

## LMD18201 3A, 55V H-Bridge

 Check for Samples: [LMD18201](#)

### FEATURES

- Delivers up to 3A Continuous Output
- Operates at Supply Voltages up to 55V
- Low  $R_{DS(ON)}$  Typically  $0.33\Omega$  per Switch at 3A
- TTL and CMOS Compatible Inputs
- No “Shoot-Through” Current
- Thermal Warning Flag Output at  $145^{\circ}\text{C}$
- Thermal Shutdown (Outputs Off) at  $170^{\circ}\text{C}$
- Internal Clamp Diodes
- Shorted Load Protection
- Internal Charge Pump with External Bootstrap Capability

### APPLICATIONS

- DC and Stepper Motor Drives
- Position and Velocity Servomechanisms
- Factory Automation Robots
- Numerically Controlled Machinery
- Computer Printers and Plotters

### DESCRIPTION

The LMD18201 is a 3A H-Bridge designed for motion control applications. The device is built using a multi-technology process which combines bipolar and CMOS control circuitry with DMOS power devices on the same monolithic structure. The H-Bridge configuration is ideal for driving DC and stepper motors. The LMD18201 accommodates peak output currents up to 6A. Current sensing can be achieved via a small sense resistor connected in series with the power ground lead. For current sensing without disturbing the path of current to the load, the LMD18201 is recommended.

### Functional Diagram

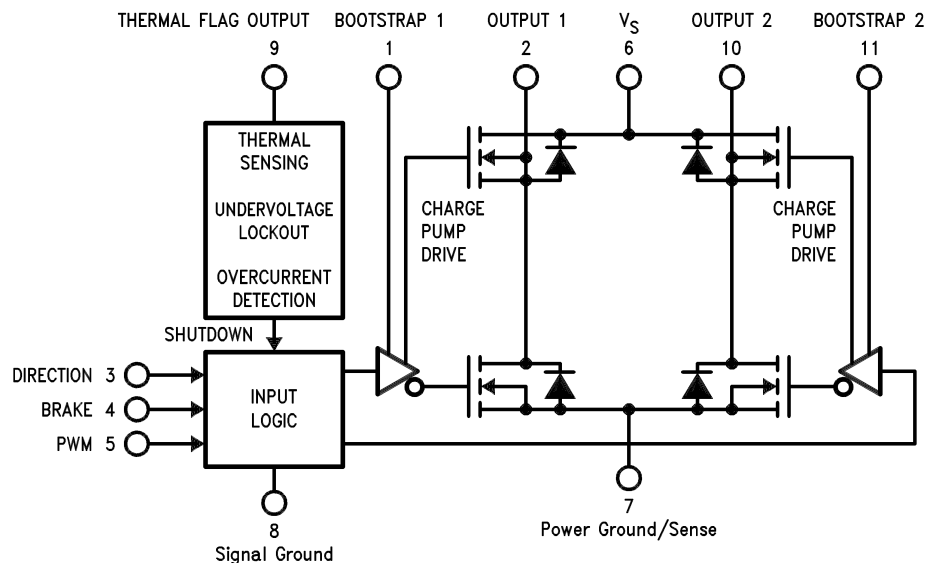


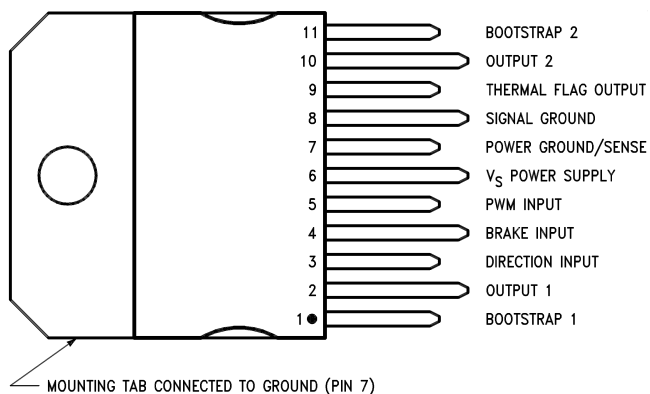
Figure 1. Functional Block Diagram of LMD18201



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### Connection Diagram



**Figure 2. Top View**  
**See Package Number NDJ0011B**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings<sup>(1)(2)</sup>

|  |                 |
|--|-----------------|
| Total Supply Voltage ( $V_S$ , Pin 6)                    | 60V             |
| Voltage at Pins 3, 4, 5 and 9                            | 12V             |
| Voltage at Bootstrap Pins (Pins 1 and 11)                | $V_{OUT} + 16V$ |
| Peak Output Current (200 ms)                             | 6A              |
| Continuous Output Current <sup>(3)</sup>                 | 3A              |
| Power Dissipation <sup>(4)</sup>                         | 25W             |
| Sense Voltage (Pin 7 to Pin 8)                           | +0.5V to -1.0V  |
| Power Dissipation ( $T_A = 25^\circ\text{C}$ , Free Air) | 3W              |
| Junction Temperature, $T_{J(\text{max})}$                | 150°C           |
| ESD Susceptibility <sup>(5)</sup>                        | 1500V           |
| Storage Temperature, $T_{STG}$                           | -40°C to +150°C |
| Lead Temperature (Soldering, 10 sec.)                    | 300°C           |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
- (3) See [Application Information](#) for details regarding current limiting.
- (4) The maximum power dissipation must be derated at elevated temperatures and is a function of  $T_{J(\text{max})}$ ,  $\theta_{JA}$ , and  $T_A$ . The maximum allowable power dissipation at any temperature is  $P_{D(\text{max})} = (T_{J(\text{max})} - T_A)/\theta_{JA}$ , or the number given in the Absolute Ratings, whichever is lower. The typical thermal resistance from junction to case ( $\theta_{JC}$ ) is 1.0°C/W and from junction to ambient ( $\theta_{JA}$ ) is 30°C/W. For ensured operation  $T_{J(\text{max})} = 125^\circ\text{C}$ .
- (5) Human-body model, 100 pF discharged through a 1.5 kΩ resistor. Except Bootstrap pins (pins 1 and 11) which are protected to 1000V of ESD.

