

# 2936-120

## 3-PHASE BRUSHLESS DC MOTOR CONTROLLER/DRIVER

Combining logic and power, the UDN2936W-120 provides commutation and drive for three-phase brushless dc motors. Each of the three outputs are rated at 45 V and  $\pm 2$  A ( $\pm 3$  A peak), and include internal ground clamp and flyback diodes. The driver also features internal commutation logic, PWM current control, and thermal shutdown protection.

The UDN2936W-120 is compatible with single-ended digital or linear Hall effect sensors. The commutating logic is programmed for 120° electrical separation. The UDN2936W-120 can replace the original UDN2936W (60° electrical separation) by simply adding an inverter at the H<sub>2</sub> input. Current control is accomplished by sensing current through an external sense resistor and pulse-width modulating the source drivers. Voltage thresholds and hysteresis can be externally set by the user. If desired, internal threshold and hysteresis defaults (300 mV, 7.5 percent) can be used. The UDN2936W-120 also includes braking and direction control. Internal protection circuitry prevents crossover current when braking or changing direction.

The UDN2936W-120 is also available for operation between -40°C and +85°C. To order, change the prefix from 'UDN' to 'UDQ'.

For maximum power-handling capability, the UDN2936W-120 is supplied in 12-pin single in-line power-tab package. An external heat sink may be required for high-current applications. The tab is at ground potential and needs no insulation.

### FEATURES

- 10 V to 45 V Operation
- $\pm 3$  A Peak Output Current
- Internal Clamp Diodes
- Internal PWM Current Control
- 120° Commutation Decoding Logic
- Thermal Shutdown Protection
- Compatible with Single-Ended or Differential Hall-Effect Sensors
- Braking and Direction Control

Always order by complete part number, e.g., **UDN2936W-120**.

