Design of a Four-Point Seat-Belt Presenter

by

Miguel Angel Chavez

Submitted to the Department of Mechanical Engineering
in partial fulfillment of the requirements for the degree of

Bachelor of Science in Mechanical Engineering

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Abstract

The ambition of this thesis was to design and prototype a seat-belt presenter of a four-point seat-belt system for the Lear Corporation. The seat-belt presenter designed is to be implemented in automobile seats in order to facilitate putting a four-point seat belt. The worked perform is the culmination of both Petr Petri and myself in our efforts to find a method to properly present a four-point seat-belt system. The design utilizes a magnet at the end of an aluminum arm that is pivoted below a person's knee on the seat. A sensor detects when a person sits down and begins a series of actions to present the seat belt. The device uses a set of four mechanical sensors to locate the position of the arm, the seat belt, and on the seat to detect when a person sits down. A control system, which utilizes logic components, then decides what direction to turn the arm in and when to stop it. The prototype that was built to simulate the seat-belt presenter appears to work well but has little details that need to worked up before a product like this enters the market. Among the most important issues to be resolved is the prototyping of the second arm on the presenter, the mounting of the motor and sensors onto the mount, use of the appropriate sensors, and to address the problem of the electrical components overheating.

Thesis supervisor: Ernesto E. Blanco
Title: Adjunct Professor of Mechanical Engineering

Acknowledgements

I would like to take this moment to thank all the people who helped make this thesis a reality. In my heaviest semester load as an undergraduate, many have contributed much of their time to help me stay on track in all my classes. Though I started this project late, it was to all these people that managed to finish all my work.

First, I wish to thank Professor Blanco and the Lear Corporation for allowing me to work on this project. To Professor Blanco, thank you for providing me with the many ideas and guidance I needed whenever I worked with you, for it would not have been possible to get to where I am right now without you. I truly thank you for all your help and patience in all the times we worked together. To the Lear Company, thank you providing me with all the materials and funding necessary to construct the prototype.

To my friends in the Electrical Engineering Department, Sauparna Das, Baris Erkmen, and Rogelio Palomera-Arias, I thank you for all your help. Thanks for providing me with the electrical components necessary to construct the control system part of my thesis. Rogelio, thanks for sharing your time and knowledge, as they were both instrumental in completing the electronic part of my project. Sauparna, the H-Bridge provided truly simplified the project and helped make the control system simple. Again, thanks for all your help.

Lastly, and most importantly, I dedicate all my work on this project and in all my four years here to my parents. You are reason why I have gone this far in my education. Where it not for your support, I could never have made through this school. I know the last four years have been hard on all of us, but I thank you for being there every time I needed you.

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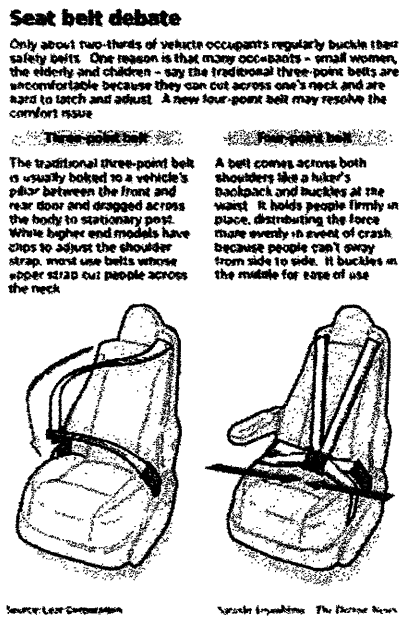
A Motor Vehicle Occupant Safety Survey released in March of 2000 reports statistics on the non-use of seat belts. Of the drivers polled that did not use seat belts all the time, more than half said they either were driving only a short distance (56%) or simply forgot to put seat belt on (53%). Among the other top reasons given were drivers being in a hurry (40%), belt being uncomfortable (37%), and only driving in light traffic (24%). Among non-users of seat belts, the main reason given for not using seat belt was belt being uncomfortable (65%).

There is a need for a way to remind automobile users (drivers and passengers) to buckle up when they sit down on a seat. In addition, current seat belt designs (three-point systems) are somewhat uncomfortable to users and could use a change in design. The Lear Corporation has designed a new four-point seat-belt system that appears to be comfortable and is more secure than the three-point seat-belt systems. The method of how to provide automobile users with a reminder to buckle up will be the purpose of this thesis.

1.2 Background

The Lear Corporation's four-point seat-belt system is a change to normal three-point seat-belt systems. To begin, the four-point seat-belt systems restrain occupants from both shoulders and the waist, instead of just one shoulder and the waist in three-point systems. This change reduces the forces the impact forces experienced by users in a car accident since force is now distributed through both shoulder belts. In addition, the users are now restrained better for side impacts. Figure 2 illustrates the difference between the two seat-belt systems.



Seat belt debate

Only about two-thirds of vehicle occupants regularly buckle their safety belts. One reason is that many occupants – small women, the elderly and children – say the traditional three-point belts are uncomfortable because they can cut across one's neck and are hard to latch and adjust. A new four-point belt may resolve the comfort issue.

Three-point belt

The traditional three-point belt is usually bolted to a vehicle's pillar between the front and rear door and dragged across the body to stationary post. While higher end models have clips to adjust the shoulder strap, most use belts whose upper strap cut people across the neck.

Four-point belt

A belt comes across both shoulders like a hiker's backpack and buckles at the waist. It holds people firmly in place, distributing the force more evenly in event of crash because people can't sway from side to side. It buckles in the middle for ease of use.

Source: Lear Corporation

[illegible] The Detroit News

Figure 2: Comparison of three-point and four-point seat-belt designs (Source Detroit News Online, http://detnews.com/2000/autos/sae/06seat/06seat.htm)

The disadvantage of the four-point seat-belt system is that buckling up is more complex than that for a three-point seat-belt system. In addition, the user must also center the belt in order to insure that it does not cause any discomfort. In order to resolve the issue of centering the two belts, Petr Petri worked on designing a coupling device that will automatically center the seatbelts. The device, pictured in figure 3, operates by having the coupled seat belts unwind and wind at the same rate, so whenever the seat belts are extended, they are extended to the same length. The two seat belts are coupled by a torsion like spring connecting the two belt assemblies. The coupling device was built and presented for the Fall 2000 semester to the Lear Corporation for the course 2.72, Elements of Mechanical Design. In order to facilitate buckling up, a seat-belt presenter will be designed.

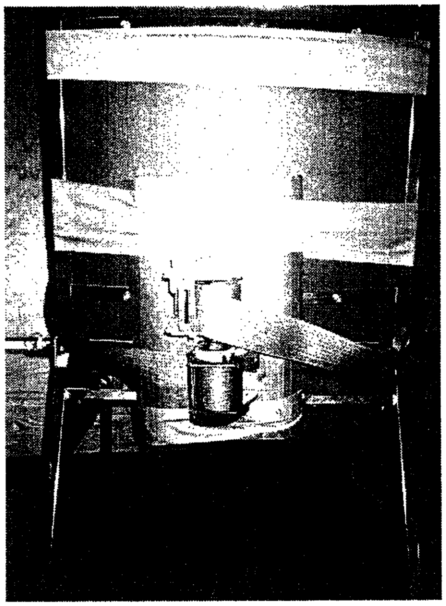


Figure 3: *Coupling device to center seat belts on four-point seat belt (designed and built by Petr Petri)*

A seat-belt presenter is a device that presents a seat belt to a person in an automobile seat. The device facilitates a person's ability to place a seat belt on. At first glance, the device appears to only serve in reducing the number of physical actions required to put a seat belt on, but indirectly, and more importantly, it also provides the person in the automobile with a visual indication of putting the seat belt on. With the reason of forgetting to buckle up accounting for about 56%, the seat belt presenter could increase seat belt usage and therefore reduce automobile injuries and fatalities. Seat belt presenters already exist and are used in some automobiles using normal three–point seat belts but the shoulder belt seems to impose an uncomfortable feeling to users and results in the seat belt not being used.

As with the coupling device, the seat-belt presenter was started by Petr Petri. He began designing and prototyping the seat-presenter in the Fall 2000, but did not finish. His work got as far as prototyping the arm out of lexan, finding the means attaching the seat belt to the arm (magnet), and remade the connecting part of the belt out of steel in order to make it attachable to the magnet. Since time ran out, he was not able to implement his design to a chair.

1.3 Scope of Design

The intention of this undergraduate thesis is to design and prototype a seat-belt presenter. Although they are for use in automobile seats, for our purposes we will mount our design onto a normal chair. The problem is further simplified by assuming that the presenter will operate in the same manner on both sides, therefore only requiring us to work on one side of it. The seat belts that would normally be mounted onto an automobile seat, now will be attached by using duct tape on the mock car seat (chair). Using the design of Petr Petri's original presenter and centering device, we will finish the design by introducing a control system to power and control a Ford windshield wiper motor. The control system will be responsible to monitor four sensors to determine what actions to take with the motor. The design was optimized a few times to reduce the number of components in order to minimize manufacturing costs.

1.4 Design Goals

Like any design project, the objectives need to be clearly defined and prioritized in order to create a list of goals and considerations. This list is can then be turned into mechanical parameters and used for an evaluation of the design.

- Durable
- Safety
- Reliable

- Robust
- Minimal Cost

The prototype seeks to be durable in order to last through the many times the seat belt will be put on and off, safety must be addressed so as to have the arm not be responsible for any injuries, lightweight in order to maintain the car weight low, must be reliable and function correctly all the time, robust to insure prototype does not fall apart during use, minimize cost in order to make it a required feature in cars instead of just being an optional feature that is too expensive. In order to keep this thesis project manageable, the design was kept relatively simple without trying to modify Petr Petri's original design. Instead the main focus went towards constructing a control system to perform the appropriate actions of the motor to rotate the arm.

2 Mechanical Design Component Overview

2.1 Seat belt

The male part of the seat belt assembly was redesigned and part of it was made out of steel in order to permit the belt to be picked up by the magnet. This change permits the presenter to automatically reset to its original position every time a user takes off the seat belt, by having the magnet attached to the arm attach to the seat belt assembly. Figure 4 shows a drawing of the seat belt.

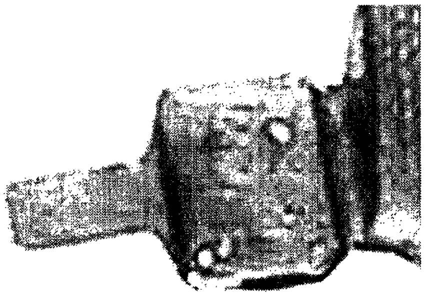


Figure 4: *Seat belt assembly of male part (prototype by Petr Petri)*

The belt is assembled by bringing together the plastic part show on the left of Figure 5 to enclose the aluminum sheet metal part in between the steel part on the right, creating the new seat belt, which attaches strongly to the magnet on the arms of the presenter.

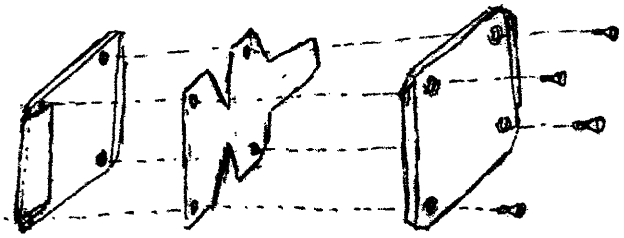


Figure 5: Hand drawn assembly of belt.

