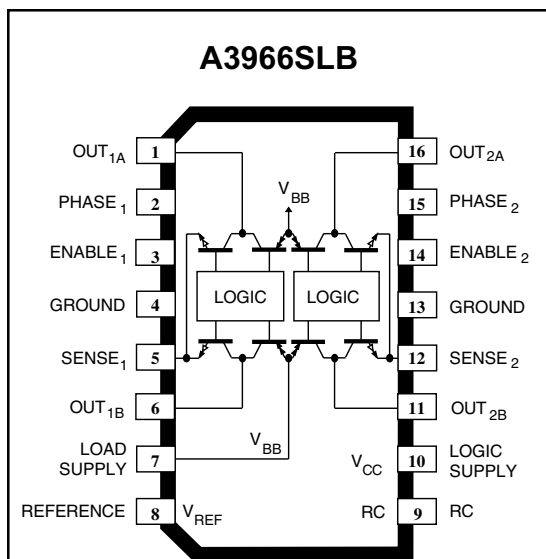


# 3966

## DUAL FULL-BRIDGE PWM MOTOR DRIVER



Dwg. PP-066-1

### ABSOLUTE MAXIMUM RATINGS

Load Supply Voltage, $V_{BB}$ .....	<b>30 V</b>
Output Current, $I_{OUT}$ (peak) .....	<b><math>\pm 750</math> mA</b>
(continuous) .....	<b><math>\pm 650</math> mA</b>
Logic Supply Voltage, $V_{CC}$ .....	<b>7.0 V</b>
Input Voltage, $V_{in}$ .....	<b>-0.3 V to <math>V_{CC} + 0.3</math> V</b>
Sense Voltage, $V_S$ .....	<b>1.0 V</b>
Package Power Dissipation ( $T_A = 25^\circ\text{C}$ ), $P_D$	
A3966SA .....	<b>2.08 W*</b>
A3966SLB .....	<b>1.87 W*</b>
Operating Temperature Range,	
$T_A$ .....	<b><math>-20^\circ\text{C}</math> to <math>+85^\circ\text{C}</math></b>
Junction Temperature,	
$T_J$ .....	<b><math>+150^\circ\text{C}</math></b>
Storage Temperature Range,	
$T_S$ .....	<b><math>-55^\circ\text{C}</math> to <math>+150^\circ\text{C}</math></b>

Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of  $150^\circ\text{C}$ .

\* Per SEMI G42-88 Specification, *Thermal Test Board Standardization for Measuring Junction-to-Ambient Thermal Resistance of Semiconductor Packages.*

The A3966SA and A3966SLB are designed to drive both windings of a two-phase bipolar stepper motor. Each device includes two H-bridges capable of continuous output currents of  $\pm 650$  mA and operating voltages to 30 V. Motor winding current can be controlled by the internal fixed-frequency, pulse-width modulated (PWM), current-control circuitry. The peak load current limit is set by the user's selection of a reference voltage and current-sensing resistors. Except for package style and pinout, the two devices are identical.

The fixed-frequency pulse duration is set by a user-selected external RC timing network. The capacitor in the RC timing network also determines a user-selectable blanking window that prevents false triggering of the PWM current-control circuitry during switching transitions.

To reduce on-chip power dissipation, the H-bridge power outputs have been optimized for low saturation voltages. The sink drivers feature Allegro's patented Satlington™ output structure. The Satlington outputs combine the low voltage drop of a saturated transistor and the high peak current capability of a Darlington.

For each bridge, a PHASE input controls load-current polarity by selecting the appropriate source and sink driver pair. For each bridge, an ENABLE input, when held high, disables the output drivers. Special power-up sequencing is not required. Internal circuit protection includes thermal shutdown with hysteresis, ground-clamp and flyback diodes, and crossover-current protection.

The A3966SA is supplied in a 16-pin dual in-line plastic package. The A3966SLB is supplied in a 16-lead plastic SOIC with copper heat sink tabs. The power tab is at ground potential and needs no electrical isolation.