Dwg. No W-188

### ABSOLUTE MAXIMUM RATINGS

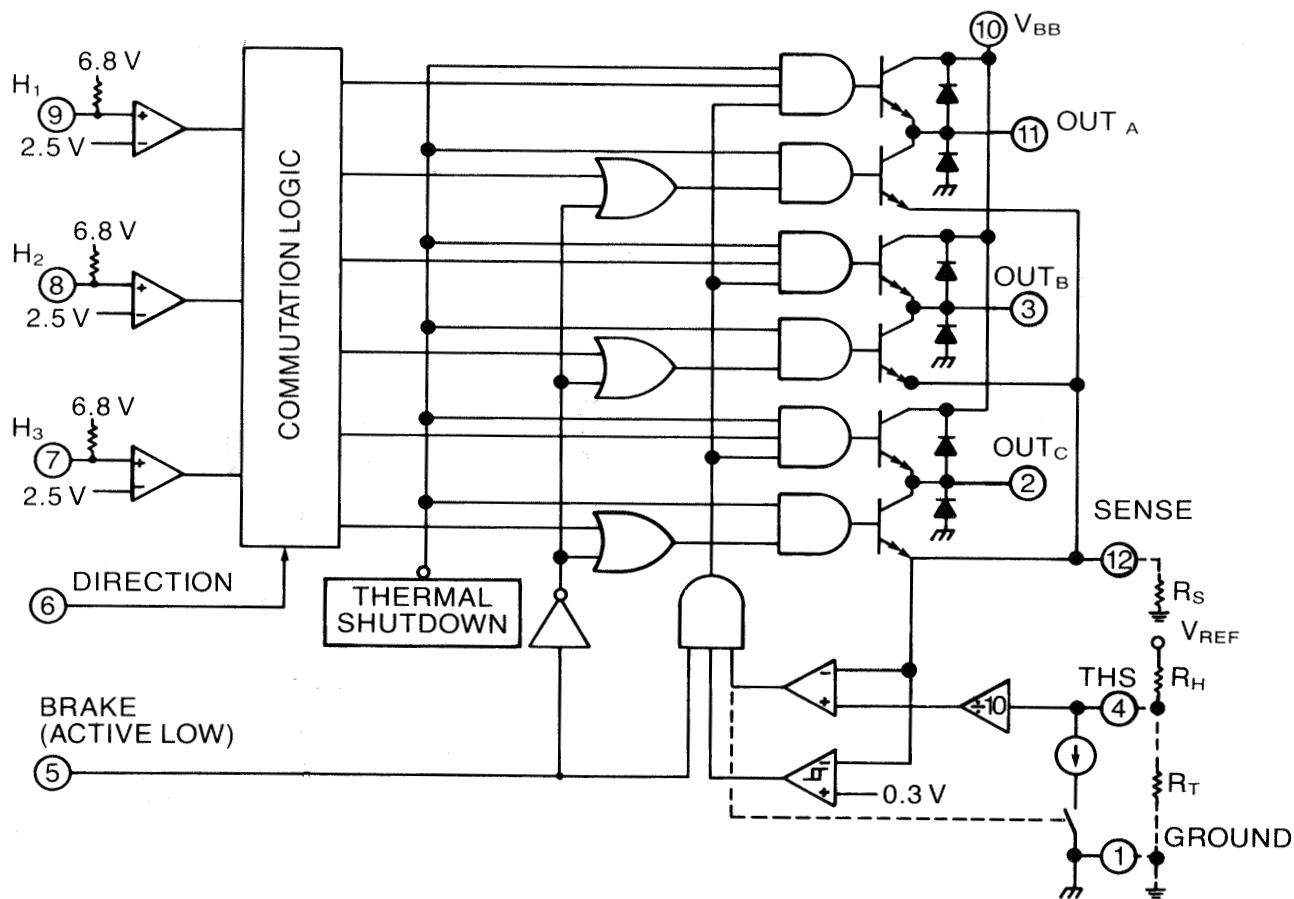
at  $T_J \leq +150^\circ\text{C}$

Supply Voltage, $V_{BB}$ .....	45 V
Output Current, $I_{OUT}$ (continuous) .....	$\pm 2.0$ A
(peak) .....	$\pm 3.0$ A
Input Voltage Range, $V_{IN}$ .....	-0.3 V to 15 V
Threshold Voltage, $V_{THS}$ .....	15 V
Package Power Dissipation, $P_D$ .....	See Graph
Operating Temperature Range, $T_A$ .....	-20°C to +85°C
Storage Temperature Range, $T_S$ .....	-55°C to +150°C

Note: Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified peak current and a junction temperature of +150°C.

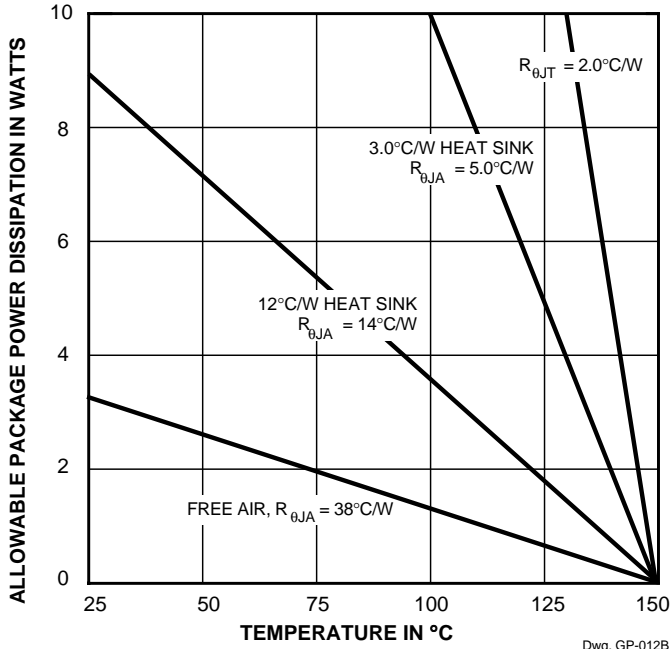
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**DC MOTOR**  
**CONTROLLER/DRIVER**

