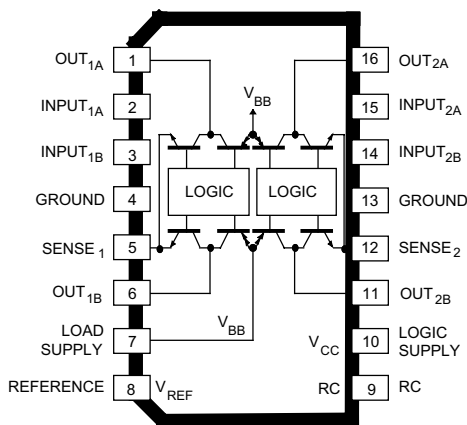


# 3968

## DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

**A3968SLB (SOIC)**



Dwg. PP-066

### 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 ( $T_A = 25^\circ\text{C}$ ), $P_D$	
A3968SA .....	<b>1.8 W*</b>
A3968SLB .....	<b>1.4 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 A3968SA and A3968SLB are designed to bidirectionally control two dc motors. 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 the Allegro® 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, the  $INPUT_A$  and  $INPUT_B$  terminals determine the load current polarity by enabling the appropriate source and sink driver pair. When a logic low is applied to both INPUTs of a bridge, the braking function is enabled. In brake mode, both source drivers are turned OFF and both sink drivers are turned ON, thereby dynamically braking the motor. When a logic high is applied to both INPUTs of a bridge, all output drivers are disabled. 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 A3968SA is supplied in a 16-pin dual in-line plastic package. The A3968SLB is supplied in a 16-pin plastic SOIC with copper heat sink tabs. The power tab is at ground potential and needs no electrical isolation. The LB package is available in a lead (Pb) free version (100% matte tin leadframe).

### FEATURES

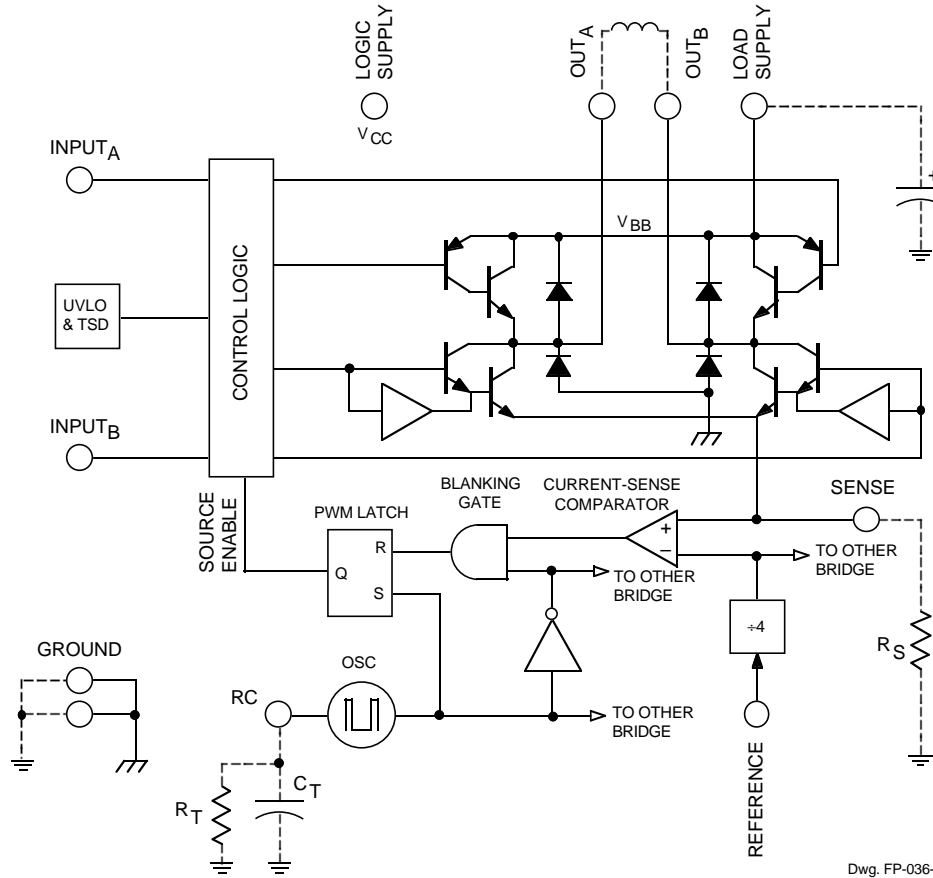
- $\pm 650$  mA Continuous Output Current
- 30 V Output Voltage Rating
- Internal Fixed-Frequency PWM Current Control
- Satlington Sink Drivers
- Brake Mode
- User-Selectable Blanking Window
- Internal Ground-Clamp & Flyback Diodes
- Internal Thermal-Shutdown Circuitry
- Crossover-Current Protection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

