

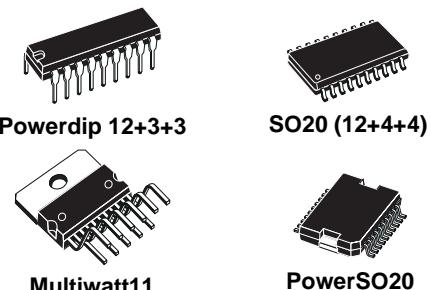
## DMOS FULL BRIDGE DRIVER

- SUPPLY VOLTAGE UP TO 48V
- 5A MAX PEAK CURRENT (2A max. for L6201)
- TOTAL RMS CURRENT UP TO  
L6201: 1A; L6202: 1.5A; L6203/L6201PS: 4A
- $R_{DS(on)}$  0.3  $\Omega$  (typical value at 25 °C)
- CROSS CONDUCTION PROTECTION
- TTL COMPATIBLE DRIVE
- OPERATING FREQUENCY UP TO 100 KHz
- THERMAL SHUTDOWN
- INTERNAL LOGIC SUPPLY
- HIGH EFFICIENCY

### DESCRIPTION

The I.C. is a full bridge driver for motor control applications realized in Multipower-BCD technology which combines isolated DMOS power transistors with CMOS and Bipolar circuits on the same chip. By using mixed technology it has been possible to optimize the logic circuitry and the power stage to achieve the best possible performance. The DMOS output transistors can operate at supply voltages up to 42V and efficiently at high switch-

### MULTIPOWER BCD TECHNOLOGY

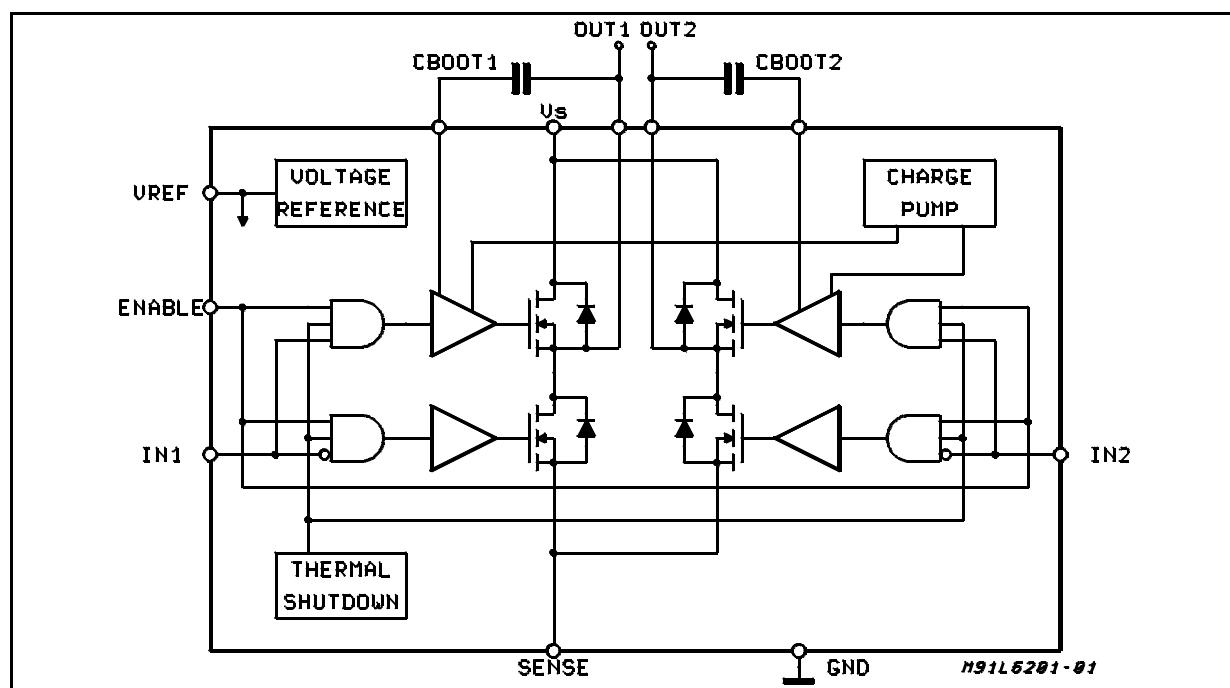


### ORDERING NUMBERS:

L6201 (SO20)  
L6201PS (PowerSO20)  
L6202 (Powerdip18)  
L6203 (Multiwatt)

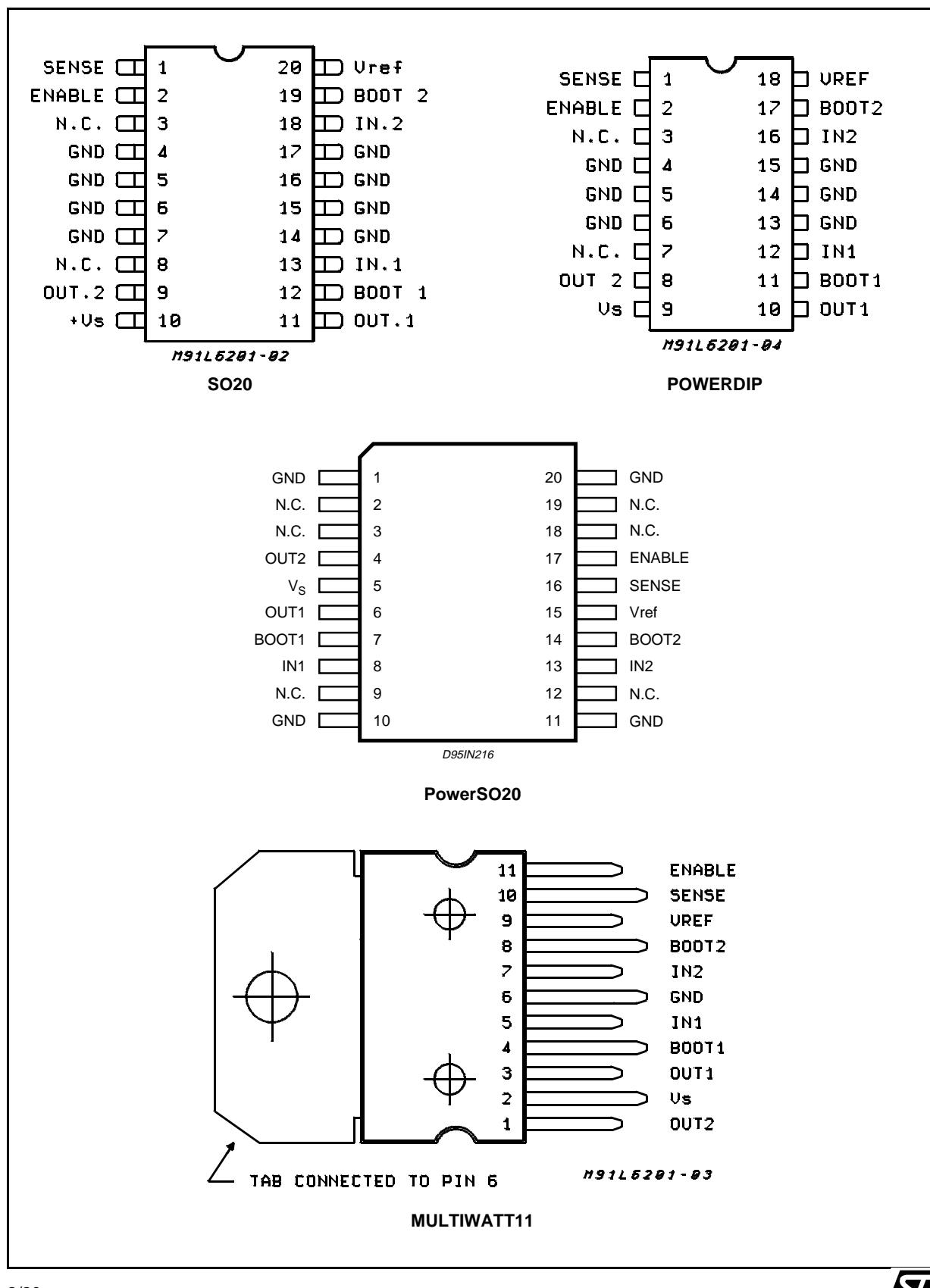
ing speeds. All the logic inputs are TTL, CMOS and  $\mu$ C compatible. Each channel (half-bridge) of the device is controlled by a separate logic input, while a common enable controls both channels. The I.C. is mounted in three different packages.

### BLOCK DIAGRAM



## L6201 - L6202 - L6203

### PIN CONNECTIONS (Top view)



**PINS FUNCTIONS**

Device				Name	Function
L6201	L6201PS	L6202	L6203		
1	16	1	10	SENSE	A resistor $R_{sense}$ connected to this pin provides feedback for motor current control.
2	17	2	11	ENAB LE	When a logic high is present on this pin the DMOS POWER transistors are enabled to be selectively driven by IN1 and IN2.
3	2,3,9,12, 18,19	3		N.C.	Not Connected
4,5	—	4	6	GND	Common Ground Terminal
—	1,10	5		GND	Common Ground Terminal
6,7	—	6		GND	Common Ground Terminal
8	—	7		N.C.	Not Connected
9	4	8	1	OUT2	Output of 2nd Half Bridge
10	5	9	2	$V_s$	Supply Voltage
11	6	10	3	OUT1	Output of first Half Bridge
12	7	11	4	BOOT1	A bootstrap capacitor connected to this pin ensures efficient driving of the upper POWER DMOS transistor.
13	8	12	5	IN1	Digital Input from the Motor Controller
14,15	—	13	6	GND	Common Ground Terminal
—	11,20	14		GND	Common Ground Terminal
16,17	—	15		GND	Common Ground Terminal
18	13	16	7	IN2	Digital Input from the Motor Controller
19	14	17	8	BOOT2	A bootstrap capacitor connected to this pin ensures efficient driving of the upper POWER DMOS transistor.
20	15	18	9	$V_{ref}$	Internal voltage reference. A capacitor from this pin to GND is recommended. The internal Ref. Voltage can source out a current of 2mA max.

**ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Value	Unit
$V_s$	Power Supply	52	V
$V_{OD}$	Differential Output Voltage (between Out1 and Out2)	60	V
$V_{IN}$ , $V_{EN}$	Input or Enable Voltage	– 0.3 to + 7	V
$I_o$	Pulsed Output Current for L6201PS/L6202/L6203 (Note 1) – Non Repetitive (< 1 ms) for L6201 for L6201PS/L6202/L6203 DC Output Current for L6201 (Note 1)	5 5 10 1	A
$V_{sense}$	Sensing Voltage	– 1 to + 4	V
$V_b$	Bootstrap Peak Voltage	60	V
$P_{tot}$	Total Power Dissipation: $T_{pins} = 90^\circ\text{C}$ for L6201 for L6202 $T_{case} = 90^\circ\text{C}$ for L6201PS/L6203 $T_{amb} = 70^\circ\text{C}$ for L6201 (Note 2) for L6202 (Note 2) for L6201PS/L6203 (Note 2)	4 5 20 0.9 1.3 2.3	W
$T_{stg}$ , $T_j$	Storage and Junction Temperature	– 40 to + 150	°C

Note 1: Pulse width limited only by junction temperature and transient thermal impedance (see thermal characteristics)

Note 2: Mounted on board with minimized dissipating copper area.