**Functional Block Diagram**

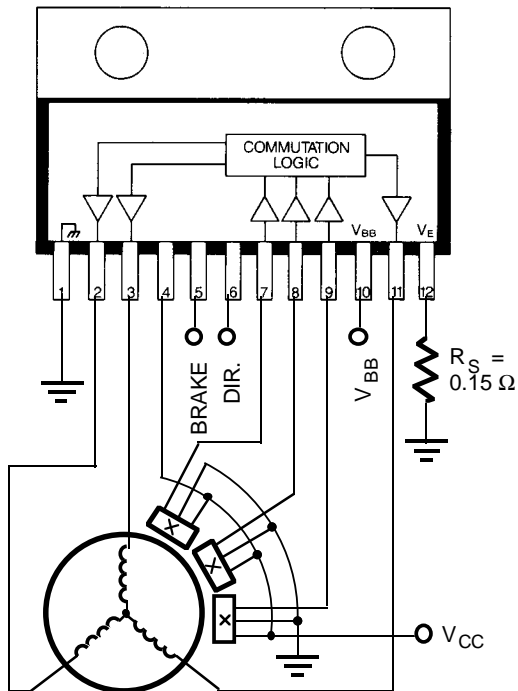


Dwg. No. W-190A

# 2936-120 3-PHASE BRUSHLESS DC MOTOR CONTROLLER/DRIVER



## Typical Application



Dwg. EP-033

## Commutation Truth Table UDN2936W-120

Hall Sensor Inputs			DIRECTION	BRAKE	Outputs		
H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>			OUT <sub>A</sub>	OUT <sub>B</sub>	OUT <sub>C</sub>
High	Low	High	Low	High	Z	Low	High
High	Low	Low	Low	High	High	Low	Z
High	High	Low	Low	High	High	Z	Low
Low	High	Low	Low	High	Z	High	Low
Low	High	High	Low	High	Low	High	Z
Low	Low	High	Low	High	Low	Z	High
High	Low	High	High	High	Z	High	Low
High	Low	Low	High	High	Low	High	Z
High	High	Low	High	High	Low	Z	High
Low	High	Low	High	High	High	Low	Z
Low	High	High	High	High	High	Z	High
Low	Low	High	High	High	High	Z	Low
X	X	X	X	Low	Low	Low	Low

X= Irrelevant

Z = High Impedance

Note that the UDN2936W-120 truth table is the same as the original UDN2936W except that the H<sub>2</sub> Hall sensor inputs are inverted.

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## ELECTRICAL CHARACTERISTICS at $T_A = +25^\circ\text{C}$ , $T_J \leq +150^\circ\text{C}$ , $V_{BB} = 45\text{ V}$

Characteristic	Symbol	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Supply Voltage Range	$V_{BB}$	Operating	10	—	45	V
Supply Current	$I_{BB}$	Outputs Open	—	32	40	mA
		$V_{BRAKE} = 0.8\text{ V}$	—	42	50	mA
Thermal Shutdown Temp.	$T_J$		—	165	—	$^\circ\text{C}$
Thermal Shutdown Hysteresis	$\Delta T_J$		—	25	—	$^\circ\text{C}$

### Output Drivers

Output Leakage Current	$I_{CEX}$	$V_{OUT} = V_{BB}$	—	—	50	$\mu\text{A}$
		$V_{OUT} = 0\text{ V}$	—	—	-50	$\mu\text{A}$
Output Saturation Voltage	$V_{CE(SAT)}$	$I_{OUT} = -1\text{ A}$	—	1.7	1.9	V
		$I_{OUT} = +1\text{ A}$	—	1.1	1.3	V
		$I_{OUT} = -2\text{ A}$	—	1.9	2.1	V
		$I_{OUT} = +2\text{ A}$	—	1.4	1.6	V
Output Sustaining Voltage	$V_{CE(sus)}$	$I_{OUT} = \pm 2\text{ A}$ , $L = 2\text{ mH}$	45	—	—	V
Clamp Diode Forward Voltage	$V_F$	$I_F = 2\text{ A}$	—	1.8	2.0	V
Clamp Diode Leakage Current	$I_R$	$V_R = 45\text{ V}$	—	—	50	$\mu\text{A}$
Output Switching Time	$t_r$	$I_{OUT} = \pm 2\text{ A}$ , Resistive Load	—	2.0	—	$\mu\text{s}$
	$t_f$	$I_{OUT} = \pm 2\text{ A}$ , Resistive Load	—	2.0	—	$\mu\text{s}$
Turn-ON Delay (Resistive Load)	$t_{on}$	Source Drivers, 0 to -2 A	—	1.25	—	$\mu\text{s}$
		Sink Drivers, 0 to +2 A	—	1.9	—	$\mu\text{s}$
Turn-OFF Delay (Resistive Load)	$t_{off}$	Source Drivers, -2 A to 0	—	1.7	—	$\mu\text{s}$
		Sink Drivers, +2 A to 0	—	0.9	—	$\mu\text{s}$

Continued next page...