## Operating Ratings<sup>(1)</sup>

|                             |                 |
|-----------------------------|-----------------|
| Junction Temperature, $T_J$ | -40°C to +125°C |
| $V_S$ Supply Voltage        | +12V to +55V    |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.

## Electrical Characteristics<sup>(1)</sup>

The following specifications apply for  $V_S = 42V$ , unless otherwise specified. **Boldface** limits apply over the entire operating temperature range,  $-40^\circ\text{C} \leq T_J \leq +125^\circ\text{C}$ , all other limits are for  $T_A = T_J = 25^\circ\text{C}$ .

| Symbol       | Parameter                      | Conditions                              | Typ  | Limit                     | Units              |
|--------------|--------------------------------|---|------|---------------------------|--------------------|
| $R_{DS(ON)}$ | Switch ON Resistance           | Output Current = 3A <sup>(2)</sup>      | 0.33 | 0.40/ <b>0.6</b>          | Ω (max)            |
| $R_{DS(ON)}$ | Switch ON Resistance           | Output Current = 6A <sup>(2)</sup>      | 0.38 | 0.45/ <b>0.6</b>          | Ω (max)            |
| $V_{CLAMP}$  | Clamp Diode Forward Drop       | Clamp Current = 3A <sup>(2)</sup>       | 1.2  | 1.5                       | V (max)            |
| $V_{IL}$     | Logic Low Input Voltage        | Pins 3, 4, 5                            |      | <b>-0.1</b><br><b>0.8</b> | V (min)<br>V (max) |
| $I_{IL}$     | Logic Low Input Current        | $V_{IN} = -0.1V$ , Pins = 3, 4, 5       |      | <b>-10</b>                | μA (max)           |
| $V_{IH}$     | Logic High Input Voltage       | Pins 3, 4, 5                            |      | <b>2</b><br><b>12</b>     | V (min)<br>V (max) |
| $I_{IH}$     | Logic High Input Current       | $V_{IN} = 12V$ , Pins = 3, 4, 5         |      | <b>10</b>                 | μA (max)           |
|              | Undervoltage Lockout           | Outputs Turn OFF                        |      | 9<br>11                   | V (min)<br>V (max) |
| $T_{JW}$     | Warning Flag Temperature       | Pin 9 $\leq 0.8V$ , $I_L = 2\text{ mA}$ | 145  |                           | °C                 |
| $V_{F(ON)}$  | Flag Output Saturation Voltage | $T_J = T_{JW}$ , $I_L = 2\text{ mA}$    | 0.15 |                           | V                  |

- (1) All limits are 100% production tested at 25°C. Temperature extreme limits are ensured via correlation using accepted SQC (Statistical Quality Control) methods. All limits are used to calculate AOQL, (Average Outgoing Quality Level).
- (2) Output currents are pulsed ( $t_W < 2\text{ ms}$ , Duty Cycle  $< 5\%$ ).

### Electrical Characteristics<sup>(1)</sup> (continued)

The following specifications apply for  $V_S = 42V$ , unless otherwise specified. **Boldface** limits apply over the entire operating temperature range,  $-40^{\circ}C \leq T_J \leq +125^{\circ}C$ , all other limits are for  $T_A = T_J = 25^{\circ}C$ .

| Symbol       | Parameter                       | Conditions                       | Typ | Limit | Units         |
|--------------|---------------------------------|----------------------------------|-----|-------|---------------|
| $I_{F(OFF)}$ | Flag Output Leakage             | $V_F = 12V$                      | 0.2 | 10    | $\mu A$ (max) |
| $T_{JSD}$    | Shutdown Temperature            | Outputs Turn OFF                 | 170 |       | $^{\circ}C$   |
| $I_S$        | Quiescent Supply Current        | All Logic Inputs Low             | 13  | 25    | mA (max)      |
| $t_{D(ON)}$  | Output Turn-On Delay Time       | Sourcing Outputs, $I_{OUT} = 3A$ | 300 |       | ns            |
|              |                                 | Sinking Outputs, $I_{OUT} = 3A$  | 300 |       | ns            |
| $t_{ON}$     | Output Turn-On Switching Time   | Bootstrap Capacitor = 10 nF      |     |       |               |
|              |                                 | Sourcing Outputs, $I_{OUT} = 3A$ | 100 |       | ns            |
|              |                                 | Sinking Outputs, $I_{OUT} = 3A$  | 80  |       | ns            |
| $t_{D(OFF)}$ | Output Turn-Off Delay Times     | Sourcing Outputs, $I_{OUT} = 3A$ | 200 |       | ns            |
|              |                                 | Sinking Outputs, $I_{OUT} = 3A$  | 200 |       | ns            |
| $t_{OFF}$    | Output Turn-Off Switching Times | Bootstrap Capacitor = 10 nF      |     |       |               |
|              |                                 | Sourcing Outputs, $I_{OUT} = 3A$ | 75  |       | ns            |
|              |                                 | Sinking Outputs, $I_{OUT} = 3A$  | 70  |       | ns            |
| $t_{PW}$     | Minimum Input Pulse Width       | Pins 3, 4 and 5                  | 1   |       | $\mu s$       |
| $t_{CPR}$    | Charge Pump Rise Time           | No Bootstrap Capacitor           | 20  |       | $\mu s$       |