### FEATURES

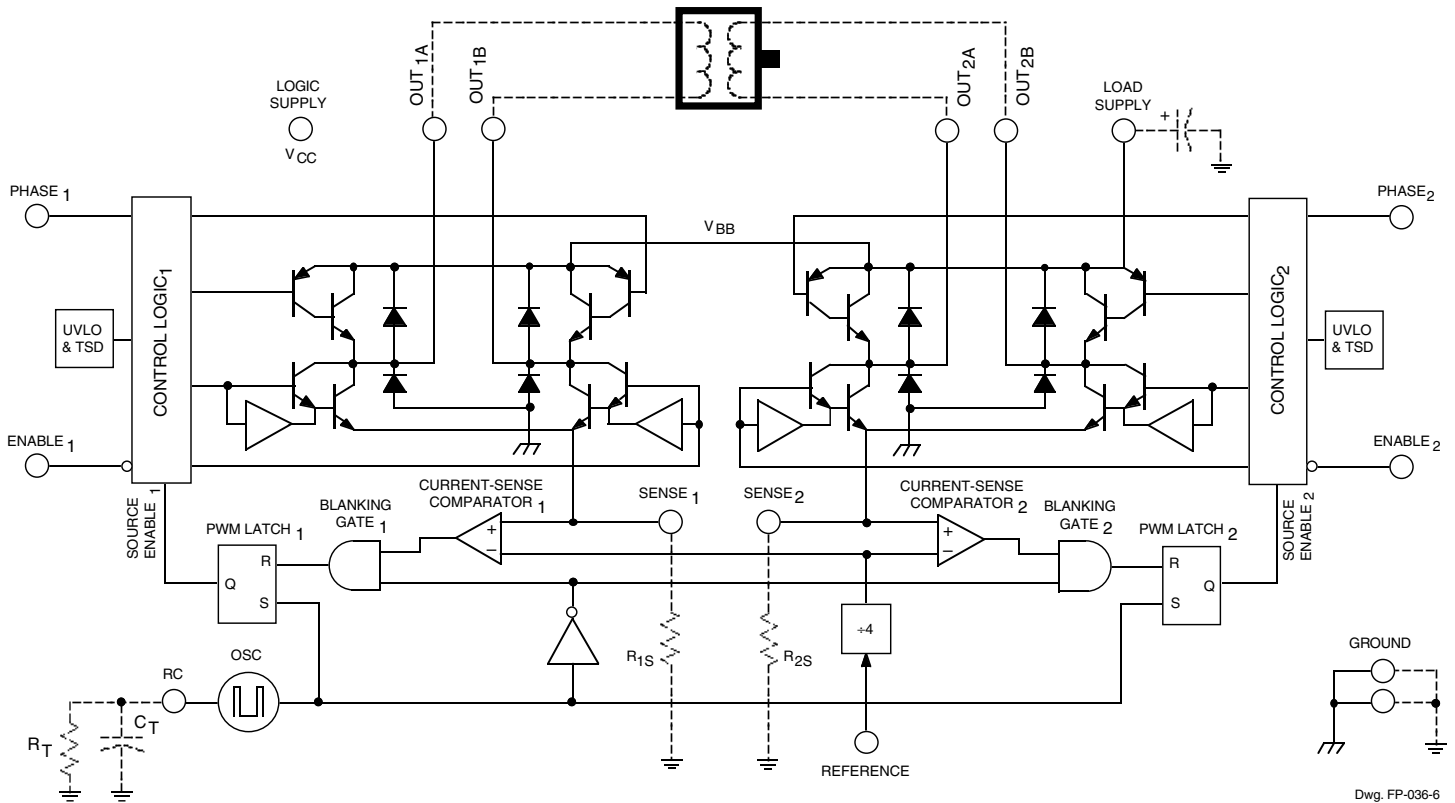
- $\pm 650$  mA Continuous Output Current
- 30 V Output Voltage Rating
- Internal Fixed-Frequency PWM Current Control
- Satlington™ Sink Drivers
- User-Selectable Blanking Window
- Internal Ground-Clamp & Flyback Diodes
- Internal Thermal-Shutdown Circuitry
- Crossover-Current Protection and UVLO Protection

Always order by complete part number:

Part Number	Package	$R_{\theta JA}$	$R_{\theta JC}$	$R_{\theta JT}$
A3966SA	16-pin DIP	$60^\circ\text{C/W}$	$38^\circ\text{C/W}$	—
A3966SLB	16-lead batwing SOIC	$67^\circ\text{C/W}$	—	$6^\circ\text{C/W}$

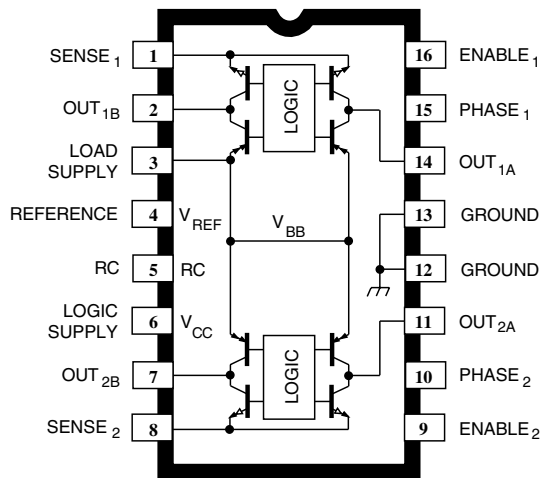
# 3966 DUAL FULL-BRIDGE PWM MOTOR DRIVER