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**ELECTRICAL CHARACTERISTICS at  $T_A = +25^\circ\text{C}$ ,  $T_J \leq +150^\circ\text{C}$ ,  $V_{BB} = 45\text{ V}$  continued**

Characteristic	Symbol	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
<b>Control Logic</b>						
Logic Input Voltage	$V_{IN(1)}$	$V_{DIR}$ or $V_{BRAKE}$	2.0	—	—	V
	$V_{IN(0)}$	$V_{DIR}$ or $V_{BRAKE}$	—	—	0.8	V
Sensor Input Voltage Threshold	$V_{IN}$	$H_1$ , $H_2$ , or $H_3$	—	2.5	—	V
Input Current	$I_{IN(1)}$	$V_{DIR} = 2\text{ V}$	—	150	200	$\mu\text{A}$
		$V_{BRAKE} = 2\text{ V}$	—	<1.0	5.0	$\mu\text{A}$
		$V_H = 5\text{ V}$	—	-190	-220	$\mu\text{A}$
	$I_{IN(0)}$	$V_{DIR} = 0.8\text{ V}$	—	35	50	$\mu\text{A}$
		$V_{BRAKE} = 0.8\text{ V}$	—	-5.0	-20	$\mu\text{A}$
		$V_H = 0.8\text{ V}$	—	-0.64	-1.0	mA
	$I_{THS}$	$V_{THS} \geq 3.0\text{ V}$	—	-8.0	-15	$\mu\text{A}$
		$V_{THS} < 3.0\text{ V}$ , $V_{SENSE} < V_{THS}/10.5$	—	-15	-30	$\mu\text{A}$
		$V_{THS} < 3.0\text{ V}$ , $V_{SENSE} > V_{THS}/9.5$	190	250	310	$\mu\text{A}$
Current Limit Threshold	—	$V_{THS}/V_{SENSE}$ at trip point, $V_{THS} < 3.0\text{ V}$	9.5	10	10.5	—
Default Sense Trip Voltage	$V_{SENSE}$	$V_{THS} \geq 3.0\text{ V}$	270	300	330	mV
Default Hysteresis	—	$V_{THS} \geq 3.0\text{ V}$	—	7.5	—	%
Deadtime	$t_d$	BRAKE or DIRECTION	—	2.0	—	$\mu\text{s}$

# 2936-120 3-PHASE BRUSHLESS DC MOTOR CONTROLLER/DRIVER

## APPLICATIONS INFORMATION

The UDN2936W-120 power driver provides commutation logic and power outputs to drive three-phase brushless dc motors.

The UDN2936W-120 is designed to interface with single-ended linear or digital Hall-effect devices (HEDs). Internal pull-up resistors allow for direct use with open-collector digital HEDs. The  $H_n$  inputs have 2.5 V thresholds.

The commutation logic provides decoding for HEDs with 120° electrical separation. At any one step in the logic sequencing, one half-bridge driver is sourcing current, one driver is sinking current, and one driver is in a high-impedance state (see Truth Table).

A logic low on the BRAKE pin turns on the three sink drivers and turns off the three source drivers, essentially shorting the motor windings to ground. During braking, the back-electromotive force generated by the motor produces a current that dynamically brakes the motor. Depending upon the rotational velocity of the motor, this current can approach the locked rotor current level (which is limited only by the motor winding resistance). During braking, the output current-limiting circuitry is disabled and care should be taken to ensure that the back-EMF generated brake current does not exceed the maximum rating (3 A peak) of the sink drivers and ground clamp diodes.

Changing the logic level of the DIRECTION pin inverts the output states, thus reversing the direction of the motor. Changing the direction of a rotating motor produces a back-EMF current similar to when braking the motor. The load current should not be allowed to exceed the maximum rating ( $\pm 3$  A peak) of the drivers.

