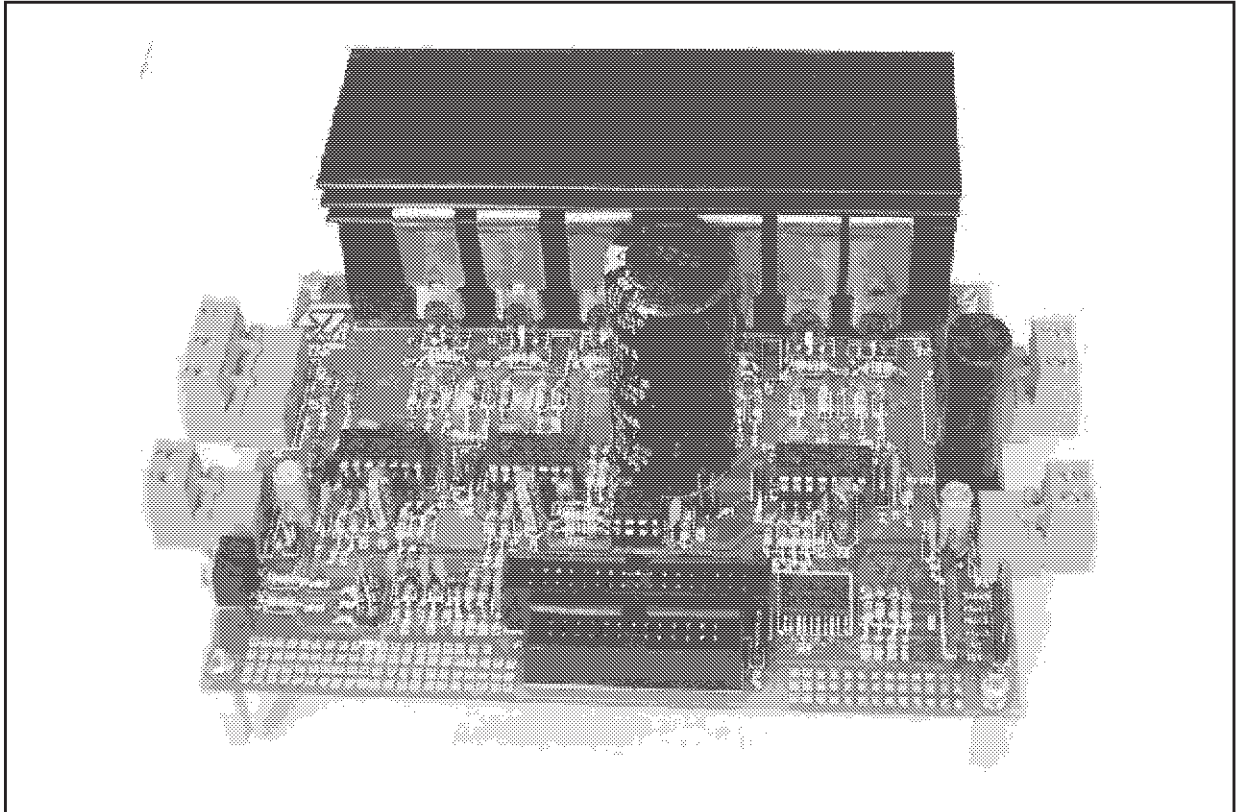




L6386: 3-PHASE DEMO BOARD

by G.P. Meloncelli



Product Description

The 3-Phase Demo Board is a reference kit for evaluation and design with the high voltage gate driver L6386. User must only provide the logical signals and the power supplies. The kit make easy to test the driver capability with different power switches and can be used as reference design for a power stage of a 3-phase motor drive.

The bemf and the hall sensors sensing circuitry allow the user to run brush-less motor like induction or permanent magnet motor, unless adding other components but providing only the logic level control signals.

System Features

- High power motor drive capability (300V-3 Amps or 7Amps depending on the power switches)
- Inrush current limitation
- On board temperature protection
- Linear current feedback
- Overload current protection
- Bemf and Hall Effect sensor build-in supply circuit

AN1315 APPLICATION NOTE

Main Information

PARAMETER	VALUE	COMMENTS
POWER INPUTS		
High voltage Bus	0-300V	High voltage continuous power supply
Current	3A (default)	Changing the power switch and the sense resistors value is possible to manage currents up to 7Amp. (STGP7NB 60HD)
POWER OUTPUTS		
Line to line output Voltage	0-300V	
Low side maximum current	4.75A +/- 10%	The user can set different values of current limitation acting on a resistor divider (According to the power switch used).
AUXILIARY SUPPLY		
Vcc	12.5V-17V	
Vdd	0V -5V	
CONTROL INPUTS		
Hin1/Lin1/Hin2/Lin2/Hin3/Lin3	0-Vcc	CMOS level
Shut Down Input	0-Vdd	CMOS level -Active low-
CONTROL OUTPUTS		
Bemf output pins BemfR / BemfS / BemfT	0-5.1V	If JP16/ JP18/JP19 are short circuited
	0-300V	If JP16/ JP18/JP19 are open
Hall sensor output pins Hall1 / Hall2 / Hall3	0-Vdd	
Over current output pin	0-Vdd	Active Low
OPERATING CONDITION		
Ambient maximum Operating temperature	75 C	Beyond value the over-temperature circuit shuts down the device.
IC' S ON BOARD		
High Voltage Drivers	L6386	
Power Switch	STGP3NB60HDFP (default)	They can be changed with the STGP7NB60HDFP
Operational Amplifier	TS272	
Transil	E6V1S3	Array of transil
SENSE RESISTOR		
Sense Resistor	110mΩ/2W	This resistor value is obtained paralleling two low inductive smd sense resistors of 220mΩ/1W each.