## FUNCTIONAL BLOCK DIAGRAM



Dwg. FP-036-6

### A3966SA



Dwg. PP-066-2

### TRUTH TABLE

PHASE	ENABLE	OUT <sub>A</sub>	OUT <sub>B</sub>
X	H	Off	Off
H	L	H	L
L	L	L	H

X = Irrelevant

**3966**  
**DUAL FULL-BRIDGE**  
**PWM MOTOR DRIVER**

**ELECTRICAL CHARACTERISTICS at  $T_A = +25^\circ\text{C}$ ,  $V_{BB} = 30\text{ V}$ ,  $V_{CC} = 4.75\text{ V to }5.5\text{ V}$ ,  $V_{REF} = 2\text{ V}$ ,  $V_S = 0\text{ V}$ ,  $56\text{ k}\Omega$  &  $680\text{ pF}$  RC to Ground (unless noted otherwise)**

Characteristic	Symbol	Test Conditions	Limits			
			Min.	Typ.	Max.	Units

**Output Drivers**

Load Supply Voltage Range	$V_{BB}$	Operating, $I_{OUT} = \pm 650\text{ mA}$ , $L = 3\text{ mH}$	$V_{CC}$	—	30	V
Output Leakage Current	$I_{CEX}$	$V_{OUT} = 30\text{ V}$	—	<1.0	50	$\mu\text{A}$
		$V_{OUT} = 0\text{ V}$	—	<-1.0	-50	$\mu\text{A}$
Output Saturation Voltage	$V_{CE(SAT)}$	Source Driver, $I_{OUT} = -400\text{ mA}$	—	1.7	2.0	V
		Source Driver, $I_{OUT} = -650\text{ mA}$	—	1.8	2.1	V
		Sink Driver, $I_{OUT} = +400\text{ mA}$ , $V_S = 0.5\text{ V}$	—	0.3	0.5	V
		Sink Driver, $I_{OUT} = +650\text{ mA}$ , $V_S = 0.5\text{ V}$	—	0.4	1.3	V
Clamp Diode Forward Voltage	$V_F$	$I_F = 400\text{ mA}$	—	1.1	1.4	V
		$I_F = 650\text{ mA}$	—	1.4	1.6	V
Motor Supply Current (No Load)	$I_{BB(ON)}$	$V_{ENABLE1} = V_{ENABLE2} = 0.8\text{ V}$	—	3.0	5.0	mA
	$I_{BB(OFF)}$	$V_{ENABLE1} = V_{ENABLE2} = 2.4\text{ V}$	—	<1.0	200	$\mu\text{A}$

**Control Logic**

Logic Supply Voltage Range	$V_{CC}$	Operating	4.75	—	5.50	V
Logic Input Voltage	$V_{IN(1)}$		2.4	—	—	V
	$V_{IN(0)}$		—	—	0.8	V
Logic Input Current	$I_{IN(1)}$	$V_{IN} = 2.4\text{ V}$	—	<1.0	20	$\mu\text{A}$
	$I_{IN(0)}$	$V_{IN} = 0.8\text{ V}$	—	<-20	-200	$\mu\text{A}$
Reference Input Volt. Range	$V_{REF}$	Operating	0.1	—	2.0	V
Reference Input Current	$I_{REF}$		-2.5	0	1.0	$\mu\text{A}$
Reference Divider Ratio	$V_{REF}/V_{TRIP}$		3.8	4.0	4.2	—
Current-Sense Comparator Input Offset Voltage	$V_{IO}$	$V_{REF} = 0\text{ V}$	-6.0	0	6.0	mV
Current-Sense Comparator Input Voltage Range	$V_S$	Operating	-0.3	—	1.0	V
Sense-Current Offset	$I_{SO}$	$I_S - I_{OUT}$ , $50\text{ mA} \leq I_{OUT} \leq 650\text{ mA}$	12	18	24	mA

NOTES: 1. Typical Data is for design information only.