## L6201 - L6202 - L6203

### THERMAL DATA

Symbol	Parameter	Value				Unit
		L6201	L6201PS	L6202	L6203	
R <sub>th</sub> j-pins	Thermal Resistance Junction-pins	max.	15	—	12	—
R <sub>th</sub> j-case	Thermal Resistance Junction Case	max.	—	—	—	3
R <sub>th</sub> j-amb	Thermal Resistance Junction-ambient	max.	85	13 (*)	60	35

(\*) Mounted on aluminium substrate.

**ELECTRICAL CHARACTERISTICS** (Refer to the Test Circuits; T<sub>j</sub> = 25°C, V<sub>s</sub> = 42V, V<sub>sens</sub> = 0, unless otherwise specified).

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V <sub>s</sub>	Supply Voltage		12	36	48	V
V <sub>ref</sub>	Reference Voltage	I <sub>REF</sub> = 2mA		13.5		V
I <sub>REF</sub>	Output Current			2		mA
I <sub>s</sub>	Quiescent Supply Current	EN = H V <sub>IN</sub> = L EN = H V <sub>IN</sub> = H I <sub>L</sub> = 0 EN = L (Fig. 1,2,3)	10 10 8	15 15 15	mA mA mA	
f <sub>c</sub>	Commutation Frequency (*)		30	100	KHz	
T <sub>j</sub>	Thermal Shutdown		150			°C
T <sub>d</sub>	Dead Time Protection		100			ns

### TRANSISTORS

<b>OFF</b>						
I <sub>DSS</sub>	Leakage Current	Fig. 11 V <sub>s</sub> = 52 V			1	mA
<b>ON</b>						
R <sub>DS</sub>	On Resistance	Fig. 4,5		0.3	0.55	Ω
V <sub>DS(ON)</sub>	Drain Source Voltage	Fig. 9 I <sub>DS</sub> = 1A I <sub>DS</sub> = 1.2A I <sub>DS</sub> = 3A  L6201 L6202 L6201PS/03	3	0.3 0.36 0.9		V V V
V <sub>sens</sub>	Sensing Voltage		-1		4	V

### SOURCE DRAIN DIODE

V <sub>sd</sub>	Forward ON Voltage	Fig. 6a and b I <sub>SD</sub> = 1A L6201 EN = L I <sub>SD</sub> = 1.2A L6202 EN = L I <sub>SD</sub> = 3A L6201PS/03 EN = L		0.9 (**) 0.9 (**) 1.35(**)		V V V
t <sub>rr</sub>	Reverse Recovery Time	$\frac{dI}{dt} = 25 \text{ A}/\mu\text{s}$ I <sub>F</sub> = 1A I <sub>F</sub> = 1.2A I <sub>F</sub> = 3A  L6201 L6202 L6203		300		ns
t <sub>fr</sub>	Forward Recovery Time			200		ns

### LOGIC LEVELS

V <sub>IN L</sub> , V <sub>EN L</sub>	Input Low Voltage		-0.3		0.8	V
V <sub>IN H</sub> , V <sub>EN H</sub>	Input High Voltage		2		7	V
I <sub>IN L</sub> , I <sub>EN L</sub>	Input Low Current	V <sub>IN</sub> , V <sub>EN</sub> = L			-10	μA
I <sub>IN H</sub> , I <sub>EN H</sub>	Input High Current	V <sub>IN</sub> , V <sub>EN</sub> = H		30		μA

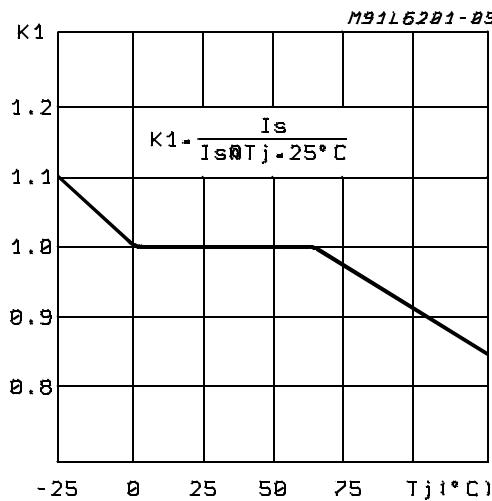
**ELECTRICAL CHARACTERISTICS (Continued)**  
LOGIC CONTROL TO POWER DRIVE TIMING

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$t_1 (V_i)$	Source Current Turn-off Delay	Fig. 12		300		ns
$t_2 (V_i)$	Source Current Fall Time	Fig. 12		200		ns
$t_3 (V_i)$	Source Current Turn-on Delay	Fig. 12		400		ns
$t_4 (V_i)$	Source Current Rise Time	Fig. 12		200		ns
$t_5 (V_i)$	Sink Current Turn-off Delay	Fig. 13		300		ns
$t_6 (V_i)$	Sink Current Fall Time	Fig. 13		200		ns
$t_7 (V_i)$	Sink Current Turn-on Delay	Fig. 13		400		ns
$t_8 (V_i)$	Sink Current Rise Time	Fig. 13		200		ns

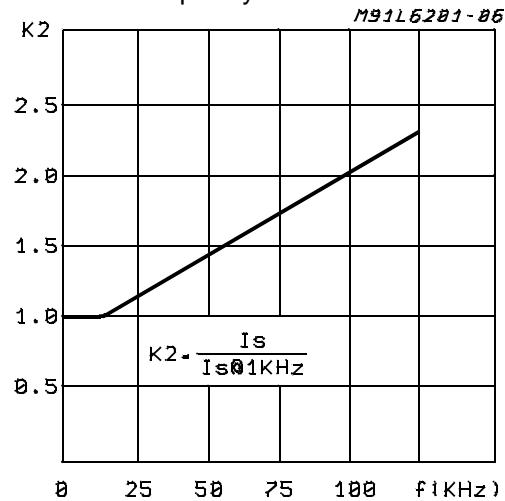
(\*) Limited by power dissipation

(\*\*) In synchronous rectification the drain-source voltage drop VDS is shown in fig. 4 (L6202/03); typical value for the L6201 is of 0.3V.

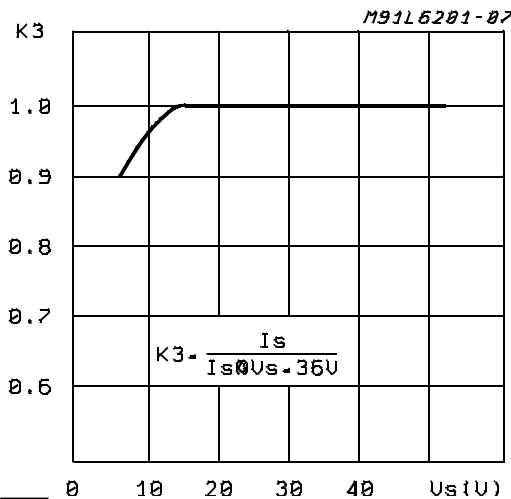
**Figure 1:** Typical Normalized  $I_S$  vs.  $T_j$



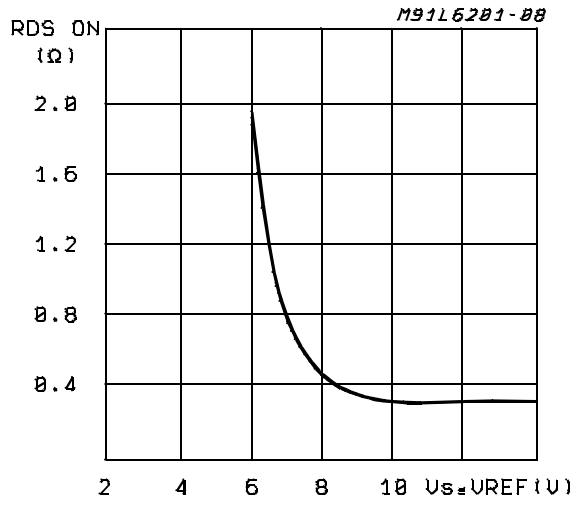
**Figure 2:** Typical Normalized Quiescent Current vs. Frequency



**Figure 3:** Typical Normalized  $I_S$  vs.  $V_S$

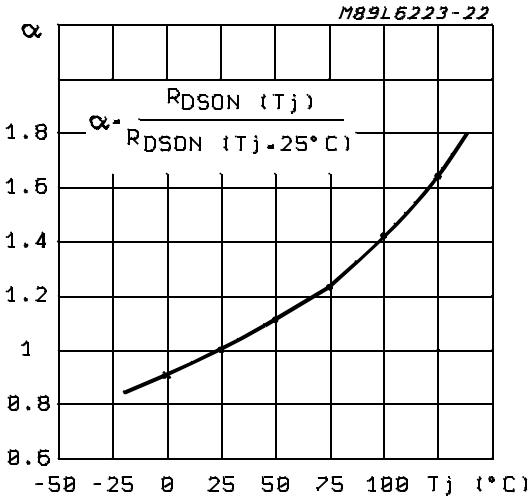


**Figure 4:** Typical  $R_{DS(on)}$  vs.  $V_S - V_{ref}$

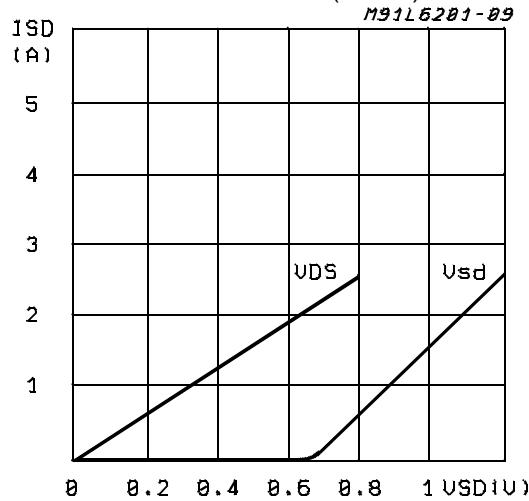


## L6201 - L6202 - L6203

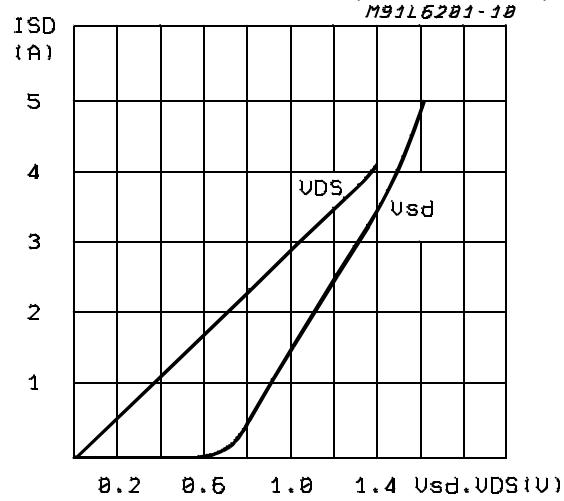
**Figure 5:** Normalized  $R_{DS(ON)}$  at 25°C vs. Temperature Typical Values