Safety Warnings

General

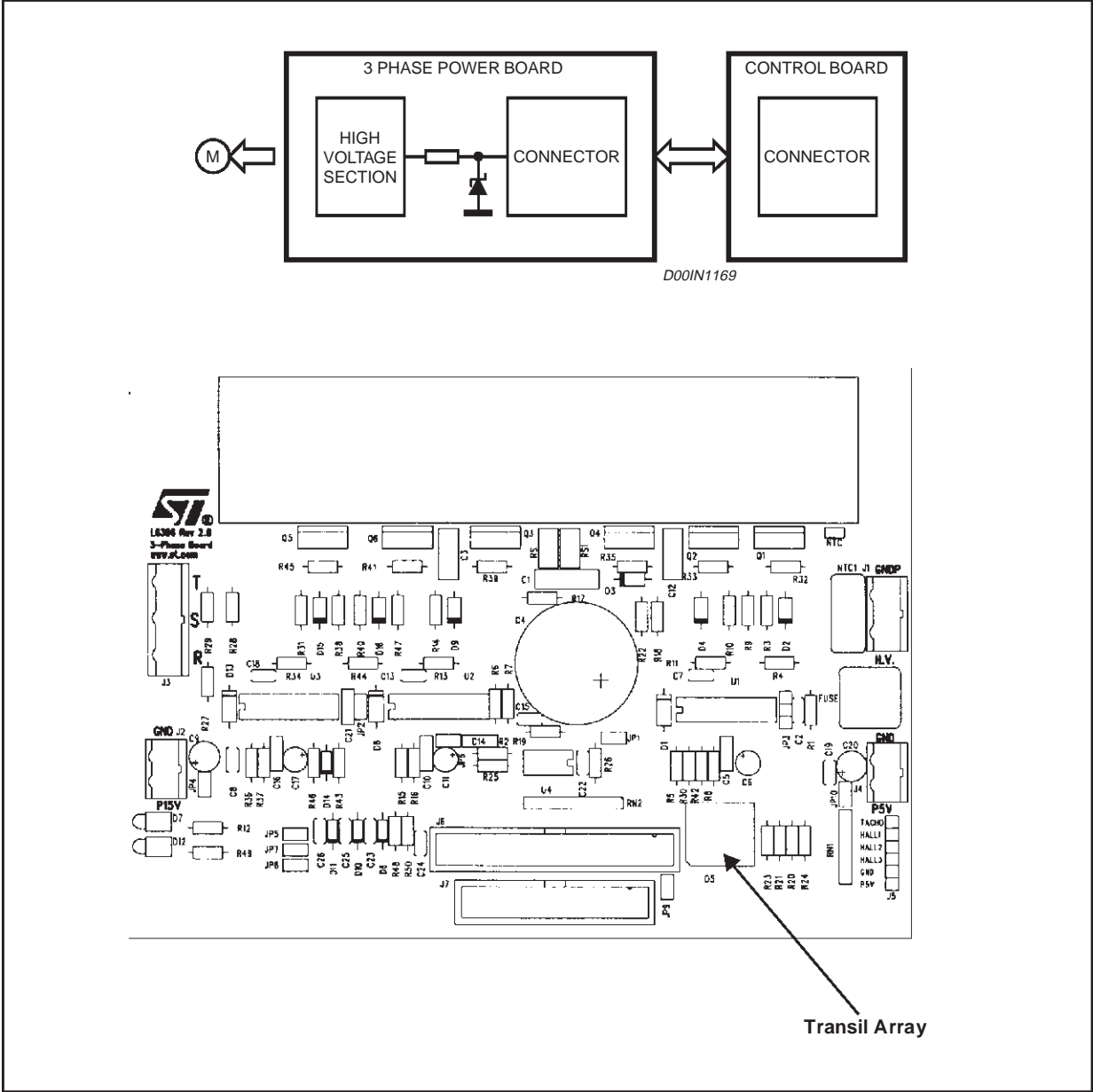
The board must be used by skilled personnel only, in fact due to the high voltage that may be present on the uninsulated parts, some care must be taken in order to avoid accident. There is no cover that protect the high voltage sections/wires from accidental human contact. After disconnection of the drive converter from the voltage supply, all the live part must not be touched immediately because of the energized capacitor.

Connectors

For the purpose of avoiding the customer control board damage, an array of Transil is used. These dangerous situations can happen when spurious high voltage spikes reaches the logical lines during fault conditions. Tran-

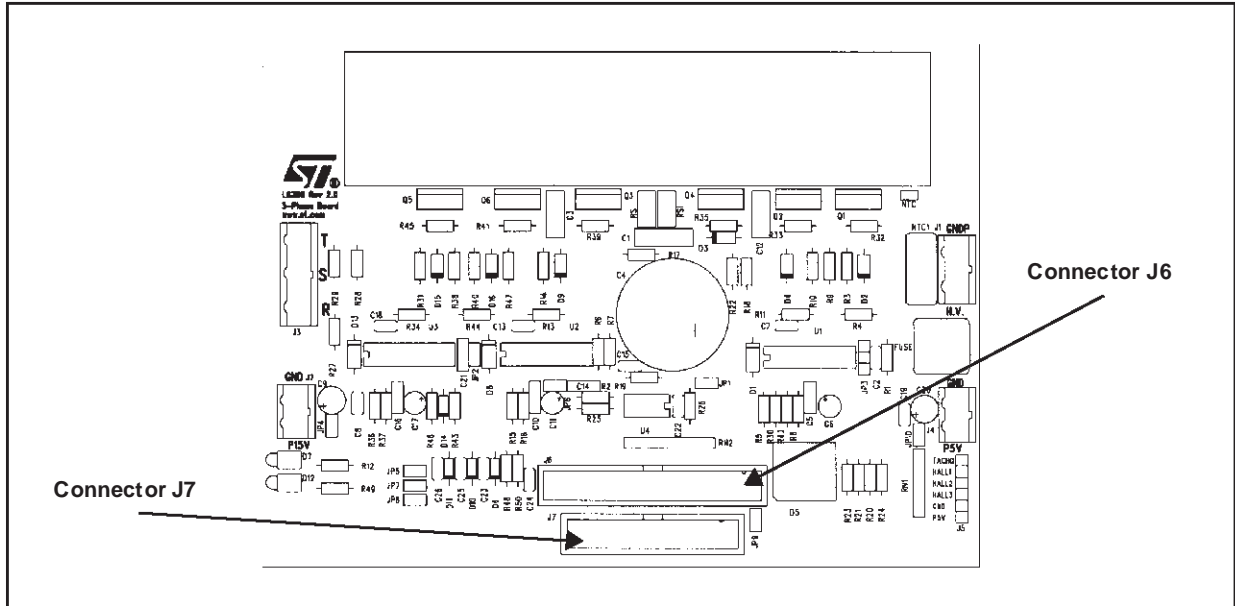
silts, together with series resistors, provide high overvoltage protection by clamping actions, and in this terms protect the connectors from voltage spikes. Series resistors limit the current absorbed from the transil during high voltage transient. Protections are not mandatory for the application, but are implemented only for protect the customer control board. Remember that there is no galvanic isolation between the power and the logical sections but only "high voltage clamping solution".

Figure 1. Overvoltage clamping protection



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LOGICAL CONNECTION



On board there are two logical connectors that must be used to provide logical signals.

- Connector J7 is compatible with the ST72141 Kanda Control Board, that is a Brushless PMDC motor development tool (<http://www.kanda.com>).
- Connector J6 is compatible with the HSW-ST9+, general purpose ST9 based control board (under development).