Part Number	Pb-free*	$R_{\theta JA}$ ( $^\circ\text{C}/\text{W}$ )	$R_{\theta JT}$ ( $^\circ\text{C}/\text{W}$ )	Package	Packing
A3968SLB-T	Yes	90	6	16-Lead SOIC	47 per tube
A3968SLBTR-T	Yes	90	6	16-Lead SOIC	1000 per reel

\*Pb-based variants are being phased out of the product line. The variants cited in this footnote are in production but have been determined to be LAST TIME BUY. This classification indicates that sale of this device is currently restricted to existing customer applications. The variants should not be purchased for new design applications because obsolescence in the near future is probable. Samples are no longer available. Status change: October 31, 2006. Deadline for receipt for LAST TIME BUY orders: April 27, 2007. These variants include: A3968SA, A3968SLB, and A3968SLBTR.

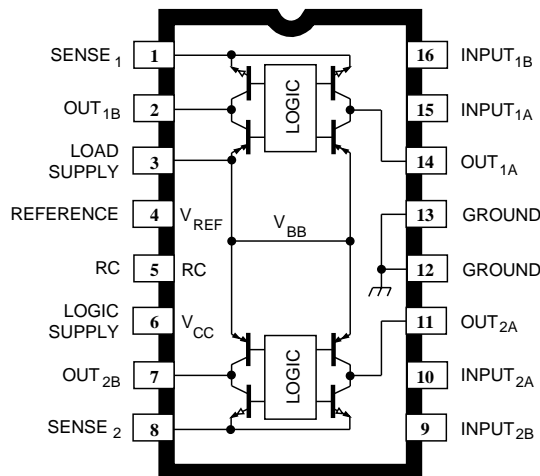
# 3968 DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

## FUNCTIONAL BLOCK DIAGRAM (one-half of circuit shown)



Dwg. FP-036-4

### A3968SA (DIP)



Dwg. PP-066-3

### TRUTH TABLE

INPUT <sub>A</sub>	INPUT <sub>B</sub>	OUT <sub>A</sub>	OUT <sub>B</sub>	Description
L	L	L	L	Brake mode
L	H	L	H	"Forward"
H	L	H	L	"Reverse"
H	H	Z	Z	Disable

Z = High impedance

**3968**  
**DUAL FULL-BRIDGE**  
**PWM MOTOR DRIVER**  
**WITH BRAKE**

**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, $I_{OUT} = +650\text{ mA}$ , $V_S = 0.5\text{ V}$	—	0.7	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)	$I_{BB(ON)}$	Both bridges ON (forward or reverse)	—	3.0	5.0	mA
	$I_{BB(OFF)}$	All INPUTs = $2.4\text{ V}$	—	<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	$V_{IO}$	$V_{REF} = 0.1\text{ V}$	-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.

# 3968

## DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

**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 (continued)</b>						
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%: Disable OFF to Source ON	—	100	—	ns
		Disable ON to Source OFF	—	500	—	ns
		Disable OFF to Sink ON	—	200	—	ns
		Disable ON to Sink OFF	—	200	—	ns
		Brake Enable to Sink ON	—	2200	—	ns
		Brake Enable 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	$I_{CC(ON)}$	Both bridges ON (forward or reverse)	—	—	50	mA
	$I_{CC(OFF)}$	All INPUTs = 2.4 V	—	—	9.0	mA
	$I_{CC(BRAKE)}$	All INPUTs = 0.8 V	—	—	95	mA

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

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



# 3968 DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

## FUNCTIONAL DESCRIPTION

**Internal PWM Current Control.** The A3968SA and A3968SLB dual H-bridges are designed to bidirectionally control two dc motors. An internal fixed-frequency PWM current-control circuit controls the load current in each motor. 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:

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

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.