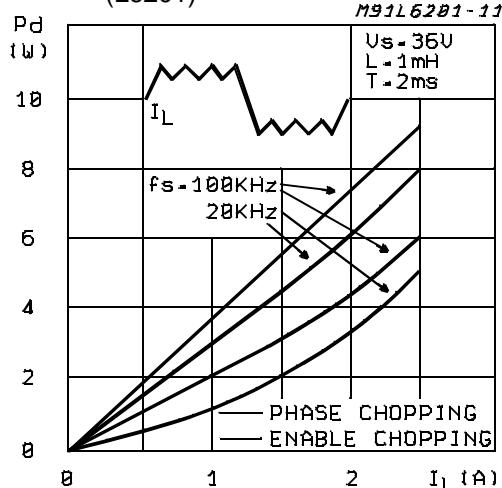
**Figure 6a:** Typical Diode Behaviour in Synchronous Rectification (L6201)



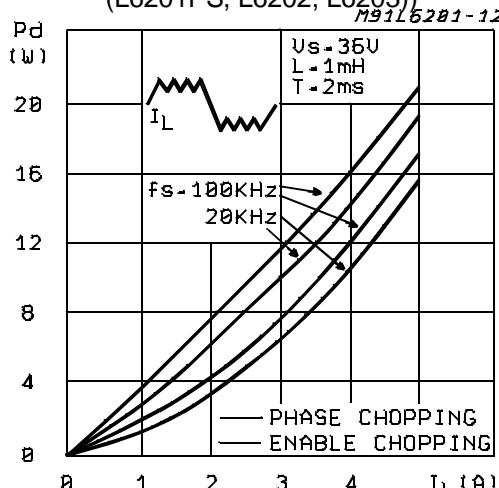
**Figure 6b:** Typical Diode Behaviour in Synchronous Rectification (L6201PS/02/03)



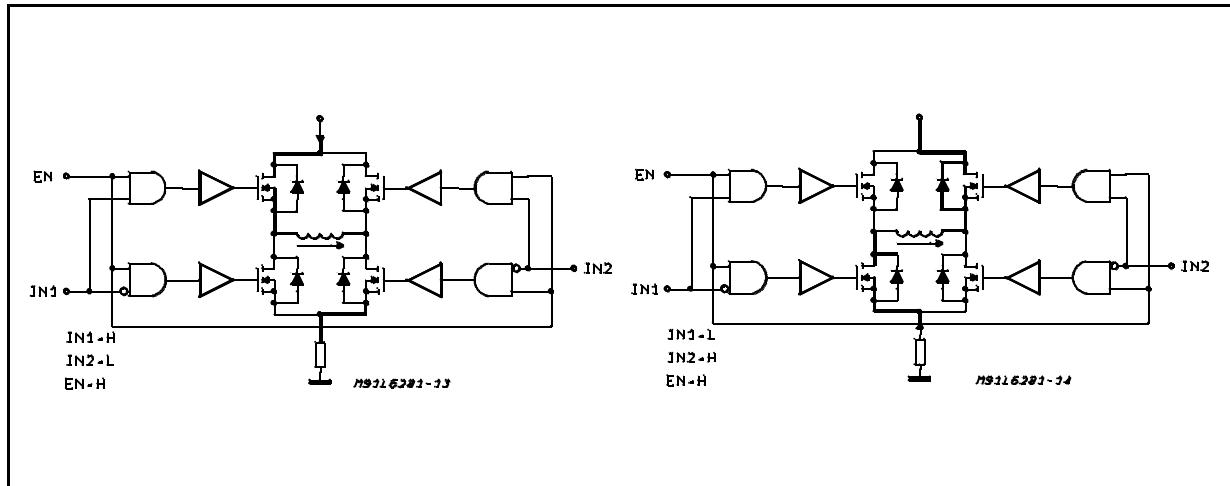
**Figure 7a:** Typical Power Dissipation vs  $I_L$  (L6201)



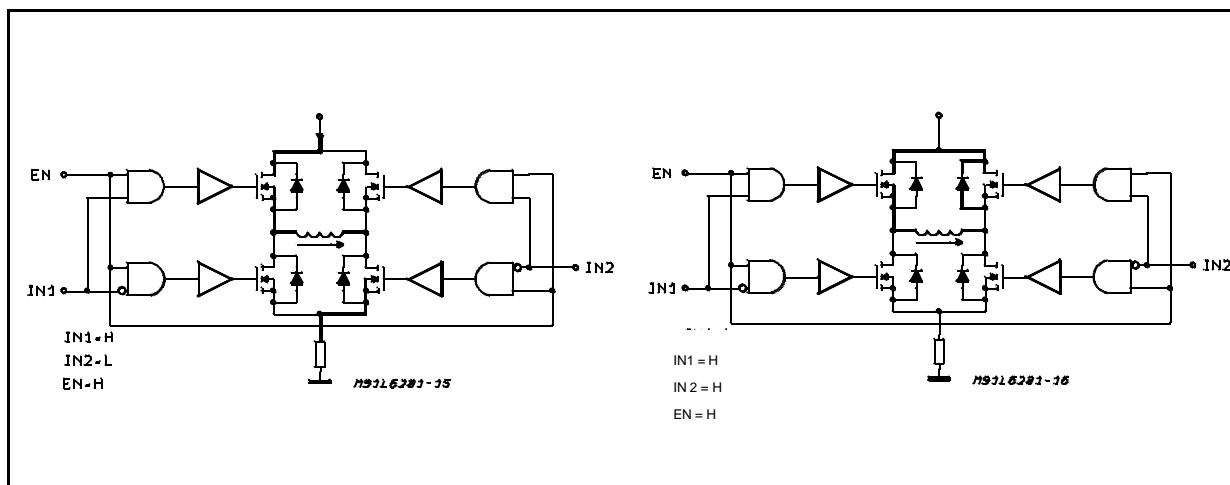
**Figure 7b:** Typical Power Dissipation vs  $I_L$  (L6201PS, L6202, L6203)