Typical Performance Characteristics

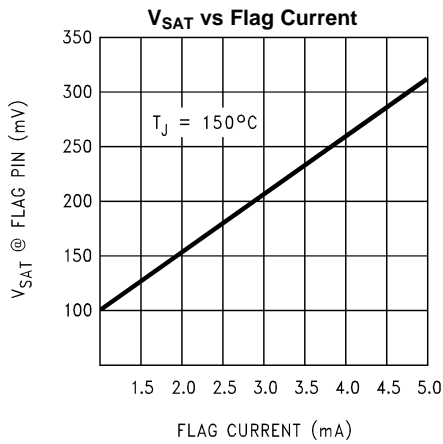


Figure 3.

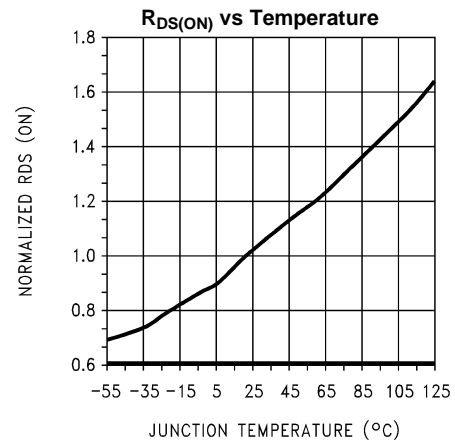


Figure 4.

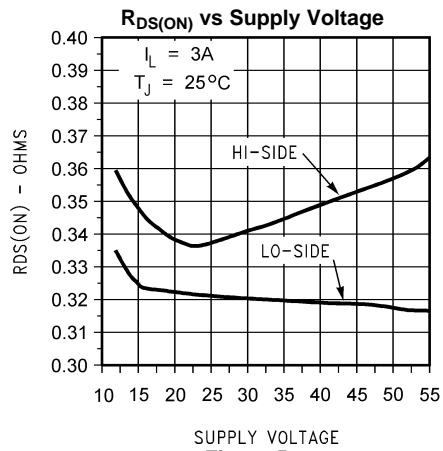


Figure 5.

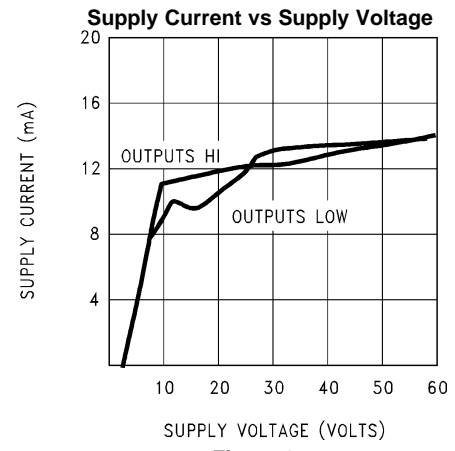


Figure 6.

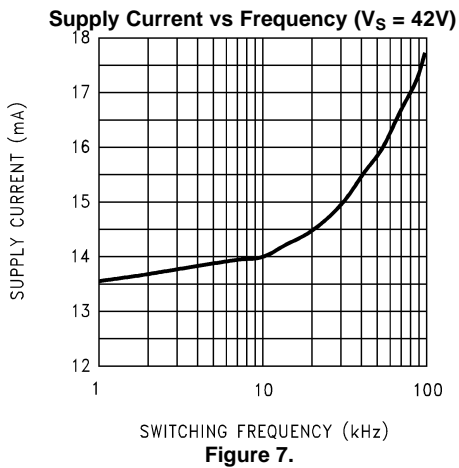


Figure 7.