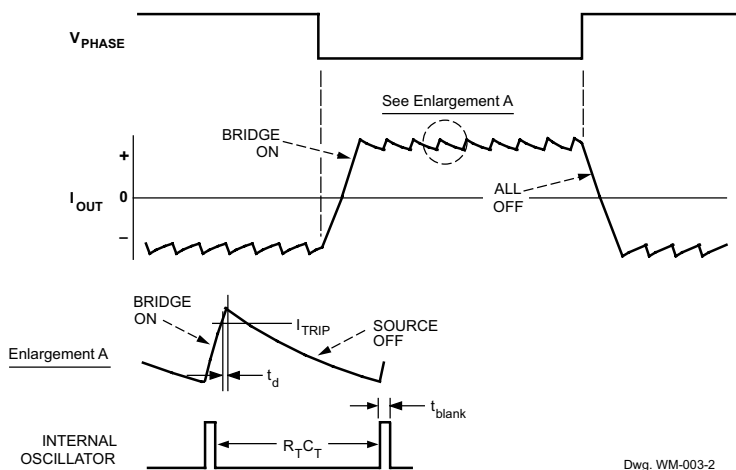
The range of recommended values for  $R_T$  and  $C_T$  are 20 k $\Omega$  to 100 k $\Omega$  and 470 pF to 1000 pF respectively. Nominal values of 56 k $\Omega$  and 680 pF result in a clock frequency of 25.4 kHz.

**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:

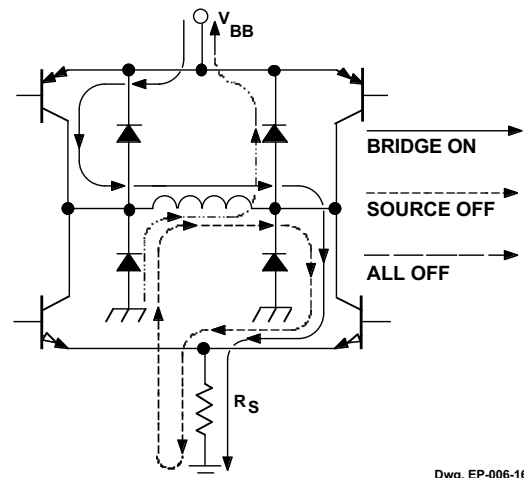
$$t_{blank} = 1900 C_T (\mu s).$$

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 load current changes polarity (direction or phase change). This internally generated blank time is approximately 1.8  $\mu s$ .



Dwg. WM-003-2



Dwg. EP-006-16

# 3968

## DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

### FUNCTIONAL DESCRIPTION (continued)

**Load Current Regulation.** Due to internal logic and switching delays ( $t_d$ ), the actual load current peak may 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  $INPUT_A$  and  $INPUT_B$  terminals should be held high, turning off all output drivers for that H-bridge.

**Logic Inputs.** The direction of current in the motor winding is determined by the state of the  $INPUT_A$  and  $INPUT_B$  terminals of each bridge (see Truth Table). An internally generated dead time ( $t_{codt}$ ) of approximately 1.8  $\mu s$  prevents cross-over current spikes that can occur when switching the motor direction.

A logic high on both INPUTs 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.

The appropriate  $INPUT_A$  or  $INPUT_B$  can be pulse-width modulated for applications that require a fast current-decay PWM. The internal current-control logic can be disabled by connecting the  $R_T C_T$  terminal to ground.

A logic low on the  $INPUT_A$  and the  $INPUT_B$  terminals will place that H-Bridge in the brake mode. Both source drivers are turned OFF and both sink drivers are turned ON. This has the effect of shorting the dc motor's back-EMF voltage, resulting in a current flow that dynamically brakes the motor.

Note that during braking the internal current-control circuitry is disabled. Therefore, care should be taken to ensure that the motor's current does not exceed the absolute maximum rating of the A3968.