An internally generated dead time ( $t_d$ ) of approximately 2  $\mu$ s prevents potentially destructive crossover currents that can occur when changing direction or braking.

Motor current is internally controlled by pulse-width modulating the source drivers with a preset hysteresis format. Load current through an external sense resistor ( $R_S$ ) is constantly monitored. When the current reaches the set trip point (determined by an external reference voltage or internal default), the source driver is disabled. Current recirculates through the ground clamp diode, motor winding, and sink driver. An internal constant-current sink reduces the trip point (hysteresis). When the decaying current reaches this lower threshold, the source driver is enabled again and the cycle repeats.

Thresholds and hysteresis can be set with external resistors, or internal defaults can be used. With  $V_{THS} > 3.0$  V, the trip point is internally set at 300 mV with 7.5% hysteresis. Load current is then determined by the equation:

$$I_{TRIP} = 0.3/R_S$$

With  $V_{THS} < 3.0$  V, the threshold, hysteresis percentage, and peak current are set with external resistors according to the equations:

$$\text{threshold voltage } (V_{THS}) = V_{REF} \times R_T / (R_H + R_T)$$

$$\text{hysteresis percentage} = R_H / 50 V_{REF}$$

$$\text{load trip current } (I_{TRIP}) = V_{THS} / 10 R_S$$

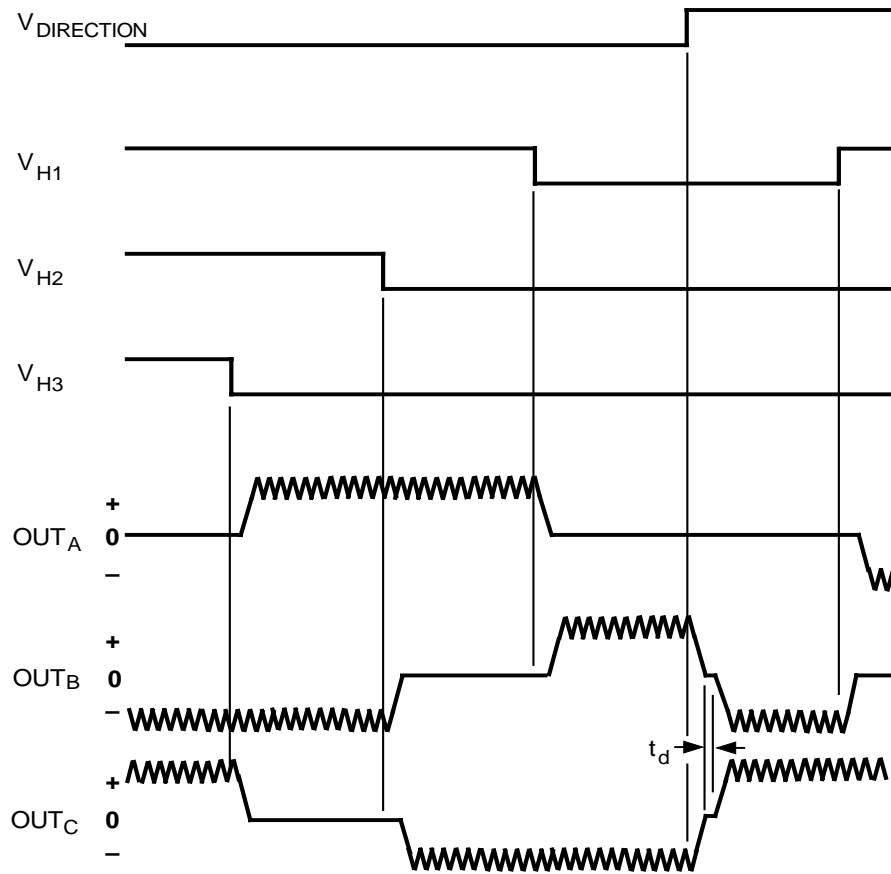
Percentage hysteresis is a fixed value independent of load current. The chopping frequency is a function of circuit parameters including load inductance, load resistance, supply voltage, hysteresis, and switching speed of the drivers.