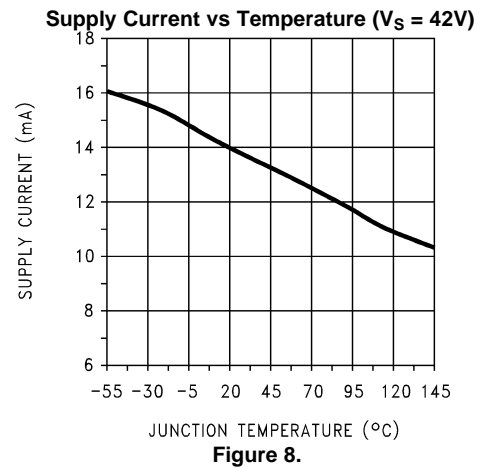
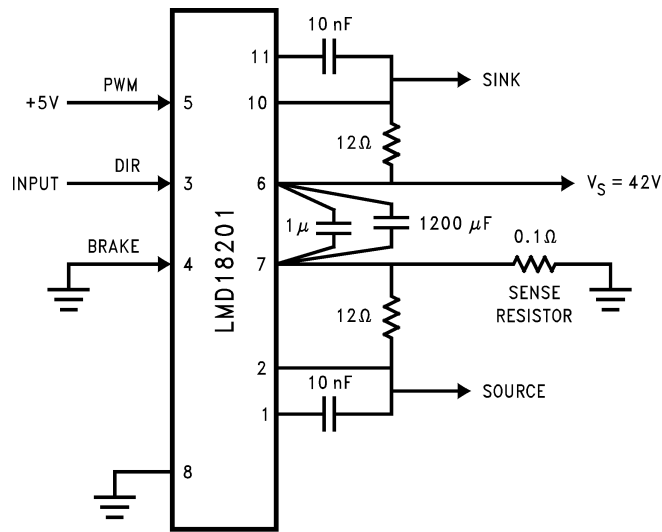
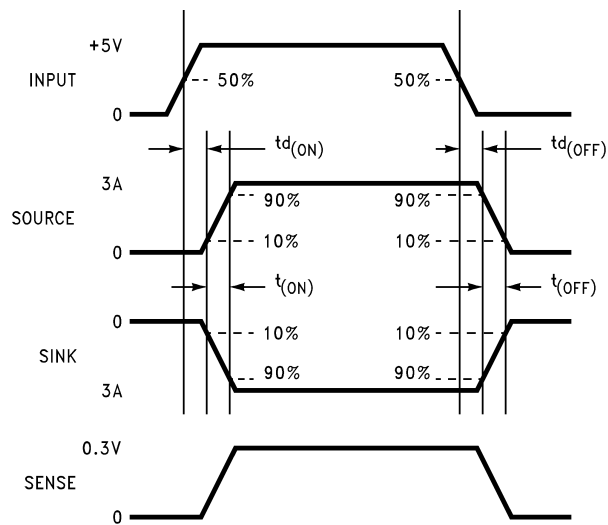


Figure 8.

TEST CIRCUIT



Switching Time Definitions



## Pinout Descriptions

(See [Test Circuit](#))

**Pin 1, BOOTSTRAP 1 Input:** Bootstrap capacitor pin for half H-Bridge number 1. The recommended capacitor (10 nF) is connected between pins 1 and 2.

**Pin 2, OUTPUT 1:** Half H-Bridge number 1 output.

**Pin 3, DIRECTION Input:** See [Logic Truth Table](#). This input controls the direction of current flow between OUTPUT 1 and OUTPUT 2 (pins 2 and 10) and, therefore, the direction of rotation of a motor load.

**Pin 4, BRAKE Input:** See [Logic Truth Table](#). This input is used to brake a motor by effectively shorting its terminals. When braking is desired, this input is taken to a logic high level and it is also necessary to apply logic high to PWM input, pin 5. The drivers that short the motor are determined by the logic level at the DIRECTION input (Pin 3): with Pin 3 logic high, both current sourcing output transistors are ON; with Pin 3 logic low, both current sinking output transistors are ON. All output transistors can be turned OFF by applying a logic high to Pin 4 and a logic low to PWM input Pin 5; in this case only a small bias current (approximately  $-1.5$  mA) exists at each output pin.

**Pin 5, PWM Input:** See [Logic Truth Table](#). How this input (and DIRECTION input, Pin 3) is used is determined by the format of the PWM Signal.

**Pin 6,  $V_S$  Power Supply**

**Pin 7, POWER GROUND/SENSE Connection:** This pin is the ground return for the power DMOS transistors of the H-Bridge. The current through the H-Bridge can be sensed by adding a small,  $0.1\Omega$ , sense resistor from this pin to the power supply ground.

**Pin 8, SIGNAL GROUND:** This is the ground return for the internal logic circuitry used to control the PWM switching of the H-Bridge.

**Pin 9, THERMAL FLAG Output:** This pin provides the thermal warning flag output signal. Pin 9 becomes active-low at  $145^\circ\text{C}$  (junction temperature). However the chip will not shut itself down until  $170^\circ\text{C}$  is reached at the junction.

**Pin 10, OUTPUT 2:** Half H-Bridge number 2 output.

**Pin 11, BOOTSTRAP 2 Input:** Bootstrap capacitor pin for half H-Bridge number 2. The recommended capacitor (10 nF) is connected between pins 10 and 11.

**Logic Truth Table**

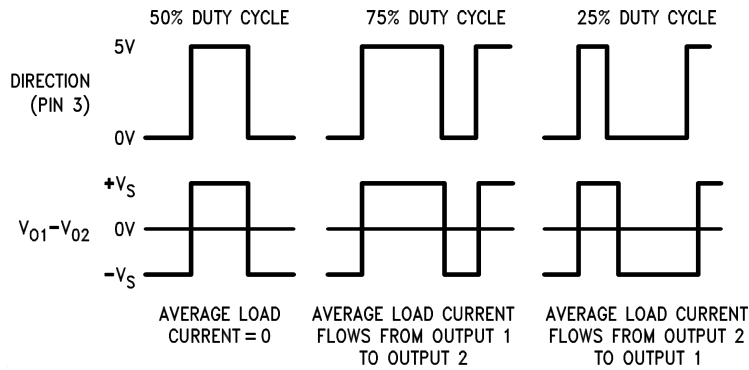
| PWM | Dir | Brake | Active Output Drivers |
|-----|-----|-------|-----------------------|
| H   | H   | L     | Source 1, Sink 2      |
| H   | L   | L     | Sink 1, Source 2      |
| L   | X   | L     | Source 1, Source 2    |
| H   | H   | H     | Source 1, Source 2    |
| H   | L   | H     | Sink 1, Sink 2        |
| L   | X   | H     | NONE                  |