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 A3968 current control employs a fixed-frequency, variable duty cycle PWM technique. If the duty cycle exceeds 50%, the current-control-regulation frequency may change.

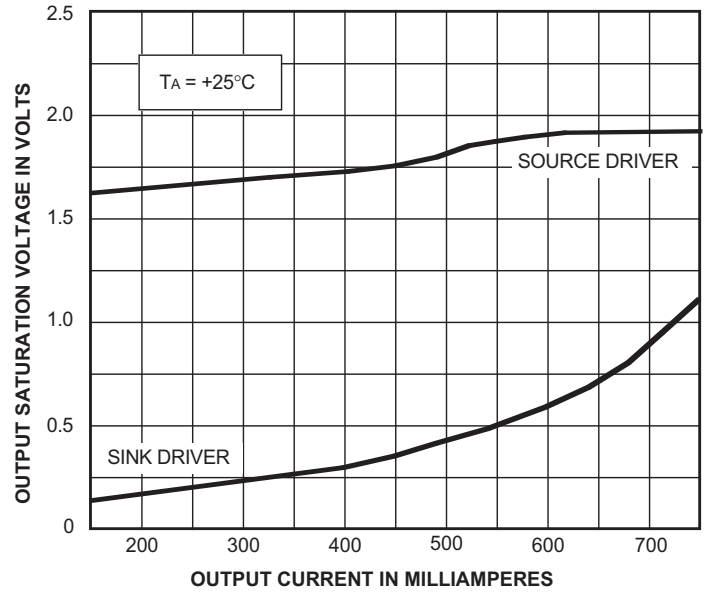
To minimize current-sensing inaccuracies caused by ground trace  $I_R$  drops, each current-sensing resistor should have a separate return to the ground terminal of the device. For low-value sense resistors, the  $I \times R$  drops in the printed-wiring board can be significant and should be taken into 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  $I \times R$  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.

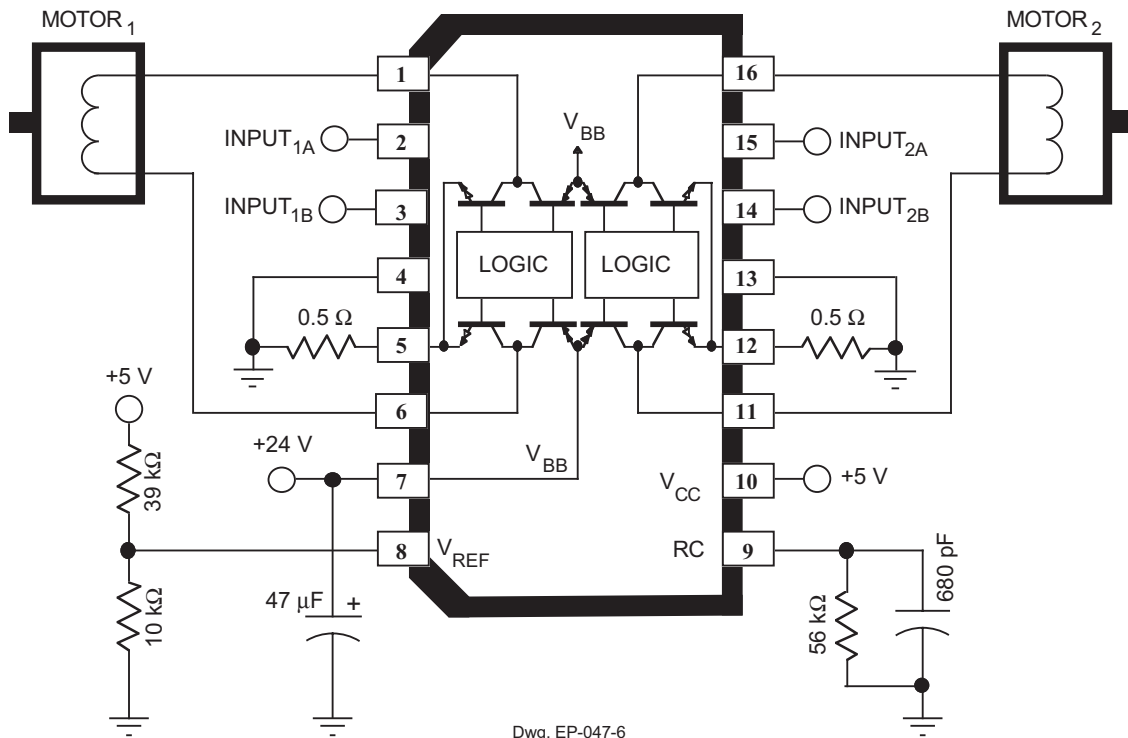
# 3968 DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

Typical output saturation voltages showing Satlington sink-driver operation.