Both the connectors are available to the user , that can connect his own control board .

Table 1.

CONNECTOR J6	
Pin Name	Pin Nr.
Lin1	21
Hin1	15
Lin2	2
Hin2	9
Lin3	7
Hin3	13
Hall1	29
Hall2	31
Hall3	33
BemfR	28
BemfS	30
BemfT	32
SD	18
Overcur	2/20
Vref	34
Current Sense	26
GND	12

○	1	2	○
○	3	4	○
○	5	6	○
○	7	8	○
○	9	10	○
○	11	12	○
○	13	14	○
○	15	16	○
○	17	18	○
○	19	20	○
○	21	22	○
○	23	24	○
○	25	26	○
○	27	28	○
○	29	30	○
○	31	32	○
○	33	34	○

CONNECTOR J7	
Pin Name	Pin Nr.
Lin1	3
Hin1	5
Lin2	7
Hin2	9
Lin3	11
Hin3	13
BemfR	17
BemfS	19
BemfT	21
OverC.	1
+5V	25
+15V	15
GND	All others

○	1	2	○
○	3	4	○
○	5	6	○
○	7	8	○
○	9	10	○
○	11	12	○
○	13	14	○
○	15	16	○
○	17	18	○
○	19	20	○
○	21	22	○
○	23	24	○
○	25	26	○

In the following section let's describe the :

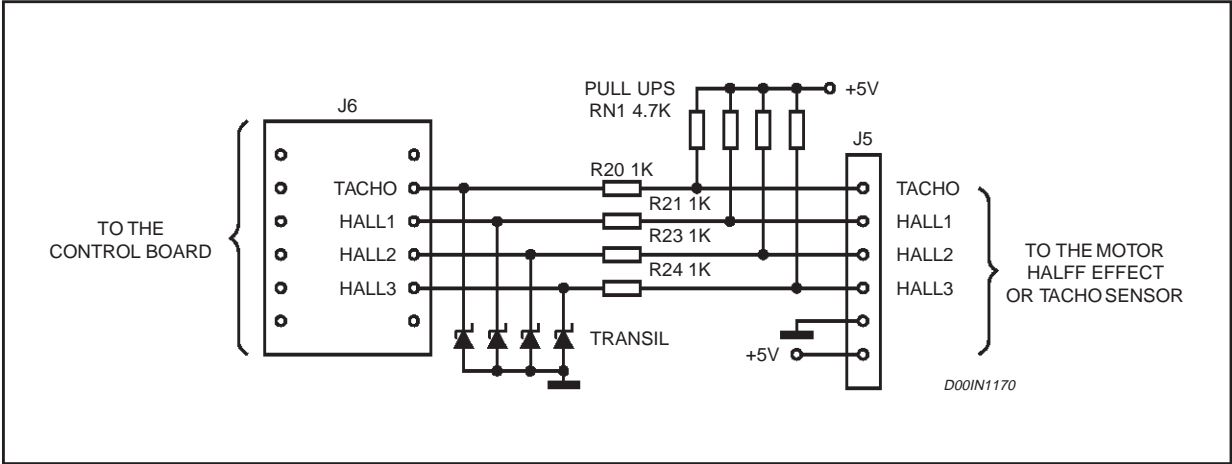
1. Logical input pin
2. Hall sensor pins
3. Bemf pin
4. Shut down (SD)
5. Analog current sensing (Current sense pin) and Over-current signal
6. Vref pin
7. Gnd pin

1) Logical input pins -Lin1, Lin2, Lin3 Hin1, Hin2, Hin3- (Connector J6 and J7)

This logic input are CMOS level compatible for ease of interfacing with the user control board.

2) Hall sensor pin Hall1, Hall2, Hall3 (Connector J6)

Figure 2. Hall effect sensor and Tacho sensor connector

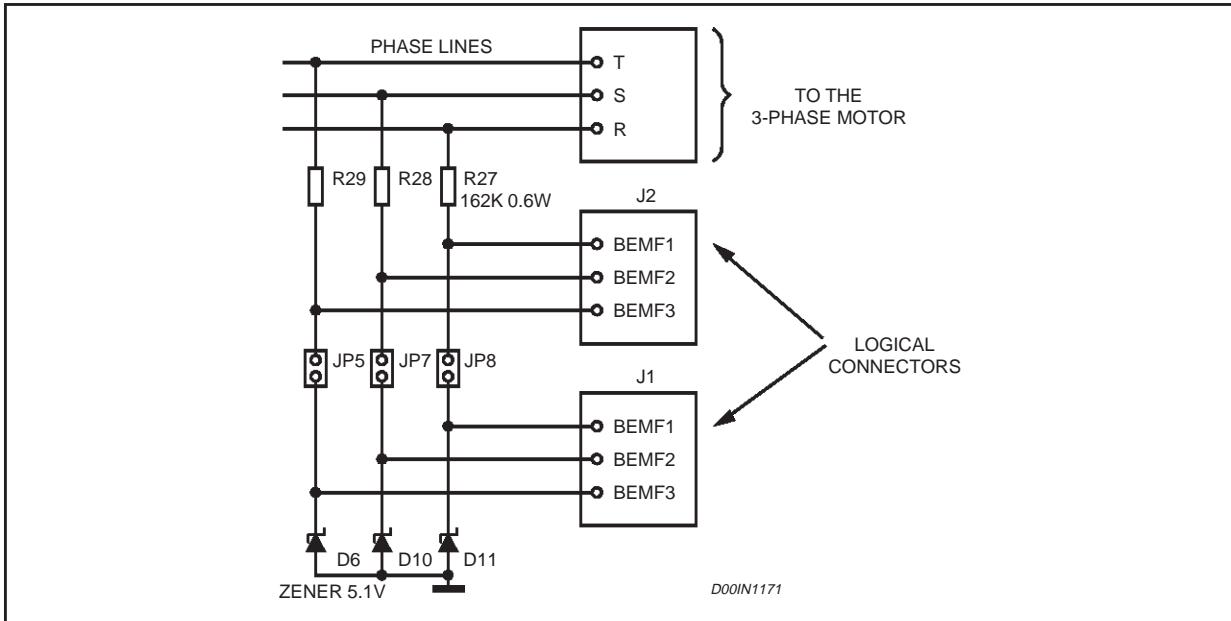


The Power board simplifies the motor position or speed readout, embedding pull up resistor as shown above (Fig.2). This permit to connect and supply the motor hall effect sensor (open drain) or the tacho sensor. An array of transil is also inserted on these lines, with the aim to protect them from accidental high voltage spikes coming from the motor connections.