2.2 Motor and Sensors Mounting

The mounting of the motor and the sensors required a light but strong metal to support their weight. It was decided to use an aluminum sheet as the mount in order to take advantage of its lightweight, ease of use, availability, and non-magnetic properties. In order to attach the mount to the aluminum sheet, it was bent and laid on the chair. The mounting holes are drilled through the bent section of the aluminum sheet and the steel part of the chair using a hand drill. Using the drill press, the appropriate holes are made on the sheet in order to mount the Ford motor. Figure 6 pictures the mount with the arm and the sensors. Figure 7 pictures the motor attached to mount from a bottom view. Placing the mechanical sensors on the mount required the use of brackets. The brackets are built using the aluminum sheet leftover from the mount. Small strips are cut, bent halfway, and drilled twice on one of the bent sides for attachment on to the mount. Holes on the mount are also to allow the wire to be passed into the bottom of the chair and to mount the brackets. The non-drilled section is covered completely with the electrical tape to prevent the bracket from closing the circuit on the sensors when they are mounted, as can be seen in Figures 9 and 10. The mount, motor and sensor assembly can be seen through Figure 8.

down and seat belt is presented. The processes are described in detail as to the position of the arm and all the sensors (Note: sensor on means the mechanical switch is being pressed and off means it is not pressed). When the top and bottom position sensors are pressed the motor is stopped. For each process there is a drawing to show the position of the arm and the direction it rotates for each action.

1) The seat is empty and the arm is at the resting position. Since there is no one on the seat, the seat sensor is off. The sensor that goes on the belt is on since the belt is attached to the magnet on the arm. The up position sensor is off and the down position is on since the arm is resting on it.

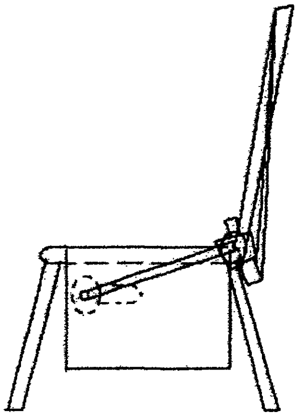


Figure 13: Original Position for Seat Belt Presenter

2) A person sits down and turns the seat sensor on. While the seat belt sensor remains on, the motor is activated by the seat sensor and begins to rotate the arm up. As a result this turns the down sensor off.

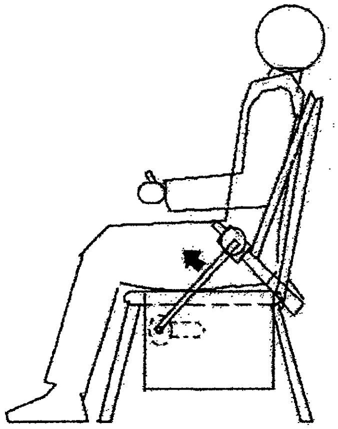


Figure 14: *Person sits down and arm rotates up.*

3) The arm reaches the top position and turns on the up position sensor. The only change between states two and state three is that the up position sensor is on and down position is off while person sensor and the seat belt sensor remain on.

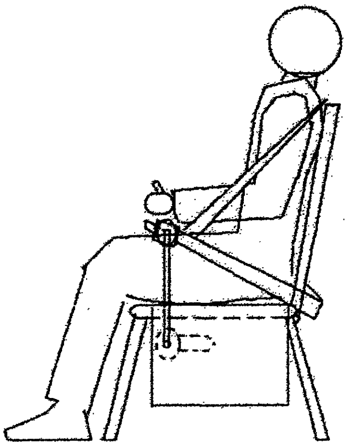


Figure 15: *Seat belt is presented.*

4) Once the seat belt is removed the belt sensor is turned off. All other sensors remain the same, but the action of removing the seat belt activates the motor to rotate the arm back down, thereby turning the up position sensor off.

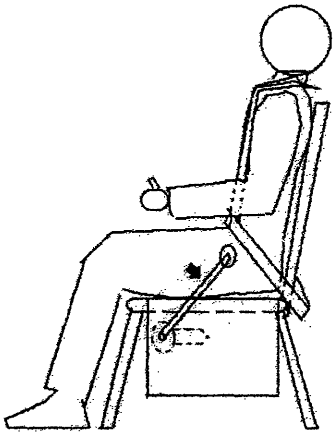


Figure 16: Removing the seat belt from magnet activates the motor to rotate back down.

5) After arm returns to original position and turns down position sensor on, thereby stopping the motor. The person sensor is on while the seat belt sensor is off. This remains the same until the user removes seat belt and it returns to the magnet. This turns the seat sensor on and begins the cycle again.

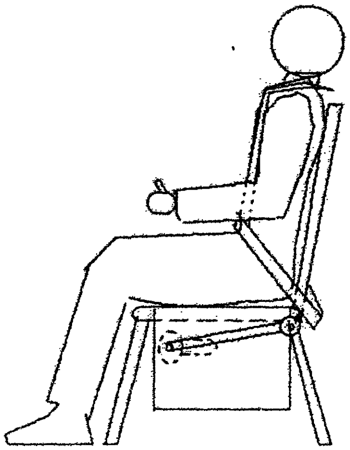


Figure 17: Person has buckled up and seat belt presenter returns to down position.

3 Electrical Circuit Design Overview

3.1 Power Source

Originally, the control system design intended to regulate power to the motor through use of a car battery and an electrical adapter powered the logic circuitry. The design proved valid and demonstrated its capability to work as planned but failed to be simple and reduce cost since it required two power sources. The problem was resolved by using a 5-volt voltage regulator to power input to the logic. This permitted the use of the car battery to power both the motor and the logic. Implementation of the proposed design into an actual car would require a modification of the power source from the direct connection to the battery to connecting it through a fuse.

3.2 Logic

In order to arrive at the logic required to perform the actions desired, outlined in the operation process of the seat belt present, a table chart listing all the possible sensor positions for the four sensors is made.

Table 1: *Logic Table and Input to H-Bridge*

State	Sensor Input Variables				Motor Control Variables		
	Down	**Up**	**Seat**	**Belt**	**Direction**	**Brake**	**PWM**
Not Possible	1	1	1	1	X	X	L
Not Possible	1	1	1	0	X	X	L
Not Possible	1	1	0	1	X	X	L
Not Possible	1	1	0	0	X	X	L
2-A	1	0	1	1	H	L	H
5	1	0	1	0	L	H	H
1	1	0	0	1	X	X (H)	L
1-B	1	0	0	0	X	X (H)	L
3	0	1	1	1	H	H	H
4-A	0	1	1	0	L	L	H
4-B-2	0	1	0	1	L	L	H
4-B-3	0	1	0	0	L	L	H
2-B	0	0	1	1	H	L	H
4-B	0	0	1	0	L	L	H
4-B-4	0	0	0	1	L	L	H
4-B-5	0	0	0	0	L	L	H

The logic is used to provide the input into the H-Bridge chip (discussed further in the next section), which takes as input three signals (direction, brake, and power). In addition to listing the sensor positions, for each possible combination a direction, option brake and power to the motor must be selected. The results are shown on Table 1.

The states listed on the left refer to the operational processes. The state whose number is followed by a letter indicates that it is part of a sub-process in that state. The states that identified by a number and letter followed by another number, for example 4-B-2, are states that might occur if the process malfunctioned. This could happen if during the process of going between states a variation occurs. In order to provide a control system that accounts for such variations, a preventive measured is taken and the output to the H-bridge is changed to account for the variation. For example if the arm is rotating up to present the seat belt but if it happens to get disengaged from the magnet, the control system then directs the motor to stop and rotate the arm back to the resting position in order to recover the seat belt. Should the seat belt not be there because the user picked it up and buckled up, then the sensors should take it to fifth state, where the arm remains at the down position. Some of the possible variations that could occur are having a person get off the seat or, as mentioned above, a seat belt gets disengaged off magnet. The states labeled 'Not Possible' show the different situations that could not occur unless a sensor broke down somewhere, therefore the H-bridge inputs become irrelevant and the power to the motor is shut off. The X's in the input for the H-bridge indicate that the case being referred to makes no difference as to what the output is, but for some cases the X's were changed to off or low positions in order to simplify logic equations.

Evaluating the results of the table, we obtain the following equations for the direction, brake, and power inputs to the H-bridge:

$$SBUD + SBU\overline{D} + SB\overline{U}D + SB\overline{UD} = DIRECTION \qquad \text{(Equation 1)}$$

$$SB\overline{U}D + S\overline{B}\,\overline{U}D + \overline{S}B\overline{U}D + \overline{S}\,\overline{B}\,\overline{U}D = BRAKE \qquad \text{(Equation 2)}$$

$$SBUD+S\overline{B}UD+\overline{S}BUD+\overline{SB}UD+\overline{S}B\overline{UD}+\overline{SB}\,\overline{U}D=\overline{P}\,\overline{WM} \qquad \text{(Equation 3)}$$

The lines above the letters indicate the sensor is off for that scenario. The letters S, B, U, and D refer to the sensors at the seat, belt, up position, and down position respectively. Equation 3, unlike the other two, indicates that the power is off whenever the cases shown arise. This results in the use of an inverter on the circuit to convert the signal from an off one to an on. Letters that are side by side indicate the AND logic function. For example, SBUD means that result of this will be a high (TRUE or 1) only if S AND B AND U AND D are all on (1). The '+' sign in the equations is actually an OR logic function which will allow the given function to occur whenever any of those cases is true. After further simplification, the equations become the following:

$$DIRECTION=SB \qquad \text{(Equation 4)}$$

$$BRAKE=SBU\overline{D}+\overline{SB}\,\overline{U}D \qquad \text{(Equation 5)}$$

$$\overline{P}\,\overline{WM}=\overline{U}D\overline{S}+UD \qquad \text{(Equation 6)}$$

The equations were simplified to the conditions above by only having the variables (sensors) that they depend on in the equation showed. The equations can now be combined in order to provide the control system circuit diagram, drawn in Figure 18.

On the breadboard, the control system looks as pictured in figure 19 and figure 20.

4 Further Work

4.1 Seat-Belt Presenter

The design proposed works to present the four-point seat-belt system well but for only one side. Work still has to be done to prototype the system for both sides. This might require coupling two motors for the two arms of the presenter to rise at the same rate. Additionally, thought has to go into whether the arms will have each react to the actions of the user jointly or separately. For example, if a user disengages the seat belt from one side first and then reaches for the other belt a couple of seconds later, whether the control system will lower both arms right after the first belt is picked up, or after both belts are picked up. The question of would each arm react individually after the belt is picked up has to be decided. Since our goal is to ensure that people buckle up, both arms should remain up until the two belts are removed from the magnets. An additional sensor should be installed on the belts in order to find out if people actually buckle up after detaching the two belts from the presenter.

In a real seat-belt presenter, the whole presenter assembly would have to be modified. The motor mount would be beneath the car seat. In contrast to our prototype, the actual seat-belt presenter would have the up/down sensors inside of the mount, underneath the seat, in order to prevent tampering. The seat sensor used for an actual presenter would have to be changed to a more appropriate one. Besides changing the method used to attach the arm to the motor, the arm would have to be made less wide. In addition, the magnet used worked properly but a separation of about 0.003 inches in order to make the force needed to separate the belt from it much smaller.

4.2 Motor

The Ford windshield wiper motor was used for its high torque. Initial experiments conducted to find out the required torque on the seat belt presenter arm indicated a need of about 6.8 N-m to 10.2

N-m. The motor was chosen for having its stall torque of 14Nm. The disadvantage is the fact that it works at high revolutions per minute. To account for this, either the voltage supplied to the motor has to be reduced or another motor should be used. Should the Ford motor still be considered, after reducing the input voltage to an optimal quantity, tests should be done to ensure motor still has enough torque to drive the arms up and present the seat belt. In course of testing the prototype, the lap belt broke and accurate results could not be obtained. The belt failed to lock when pulled quickly. Though the motor may rotate too fast, using a 10-volt voltage regulator to reduce the input voltage into the H-bridge, which controls the motor, may be yield to desired results.