## APPLICATION INFORMATION

### TYPES OF PWM SIGNALS

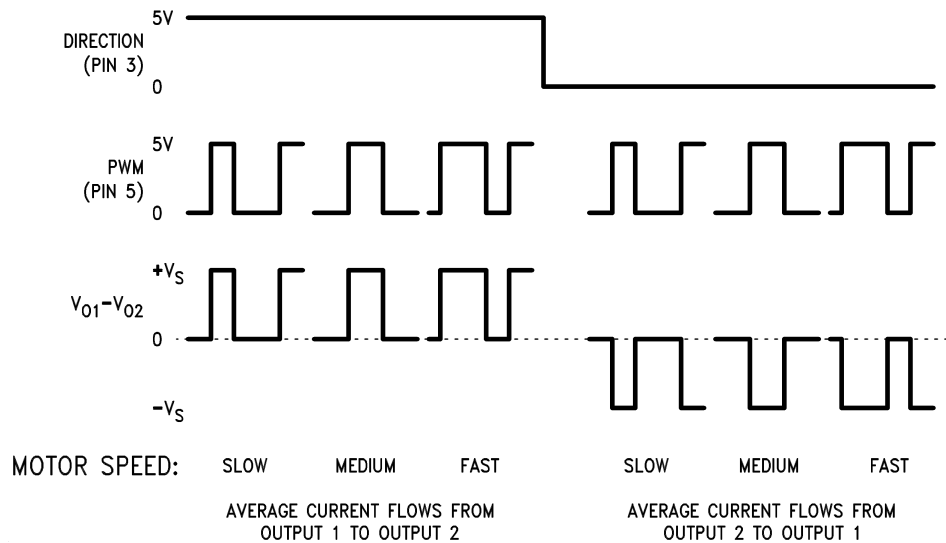
The LMD18201 readily interfaces with different forms of PWM signals. Use of the part with two of the more popular forms of PWM is described in the following paragraphs.

**Simple, locked anti-phase PWM** consists of a single, variable duty-cycle signal in which is encoded both direction and amplitude information (see [Figure 9](#)). A 50% duty-cycle PWM signal represents zero drive, since the net value of voltage (integrated over one period) delivered to the load is zero. For the LMD18201, the PWM signal drives the direction input (pin 3) and the PWM input (pin 5) is tied to logic high.



**Figure 9. Locked Anti-Phase PWM Control**

**Sign/magnitude PWM** consists of separate direction (sign) and amplitude (magnitude) signals (see [Figure 10](#)). The (absolute) magnitude signal is duty-cycle modulated, and the absence of a pulse signal (a continuous logic low level) represents zero drive. Current delivered to the load is proportional to pulse width. For the LMD18201, the DIRECTION input (pin 3) is driven by the sign signal and the PWM input (pin 5) is driven by the magnitude signal.



**Figure 10. Sign/Magnitude PWM Control**



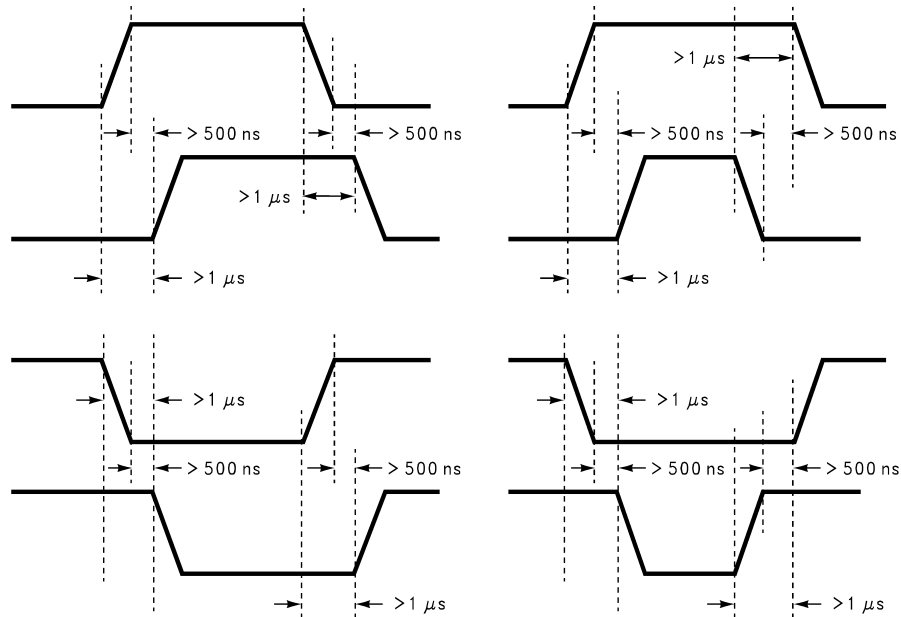


Figure 11. Transitions in Brake, Direction, or PWM Must be Separated by At Least 1 μsec

## SIGNAL TRANSITION REQUIREMENTS

To ensure proper internal logic performance, it is good practice to avoid aligning the falling and rising edges of input signals. A delay of at least 1 μsec should be incorporated between transitions of the Direction, Brake, and/or PWM input signals. A conservative approach is to be sure there is at least 500ns delay between the end of the first transition and the beginning of the second transition. See [Figure 11](#).