The UDN2936W-120 outputs are rated for normal operating currents of up to  $\pm 2$  A and startup currents to  $\pm 3$  A (see cautions above regarding braking and changing of motor direction). Internal power ground-clamp and flyback diodes protect the outputs from the voltage transients that occur when switching inductive loads. All devices also feature thermal protection circuitry. If the junction temperature reaches +165°C, the thermal shutdown circuitry turns off all output drivers. The outputs are re-enabled when the junction cools down to approximately +140°C. This protection is only intended to protect the device from failures due to excessive junction temperature or loss of heat sinking and should not imply that output short circuits are permitted.

As with all high-power integrated circuits, the printed wiring board should utilize a heavy ground plane. For optimum performance, the drivers should be soldered directly into the board. The power supply should be decoupled with an electrolytic capacitor ( $> 10 \mu$ F) as close as possible to the device supply pin ( $V_{BB}$ ).

**Replacing the UDN2936W.** The original UDN2936W can be easily replaced with a UDN2936W-120 by inserting an inverter (two resistors and a 2N3904 or 2N2222) between the  $H_2$  Hall sensor and pin 8 of the UDN2936W-120, as shown in the figure on the next page. If an extra inverter is available, be certain that a pull-up for the Hall sensor is provided.

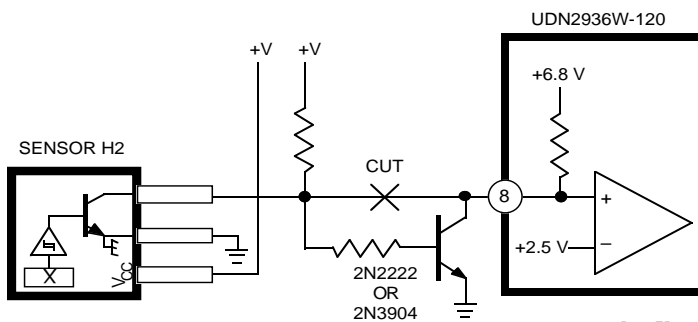
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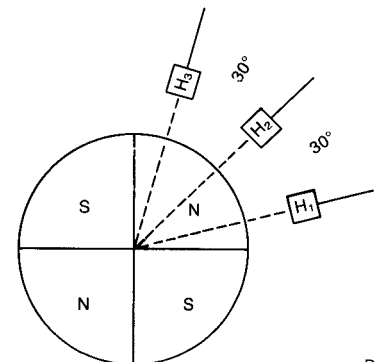
Dwg. WM-002-1

## Replacing the original UDN2936W

## Typical Hall-Effect Sensor Locations



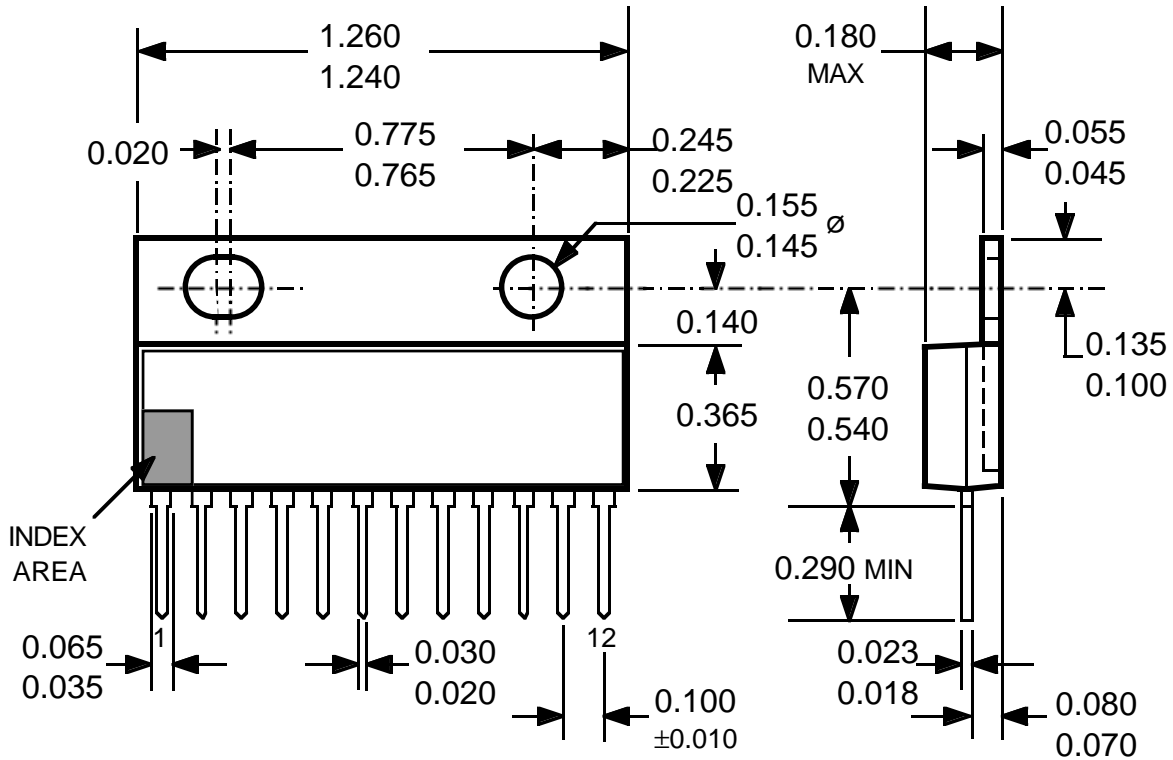
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Dwg. No. W-193