2. Negative current is defined as coming out of (sourcing) the specified device terminal.

# 3966

## DUAL FULL-BRIDGE PWM MOTOR DRIVER

**ELECTRICAL CHARACTERISTICS** at  $T_A = +25^\circ\text{C}$ ,  $V_{BB} = 30\text{ V}$ ,  $V_{CC} = 4.75\text{ V to }5.5\text{ V}$ ,  $V_{REF} = 2\text{ V}$ ,  $V_S = 0\text{ V}$ ,  $56\text{ k}\Omega$  &  $680\text{ pF}$  RC to Ground (unless noted otherwise) (cont.)

Characteristic	Symbol	Test Conditions	Limits			
			Min.	Typ.	Max.	Units
<b>Control Logic</b> (continued)						
PWM RC Frequency	$f_{osc}$	$C_T = 680\text{ pF}$ , $R_T = 56\text{ k}\Omega$	22.9	25.4	27.9	kHz
PWM Propagation Delay Time	$t_{PWM}$	Comparator Trip to Source OFF	—	1.0	1.4	$\mu\text{s}$
		Cycle Reset to Source ON	—	0.8	1.2	$\mu\text{s}$
Cross-Over Dead Time	$t_{codt}$	1 k $\Omega$ Load to 25 V	0.2	1.8	3.0	$\mu\text{s}$
Propagation Delay Times	$t_{pd}$	$I_{OUT} = \pm 650\text{ mA}$ , 50% to 90%: ENABLE ON to Source ON	—	100	—	ns
		ENABLE OFF to Source OFF	—	500	—	ns
		ENABLE ON to Sink ON	—	200	—	ns
		ENABLE OFF to Sink OFF	—	200	—	ns
		PHASE Change to Sink ON	—	2200	—	ns
		PHASE Change to Sink OFF	—	200	—	ns
		PHASE Change to Source ON	—	2200	—	ns
		PHASE Change to Source OFF	—	200	—	ns
Thermal Shutdown Temp.	$T_J$		—	165	—	$^\circ\text{C}$
Thermal Shutdown Hysteresis	$\Delta T_J$		—	15	—	$^\circ\text{C}$
UVLO Enable Threshold	$V_{T(UVLO)+}$	Increasing $V_{CC}$	—	4.1	4.6	V
UVLO Hysteresis	$V_{T(UVLO)hys}$		0.1	0.6	—	V
Logic Supply Current	$I_{CC(ON)}$	$V_{ENABLE 1} = V_{ENABLE 2} = 0.8\text{ V}$	—	—	50	mA
	$I_{CC(OFF)}$	$V_{ENABLE 1} = V_{ENABLE 2} = 2.4\text{ V}$	—	—	9.0	mA

NOTES: 1. Typical Data is for design information only.

2. Negative current is defined as coming out of (sourcing) the specified device terminal.

## FUNCTIONAL DESCRIPTION

**Internal PWM Current Control.** The A3966SA and A3966SLB dual H-bridges are designed to drive both windings of a bipolar stepper motor. Load current can be controlled in each motor winding by an internal fixed-frequency PWM control circuit. The current-control circuitry works as follows: when the outputs of the H-bridge are turned on, current increases in the motor winding. The load current is sensed by the current-control comparator via an external sense resistor ( $R_S$ ). Load current continues to increase until it reaches the predetermined value, set by the selection of external current-sensing resistors and reference input voltage ( $V_{REF}$ ) according to the equation:

$$I_{TRIP} = I_{OUT} + I_{SO} = V_{REF}/(4 R_S)$$

where  $I_{SO}$  is the sense-current error (typically 18 mA) due to the base-drive current of the sink driver transistor.

At the trip point, the comparator resets the source-enable latch, turning off the source driver of that H-bridge. The source turn off of one H-bridge is independent of the other H-bridge. Load inductance causes the current to recirculate through the sink driver and ground-clamp diode. The current decreases until the internal clock oscillator sets the source-enable latches of both H-bridges, turning on the source drivers of both bridges. Load current increases again, and the cycle is repeated.

The frequency of the internal clock oscillator is set by the external timing components  $R_T C_T$ . The frequency can be approximately calculated as:

$$f_{osc} = 1/(R_T C_T + t_{blank})$$

where  $t_{blank}$  is defined below.