## USING THE THERMAL WARNING FLAG

The THERMAL FLAG output (pin 9) is an open collector transistor. This permits a wired OR connection of thermal warning flag outputs from multiple LMD18201's, and allows the user to set the logic high level of the output signal swing to match system requirements. This output typically drives the interrupt input of a system controller. The interrupt service routine would then be designed to take appropriate steps, such as reducing load currents or initiating an orderly system shutdown. The maximum voltage compliance on the flag pin is 12V.

## SUPPLY BYPASSING

During switching transitions the levels of fast current changes experienced may cause troublesome voltage transients across system stray inductances.

It is normally necessary to bypass the supply rail with a high quality capacitor(s) connected as close as possible to the  $V_S$  Power Supply (Pin 6) and POWER GROUND (Pin 7). A 1 μF high-frequency ceramic capacitor is recommended. Care should be taken to limit the transients on the supply pin below the Absolute Maximum Rating of the device. When operating the chip at supply voltages above 40V a voltage suppressor (transorb) such as P6KE62A is recommended from supply to ground. Typically the ceramic capacitor can be eliminated in the presence of the voltage suppressor. Note that when driving high load currents a greater amount of supply bypass capacitance (in general at least 100 μF per Amp of load current) is required to absorb the recirculating currents of the inductive loads.

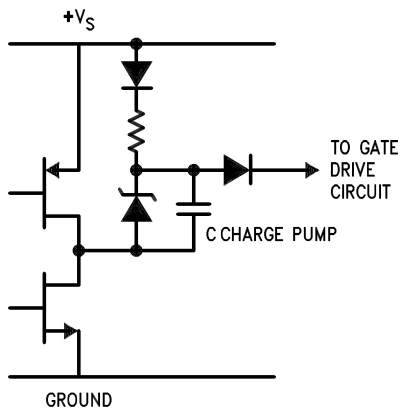
## CURRENT LIMITING

Current limiting protection circuitry has been incorporated into the design of the LMD18201. With any power device it is important to consider the effects of the substantial surge currents through the device that may occur as a result of shorted loads. The protection circuitry monitors the current through the upper transistors and shuts off the power device as quickly as possible in the event of an overload condition (the threshold is set to approximately 10A). In a typical motor driving application the most common overload faults are caused by shorted motor windings and locked rotors. Under these conditions the inductance of the motor (as well as any series inductance in the  $V_{CC}$  supply line) serves to reduce the magnitude of a current surge to a safe level for the LMD18201. Once the device is shut down, the control circuitry will periodically try to turn the power device back on. This feature allows the immediate return to normal operation once the fault condition has been removed. While the fault remains however, the device will cycle in and out of thermal shutdown. This can create voltage transients on the  $V_{CC}$  supply line and therefore proper supply bypassing techniques are required.

The most severe condition for any power device is a direct, hard-wired (“screwdriver”) long term short from an output to ground. This condition can generate a surge of current through the power device on the order of 15 Amps and require the die and package to dissipate up to 500W of power for the short time required for the protection circuitry to shut off the power device. This energy can be destructive, particularly at higher operating voltages (>30V) so some precautions are in order. Proper heat sink design is essential and it is normally necessary to heat sink the  $V_{CC}$  supply pin (pin 6) with 1 square inch of copper on the PC board.

## INTERNAL CHARGE PUMP AND USE OF BOOTSTRAP CAPACITORS

To turn on the high-side (sourcing) DMOS power devices, the gate of each device must be driven approximately 8V more positive than the supply voltage. To achieve this an internal charge pump is used to provide the gate drive voltage. As shown in (Figure 12), an internal capacitor is alternately switched to ground and charged to about 14V, then switched to  $V_S$  thereby providing a gate drive voltage greater than  $V_S$ . This switching action is controlled by a continuously running internal 300 kHz oscillator. The rise time of this drive voltage is typically 20  $\mu$ s which is suitable for operating frequencies up to 1 kHz.



**Figure 12. Internal Charge Pump Circuitry**

For higher switching frequencies, the LMD18201 provides for the use of external bootstrap capacitors. The bootstrap principle is in essence a second charge pump whereby a large value capacitor is used which has enough energy to quickly charge the parasitic gate input capacitance of the power device resulting in much faster rise times. The switching action is accomplished by the power switches themselves (Figure 13). External 10 nF capacitors, connected from the outputs to the bootstrap pins of each high-side switch provide typically less than 100 ns rise times allowing switching frequencies up to 500 kHz.