4.3 Changes to the Control System

The control system needs to be changed in order to address the issue of the second side of the presenter. The logic will now have to account for two up/down position sensors, two belt sensors, and possibly an extra sensor to determine whether the person buckled up or not. Two H-bridges might need to be used in order to drive two motors, that is unless an alternative motor can be found that can drive both arms at the same time is found (Note: Through gears, the same Ford motor could be used to drive both arms). Another issue that needs to be addressed is the introduction of delays. As is, the control system activates the motor and rotates the arm up immediately after the sensor is turned on. This poses the problem of having the arm rotate up when a person is in the process of sitting down and possibly cause harm to the person. The delay would give a person sitting down a few seconds before rotating the arm up. The LMD-18200 H-bridge being used is in need of a heat sink in order to prevent chip from burning. Though H-bridge automatically turns off once it reaches a certain temperature as a safety precaution, the correct functionality of the seat-belt presenter may be compromised. Lastly, the present control system is built on a breadboard but for use in real life, the control system would have to be put on a printed circuit and use smaller electrical components.

5 Appendices

5.1 Appendix A (Part Drawings)

The following are the part drawing for the arm and the mount, two important parts of this thesis. Figure 22 and Figure 23 illustrate the top and side view of the arm. As for Figure 24, 25, and 26, they illustrate to top, side, and edge views of the mount. Of the characteristics on the mount missing from these part drawings are the holes to mount the sensors. They were not included since they are just there to serve the purpose of having the motor stop, the can be placed anywhere on a line in which the arm is desired to stop. The only requirement is that there are two holes on the brackets in order to ensure that the sensors don't rotate about one screw and have the motor not be able to come to a stop since the sensors stops it is not there anymore.

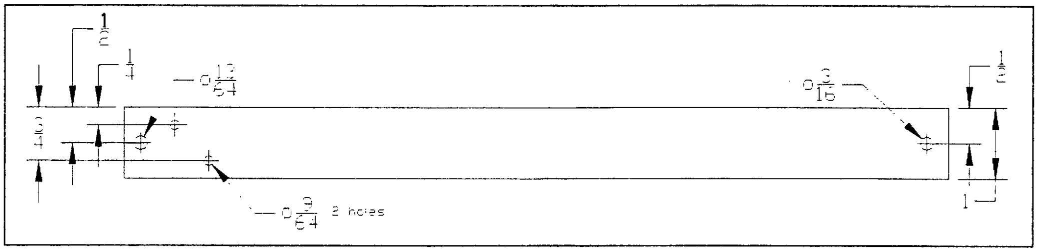


Figure 22: *Part Drawing - Top View of Mechanical Arm*

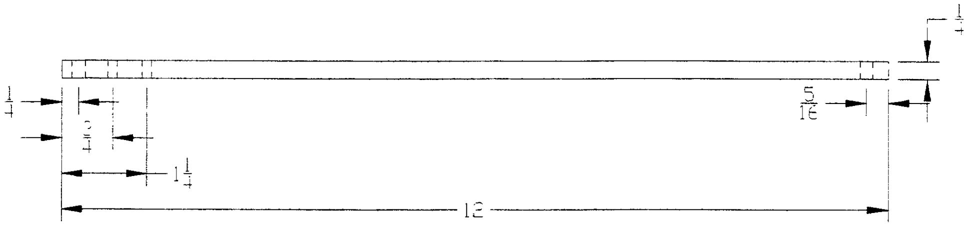


Figure 23: *Part Drawing - Front View of Mechanical Arm*

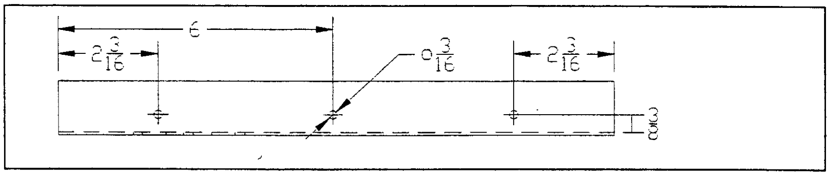


Figure 24: *Part Drawing - Top View of Mounting Plate*

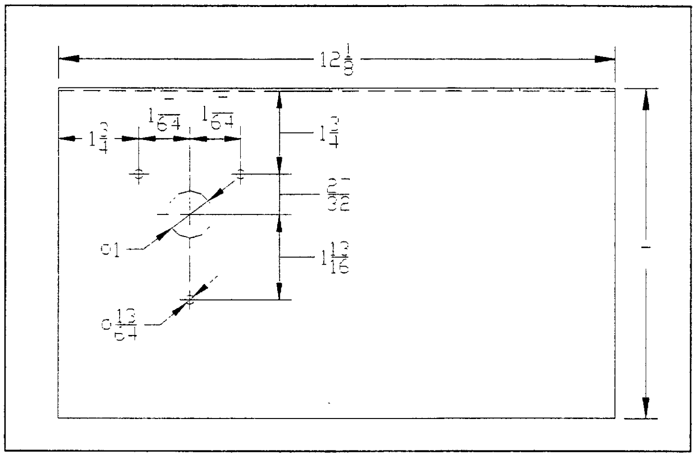


Figure 25: *Part Drawing - Front View of Mounting Plate*

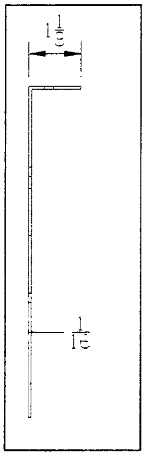


Figure 26: *Part Drawing - Side View of Mounting Plate*

5.2 Appendix B (Electrical Components)

The following is a list of electrical components used to built the control system:

1.	Fairchild Semiconductor Hex Inverter Gates 74LS04	(1)
2.	Fairchild Semiconductor Quad 2-Input AND Gate 74LS08	(2)
3.	78L05Fairchild Semiconductor Quad 2-Input OR Gate 74LS32	(1)
4.	Fairchild Semiconductor 5 Volt Voltage Regulator	(1)
5.	National Semiconductor 3A, 55V H-Bridge LMD18200	(1)
6.	Resistor 210 Ω	(4)
7.	Resistor 470 Ω	(1)
8.	Capacitor 10 nF	(2)
9.	Capacitor 200 μF	(1)
10.	Capacitor 0.33 μF	(1)
11.	Capacitor 0.1 μF	(1)
12.	Capacitor 0.01 μF	(1)
13.	3M Solderless Breadboard	(1)
14.	Active Electronics Keyswitch (Mechanical)	(4)
15.	Red/White Rolls 22 Gauge Wire	(2)
16.	Clear High Grade Speaker 16 Gauge Wire	(1)
17.	Electrical Tape	(1)
18.	Mode Electronics 2-position .100" straight PC Header	(2)
19.	Mode Electronics 2-position wire connectors c/w contacts	(2)
20.	Waldom Electronics 0.93" Connectors	(2)

5.3 Appendix C (Control System Calculations)

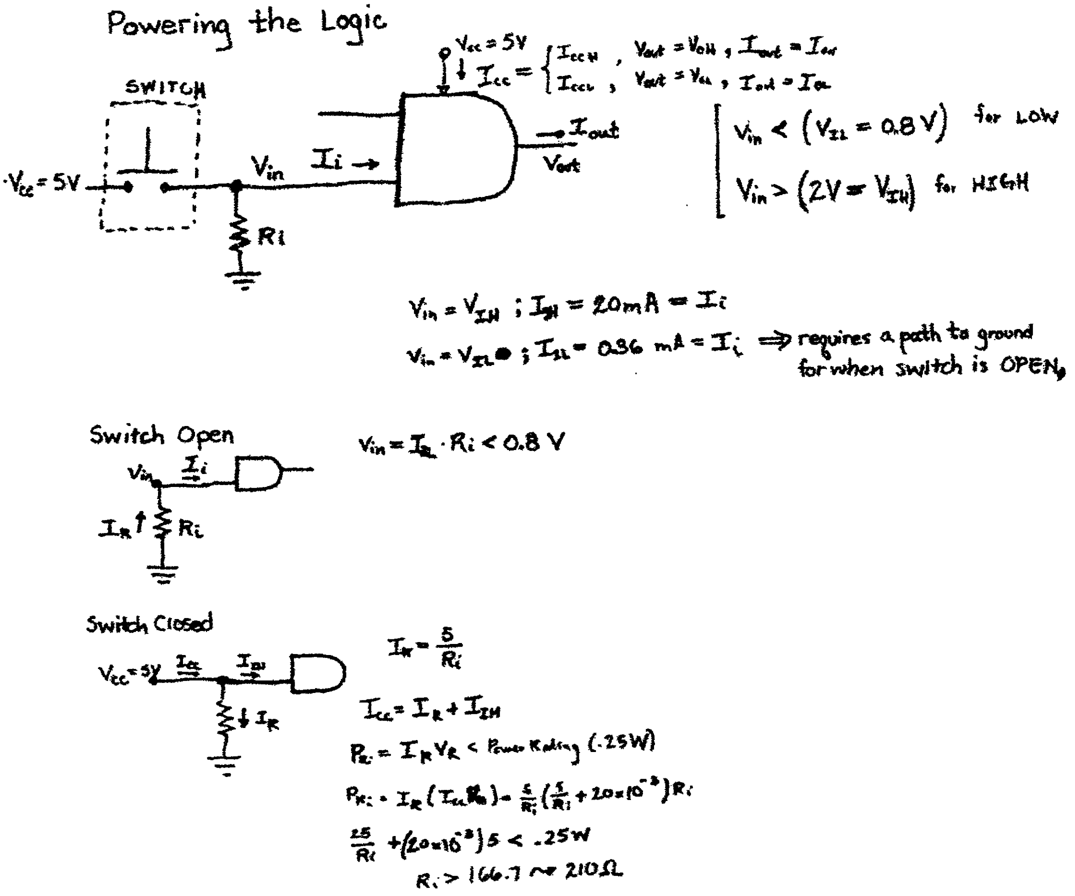


Figure 27: Calculation of required resistance into logic.

5.4 Appendix D (Ford Windshield Wiper Motor Specifications)

The following data is for the Ford Motor used in the prototype. The motor was donated for this project by the staff of Course 2.007, Design for Manufacturing I. The data was obtained from the 2.007 Course Homepage. A part drawing of the Ford motor can be seen in Figure 28 and a Torque vs. speed graph is in Figure 29.