3) Bemf Pins (connector J6 and J7):

No external wired circuitry is needed for reading the phase voltage. Infact the Bemf pins are connected via a resistor to the phase lines, like shown in fig.3.

Figure 3. Bemf connectors pins.



4) Shut down pin -SD- (Connector J6):

SD pin (connector J6) behaves as :

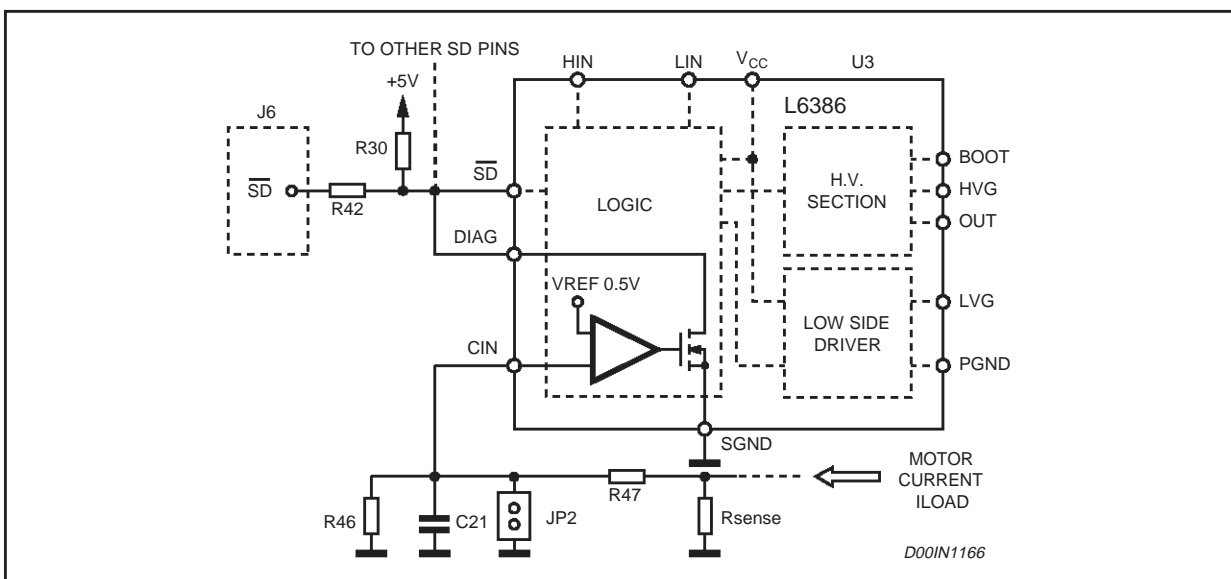
1. input pin: all the power switches are turned off putting this pin low ;
2. output pin: the control board can get information about the overcurrent or the over-temperature protection.

Overcurrent protection:

Default Settings:

- # 4.5 Amps;
- # JP2 open.

Figure 4. : Over-current protection circuit



The fast overcurrent protection is implemented using the built in comparator and the shut down pin. Current protection avoid that, under fault condition, the current flowing on the sense resistor reaches dangerous levels. The user can easily set this limit acting on the divider composed by R46 and R47.

$$I_{limit} = 0.5 \cdot \frac{R47 + R46}{R_{sense} \cdot R46}$$

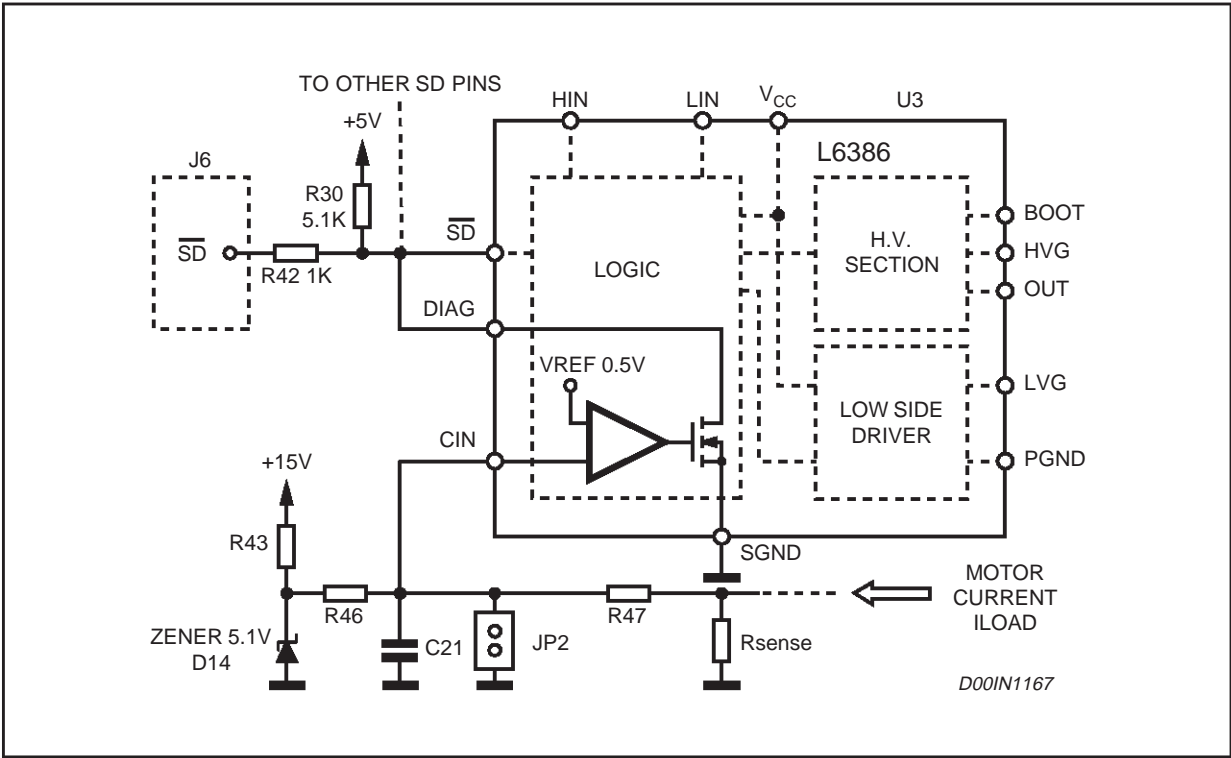
The 0.5V inside the formula is the internal comparator threshold . This current protection circuitry can be used only when the maximum Rsense voltage is bigger than the 0.5V threshold. If :

$$R_{sense} \cdot I_{limit} < 0.5V$$

a resistor and a zener can be used to provide a "D.C. level" to the comparator Cin pin (Fig. nr.5).On the default board configuration the zener D14 and the resistor R43 are not mounted.