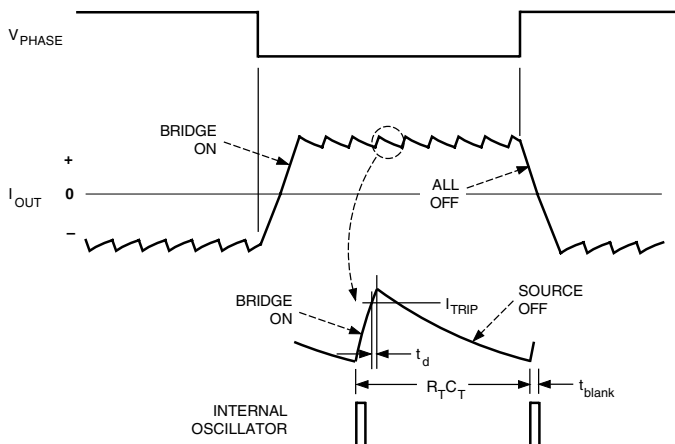
The range of recommended values for  $R_T$  and  $C_T$  are 20 k $\Omega$  to 100 k $\Omega$  and 470 pF to 1000 pF respectively. Nominal values of 56 k $\Omega$  and 680 pF result in a clock frequency of 25 kHz.

**Current-Sense Comparator Blanking.** When the source driver is turned on, a current spike occurs due to the reverse-recovery currents of the clamp diodes and switching transients related to distributed capacitance in the load. To prevent this current spike from erroneously resetting the source enable latch, the current-control comparator output is blanked for a short period of time when the source driver is turned on. The blanking time is set by the timing component  $C_T$  according to the equation:

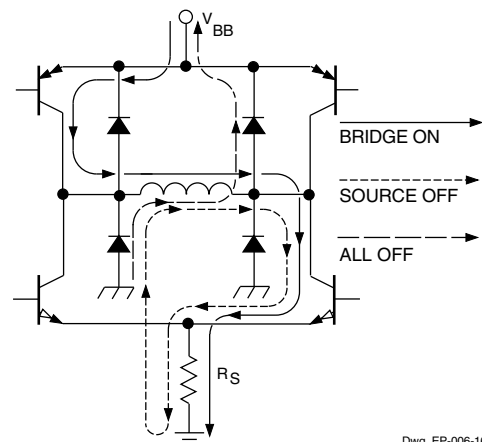
$$t_{blank} = 1900 C_T (\mu s).$$

A nominal  $C_T$  value of 680 pF will give a blanking time of 1.3  $\mu s$ .

The current-control comparator is also blanked when the H-bridge outputs are switched by the PHASE or ENABLE inputs. This internally generated blank time is approximately 1  $\mu s$ .



Dwg. WM-003-2



Dwg. EP-006-16

# 3966

## DUAL FULL-BRIDGE PWM MOTOR DRIVER

### FUNCTIONAL DESCRIPTION (continued)

**Load Current Regulation.** Due to internal logic and switching delays ( $t_d$ ), the actual load current peak will be slightly higher than the  $I_{TRIP}$  value. These delays, plus the blanking time, limit the minimum value the current control circuitry can regulate. To produce zero current in a winding, the ENABLE terminal should be held high, turning off all output drivers for that H-bridge.

**Logic Inputs.** A logic high on the PHASE input results in current flowing from  $OUT_A$  to  $OUT_B$  of that H-bridge. A logic low on the PHASE input results in current flowing from  $OUT_B$  to  $OUT_A$ . An internally generated dead time ( $t_{codt}$ ) of approximately 1  $\mu s$  prevents cross-over current spikes that can occur when switching the PHASE input.

A logic high on the ENABLE input turns off all four output drivers of that H-bridge. This results in a fast current decay through the internal ground clamp and flyback diodes. A logic low on the ENABLE input turns on the selected source and sink driver of that H-bridge.

The ENABLE inputs can be pulse-width modulated for applications that require a fast current-decay PWM. If external current-sensing circuitry is used, the internal current-control logic can be disabled by connecting the  $R_T C_T$  terminal to ground.

The REFERENCE input voltage is typically set with a resistor divider from  $V_{CC}$ . This reference voltage is internally divided down by 4 to set up the current-comparator trip-voltage threshold. The reference input voltage range is 0 to 2 V.

**Output Drivers.** To minimize on-chip power dissipation, the sink drivers incorporate a Satlington™ structure. The Satlington output combines the low  $V_{CE(sat)}$  features of a saturated transistor and the high peak-current capability of a Darlington (connected) transistor. A graph showing typical output saturation voltages as a function of output current is on the next page.

**Miscellaneous Information.** Thermal protection circuitry turns off all output drivers should the junction temperature reach +165 °C (typical). This is intended only to protect the device from failures due to excessive junction temperatures and should not imply that output short circuits are permitted. Normal operation is resumed when the junction temperature has decreased about 15 °C.