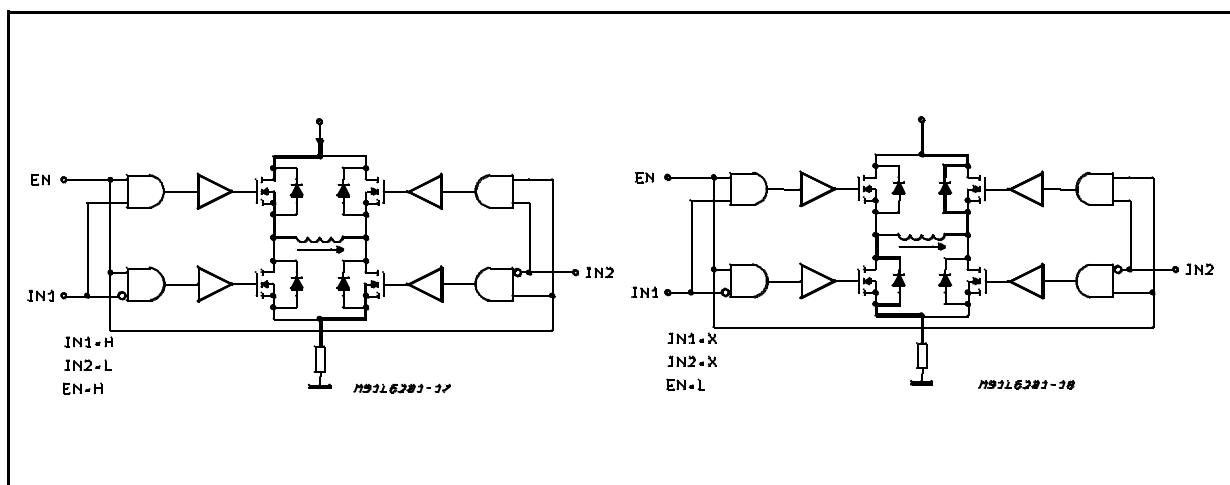
**Figure 8a:** Two Phase Chopping



**Figure 8b:** One Phase Chopping



**Figure 8c:** Enable Chopping



## L6201 - L6202 - L6203

### TEST CIRCUITS

Figure 9: Saturation Voltage

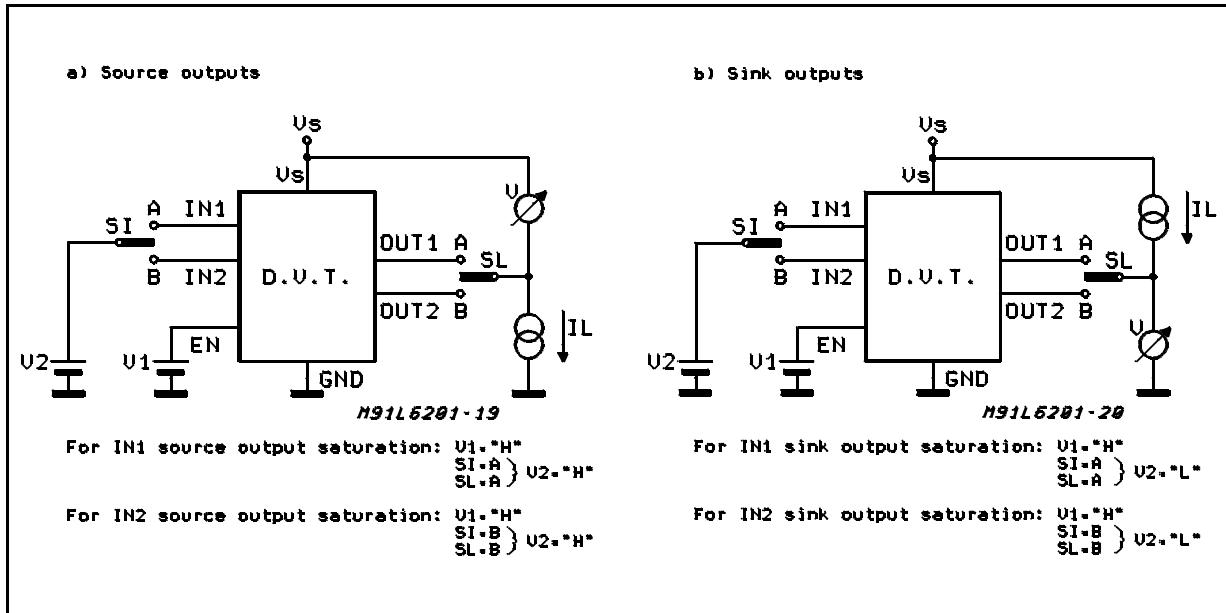


Figure 10: Quiescent Current

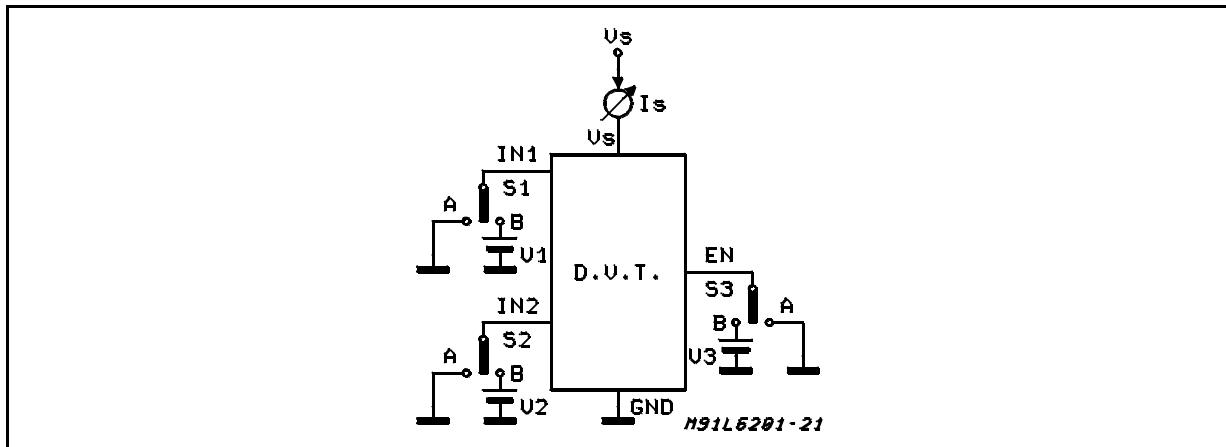


Figure 11: Leakage Current

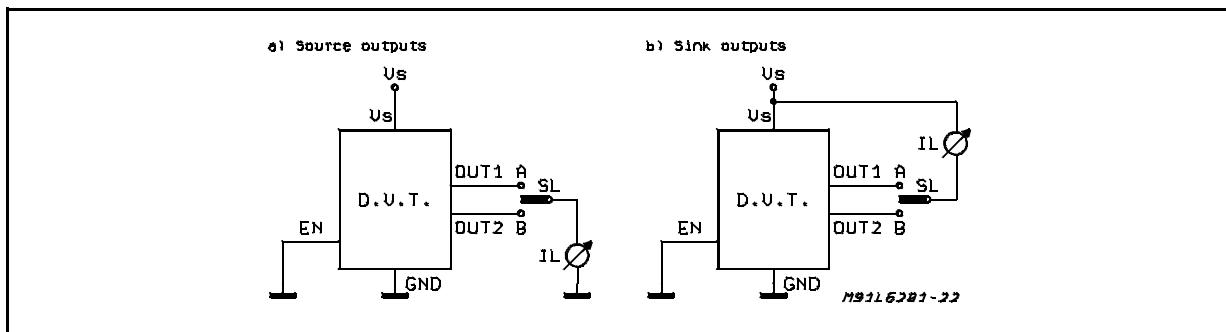


Figure 12: Source Current Delay Times vs. Input Chopper

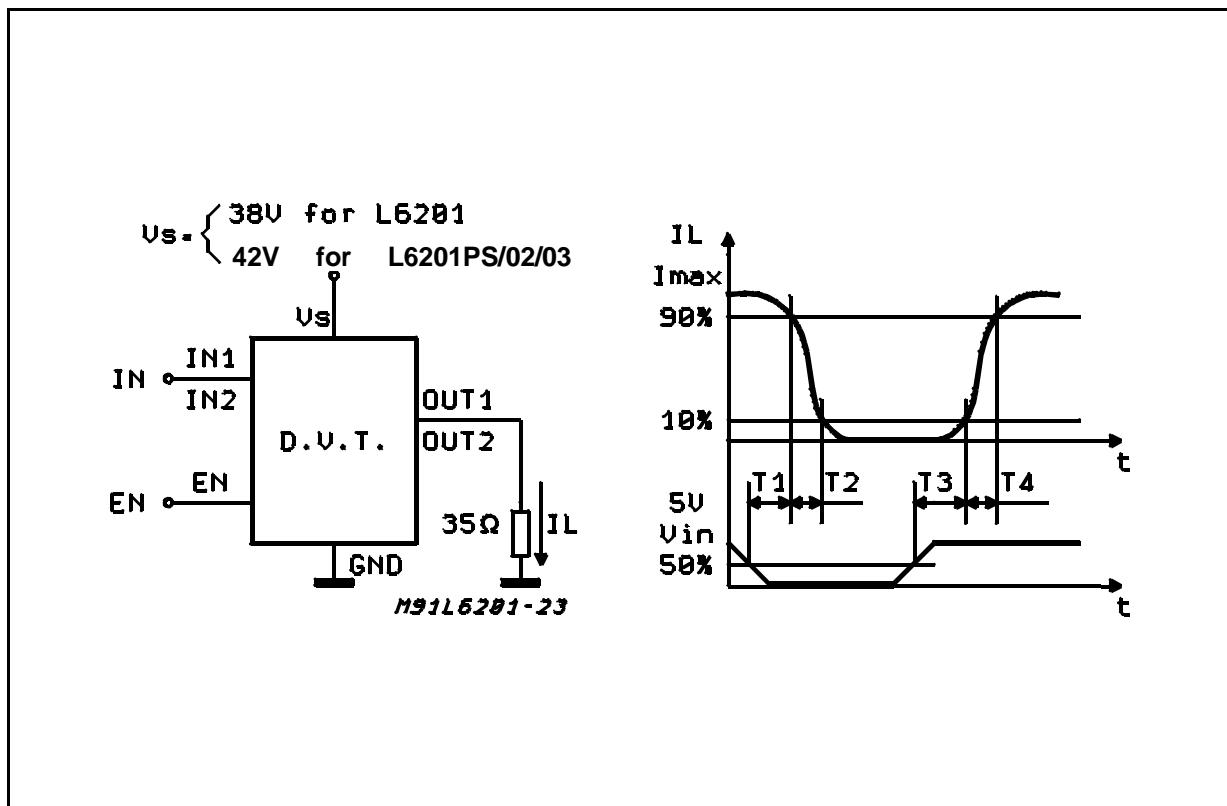
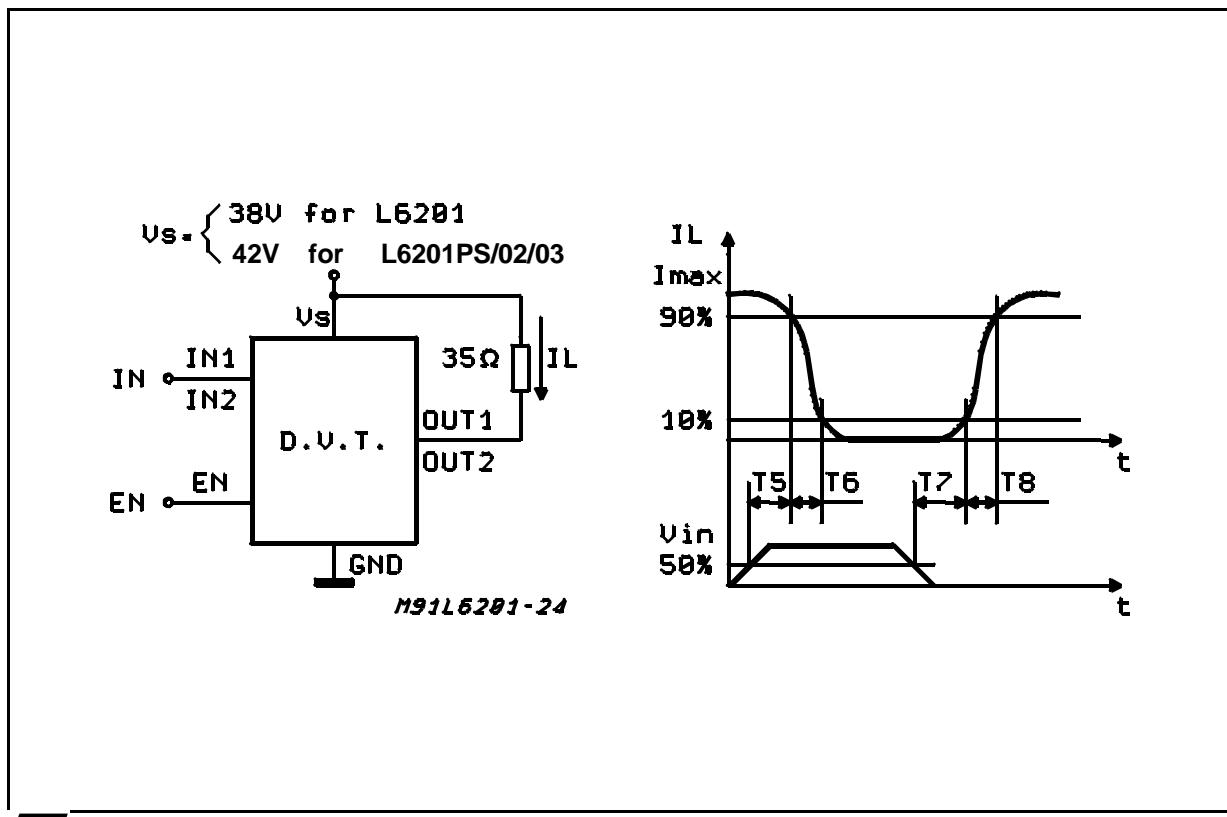


Figure 13: Sink Current Delay Times vs. Input Chopper



### CIRCUIT DESCRIPTION

The L6201/1PS/2/3 is a monolithic full bridge switching motor driver realized in the new Multipower-BCD technology which allows the integration of multiple, isolated DMOS power transistors plus mixed CMOS/bipolar control circuits. In this way it has been possible to make all the control inputs TTL, CMOS and  $\mu$ C compatible and eliminate the necessity of external MOS drive components. The Logic Drive is shown in table 1.