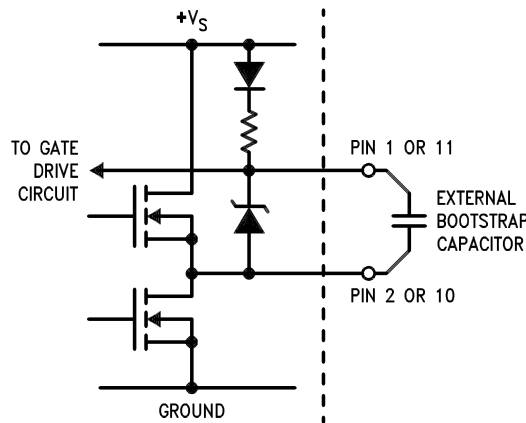


Figure 13. Bootstrap Circuitry

### INTERNAL PROTECTION DIODES

A major consideration when switching current through inductive loads is protection of the switching power devices from the large voltage transients that occur. Each of the four switches in the LMD18201 have a built-in protection diode to clamp transient voltages exceeding the positive supply or ground to a safe diode voltage drop across the switch.

The reverse recovery characteristics of these diodes, once the transient has subsided, is important. These diodes must come out of conduction quickly and the power switches must be able to conduct the additional reverse recovery current of the diodes. The reverse recovery time of the diodes protecting the sourcing power devices is typically only 70 ns with a reverse recovery current of 1A when tested with a full 3A of forward current through the diode. For the sinking devices the recovery time is typically 100 ns with 4A of reverse current under the same conditions.

### TYPICAL APPLICATIONS

#### BASIC MOTOR DRIVER

The LMD18201 can directly interface to any Sign/Magnitude PWM controller. The LM629 is a motion control processor that outputs a Sign/Magnitude PWM signal to coordinate either positional or velocity control of DC motors. The LMD18201 provides fully protected motor driver stage.

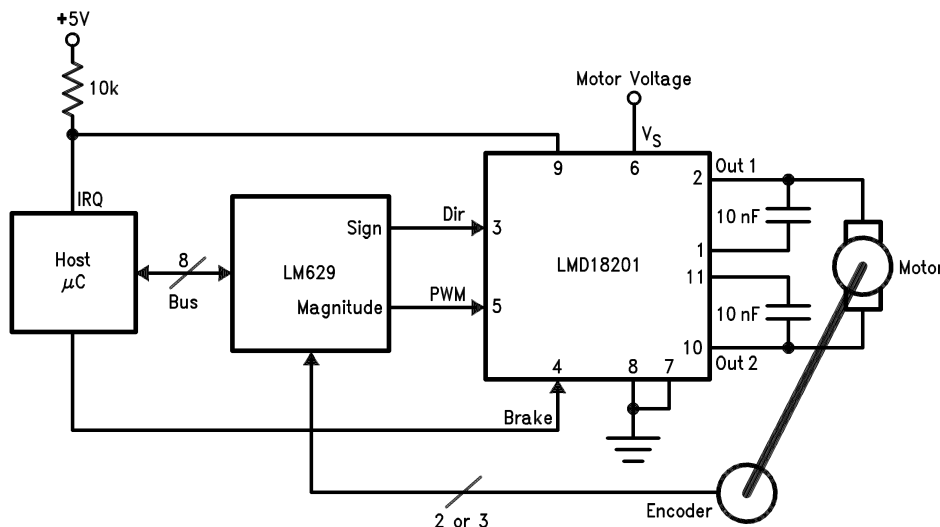
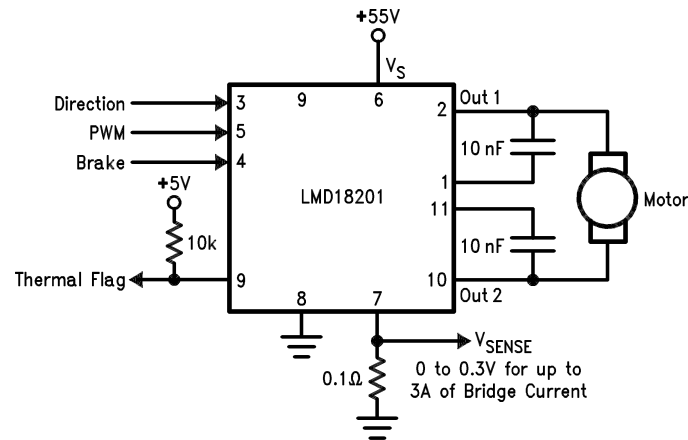


Figure 14. Basic Motor Driver

## CURRENT SENSING

In many motor control applications it is desirable to sense and control the current through the motor. For these types of applications a companion product, the LMD18200, is also available. The LMD18200 is identical to the LMD18201 but has current sensing transistors that output a current directly proportional to the current conducted by the two upper DMOS power devices to a separate current sense pin. This technique does not require a low valued, power sense resistor and does not subtract from the available voltage drive to the motor.

To sense the bridge current through the LMD18201 requires the addition of a small sense resistor between the power ground/sense pin (Pin 7) and the actual circuit ground (see Figure 15). This resistor should have a value of  $0.1\Omega$  or less to stay within the allowable voltage compliance of the sense pin, particularly at higher operating current levels. The voltage between power ground/sense (Pin 7) and the signal ground (Pin 8) must stay within the range of  $-1V$  to  $+0.5V$ . Internally there is approximately  $25\Omega$  between pins 7 and 8 and this resistance will slightly reduce the value of the external sense resistor. Approximately 70% of the quiescent supply current (10 mA) flows out of pin 7. This will cause a slight offset to the voltage across the sense resistor when the bridge is not conducting. During reverse recovery of the internal protection diodes the voltage compliance between pins 7 and 8 may be exceeded. The duration of these spikes however are only approximately 100 ns and do not have enough time or energy to disrupt the operation of the LMD18201.