The A3966 current control employs a fixed-frequency, variable duty cycle PWM technique. As a result, the current-control regulation may become unstable if the duty cycle exceeds 50%.

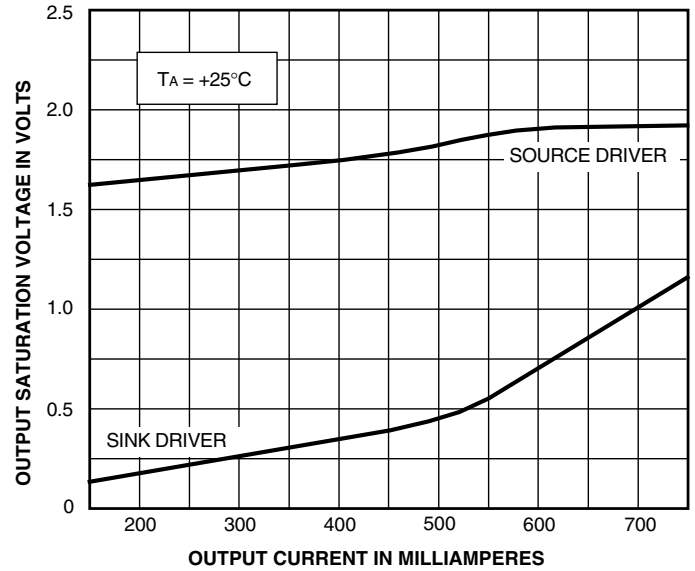
To minimize current-sensing inaccuracies caused by ground trace  $I_R$  drops, each current-sensing resistor should have a separate return to the ground terminal of the device. For low-value sense resistors, the  $I \cdot R$  drops in the printed-wiring board can be significant and should be taken into account. The use of sockets should be avoided as their contact resistance can cause variations in the effective value of  $R_S$ .

The LOAD SUPPLY terminal,  $V_{BB}$ , should be decoupled with an electrolytic capacitor (47  $\mu F$  recommended) placed as close to the device as physically practical. To minimize the effect of system ground IR drops on the logic and reference input signals, the system ground should have a low-resistance return to the load supply voltage.

The frequency of the clock oscillator will determine the amount of ripple current. A lower frequency will result in higher current ripple, but reduced heating in the motor and driver IC due to a corresponding decrease in hysteretic core losses and switching losses respectively. A higher frequency will reduce ripple current, but will increase switching losses and EMI.

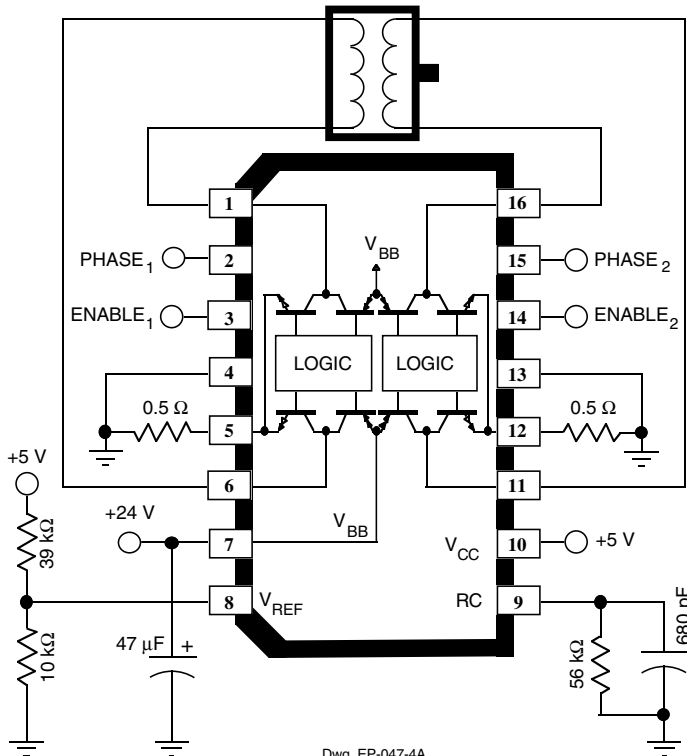
# 3966 DUAL FULL-BRIDGE PWM MOTOR DRIVER

**Typical output saturation  
voltages showing Satlington™  
sink-driver operation.**



Dwg. GP-064-1

## TYPICAL APPLICATION



Dwg. EP-047-4A

*The products described here are manufactured under one or more U.S. patents or U.S. patents pending.*

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**3966**  
***DUAL FULL-BRIDGE***  
***PWM MOTOR DRIVER***