Table 1

Inputs		Output Mosfets (*)
	IN1 IN2	
$V_{EN} = H$	L L	Sink 1, Sink 2
	L H	Sink 1, Source 2
	H L	Source 1, Sink 2
	H H	Source 1, Source 2
$V_{EN} = L$	X X	All transistors turned off

L = Low      H = High      X = DON'T care

(\*) Numbers referred to INPUT1 or INPUT2 controlled output stages

Although the device guarantees the absence of cross-conduction, the presence of the intrinsic diodes in the POWER DMOS structure causes the generation of current spikes on the sensing terminals. This is due to charge-discharge phenomena in the capacitors C1 & C2 associated with the drain source junctions (fig. 14). When the output switches from high to low, a current spike is generated associated with the capacitor C1. On the low-to-high transition a spike of the same polarity is generated by C2, preceded by a spike of the opposite polarity due to the charging of the input capacity of the lower POWER DMOS transistor (fig. 15).

Figure 14: Intrinsic Structures in the POWER DMOS Transistors

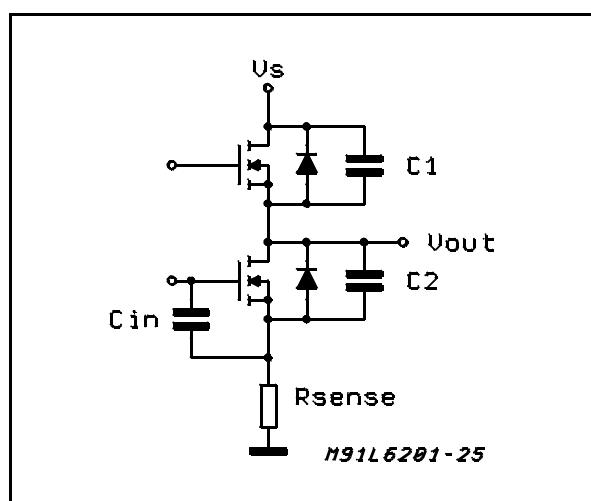
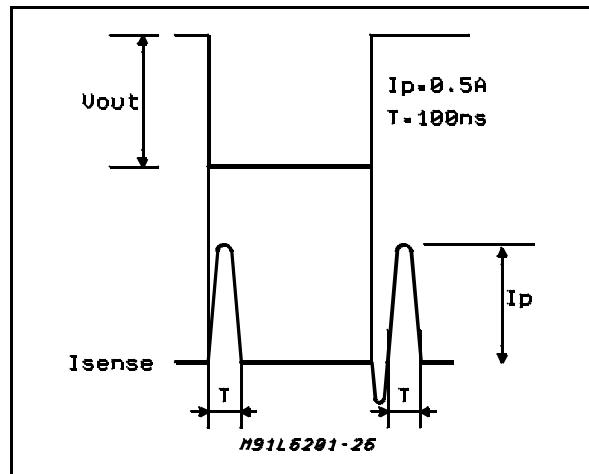


Figure 15: Current Typical Spikes on the Sensing Pin



### TRANSISTOR OPERATION

#### ON State

When one of the POWER DMOS transistor is ON it can be considered as a resistor  $R_{DS(ON)}$  throughout the recommended operating range. In this condition the dissipated power is given by :

$$P_{ON} = R_{DS(ON)} \cdot I_{DS}^2 (\text{RMS})$$

The low  $R_{DS(ON)}$  of the Multipower-BCD process can provide high currents with low power dissipation.

#### OFF State

When one of the POWER DMOS transistor is OFF the  $V_{DS}$  voltage is equal to the supply voltage and only the leakage current  $I_{DS(on)}$  flows. The power dissipation during this period is given by :

$$P_{OFF} = V_s \cdot I_{DS(on)}$$

The power dissipation is very low and is negligible in comparison to that dissipated in the ON STATE.

#### Transitions

As already seen above the transistors have an intrinsic diode between their source and drain that can operate as a fast freewheeling diode in switched mode applications. During recirculation with the ENABLE input high, the voltage drop across the transistor is  $R_{DS(ON)} \cdot I_D$  and when it reaches the diode forward voltage it is clamped. When the ENABLE input is low, the POWER MOS is OFF and the diode carries all of the recirculation current. The power dissipated in the transitional times in the cycle depends upon the voltage-current waveforms and in the driving mode. (see Fig. 7ab and Fig. 8abc).

$$P_{trans.} = I_{DS}(t) \cdot V_{DS}(t)$$



## Bootstrap Capacitors

To ensure that the POWER DMOS transistors are driven correctly gate to source voltage of typ. 10 V must be guaranteed for all of the N-channel DMOS transistors. This is easy to be provided for the lower POWER DMOS transistors as their sources are referred to ground but a gate voltage greater than the supply voltage is necessary to drive the upper transistors. This is achieved by an internal charge pump circuit that guarantees correct DC drive in combination with the bootstrap circuit. For efficient charging the value of the bootstrap capacitor should be greater than the input capacitance of the power transistor which is around 1 nF. It is recommended that a capacitance of at least 10 nF is used for the bootstrap. If a smaller capacitor is used there is a risk that the POWER transistors will not be fully turned on and they will show a higher RDS (ON). On the other hand if an elevated value is used it is possible that a current spike may be produced in the sense resistor.

## Reference Voltage

To bypass the internal Ref. Volt. circuit it is recommended that a capacitor be placed between its pin and ground. A value of 0.22  $\mu$ F should be sufficient for most applications. This pin is also protected against a short circuit to ground: a max. current of 2mA max. can be sunked out.

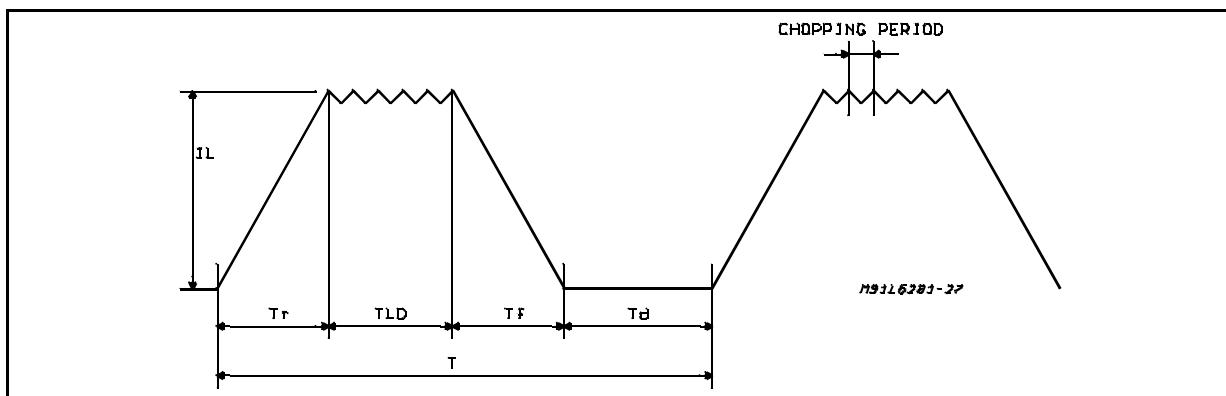
## Dead Time

To protect the device against simultaneous conduction in both arms of the bridge resulting in a rail to rail short circuit, the integrated logic control provides a dead time greater than 40 ns.

## Thermal Protection

A thermal protection circuit has been included that will disable the device if the junction temperature reaches 150 °C. When the temperature has fallen to a safe level the device restarts the input and enable signals under control.

**Figure 16.**



## L6201 - L6202 - L6203

### Quiescent Energy

The last contribution to the energy dissipation is due to the quiescent supply current and is given by:

$$\text{EQUIESCENT} = I_{\text{QUIESCENT}} \cdot V_s \cdot T$$

### Total Energy Per Cycle

$$\begin{aligned} E_{\text{TOT}} = & E_{\text{OFF/ON}} + E_{\text{LD}} + E_{\text{COM}} + \\ & + E_{\text{ON/OFF}} + \text{EQUIESCENT} \end{aligned}$$

The Total Power Dissipation  $P_{\text{DIS}}$  is simply :

$$P_{\text{DIS}} = E_{\text{TOT}} / T$$

$T_r$  = Rise time

$T_{\text{LD}}$  = Load drive time

$T_f$  = Fall time

$T_d$  = Dead time

$T$  = Period

$$T = T_r + T_{\text{LD}} + T_f + T_d$$

motor.

The L6506 senses the voltage across the sense resistor  $R_s$  to monitor the motor current: it compares the sensed voltage both to control the speed and during the brake of the motor.

Between the sense resistor and each sense input of the L6506 a resistor is recommended; if the connections between the outputs of the L6506 and the inputs of the L6203 need a long path, a resistor must be added between each input of the L6203 and ground.

A snubber network made by the series of  $R$  and  $C$  must be foreseen very near to the output pins of the I.C.; one diode (BYW98) is connected between each power output pin and ground as well.

The following formulas can be used to calculate the snubber values:

$$R \approx V_s / I_p$$

$$C = I_p / (dV/dt) \text{ where:}$$

$V_s$  is the maximum Supply Voltage foreseen on the application;

$I_p$  is the peak of the load current;

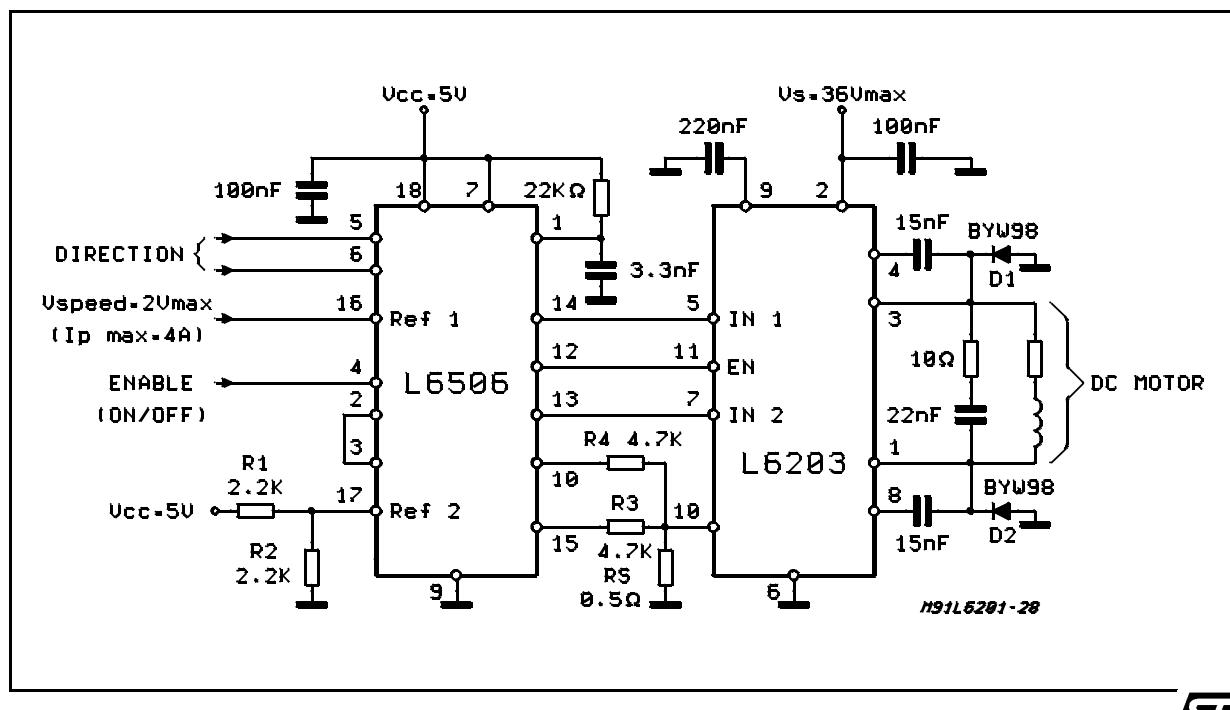
$dV/dt$  is the limited rise time of the output voltage (200V/ $\mu$ s is generally used).