**2936-120**  
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**Dimensions in Inches**  
 (controlling dimensions)



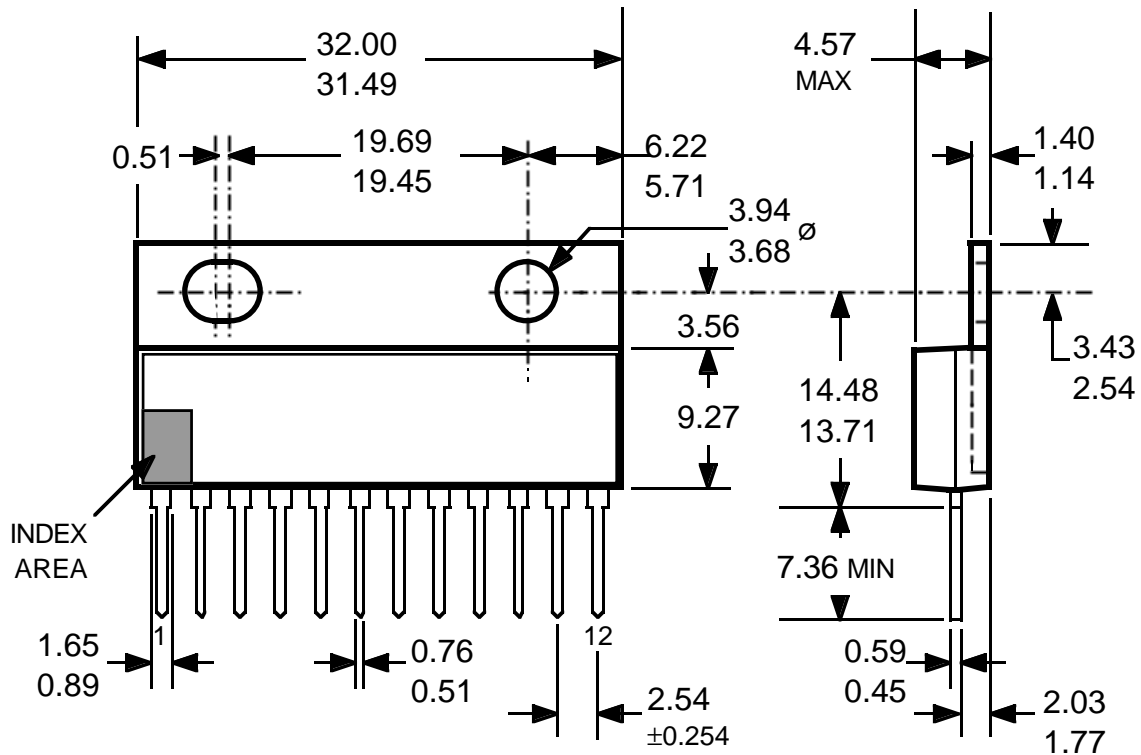
Dwg. MP-007 in

- NOTES: 1. Lead thickness is measured at seating plane or below.  
 2. Lead spacing tolerance is non-cumulative  
 3. Exact body and lead configuration at vendor's option within limits shown.  
 4. Lead gauge plane is 0.030" below seating plane.  
 5. Supplied in standard sticks/tubes of 15 devices.