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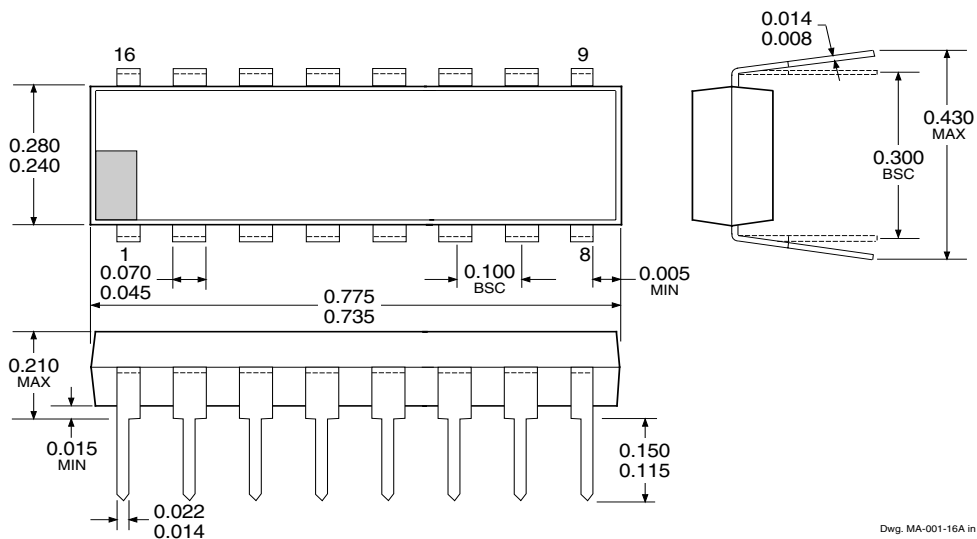
# 3966

## DUAL FULL-BRIDGE

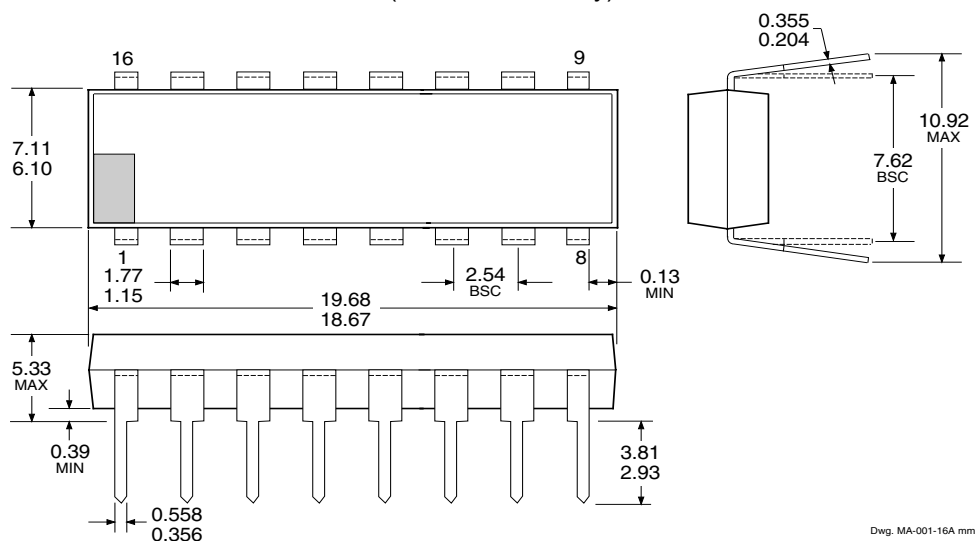
### PWM MOTOR DRIVER

#### A3966SA

Dimensions in Inches  
(controlling dimensions)



Dimensions in Millimeters  
(for reference only)