If the Power Supply Cannot Sink Current, a suitable large capacitor must be used and connected near the supply pin of the L6203. Sometimes a capacitor at pin 17 of the L6506 let the application better work. For motor current up to 2A max., the L6202 can be used in a similar circuit configuration for which a typical Supply Voltage of 24V is recommended.

### DC Motor Speed Control

Since the I.C. integrates a full H-Bridge in a single package it is ideally suited for controlling DC motors. When used for DC motor control it performs the power stage required for both speed and direction control. The device can be combined with a current regulator like the L6506 to implement a transconductance amplifier for speed control, as shown in figure 17. In this particular configuration only half of the L6506 is used and the other half of the device may be used to control a second

Figure 17: Bidirectional DC Motor Control

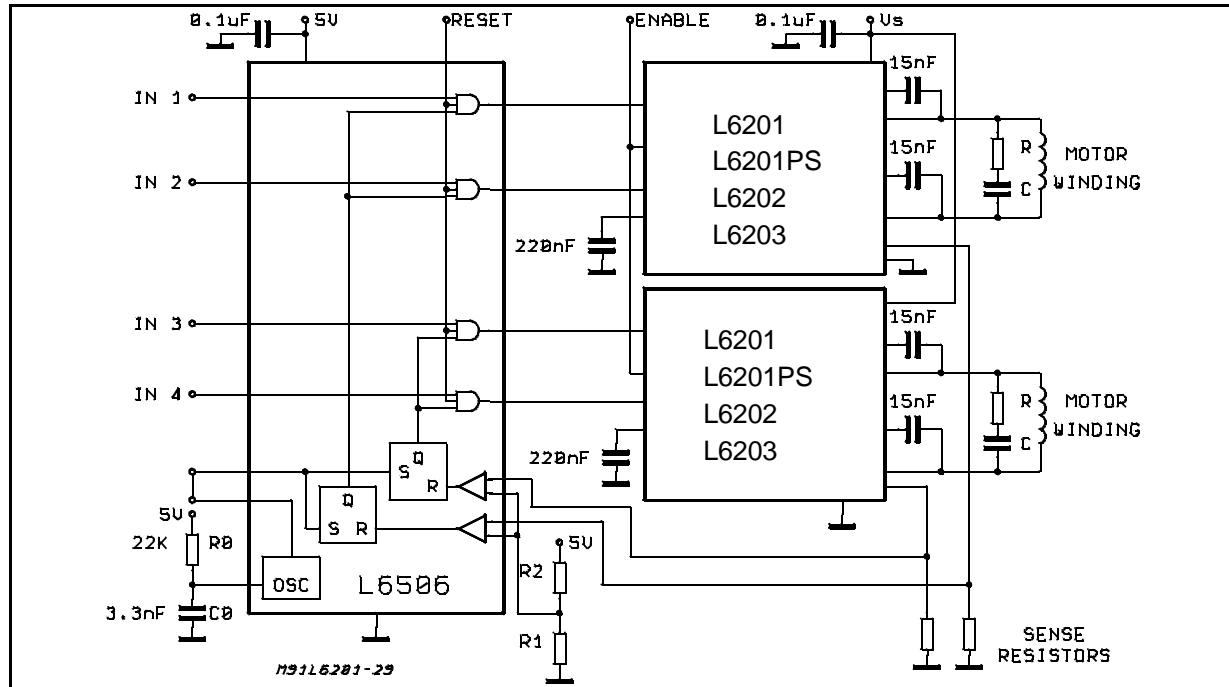


### BIPOLAR STEPPER MOTORS APPLICATIONS

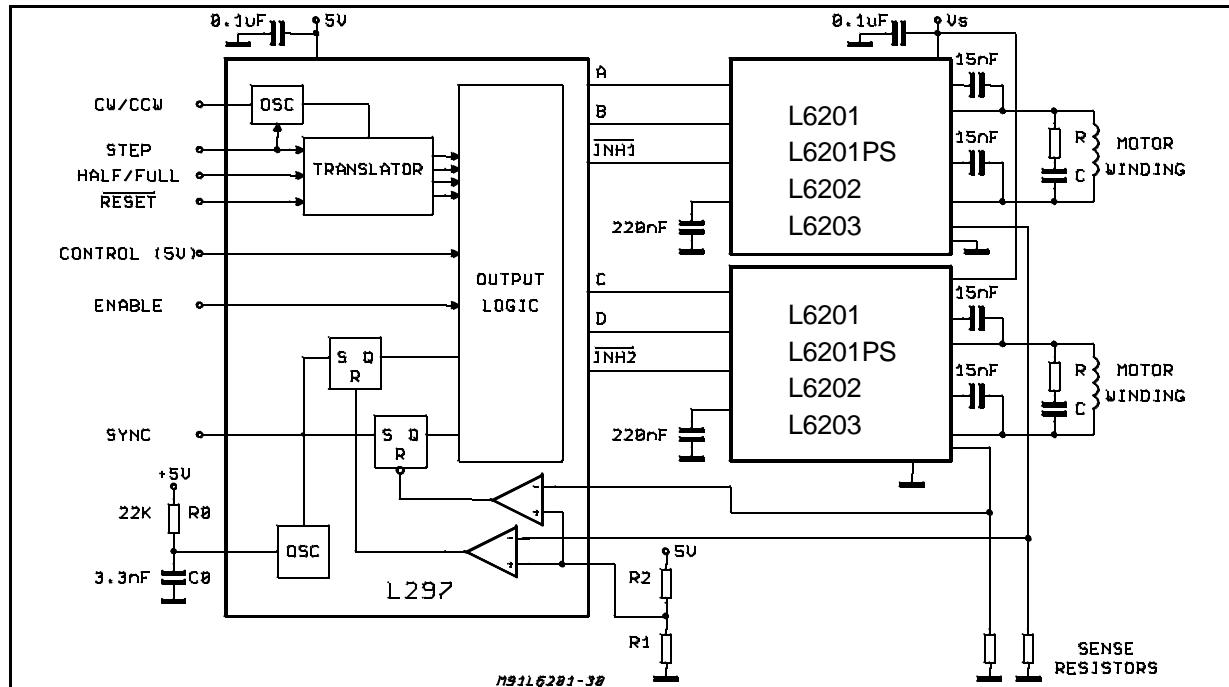
Bipolar stepper motors can be driven with one L6506 or L297, two full bridge BCD drivers and very few external components. Together these three chips form a complete microprocessor-to-stepper motor interface is realized.

As shown in Fig. 18 and Fig. 19, the controller connect directly to the two bridge BCD drivers. External component are minimized: an R.C. network to set the chopper frequency, a resistive divider (R1; R2) to establish the comparator reference voltage and a snubber network made by R and C in series (See DC Motor Speed Control).

**Figure 18:** Two Phase Bipolar Stepper Motor Control Circuit with Chopper Current Control



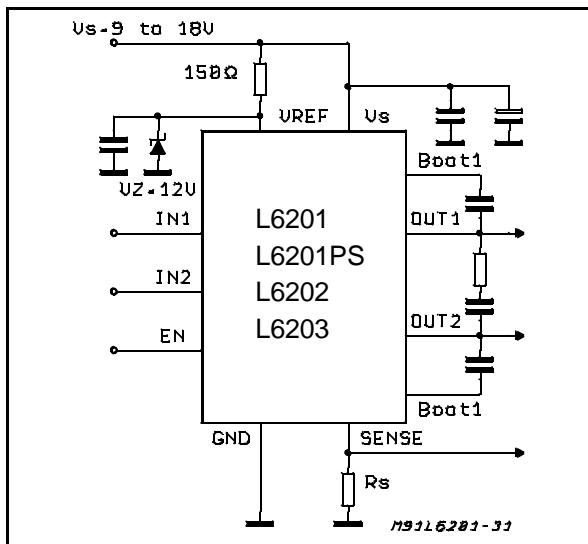
**Figure 19:** Two Phase Bipolar Stepper Motor Control Circuit with Chopper Current Control and Translator



## L6201 - L6202 - L6203

It could be requested to drive a motor at  $V_s$  lower than the minimum recommended one of 12V (See Electrical Characteristics); in this case, by accepting a possible small increase in the  $R_{DS\text{ (ON)}}$  resistance of the power output transistors at the lowest Supply Voltage value, may be a good solution the one shown in Fig. 20.

**Figure 20:** L6201/1P/2/3 Used at a Supply Voltage Range Between 9 and 18V



### THERMAL CHARACTERISTICS

Thanks to the high efficiency of this device, often a true heatsink is not needed or it is simply obtained by means of a copper side on the P.C.B. (L6201/2).

Under heavy conditions, the L6203 needs a suitable cooling.

By using two square copper sides in a similar way as it shown in Fig. 23, Fig. 21 indicates how to choose the on board heatsink area when the L6201 total power dissipation is known since:

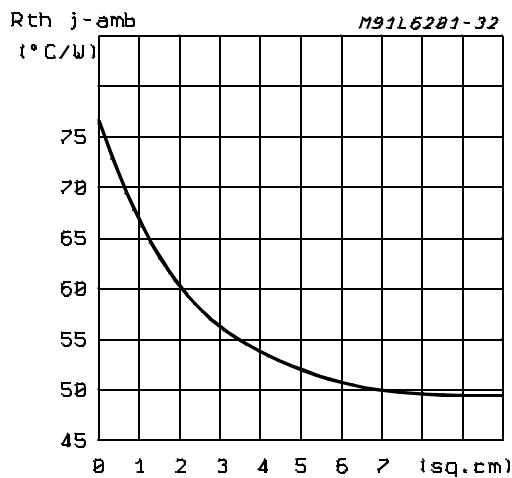
$$R_{Th\text{ j-amb}} = (T_{j\text{ max.}} - T_{amb\text{ max.}}) / P_{tot}$$

Figure 22 shows the Transient Thermal Resistance vs. a single pulse time width.