Protections is disabled by shorting the jumper JP2

Figure 5. D.C. level shift for overcurrent protection circuit



The capacitor indicated as C21 (default value 2.2nF ceramic) helps to prevent that voltage spikes across the sense resistor causes spurious shut down conditions.

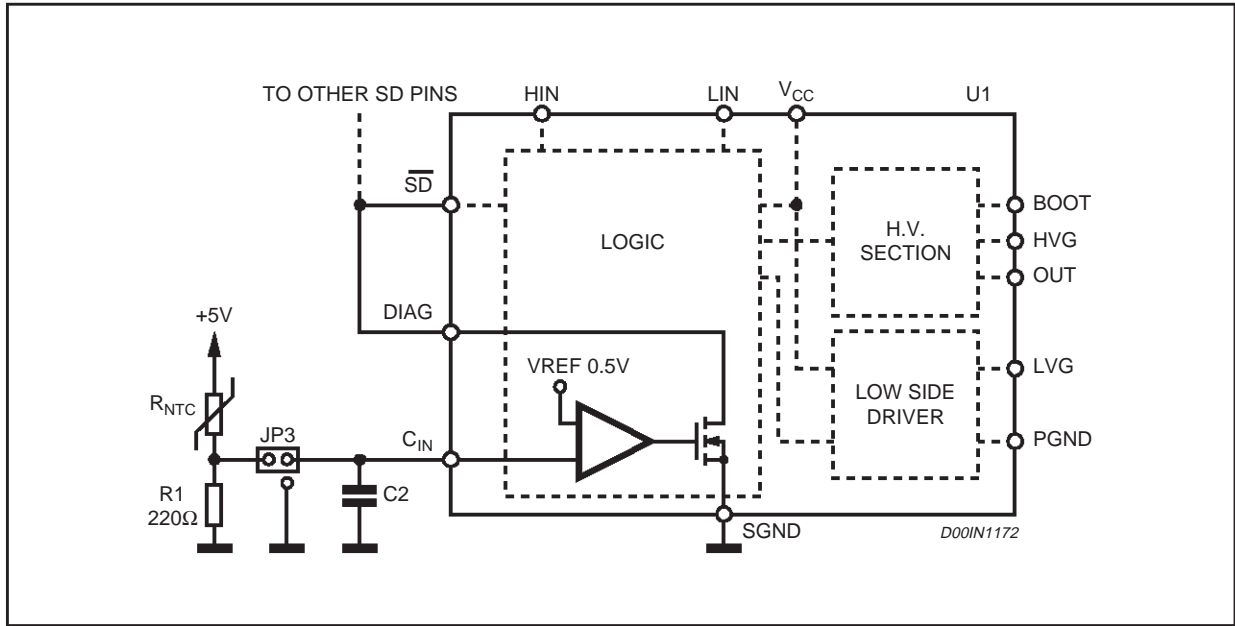
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Overtemperature protection:

Default Setting:

- # 75 Celsius (near);
- # Jumper JP3 as shown in figure nr.6.

Figure 6. Thermal protection shut down



Thermal protection shut down the devices when the temperature permit to the NTC resistor to reach this value:

$$R_{NTC}^{T_{max}} = \frac{5}{0.5} \cdot R_1 - R_1$$

The maximum temperature (Kelvin) will be:

$$T_{max} = \frac{1}{\frac{1}{B} \cdot \frac{R_{NTC}^{T_{max}}}{R_{NTC}^{T_n}} + \frac{1}{T_n}} \quad [K]$$

Where:

- B=3550K (depending from the NTC type and from the temperature range)
- $R_{NTC}^{T_{max}}$: NTC resistor value at T_{max} temperature
- $R_{NTC}^{T_n}$: NTC resistor value at $T_n = 298K$

With the default values the thermal shut down become active when the operating ambient temperature is around 75 Celsius. The NTC resistor is put close to the heat sink, because it is the highest temperature zone. It is up to the user to set this temperature value changing R1 value.

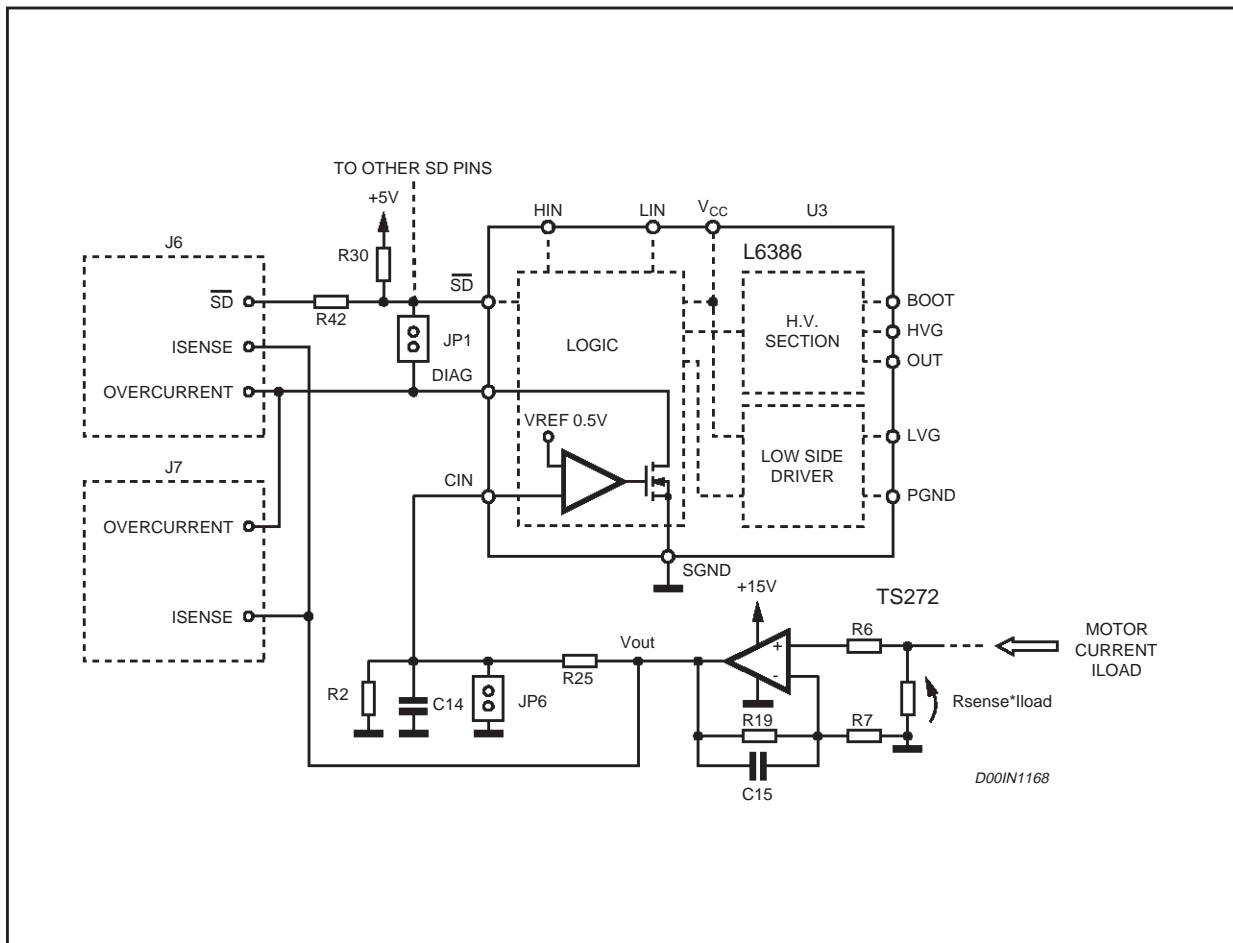
5) Analog Current Sensing (connector J6 and J7)