Dwg. GP-064-1A

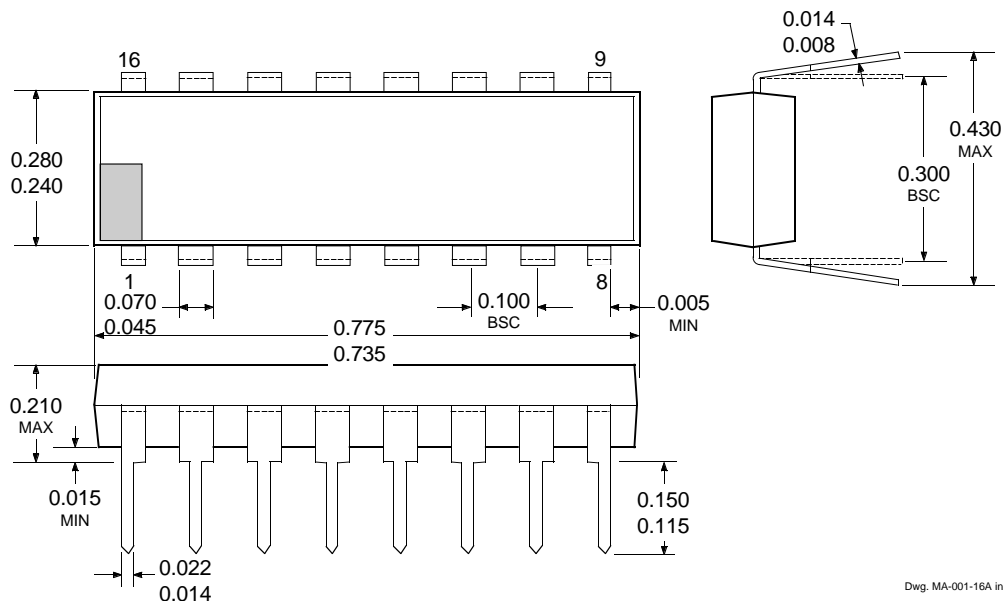
## TYPICAL APPLICATION



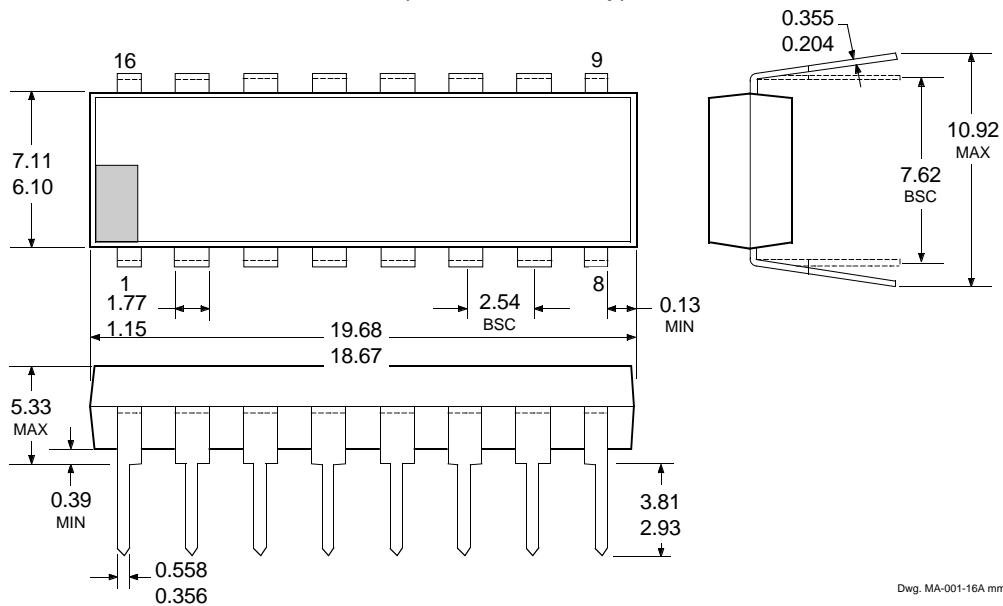
Dwg. EP-047-6

# 3968 DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

## A3968SA (DIP) Dimensions in Inches (controlling dimensions)



## Dimensions in Millimeters (for reference only)

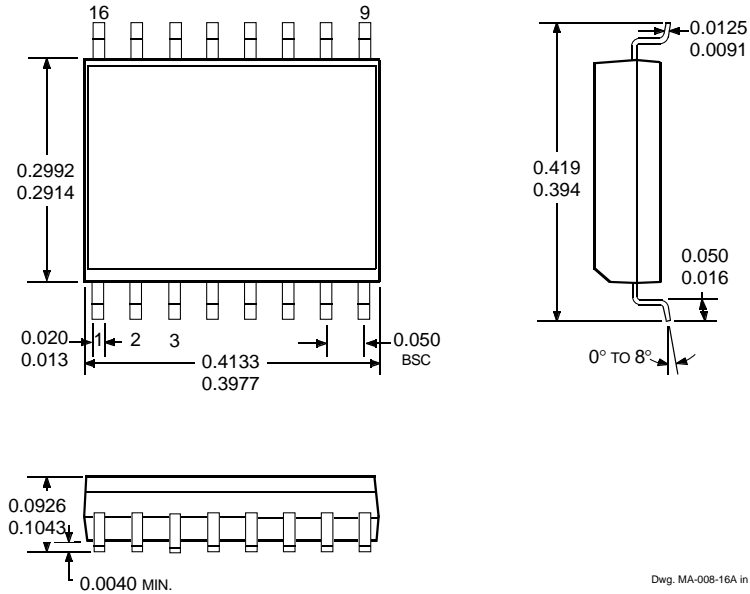


- NOTES: 1. Exact body and lead configuration at vendor's option within limits shown.  
 2. Lead spacing tolerance is non-cumulative.  