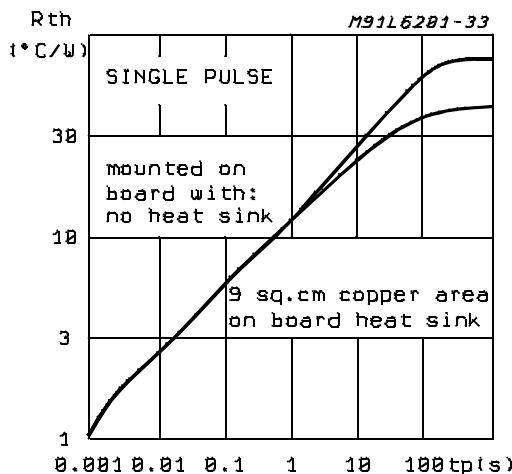
Figure 23 and 24 refer to the L6202.

For the Multiwatt L6203 addition information is given by Figure 25 (Thermal Resistance Junction-Ambient vs. Total Power Dissipation) and Figure 26 (Peak Transient Thermal Resistance vs. Repetitive Pulse Width) while Figure 27 refers to the single pulse Transient Thermal Resistance.

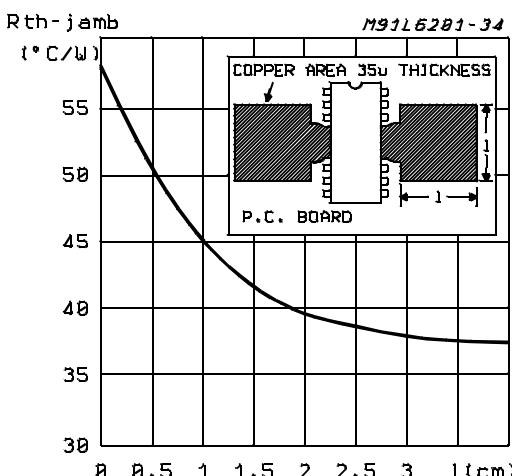
**Figure 21:** Typical  $R_{Th\text{ j-amb}}$  vs. "On Board" Heatsink Area (L6201)



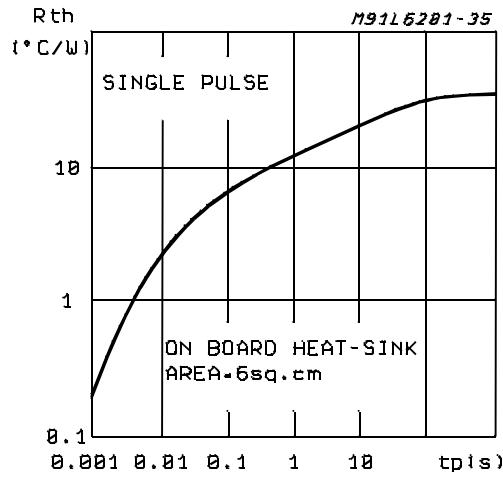
**Figure 22:** Typical Transient  $R_{Th}$  in Single Pulse Condition (L6201)



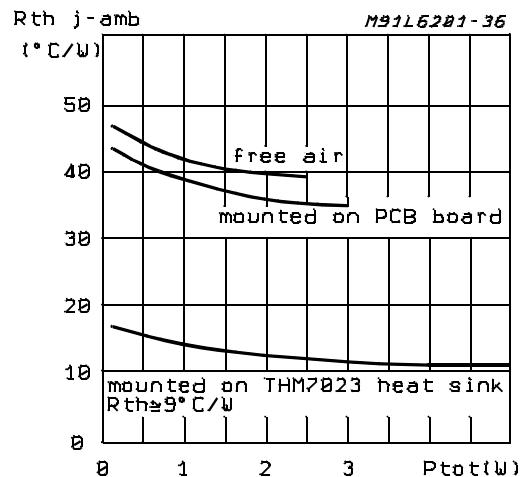
**Figure 23:** Typical  $R_{Th\text{ j-amb}}$  vs. Two "On Board" Square Heatsink (L6202)



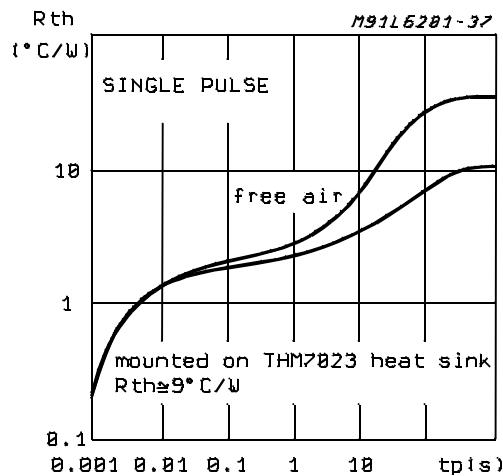
**Figure 24:** Typical Transient Thermal Resistance for Single Pulses (L6202)



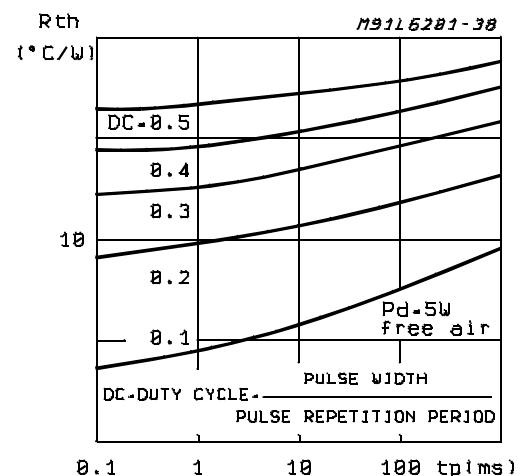
**Figure 25:** Typical  $R_{Th,j-amb}$  of Multiwatt Package vs. Total Power Dissipation



**Figure 26:** Typical Transient Thermal Resistance for Single Pulses with and without Heatsink (L6203)

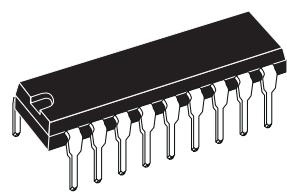


**Figure 27:** Typical Transient Thermal Resistance versus Pulse Width and Duty Cycle (L6203)

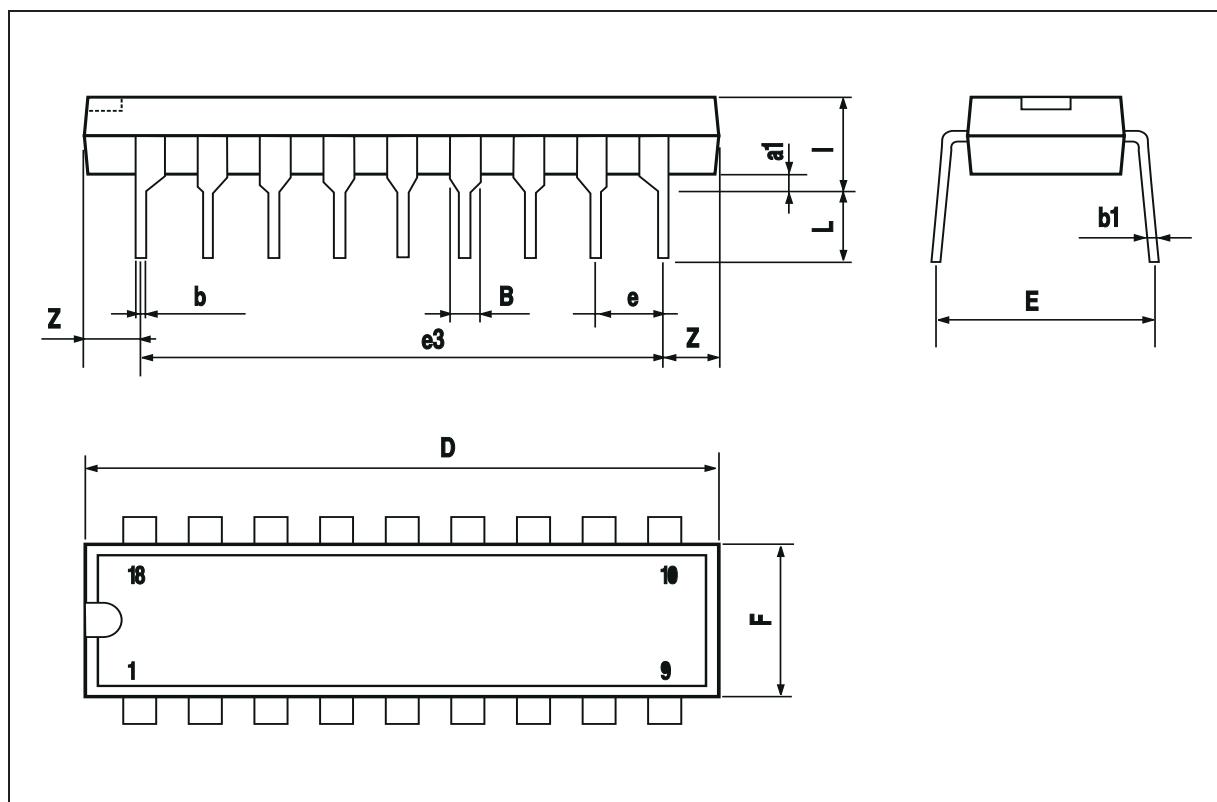


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	0.85		1.40	0.033		0.055
b		0.50			0.020	
b1	0.38		0.50	0.015		0.020
D			24.80			0.976
E		8.80			0.346	
e		2.54			0.100	
e3		20.32			0.800	
F			7.10			0.280
I			5.10			0.201
L		3.30			0.130	
Z			2.54			0.100

