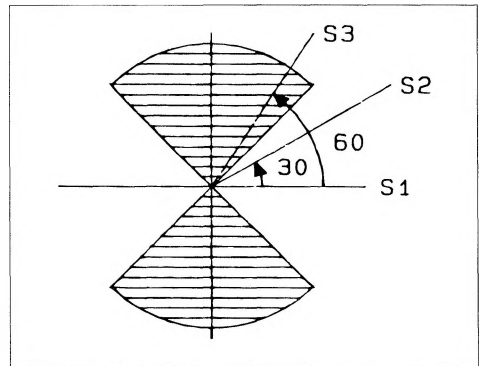
The L6231 assumes that the positioning of the Hall Effect sensors in a three-phase brushless DC bipolar motor are at 30 intervals. One can imagine two "windows" on the rotor each of which is 90 wide and 180 apart, see fig. 4. As a window passes over a sensor, the sensor output goes high. The timing diagram, fig.3, shows the waveforms produced. These waveforms must appear at the Hall Effect Inputs of the L6231. Note that the rotation in fig. 4 must be counter-clockwise for forward rotation of the motor in whatever manner that is defined for the motor.

Fig. 4 is a stylized concept for determining the Hall Effect code pattern and does not reflect the actual direction of rotation of the motor in a physical sense. If a motor is chosen whose sensor outputs do not match the L6231 desired input pattern, a signal set conversion must be determined. It is helpful to visualize this by developing a diagram similar to that of fig. 4.

For example, let us examine the output pattern of a different type of motor (fig. 5). Assuming 90 windows

at 180 intervals, then with respect to fig. 4, a similar diagram, fig. 6, results in sensors 60 apart with the windows rotating clockwise. This situation results in a "forward" rotation of the motor.

Figure 4.



Since S3 is the first sensor encountered by the window in fig. 6, this should be used for the L6231 Hall Effect Input, H1. After 30° of rotation CW, the H2 input of the L6231 must go high. The inverse of S1 from the motor would satisfy this. After an additional 30° of rotation, the H3 input must go high. The S2 sensor is encountered by the window. Thus, S2 is applied to this input, H3. By continuing around the diagram, one can develop a pattern which matches that for the L6231.

Figure 5.

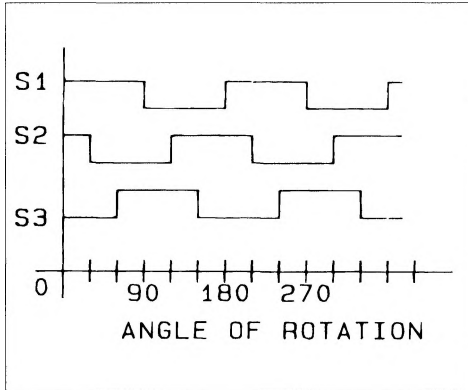
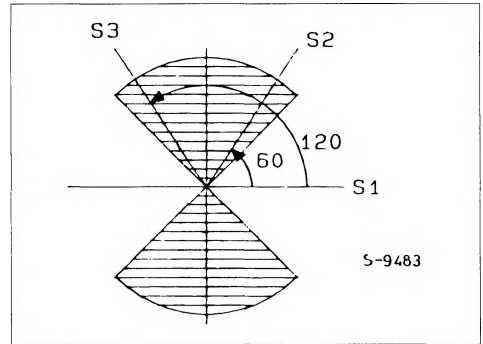


Figure 6.



Thus, the conversion table for this particular motor is :

Motor Sensors	L6230 Inputs
S3	H1
S1	H2
S2	H3

Note, for the inverted signal from S1 an actual inverter gate is not necessary with the L6231. Since the L6231 has differential inputs, the negative input pin may be used. Therefore, with TTL compatible Hall Effect sensors, the positive input is connected to a reference point along with the other negative inputs.