**Figure 15. Current Sensing**

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**REVISION HISTORY**

| <b>Changes from Revision C (April 2013) to Revision D</b>  | <b>Page</b>              |
|--|--------------------------|
| <hr/> <ul style="list-style-type: none"><li>• Changed layout of National Data Sheet to TI format .....</li></ul> | <hr/> <a href="#">12</a> |

**PACKAGING INFORMATION**

| Orderable part number          | Status<br>(1) | Material type<br>(2) | Package   Pins    | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|--------------------------------|---------------|----------------------|-------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">LMD18201T/NOPB</a> | Active        | Production           | TO-220 (NDJ)   11 | 20   TUBE             | Yes         | SN                                   | Level-1-NA-UNLIM                  | -40 to 125   | LMD18201T P+        |
| LMD18201T/NOPB.B               | Active        | Production           | TO-220 (NDJ)   11 | 20   TUBE             | Yes         | SN                                   | Level-1-NA-UNLIM                  | -40 to 125   | LMD18201T P+        |

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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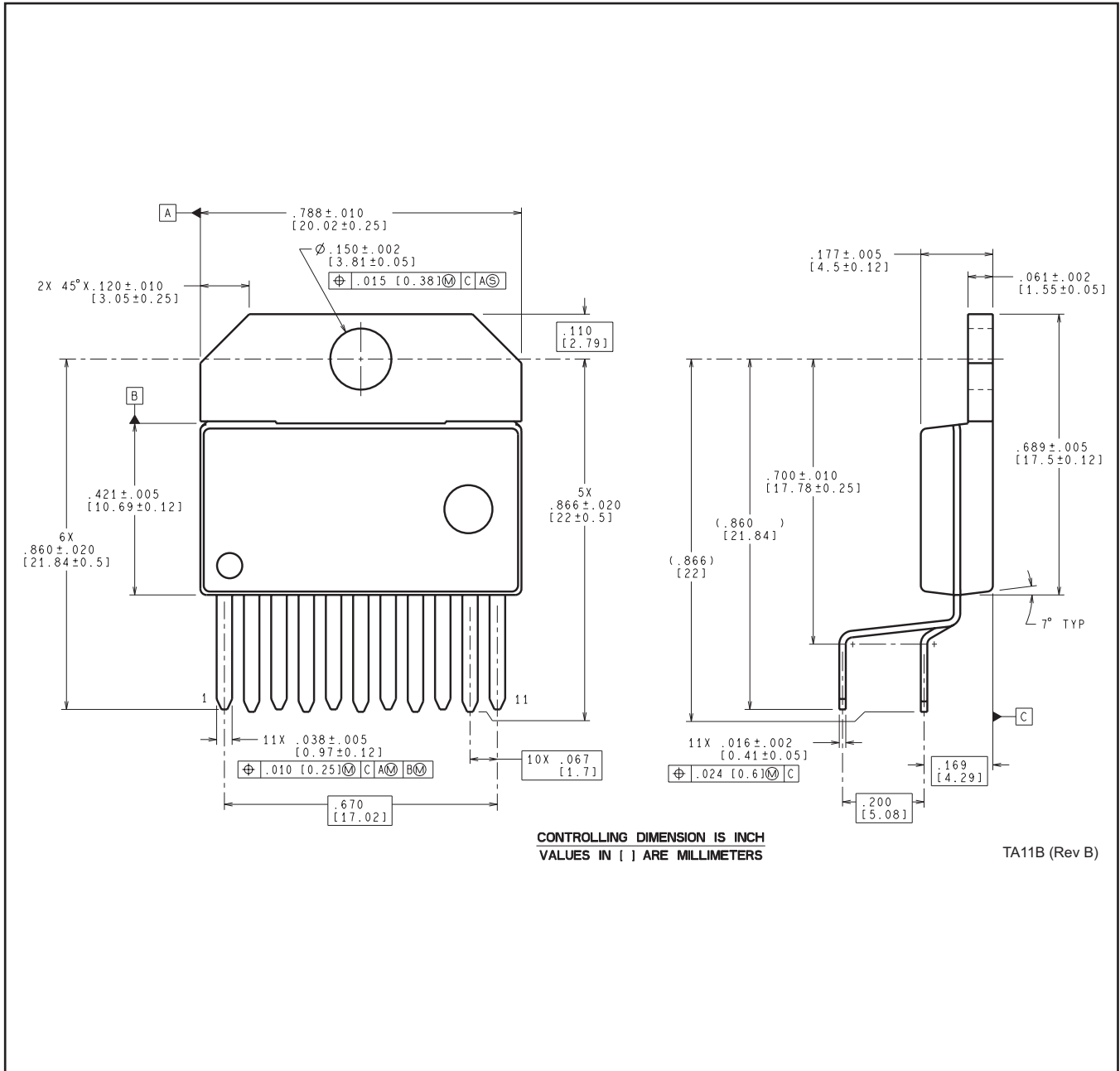
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**TUBE**


\*All dimensions are nominal

| Device           | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|------------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| LMD18201T/NOPB   | NDJ          | TO-220       | 11   | 20  | 502    | 34     | 12192  | 0      |
| LMD18201T/NOPB.B | NDJ          | TO-220       | 11   | 20  | 502    | 34     | 12192  | 0      |

NDJ0011B



TA11B (Rev B)



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