Default Settings:

- # Overcurrent trip point 5.3 Amps;
- # JP1 Open;
- # JP6 Closed.

Pin 26 on connector J6 and pin 23 on connector J7 can be used to get information about the load current value. Infact the Power Board embeds the TS272 operational amplifier that read the voltage across the sense resistor.

Figure 7. Current sensing circuitry



$$V_{out} = \frac{R_{19}}{R_7} \cdot (R_{sense} \cdot I_{load}) \cdot \frac{1}{R_{19} \cdot C_{15} \cdot s + 1} = 0.56 \cdot I_{load} \cdot \frac{1}{1.12 \cdot 10^{-6} \cdot s + 1} \quad [V]$$

Overcurrent pin, present on both the connectors, becomes low when the load current reaches the threshold level (set by the divider composed by R2 and R25):

$$I_{limit} = 0.5 \cdot \frac{1}{R_{sense}} \cdot \frac{R_7}{R_{19}} \cdot \frac{R_2 + R_{25}}{R_2} = 5.3 \quad [A]$$

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The default trip point is set to 5.3 Amps. With the jumper JP1 it is possible to use this signal also for drivers shut down. The jumper must be closed when the ST72141 Kanda control board is used.

The protection is disabled when JP6 is shorted to ground.

7) Vref pin (connector J6)

On this pin it is possible to set the voltage reference with the help of the divider R50 and R48. Reference can be used by the control board for analog conversion.

6) GND pin (connector J6 and J7)

The ground pins are connected to the board signal ground.

POWER CONNECTORS

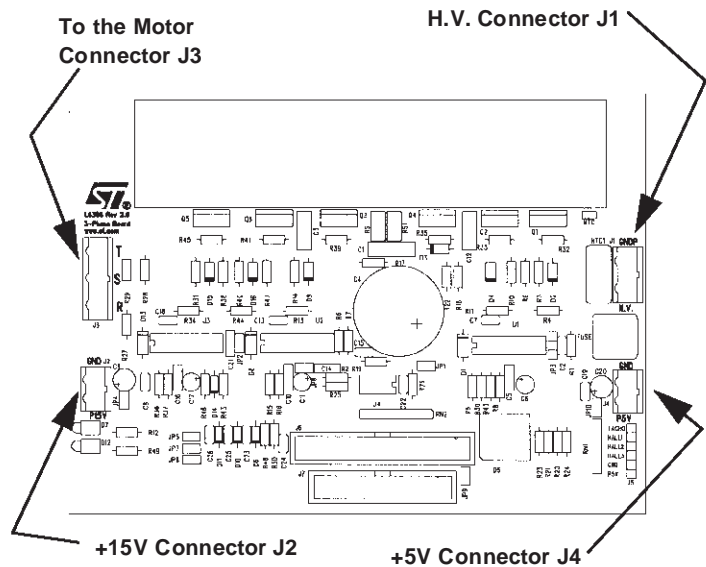
On board there are four power connectors:

1. J 1: provide the H.V. supply;
2. J2, J4: 15V and 5V supply;
3. J3: Motor Phase connector.

1) H.V. Supply (J1):

The maximum voltage allowed is 300V. Be careful : there is no protection under the reversed polarity on H.V. supply.

NTC of 10 Ohm and 5.1 W is used to suppress high inrush current surges, which occur when the bulk capacitor is charged.



2) 5V(J4)/15V(J2) Supply:

If the ST72141 Kanda control board is used the external power supply is not necessary. In this case the Kanda control board provide +5V and +15V via flat cable.

The external power supply is mandatory when the logical connector J6 is used (jumpers JP10 and JP14 closed). On board there are also two green leds that indicate when 5 V and 15 V are present.

Remember that there is no protection that can avoid damage if supply is given in reverse polarity .

3) Motor Phases Connector (J3)

By way of this connector it is possible to supply the 3 phase motor.

FURTHER COMPONENT SELECTION

In the following let's talk about:

1. Bootstrap capacitor
2. External diode
3. Current sense resistor
4. Resistors on the L6386 Out pin
5. Heat sink
6. Power Switches

1) Bootstrapp capacitor

Default setting: 470nF Ceramic

The board is a "demo board", so it is quite difficult to select the right capacitor value, because it depends mainly on the user switching frequency. The default value is 470nF, but the user must select the most appropriate dimension according to the switching frequency like shown in the application notes AN1299 or AN994. Suggested values are within the range 100nF-560nF, no-electrolytic due to the high leakage current.

2) External ultra fast diode

Default setting: Not Mounted

The Power Board use the L6386 built in bootstrap diode, but it is also possible to use an external ultra-fast diode, suggested the STTA106 (for off line application), when the internal diode can not be used (see AN1299).

3) Current Sense Resistor

Default Setting: two paralleled 0.22 /1W each

Two low inductive current sense resistors are used in parallel, 0.22Ohm and 1W each. The maximum current allowed through them is:

$$I_{\text{sense}}^{\text{max}} = \sqrt{\frac{P_{\text{max}}}{R_{\text{sense}}}} = \sqrt{\frac{2\text{W}}{0.11\Omega}} = 4.26\text{A}$$

limited by the maximum power dissipated. The user can change the sense resistor values according to the maximum current rating that it is used.

4) L6386 Out pin resistor.