Clockwise:

No Load High Speed @ 13.8 volts (Yellow & White)	81 rpm
Stall Torque (Yellow & White)	7.5 N-m = 66.4 in-lbf
No Load Low Speed @ 13.8 volts (Black & White)	50 rpm
Stall Torque (Black & White)	14 N-m = 123.9 in-lbf

Counter-Clockwise:

No Load High Speed @ 13.8 volts (Yellow & White)	66 rpm
Stall Torque (Yellow & White)	5 N-m = 44.2 in-lbf
No Load Low Speed @ 13.8 volts (Black & White)	No Data
Stall Torque (Black & White)	No Data
Nominal Voltage	13.8 Volts
Overall Length	197 mm = 7.75 in
Overall Height	101 mm = 4.0 in
Shaft Mounting	¼ - 20 x 1.0
Body Diameter	61 mm = 2.4 in
Mounting Holes (3)	¼ - 20 x 1.0
Overall Weight	1417 g = 3.13 lbs

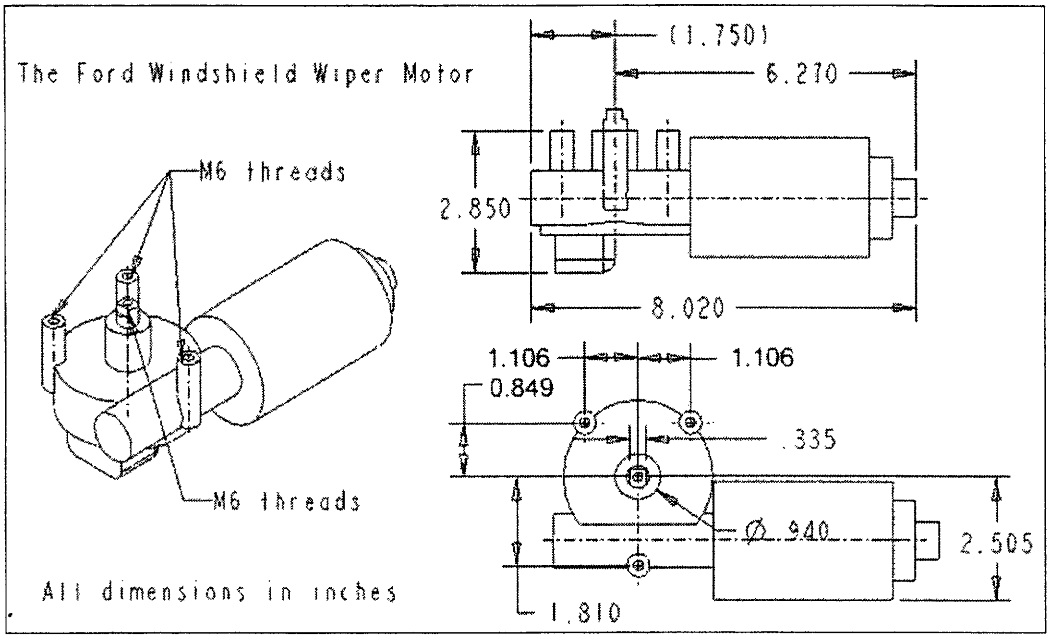


Figure 28: *Ford Motor Part Drawing*

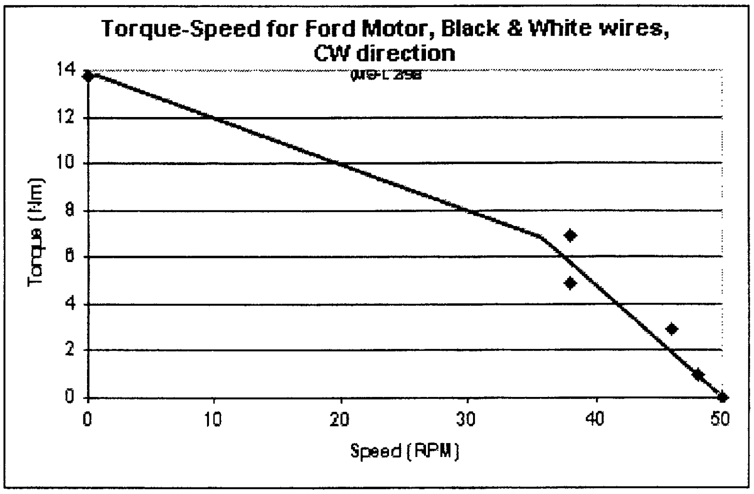
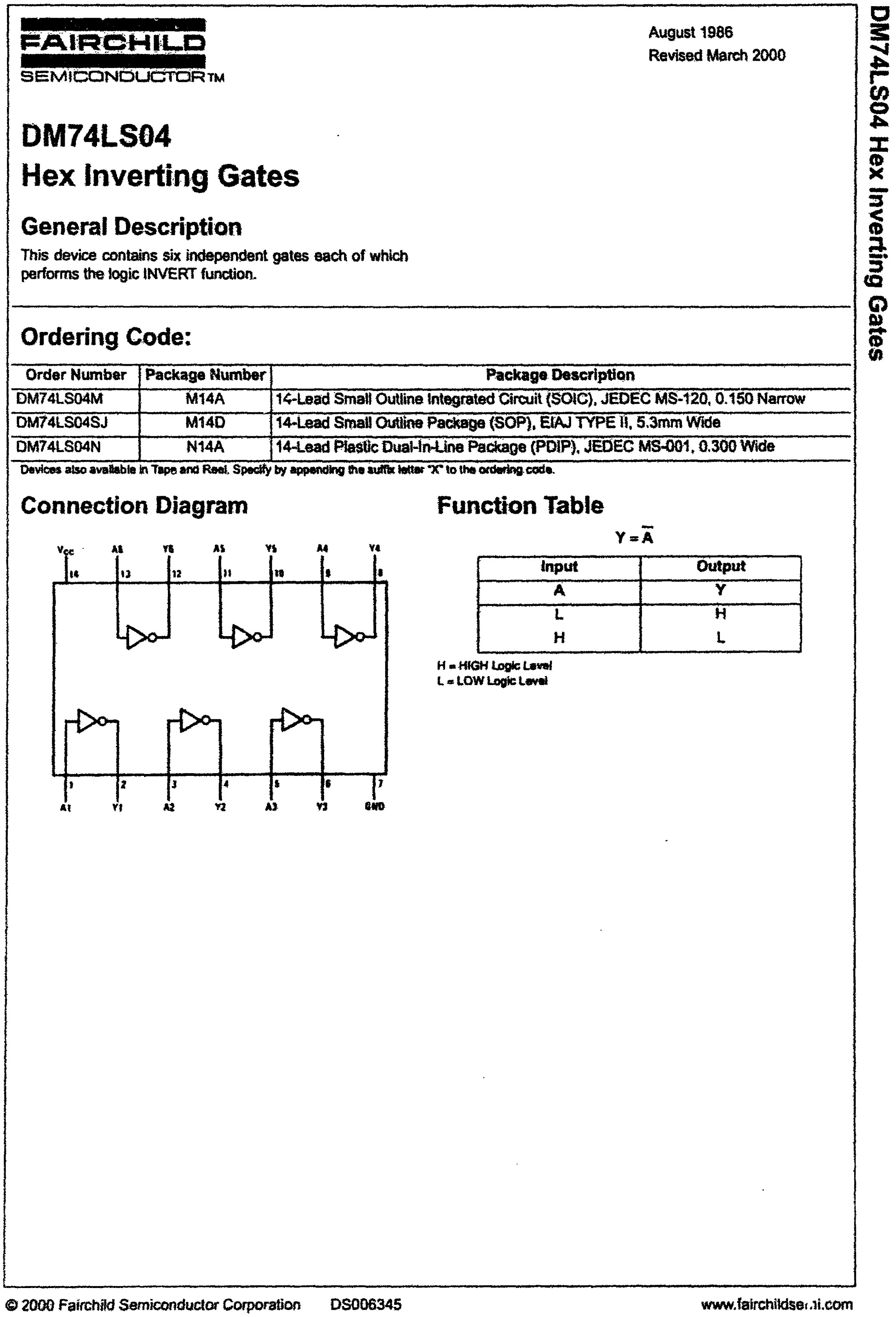


Figure 29: *Ford Motor Torque vs. Speed curve in CW direction*

5.5 Appendix E (Electrical Component Data Sheets)



FAIRCHILD
SEMICONDUCTOR™

August 1986
Revised March 2000

DM74LS04 Hex Inverting Gates

DM74LS04
Hex Inverting Gates

General Description

This device contains six independent gates each of which performs the logic INVERT function.

Ordering Code:

Order Number	Package Number	Package Description
DM74LS04M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow
DM74LS04SJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
DM74LS04N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram

Function Table

$Y = \overline{A}$

Input	Output
A	Y
L	H
H	L

H = HIGH Logic Level
L = LOW Logic Level

DS006345 www.fairchildse.ni.com

Absolute Maximum Ratings(Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−0.4	mA
I_{OL}	LOW Level Output Current			8	mA
T_A	Free Air Operating Temperature	0		70	°C

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA			−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IL} = Max	2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IH} = Min		0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V			0.1	mA
I_{IH}	HIGH Level Input Current	V_{CC} = Max, V_I = 2.7V			20	µA
I_{IL}	LOW Level Input Current	V_{CC} = Max, V_I = 0.4V			−0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	−20		−100	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} = Max		1.2	2.4	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} = Max		3.6	6.6	mA

Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

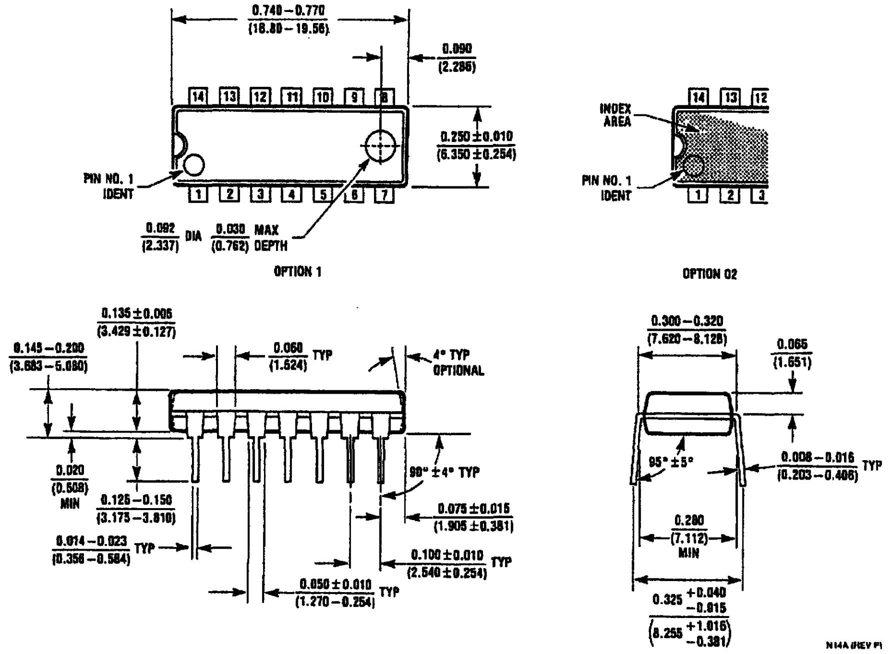
Note 3: *Not more than one output should be shorted at a time, and the duration should not exceed one second.*

Switching Characteristics

at V_{CC} = 5V and T_A = 25°C

Symbol	Parameter	R_L = 2 kΩ				Units
		C_L = 15 pF		C_L = 50 pF		
		Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	3	10	4	15	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	3	10	4	15	ns

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide
Package Number N14A

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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SEMICONDUCTOR™

August 1986
Revised March 2000

DM74LS08
Quad 2-Input AND Gates

General Description

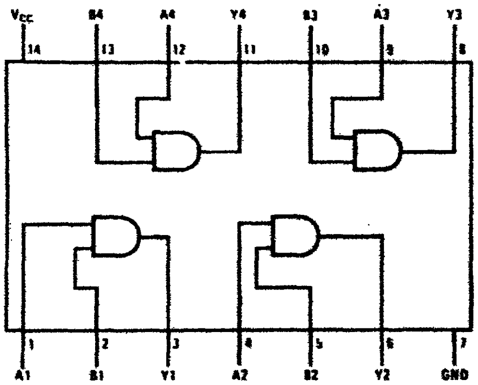
This device contains four independent gates each of which performs the logic AND function.