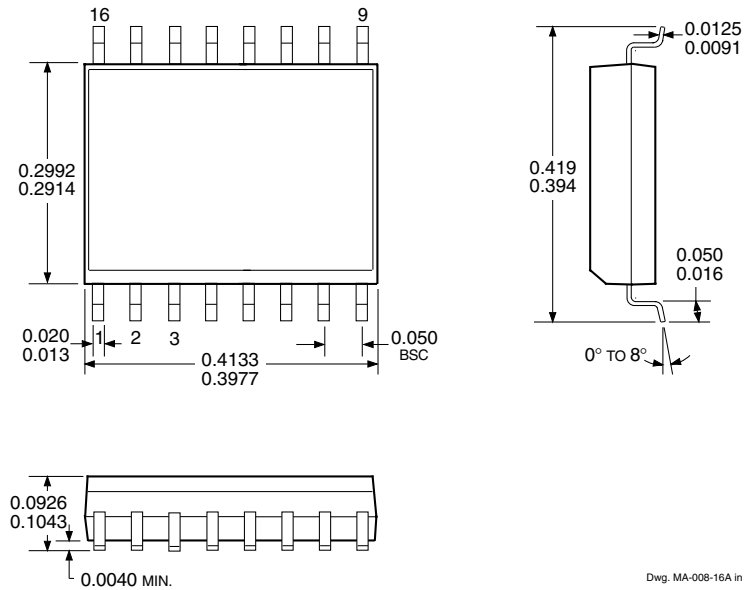


- NOTES: 1. Exact body and lead configuration at vendor's option within limits shown.  
 2. Lead spacing tolerance is non-cumulative  
 3. Lead thickness is measured at seating plane or below.

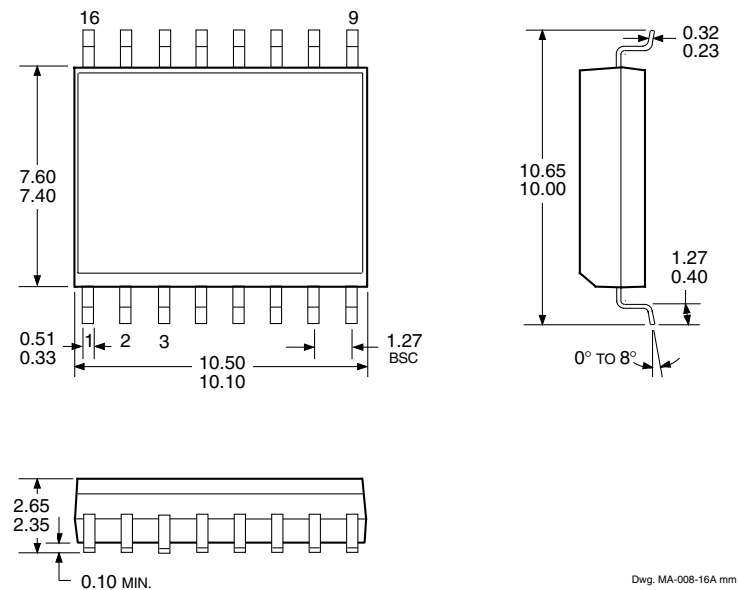
# 3966 DUAL FULL-BRIDGE PWM MOTOR DRIVER

## A3966SLB

Dimensions in Inches  
(for reference only)



Dimensions in Millimeters  
(controlling dimensions)



- NOTES:
1. Exact body and lead configuration at vendor's option within limits shown.
  2. Lead spacing tolerance is non-cumulative
  3. Webbed lead frame. Leads 4 and 13 are internally one piece.

**3966**  
**DUAL FULL-BRIDGE**  
**PWM MOTOR 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	—	50 V	3932
3-Phase Power MOSFET Controller	—	50 V	7600
2-Phase Hall-Effect Sensor/Driver	400 mA	26 V	3626
Bidirectional 3-Phase Back-EMF Controller/Driver	±600 mA	14 V	8906
2-Phase Hall-Effect Sensor/Driver	900 mA	14 V	3625
3-Phase Back-EMF Controller/Driver	±900 mA	14 V	8902–A
3-Phase Controller/Drivers	±2.0 A	45 V	2936 & 2936-120
<b>INTEGRATED BRIDGE DRIVERS FOR DC AND BIPOLAR STEPPER MOTORS</b>			
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
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 Full Bridge	±1.3 A	50 V	3953
PWM Current-Controlled Dual Full Bridge	±1.5 A	45 V	2917
PWM Current-Controlled Dual Full Bridge	±1.5 A	45 V	2918
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
Dual Full-Bridge Driver	±2.0 A	50 V	2998
PWM Current-Controlled Full Bridge	±2.0 A	50 V	3952
DMOS Full Bridge PWM Driver	±2.0 A	50 V	3958
Dual DMOS Full Bridge	±2.5 A	50 V	3971
<b>UNIPOLAR STEPPER MOTOR &amp; OTHER DRIVERS</b>			
Voice-Coil Motor Driver	±500 mA	6 V	8932–A
Voice-Coil Motor Driver	±800 mA	16 V	8958
Unipolar Stepper-Motor Quad Drivers	1 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	1.8 A	50 V	2544
Unipolar Stepper-Motor Quad Driver	3 A	46 V	7026
Unipolar Microstepper-Motor Quad Driver	3 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.