Default resistor value: 0 Ω

On board there is one resistor on the L6386 out pin. These resistors (one for each driver), called as R9,R17 and R18, are used to improve the driver immunity at the out pin below ground spikes. Resistor positioned between the out pin and the center of the half bridge, help to avoid cross-conduction or drivers unwanted behaviors, when the out pin undervoltage (measured respect to the signal ground) exceed -18 V. Suggested values are within the range 10-220. Note that this resistors are on the high side turn off gate loop, so they have a double function:

- 1) improve the device immunity to the out pin below ground spikes ;
- 2) set the high side turn off time (in this case the user must short the resistors called as R4,R14,R34).

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5) Heat sink

The heat sink used has a thermal resistance of 2.34 C/W. (EL. BO. MEC. Thermalloy)

6) Power Switches

Default : STGP3NB60HDFP

Freewheeling diodes are inside the IGBT, so no external diodes are required. The user can easily change the power stage with different switches (i.e. STGP7NB60HD), in order to test the L6386 driver capability with different current ratings and with different bus voltages.

LAYOUT COMMENTS

1) Power and signal ground

The board layout is done in order to split the ground into:

- power ground: is the "high current" path. We must have in mind the following facts:
 - the total amount of resistance and inductance exhibited is directly proportional to the trace's length and inversely proportional to his width.
 - poor power ground trace's dimensions will increase the resistance, but first of all the parasitic inductance. It means that with fixed the spurious spikes across the traces are bigger. This could affect the driver proper functionality and increase the EMI generated by the inverter.
- signal ground: it is the reference for all the "logic" circuitry .It is a very sensitive ground and must be connected to the power ground in a specific point: the common end of the sense resistors. The purpose of this connections is to create a low noise ground reference. Note that this ground path carries only low currents values, needed for the logical sections.

The following picture show a principle schema about the grounds layout on the demo board. Note that the signal ground is connected to the power ground only in a single common point. As a good rule, the logical section, is filled with signal ground metal. This action will improve the EMI performance, infact large copper areas capture and dissipate RF frequency better.

Figure 8. Power ground layout (principle schema)

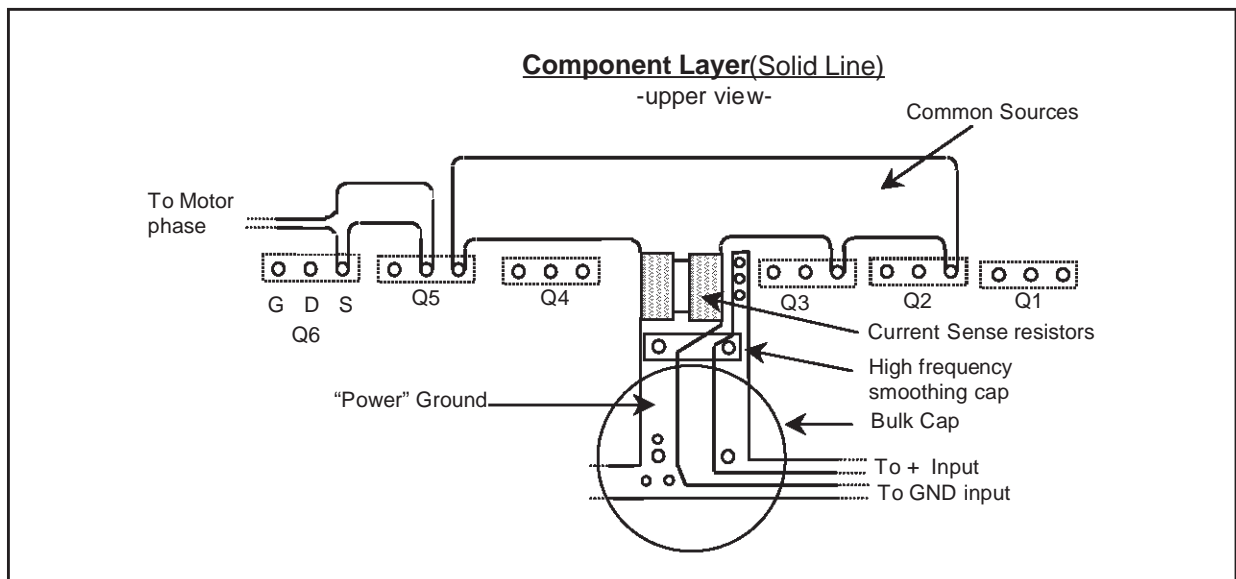
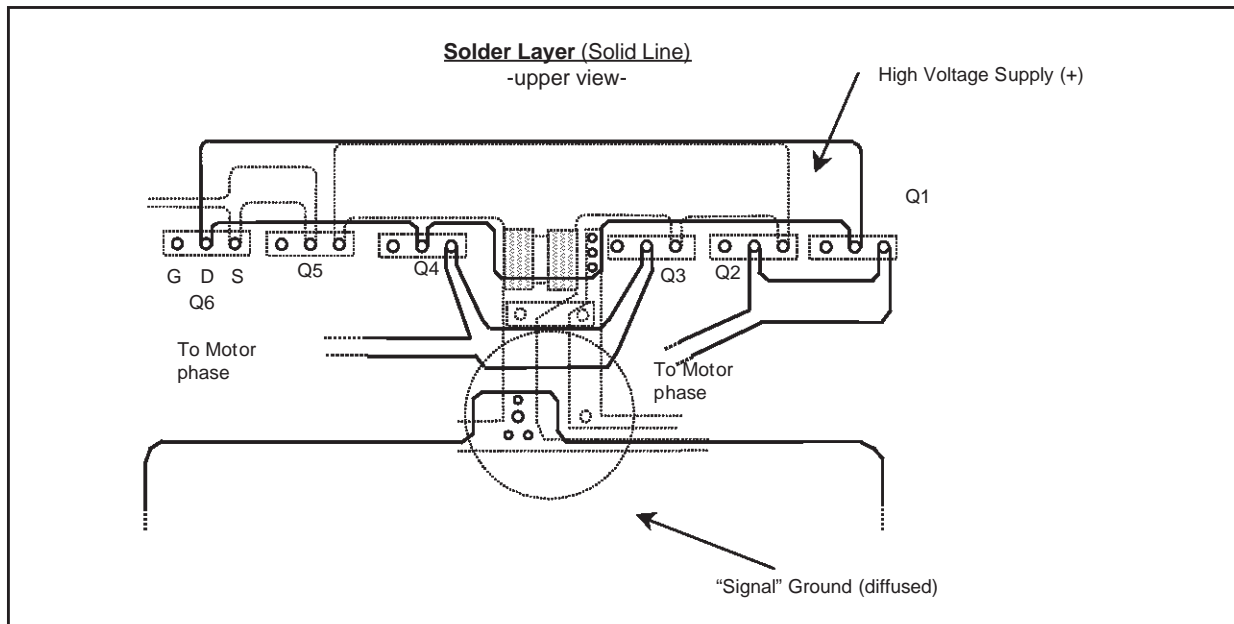