Ordering Code:

Order Number	Package Number	Package Description
DM74LS08M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow
DM74LS08SJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
DM74LS08N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



Function Table

$Y = AB$

Inputs		Output
A	B	Y
L	L	L
L	H	L
H	L	L
H	H	H

H = HIGH Logic Level
L = LOW Logic Level

Absolute Maximum Ratings(Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−0.4	mA
I_{OL}	LOW Level Output Current			8	mA
T_A	Free Air Operating Temperature	0		70	°C

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA			−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IH} = Min	2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IL} = Max		0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V			0.1	mA
I_{IH}	HIGH Level Input Current	V_{CC} = Max, V_I = 2.7V			20	µA
I_{IL}	LOW Level Input Current	V_{CC} = Max, V_I = 0.4V			−0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	−20		−100	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} = Max		2.4	4.8	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} = Max		4.4	8.8	mA

Switching Characteristics

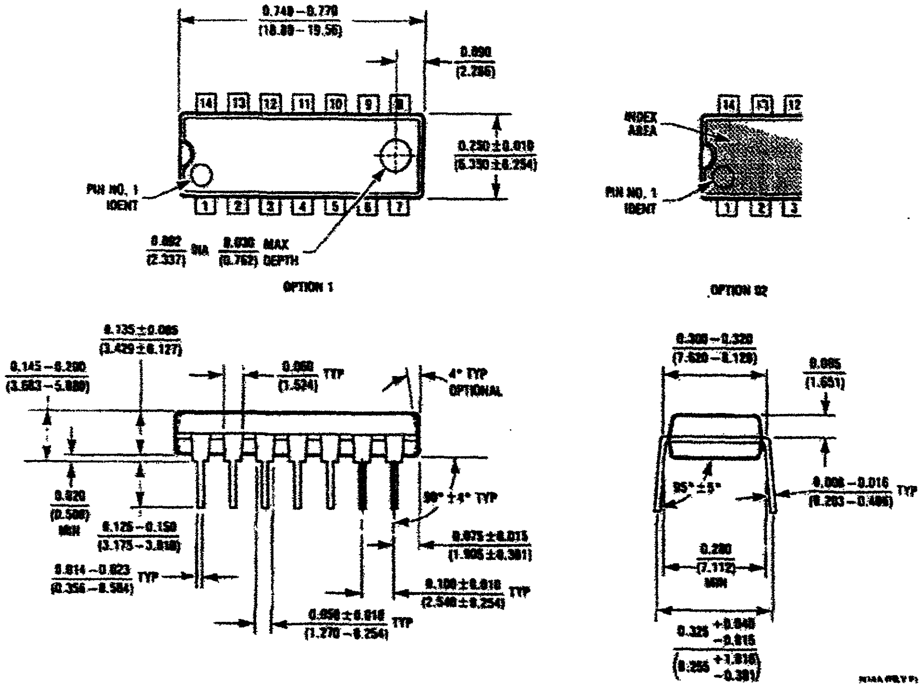
at V_{CC} = 5V and T_A = 25°C

Symbol	Parameter	R_L = 2 kΩ				Units
		C_L = 15 pF		C_L = 50 pF		
		Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	4	13	6	18	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	3	11	5	18	ns

Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 3: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide
Package Number N14A

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FAIRCHILD
SEMICONDUCTOR™

June 1986
Revised March 2000

DM74LS32
Quad 2-Input OR Gate

General Description

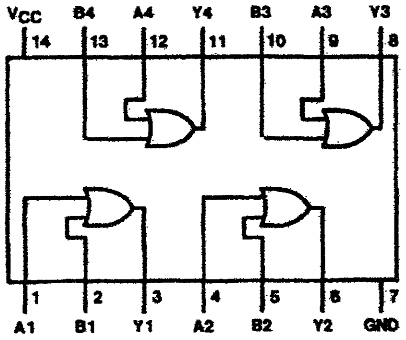
This device contains four independent gatos each of which performs the logic OR function.

Ordering Code:

Order Number	Package Number	Package Description
DM74LS32M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow
DM74LS32SJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
DM74LS32N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



Function Table

$Y = A + B$

Inputs		Output
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	H

H = HIGH Logic Level
L = LOW Logic Level

Absolute Maximum Ratings(Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0□C to □70□C
Storage Temperature Range	□65□C to □150□C

Note 1: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			□0.4	mA
I_{OL}	LOW Level Output Current			8	mA
T_A	Free Air Operating Temperature	0		70	□C

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} □Min, I_I □□18 mA			□1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} □Min, I_{OH} □Max V_{IH} □Min	2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} □Min, I_{OL} □Max V_{IL} □Max		0.35	0.5	V
		I_{OL} □4 mA, V_{CC} □Min		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} □Max, V_I □7V			0.1	mA
I_{IH}	HIGH Level Input Current	V_{CC} □Max, V_I □2.7V			20	□A
I_{IL}	LOW Level Input Current	V_{CC} □Max, V_I □0.4V			□0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} □Max (Note 3)	□20		□100	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} □Max		3.1	6.2	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} □Max		4.9	9.8	mA

Note 2: All typicals are at V_{CC} □5V, T_A □25□C.

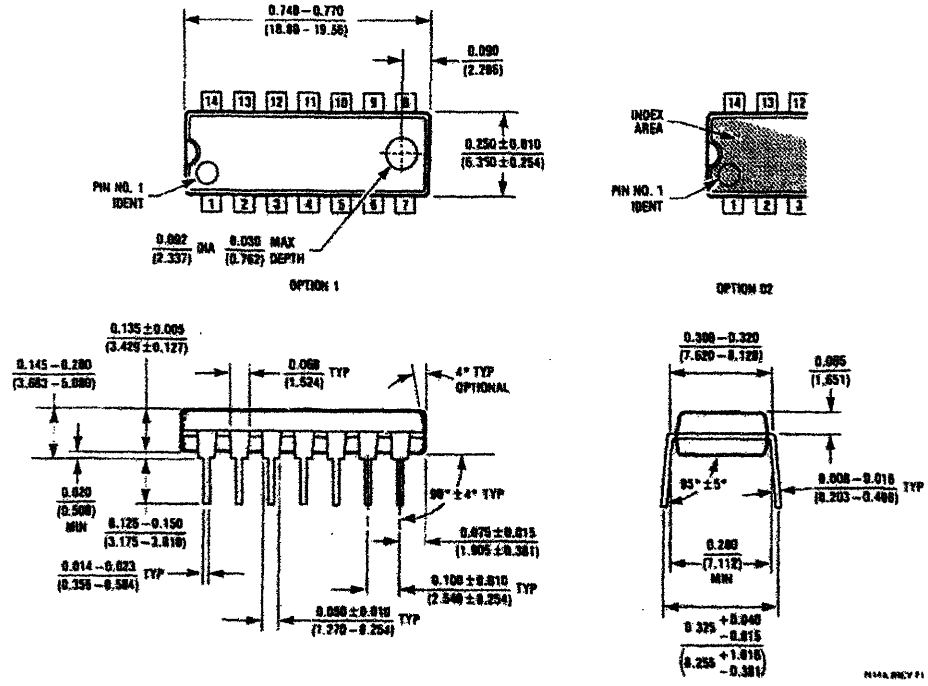
Note 3: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Switching Characteristics

at V_{CC} □5V and T_A □25□C

Symbol	Parameter	R_L □2 k□				Units
		C_L □15 pF		C_L □50 pF		
		Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	3	11	4	15	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	3	11	4	15	ns

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide
Package Number N14A

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MC78LXXA/LM78LXXA

3-terminal 0.1A positive voltage regulator

Features

- Maximum Output Current of 100mA
- Output Voltage of 5V, 6V, 8V, 9V,10V, 12V, 15V, 18V and 24V
- Thermal Overload Protection
- Short Circuit Current Limiting
- Output Voltage Offered in ± 5% Tolerance

Description

The MC78LXXA/LM78LXXA series of fixed voltage monolithic integrated circuit voltage regulators are suitable for application that required supply current up to 100mA.

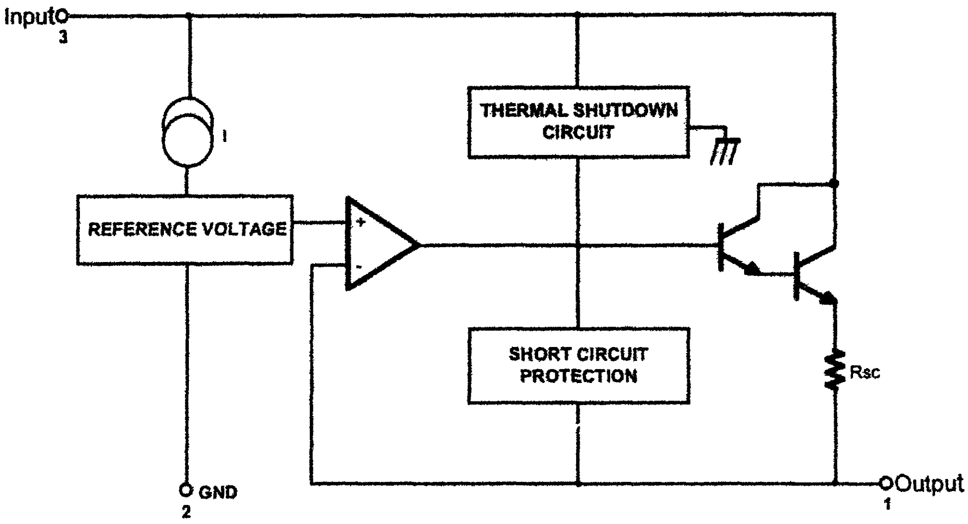
TO-92

1: Output 2: GND 3: Input

8-SOP

1: Output 2: GND 3: GND 4: NC
5: NC 6: GND 7: GND 8: Input

Internal Block Diagram



Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V, 8V) (for V_O = 12V to 18V) (for V_O = 24V	V_I	30 35 40	V V V
Operating Junction Temperature Range	T_J	0 ~ +150	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Electrical Characteristics(MC78L05A/LM78L05A)

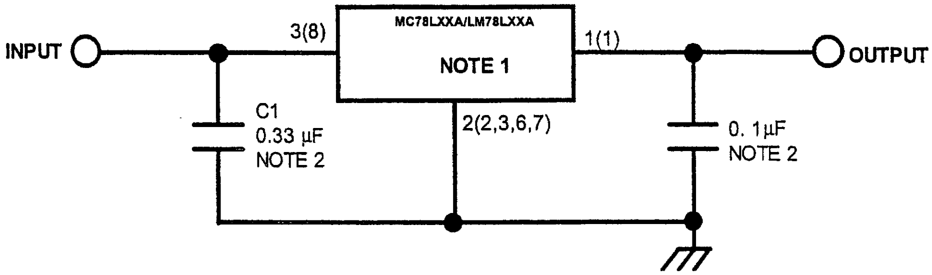
(V_I = 10V, I_O = 40mA, 0 °C ≤ T_J ≤ 125 °C, C_I = 0.33 μF, C_O = 0.1μF, unless otherwise specified. (Note 1)

Parameter		Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage		V_O	T_J = 25 °C		4.8	5.0	5.2	V
Line Regulation		ΔV_O	T_J = 25 °C	7V ≤ V_I ≤ 20V	-	8	150	mV
				8V ≤ V_I ≤ 20V	-	6	100	mV
Load Regulation		ΔV_O	T_J = 25 °C	1mA ≤ I_O ≤ 100mA	-	11	60	mV
				1mA ≤ I_O ≤ 40mA	-	5.0	30	mV
Output Voltage		V_O	7V ≤ V_I ≤ 20V	1mA ≤ I_O ≤ 40mA	-	-	5.25	V
			7V ≤ V_I ≤ V_{MAX} (Note 2)	1mA ≤ I_O ≤ 70mA	4.75	-	5.25	V
Quiescent Current		I_Q	T_J = 25 °C		-	2.0	5.5	mA
Quiescent Current Change	with line	ΔI_Q	8V ≤ V_I ≤ 20V		-	-	1.5	mA
	with load	ΔI_Q	1mA ≤ I_O ≤ 40 mA		-	-	0.1	mA
Output Noise Voltage		V_N	T_A = 25 °C, 10Hz ≤ f ≤ 100KHz		-	40	-	μV
Temperature Coefficient of V_O		$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.65	-	mV/ °C
Ripple Rejection		RR	f = 120Hz, 8V ≤ V_I ≤ 18V, T_J = 25 °C		41	80	-	dB
Dropout Voltage		V_D	T_J = 25 °C		-	1.7	-	V

Notes:

1. The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperature as indicated at the initiation of tests.
2. Power dissipation ≤ 0.75W.