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**Dimensions in Millimeters**  
(for reference only)



Dwg. MP-007 mm

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- NOTES: 1. Lead thickness is measured at seating plane or below.  
2. Lead spacing tolerance is non-cumulative  
3. Exact body and lead configuration at vendor's option within limits shown.  
4. Lead gauge plane is 0.762 mm below seating plane.  
5. Supplied in standard sticks/tubes of 15 devices.

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**CONTROLLER/DRIVER**

**MOTOR DRIVERS**

Function	Output Ratings*		Part Number†
<b>INTEGRATED CIRCUITS FOR BRUSHLESS DC MOTORS</b>			
3-Phase Power MOSFET Controller	—	28 V	3933
3-Phase Power MOSFET Controller	—	40 V	3935
3-Phase Power MOSFET Controller	—	50 V	3932
3-Phase Back-EMF Controller/Driver	±900 mA	14 V	8902-A
3-Phase PWM Current-Controlled DMOS Driver	±3 A	50 V	3936
<b>INTEGRATED BRIDGE DRIVERS FOR DC AND BIPOLAR STEPPER MOTORS</b>			
PWM Current-Controlled Dual Full Bridge	±500 mA	18 V	3965
Dual Full Bridge with Protection & Diagnostics	±500 mA	30 V	3976
PWM Current-Controlled Dual Full Bridge	±650 mA	30 V	3966
PWM Current-Controlled Dual Full Bridge	±650 mA	30 V	3968
Microstepping Translator/Dual Full Bridge	±750 mA	30 V	3967
PWM Current-Controlled Dual Full Bridge	±750 mA	45 V	2916
PWM Current-Controlled Dual Full Bridge	±750 mA	45 V	2919
PWM Current-Controlled Dual Full Bridge	±750 mA	45 V	6219
PWM Current-Controlled Dual Full Bridge	±800 mA	33 V	3964
PWM Current-Controlled Dual DMOS Full Bridge	±1.0 A	35 V	3973
PWM Current-Controlled Full Bridge	±1.3 A	50 V	3953
PWM Current-Controlled Dual Full Bridge	±1.5 A	45 V	2917
PWM Current-Controlled DMOS Full Bridge	±1.5 A	50 V	3948
PWM Current-Controlled Microstepping Full Bridge	±1.5 A	50 V	3955
PWM Current-Controlled Microstepping Full Bridge	±1.5 A	50 V	3957
PWM Current-Controlled Dual DMOS Full Bridge	±1.5 A	50 V	3972
PWM Current-Controlled Dual DMOS Full Bridge	±1.5 A	50 V	3974
PWM Current-Controlled Full Bridge	±2.0 A	50 V	3952
PWM Current-Controlled DMOS Full Bridge	±2.0 A	50 V	3958
Microstepping Translator/Dual DMOS Full Bridge	±2.5 A	35 V	3977
Dual DMOS Full Bridge	±2.5 A	50 V	3971
PWM Current-Controlled DMOS Full Bridge	±3.0 A	50 V	3959
<b>UNIPOLAR STEPPER MOTOR &amp; OTHER DRIVERS</b>			
Unipolar Stepper-Motor Quad Drivers	1.0 A	46 V	7024 & 7029
Unipolar Microstepper-Motor Quad Driver	1.2 A	46 V	7042
Unipolar Stepper-Motor Translator/Driver	1.25 A	50 V	5804
Unipolar Stepper-Motor Quad Driver	1.8 A	50 V	2540
Unipolar Stepper-Motor Quad Driver	3.0 A	46 V	7026
Unipolar Microstepper-Motor Quad Driver	3.0 A	46 V	7044

\* Current is maximum specified test condition, voltage is maximum rating. See specification for sustaining voltage limits or over-current protection voltage limits. Negative current is defined as coming out of (sourcing) the output.

† Complete part number includes additional characters to indicate operating temperature range and package style.

Also, see 3175, 3177, 3235, and 3275 Hall-effect sensors for use with brushless dc motors.