**OUTLINE AND  
MECHANICAL DATA**

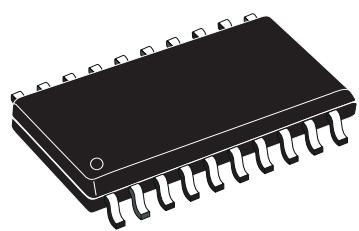


**Powerdip 18**

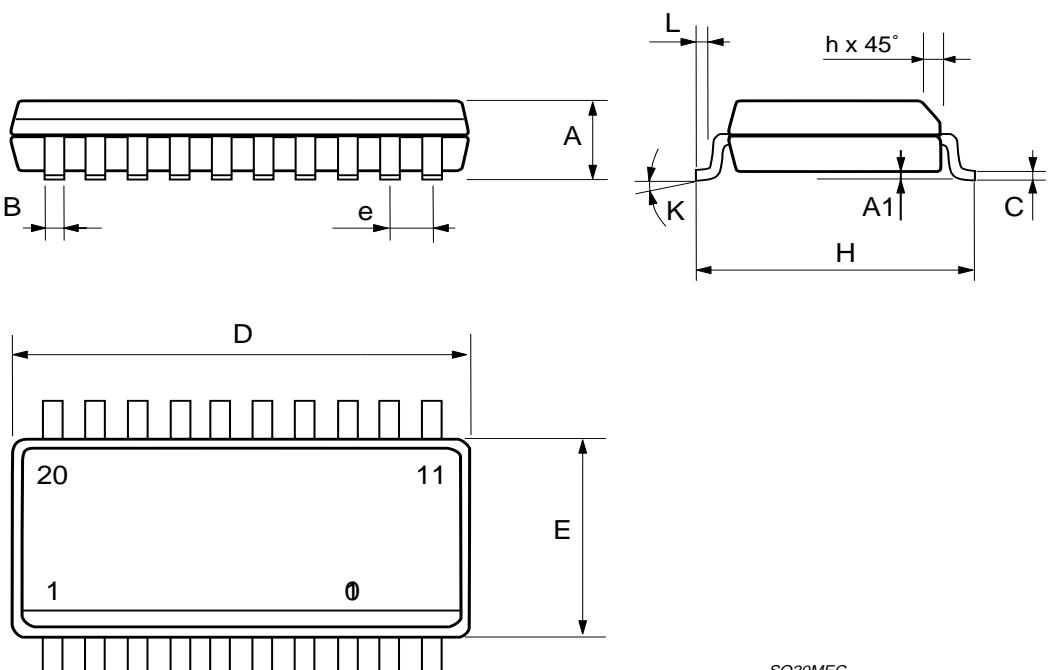


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	2.35		2.65	0.093		0.104
A1	0.1		0.3	0.004		0.012
B	0.33		0.51	0.013		0.020
C	0.23		0.32	0.009		0.013
D	12.6		13	0.496		0.512
E	7.4		7.6	0.291		0.299
e		1.27			0.050	
H	10		10.65	0.394		0.419
h	0.25		0.75	0.010		0.030
L	0.4		1.27	0.016		0.050
K	0° (min.) 8° (max.)					

### OUTLINE AND MECHANICAL DATA



**SO20**



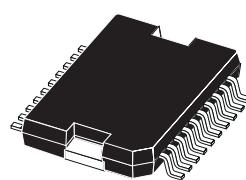
## L6201 - L6202 - L6203

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			3.6			0.142
a1	0.1		0.3	0.004		0.012
a2			3.3			0.130
a3	0		0.1	0.000		0.004
b	0.4		0.53	0.016		0.021
c	0.23		0.32	0.009		0.013
D (1)	15.8		16	0.622		0.630
D1	9.4		9.8	0.370		0.386
E	13.9		14.5	0.547		0.570
e		1.27			0.050	
e3		11.43			0.450	
E1 (1)	10.9		11.1	0.429		0.437
E2			2.9			0.114
E3	5.8		6.2	0.228		0.244
G	0		0.1	0.000		0.004
H	15.5		15.9	0.610		0.626
h			1.1			0.043
L	0.8		1.1	0.031		0.043
N	8° (typ.)					
S	8° (max.)					
T		10			0.394	

(1) "D and E1" do not include mold flash or protrusions.  
- Mold flash or protrusions shall not exceed 0.15mm (0.006")  
- Critical dimensions: "E", "G" and "a3".

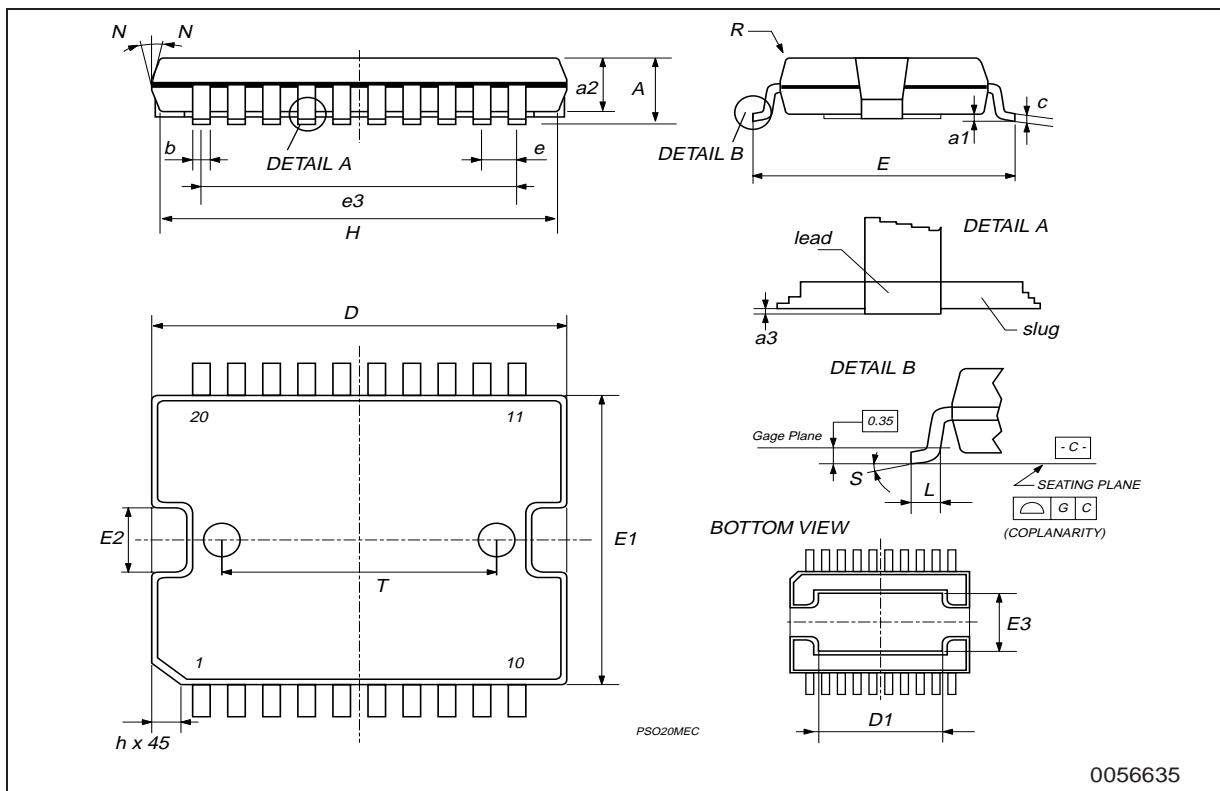
## OUTLINE AND MECHANICAL DATA

Weight: 1.9gr



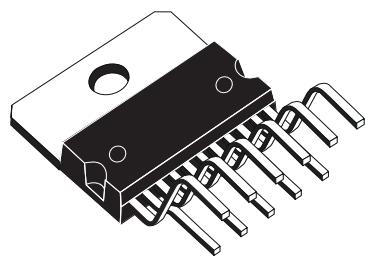
JEDEC MO-166

PowerSO20

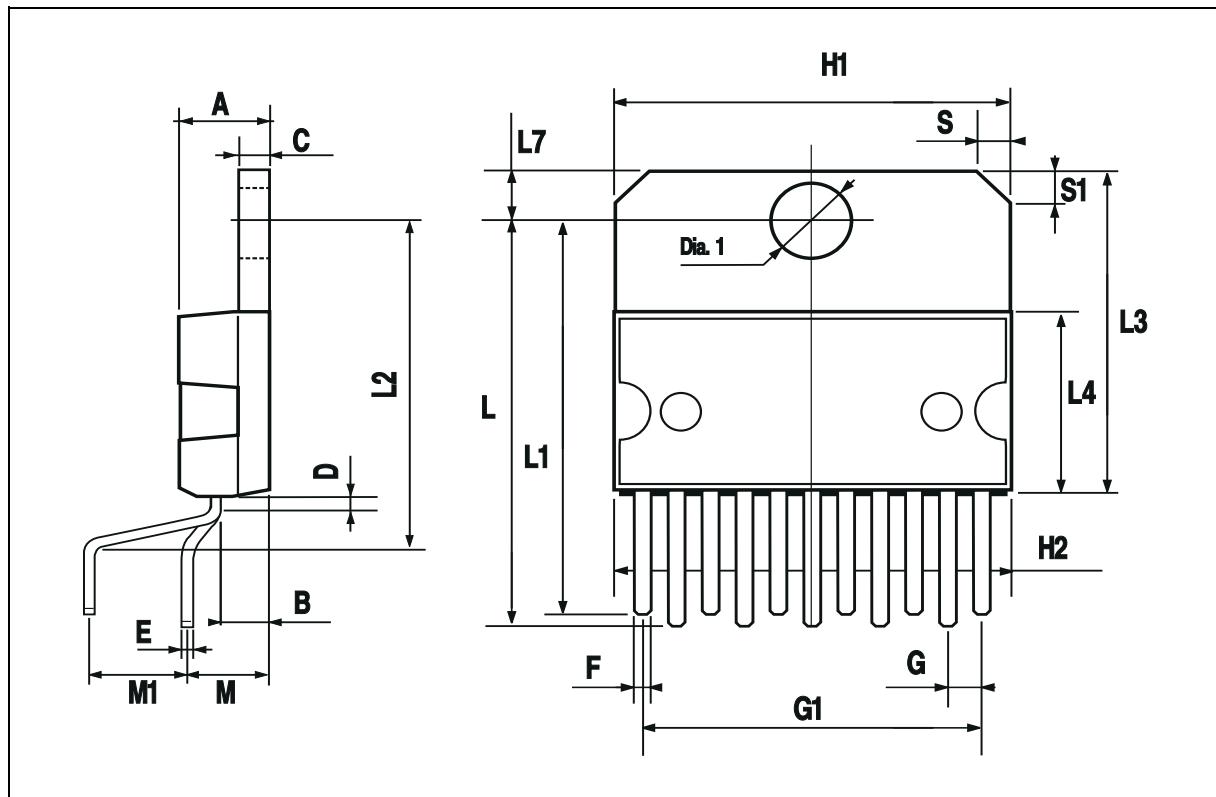


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
D		1			0.039	
E	0.49		0.55	0.019		0.022
F	0.88		0.95	0.035		0.037
G	1.45	1.7	1.95	0.057	0.067	0.077
G1	16.75	17	17.25	0.659	0.669	0.679
H1	19.6			0.772		
H2			20.2			0.795
L	21.9	22.2	22.5	0.862	0.874	0.886
L1	21.7	22.1	22.5	0.854	0.87	0.886
L2	17.4		18.1	0.685		0.713
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L7	2.65		2.9	0.104		0.114
M	4.25	4.55	4.85	0.167	0.179	0.191
M1	4.73	5.08	5.43	0.186	0.200	0.214
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

### OUTLINE AND MECHANICAL DATA



Multiwatt11 V



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