Typical Application



'( )' : 8SOP Type

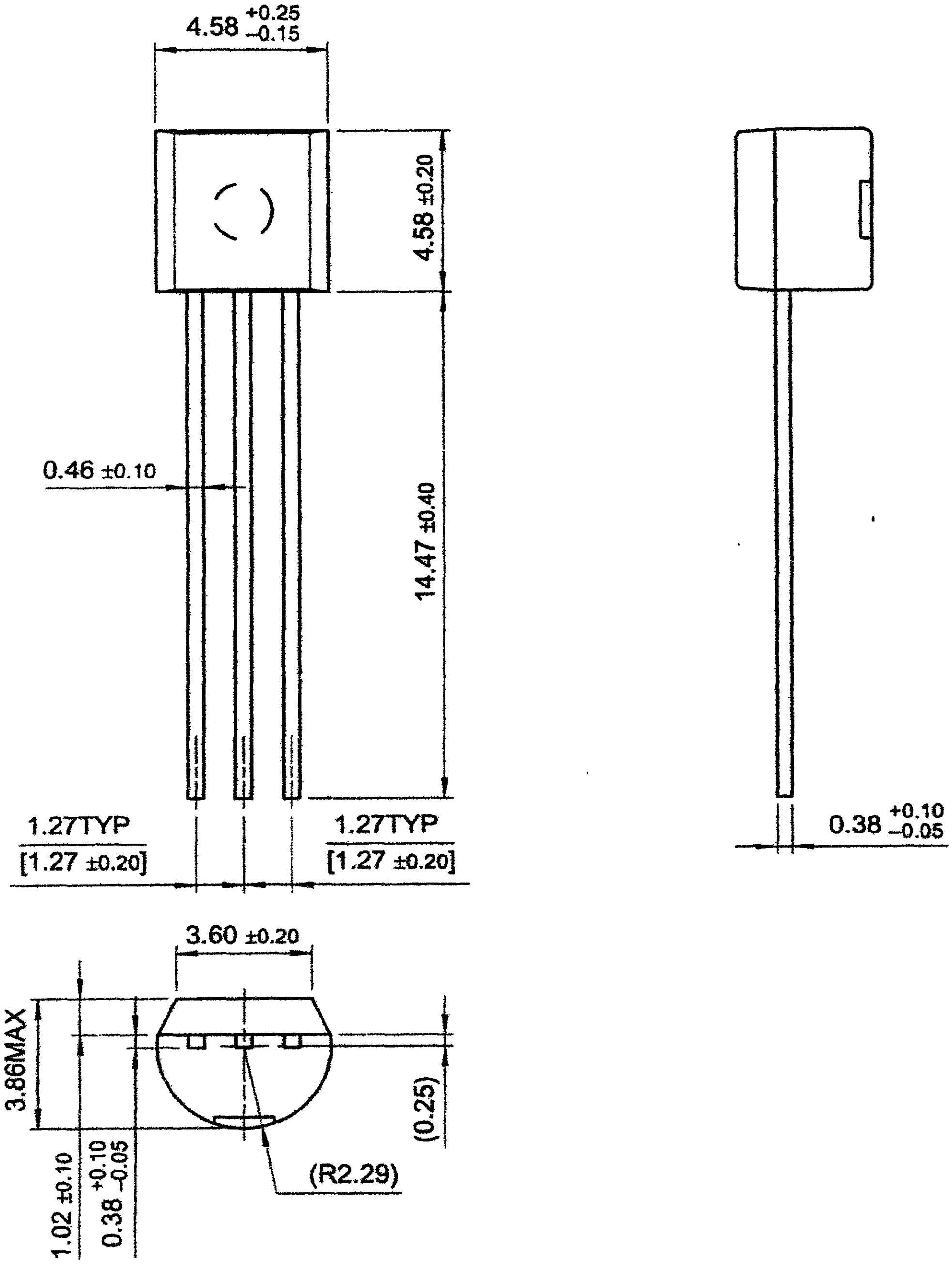
Notes:

1. To specify an output voltage, substitute voltage value for "XX".
2. Bypass Capacitors are recommend for optimum stability and transient response and should be located as close as possible to the regulator

Mechanical Dimensions

Package

TO-92



National Semiconductor

December 1999

LMD18200
3A, 55V H-Bridge

General Description

The LMD18200 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. Ideal for driving DC and stepper motors; the LMD18200 accommodates peak output currents up to 6A. An innovative circuit which facilitates low-loss sensing of the output current has been implemented.

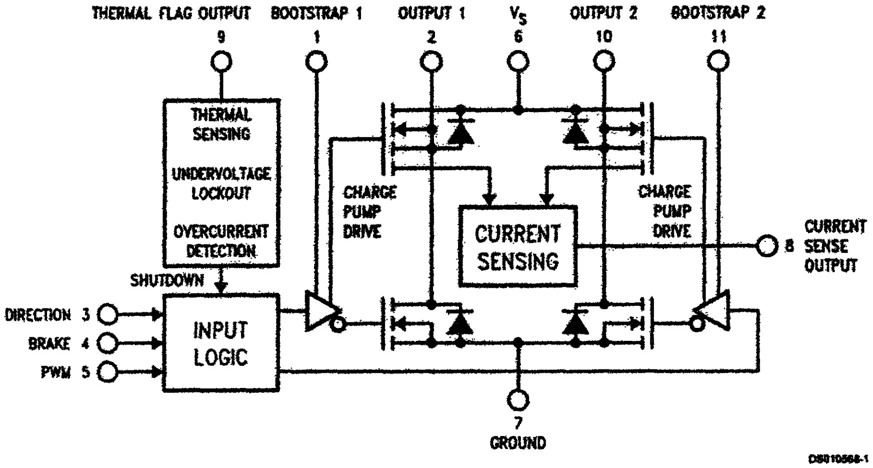
Features

- Delivers up to 3A continuous output
- Operates at supply voltages up to 55V
- Low R_{DS} (ON) typically 0.3Ω per switch
- TTL and CMOS compatible inputs
- No "shoot-through" current
- Thermal warning flag output at 145°C
- Thermal shutdown (outputs off) at 170°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

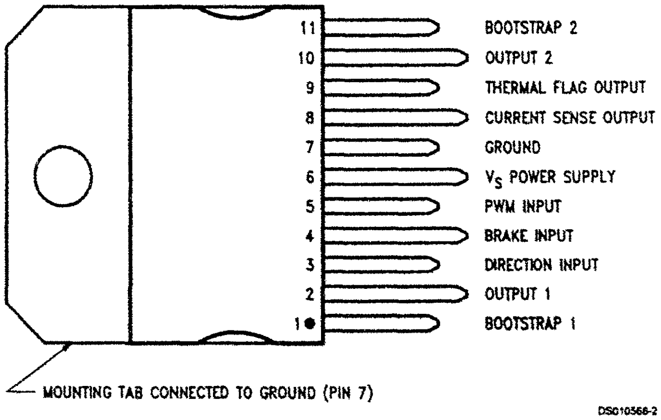
Functional Diagram



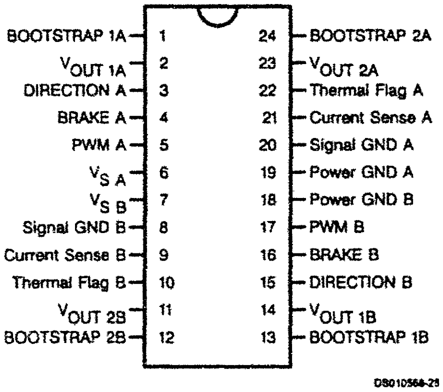
DS010568-1

FIGURE 1. Functional Block Diagram of LMD18200

Connection Diagrams and Ordering Information



11-Lead TO-220 Package
Top View
Order Number LMD18200T
See NS Package TA11B



24-Lead Dual-In-Line Package
Top View
Order Number LMD18200-2D-QV
5962-9232501VXA
LMD18200-2D/883
5962-9232501MXA
See NS Package DA24B

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Total Supply Voltage (V_S, Pin 6)	60V
Voltage at Pins 3, 4, 5, 8 and 9	12V
Voltage at Bootstrap Pins (Pins 1 and 11)	V_{OUT} +16V
Peak Output Current (200 ms)	6A
Continuous Output Current (Note 2)	3A
Power Dissipation (Note 3)	25W
Power Dissipation (T_A = 25°C, Free Air)	3W
Junction Temperature, $T_{J(max)}$	150°C
ESD Susceptibility (Note 4)	1500V
Storage Temperature, T_{STG}	−40°C to +150°C
Lead Temperature (Soldering, 10 sec.)	300°C

Operating Ratings (Note 1)

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

Electrical Characteristics (Note 5)

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

Symbol	Parameter	Conditions	Typ	Limit	Units
R_{DS} (ON)	Switch ON Resistance	Output Current = 3A (Note 6)	0.33	**0.4/0.6**	Ω (max)
R_{DS} (ON)	Switch ON Resistance	Output Current = 6A (Note 6)	0.33	**0.4/0.6**	Ω (max)
V_{CLAMP}	Clamp Diode Forward Drop	Clamp Current = 3A (Note 6)	1.2	**1.5**	V (max)
V_{IL}	Logic Low Input Voltage	Pins 3, 4, 5		**−0.1**	V (min)
				0.8	V (max)
I_{IL}	Logic Low Input Current	V_{IN} = −0.1V, Pins = 3, 4, 5		**−10**	µA (max)
V_{IH}	Logic High Input Voltage	Pins 3, 4, 5		**2**	V (min)
				12	V (max)
I_{IH}	Logic High Input Current	V_{IN} = 12V, Pins = 3, 4, 5		**10**	µA (max)
	Current Sense Output	I_{OUT} = 1A (Note 8)	377	**325/300**	µA (min)
				425/450	µA (max)
	Current Sense Linearity	$1A \le I_{OUT} \le 3A$ (Note 7)	±6	**±9**	%
	Undervoltage Lockout	Outputs turn OFF		**9**	V (min)
				11	V (max)
T_{JW}	Warning Flag Temperature	Pin 9 ≤ 0.8V, I_L = 2 mA	145		°C
V_F(ON)	Flag Output Saturation Voltage	$T_J = T_{JW}$, I_L = 2 mA	0.15		V
I_F(OFF)	Flag Output Leakage	V_F = 12V	0.2	10	µA (max)
T_{JSD}	Shutdown Temperature	Outputs Turn OFF	170		°C
I_S	Quiescent Supply Current	All Logic Inputs Low	13	25	mA (max)
t_{Don}	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_{Doff}	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		µs
t_{cpr}	Charge Pump Rise Time	No Bootstrap Capacitor	20		µs

Electrical Characteristics Notes

Note 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.

Note 2: See Application Information for details regarding current limiting.

Note 3: *The maximum power dissipation must be derated at elevated temperatures and is a function of* $T_{J(max)}$, θ_{JA}, *and* T_A. *The maximum allowable power dissipation at any temperature is* $P_{D(max)} = (T_{J(max)} - T_A)/\theta_{JA}$, or the number given in the Absolute Ratings, whichever is lower. The typical thermal resistance from junction to case (θ_{JC}) is 1.0°C/W and from junction to ambient (θ_{JA}) is 30°C/W. For guaranteed operation $T_{J(max)} = 125°C$.