 3. Lead thickness is measured at seating plane or below.  
 4. Supplied in standard sticks/tubes of 25 devices.

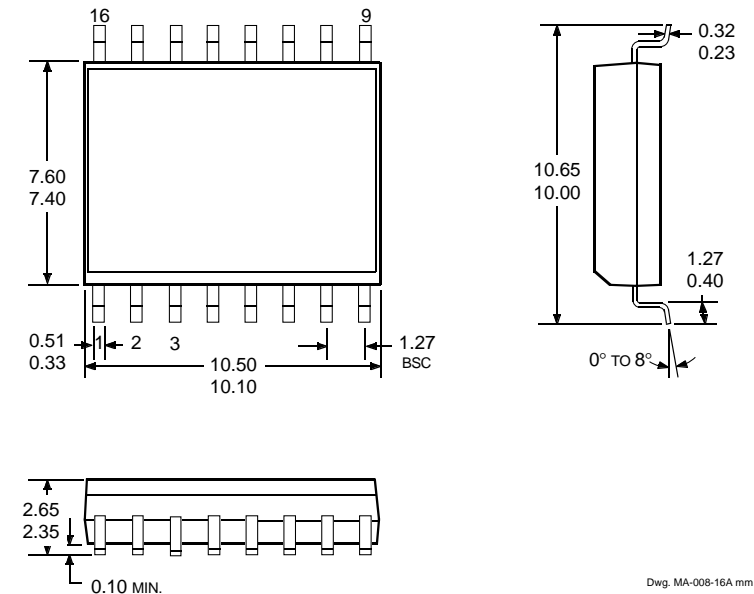


# 3968 DUAL FULL-BRIDGE PWM MOTOR DRIVER WITH BRAKE

## A3968SLB (SOIC) 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.  
 4. Supplied in standard sticks/tubes of 47 devices, or add "TR" to part number for tape and reel.

**3968**  
**DUAL FULL-BRIDGE**  
**PWM MOTOR DRIVER**  
**WITH BRAKE**

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