Note 4: 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.

Note 5: All limits are 100% production tested at 25°C. Temperature extreme limits are guaranteed via correlation using accepted SQC (Statistical Quality Control) methods. All limits are used to calculate AOQL, (Average Outgoing Quality Level).

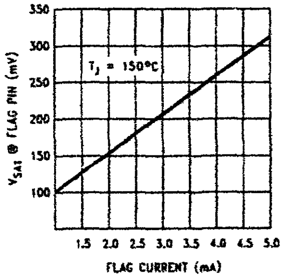
Note 6: Output currents are pulsed (t_W < 2 ms, Duty Cycle < 5%).

Note 7: Regulation is calculated relative to the current sense output value with a 1A load.

Note 8: Selections for tighter tolerance are available. Contact factory.

Typical Performance Characteristics

V_{SAT} vs Flag Current



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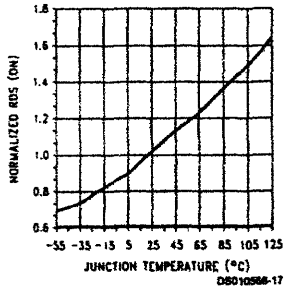
R_{DS} (ON) vs Temperature



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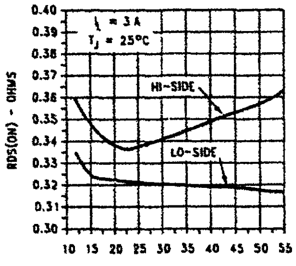
R_{DS} (ON) vs Supply Voltage



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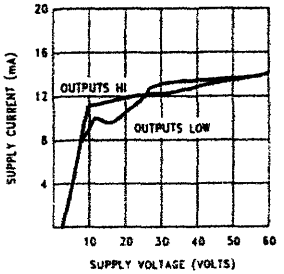
Supply Current vs Supply Voltage



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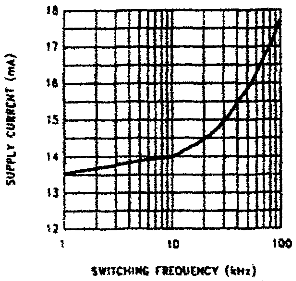
Supply Current vs Frequency (V_S = 42V)



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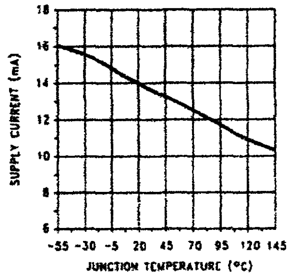
Supply Current vs Temperature (V_S = 42V)



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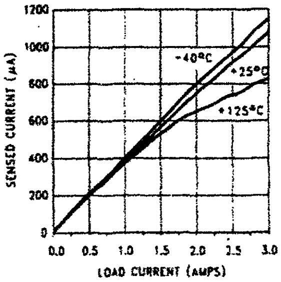
Current Sense Output vs Load Current



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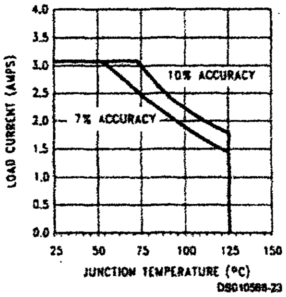
Current Sense Operating Region



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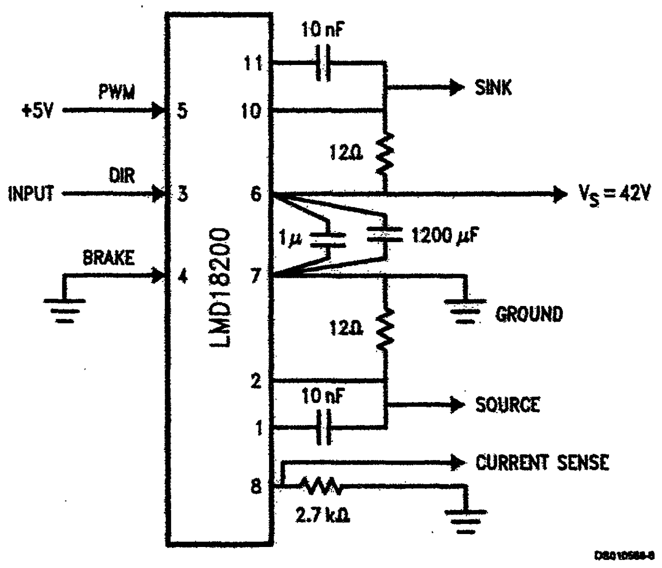
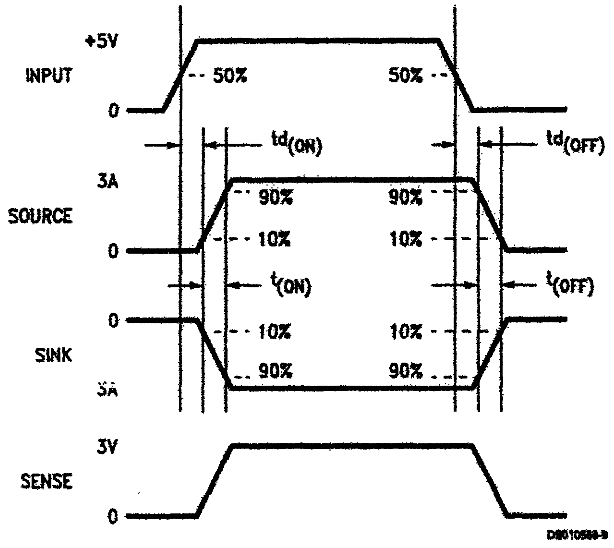
Test Circuit



Switching Time Definitions



Pinout Description (See Connection Diagram)

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 *Table 1*. 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 *Table 1*. 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 *Table 1*. How this input (and DIRECTION input, Pin 3) is used is determined by the format of the PWM Signal.

Pinout Description

(See Connection Diagram) (Continued)

Pin 6, V_S Power Supply

Pin 7, GROUND Connection: This pin is the ground return, and is internally connected to the mounting tab.

Pin 8, CURRENT SENSE Output: This pin provides the sourcing current sensing output signal, which is typically 377 µA/A.

Pin 9, THERMAL FLAG Output: This pin provides the thermal warning flag output signal. Pin 9 becomes active-low at 145°C (junction temperature). However the chip will not shut itself down until 170°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.

TABLE 1. 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 LMD18200 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 2*). 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 LMD18200, the PWM signal drives the direction input (pin 3) and the PWM input (pin 5) is tied to logic high.

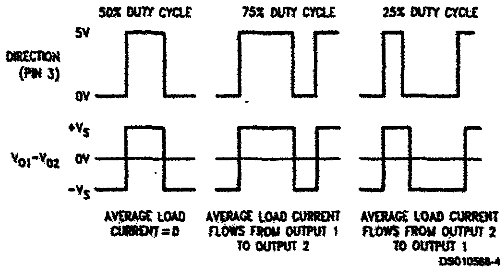


FIGURE 2. Locked Anti-Phase PWM Control

Sign/magnitude PWM consists of separate direction (sign) and amplitude (magnitude) signals (see *Figure 3*). 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 LMD18200, the DIRECTION input (pin 3) is driven by the sign signal and the PWM input (pin 5) is driven by the magnitude signal.

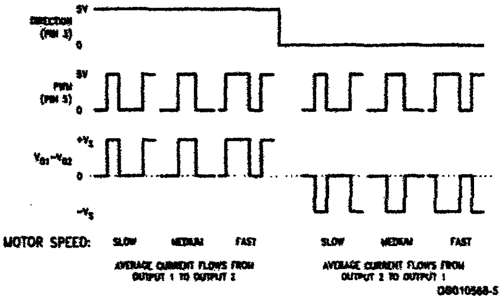


FIGURE 3. Sign/Magnitude PWM Control

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 be sure there is at least 500ns delay between the end of the first transition and the beginning of the second transition. See *Figure 4*.

Application Information (Continued)

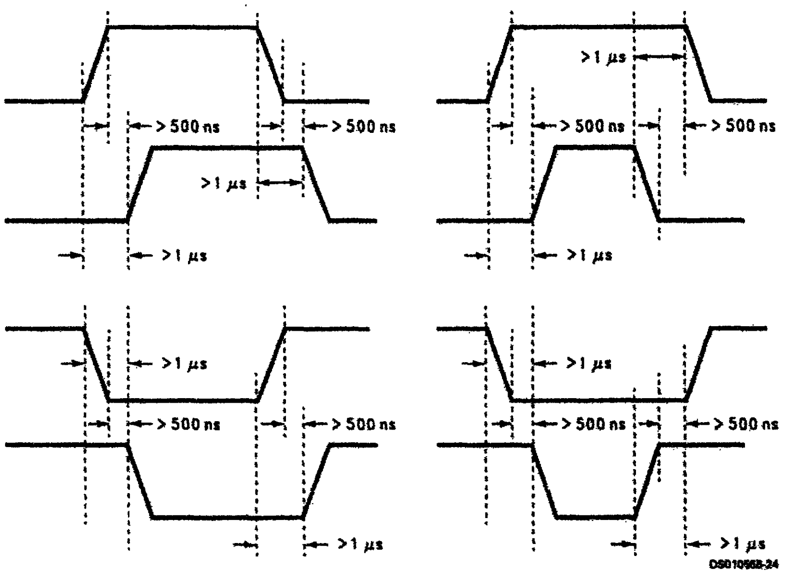


FIGURE 4. Transitions in Brake, Direction, or PWM Must Be Separated By At Least 1 µsec

USING THE CURRENT SENSE OUTPUT

The CURRENT SENSE output (pin 8) has a sensitivity of 377 µA per ampere of output current. For optimal accuracy and linearity of this signal, the value of voltage generating resistor between pin 8 and ground should be chosen to limit the maximum voltage developed at pin 8 to 5V, or less. The maximum voltage compliance is 12V.

It should be noted that the recirculating currents (free wheeling currents) are ignored by the current sense circuitry. Therefore, only the currents in the upper sourcing outputs are sensed.

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 LMD18200'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 inductance.

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 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 LMD18200. 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 this increase in current (the threshold is set to approximately 10 Amps) and shuts off the power device as quickly as possible in the event of an overload condition. 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 LMD18200. 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 in the event that 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 500 Watts 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 PCB.

Application Information (Continued)

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 5*, an internal capacitor is alternately switched to ground and charged to about 14V, then switched to V supply thereby providing a gate drive voltage greater than V supply. This switching action is controlled by a continuously running internal 300 kHz oscillator. The rise time of this drive voltage is typically 20 µs which is suitable for operating frequencies up to 1 kHz.

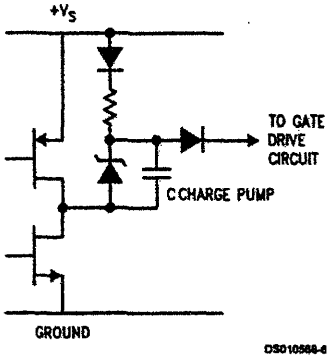


FIGURE 5. Internal Charge Pump Circuitry

For higher switching frequencies, the LMD18200 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 6*. 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.

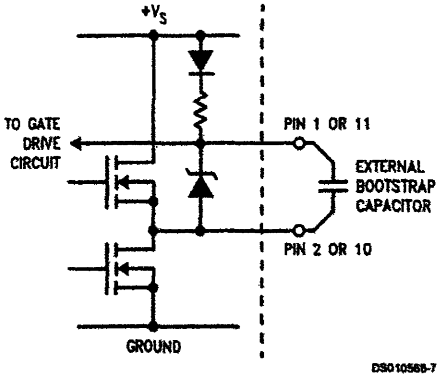


FIGURE 6. Bootstrap Circuitry

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 LMD18200 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 6A 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

FIXED OFF-TIME CONTROL

This circuit controls the current through the motor by applying an average voltage equal to zero to the motor terminals for a fixed period of time, whenever the current through the motor exceeds the commanded current. This action causes the motor current to vary slightly about an externally controlled average level. The duration of the Off-period is adjusted by the resistor and capacitor combination of the LM555. In this circuit the Sign/Magnitude mode of operation is implemented (see Types of PWM Signals).

Typical Applications (Continued)

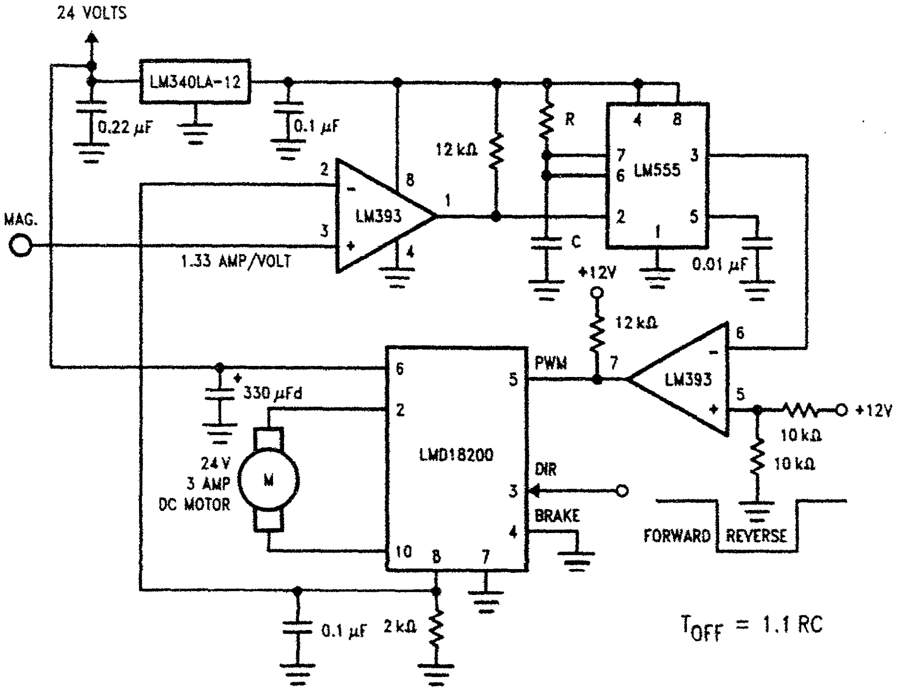


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FIGURE 7. Fixed Off-Time Control

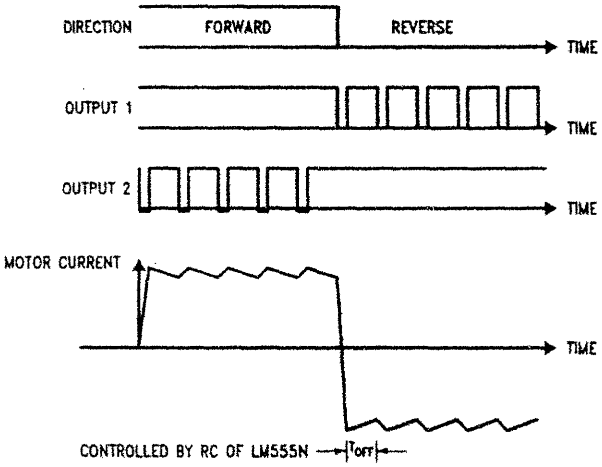

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FIGURE 8. Switching Waveforms

TORQUE REGULATION

Locked Anti-Phase Control of a brushed DC motor. Current sense output of the LMD18200 provides load sensing. The LM3525A is a general purpose PWM controller. The relationship of peak motor current to adjustment voltage is shown in *Figure 10.*

Typical Applications (Continued)

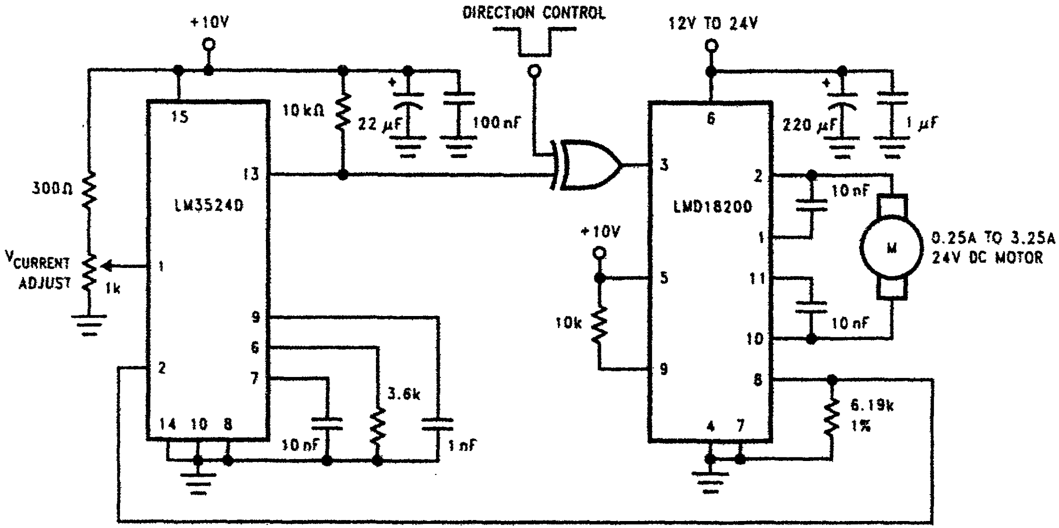

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FIGURE 9. Locked Anti-Phase Control Regulates Torque

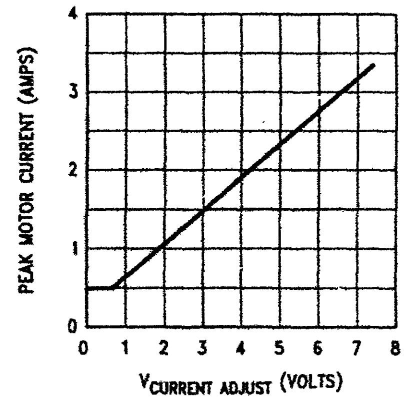

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FIGURE 10. Peak Motor Current vs Adjustment Voltage

VELOCITY REGULATION

Utilizes tachometer output from the motor to sense motor speed for a locked anti-phase control loop. The relationship of motor speed to the speed adjustment control voltage is shown in *Figure 12.*

Typical Applications (Continued)

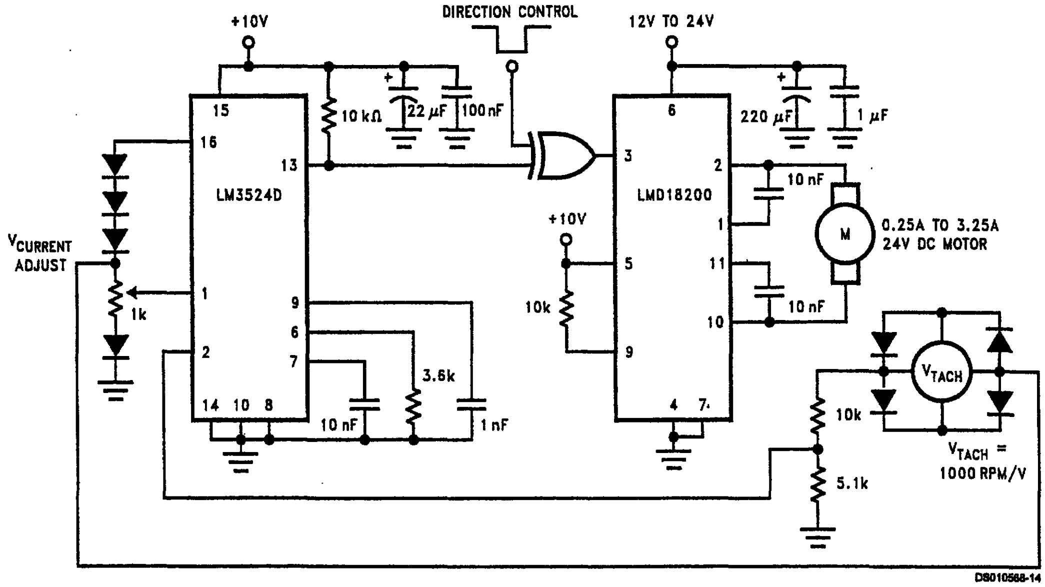


FIGURE 11. Regulate Velocity with Tachometer Feedback

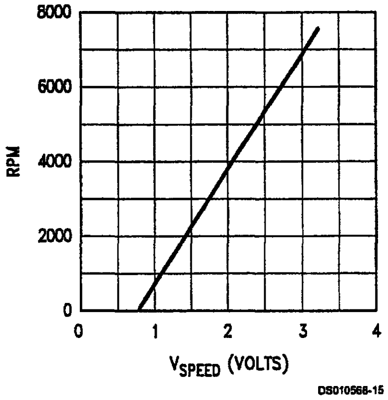
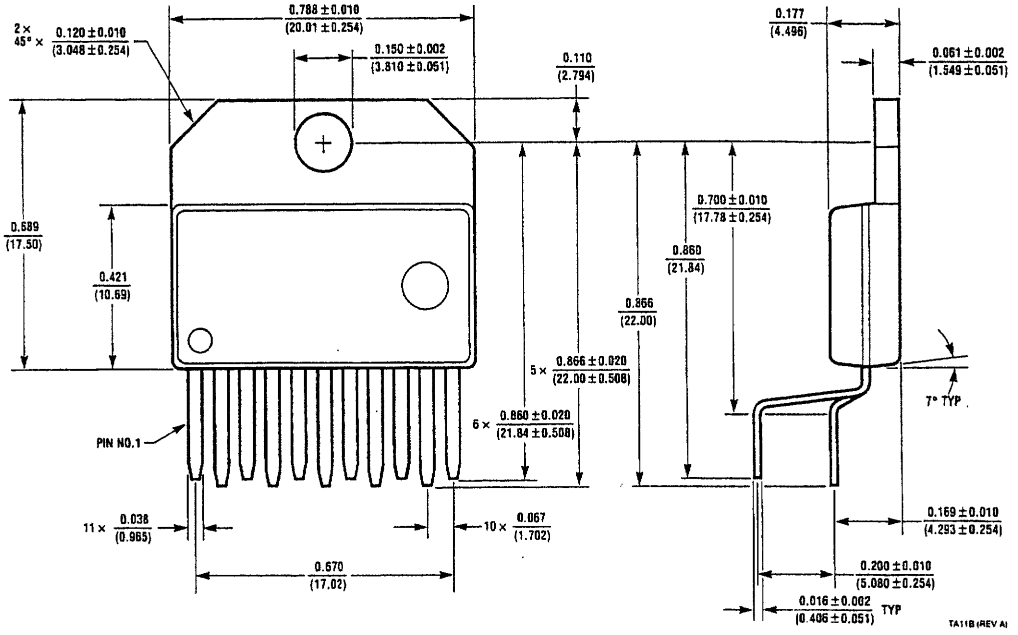


FIGURE 12. Motor Speed vs Control Voltage

Physical Dimensions inches (millimeters) unless otherwise noted



11-Lead TO-220 Power Package (T)
Order Number LMD18200T
NS Package Number TA11B