Figure 9. Signal ground layout (principle schema)



2) Gate Drive Loops

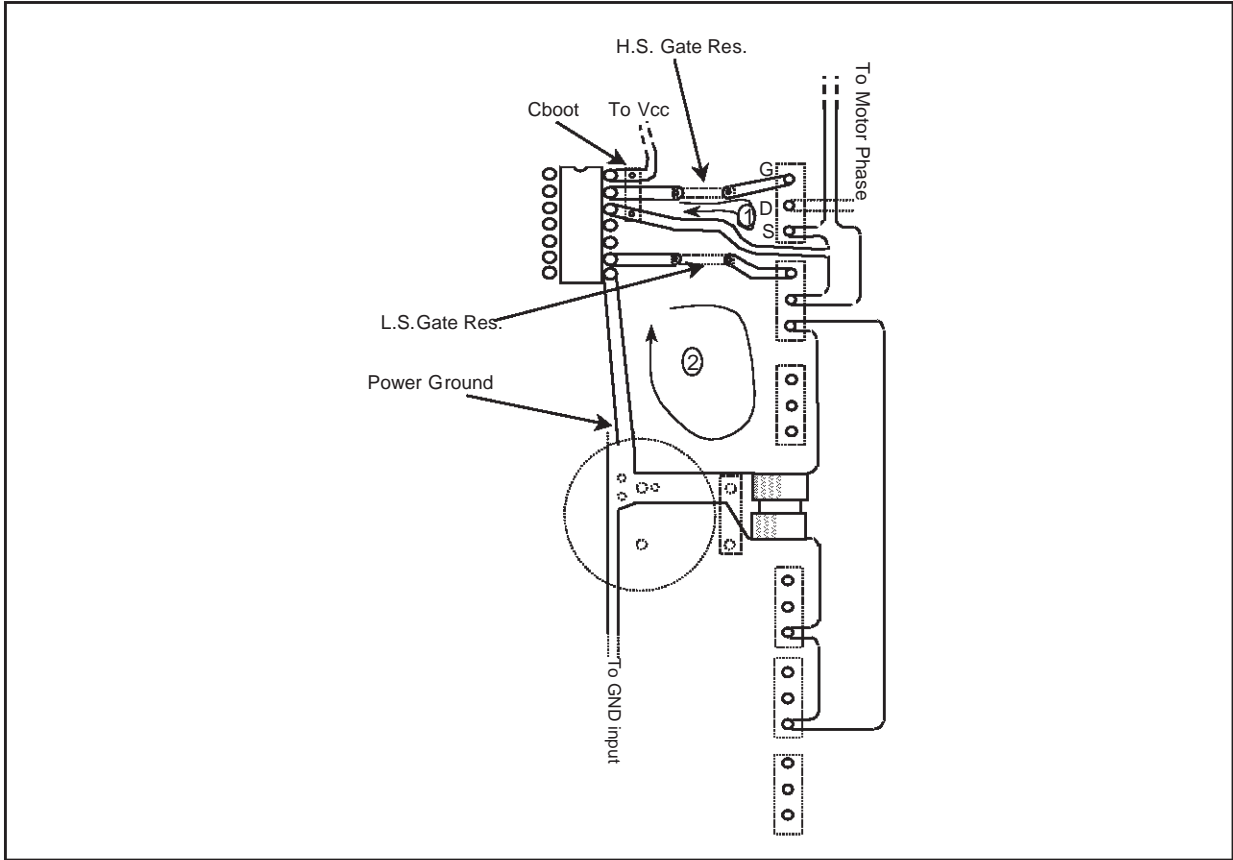
The layout must optimize also the gate drive loops in order to improve mainly the power switch turn on immunity. High dV/dt values between power switch drain-source, inject current inside the gate drive path via the drain-gate capacitance. This impulsive current must be absorbed by the driver. But if the gate drive loop is not well optimized and has long and thin trace, the parasitic inductance can lead to the power switch turn on. This is called "induced turn on".

Picture nr.10 shows:

- ·high side gate drive loop (indicated as 1)
- ·Low side gate drive loop (indicated as 2)

Gate drive loops must carry all the gate current that is in the order of hundreds of milliamps: our L6386 driver can supply up to 400mA and sink up to 600mA !

Figure 10. Gate drive loop (principle schema)

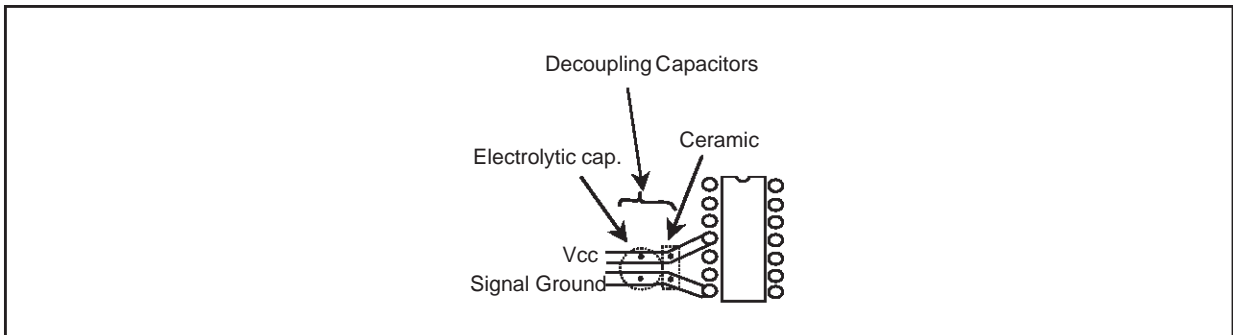


3) L6386 Driver supply

L6386 power supply must be within the range of 12.5-17V.

Good layout rule suggest to filter the IC power supply with capacitors connected as close as possible to the device. This is done with the aim to avoid the Vcc drop during the commutation (high/low side turn on). Remember: the current sinked by the supply line (Vcc), when the low side switch is turned on, can be up to 400mA. Parasitic inductance associated to long and thin power supply traces can lead to big drop on the Vcc voltage. Ceramic and electrolytic caps are generally paralled in order to provide good filtering actions for both low and at fast signals.

Figure 11. Power supply decoupling capacitors (principle schema)



L6386 Troubleshooting

In the following section the most frequently asked questions are described:

1 . PROBLEM: the L6386 doesn' t work at all

What to check:

- a) Check the L6386 Supply voltage (pin 4), putting the oscilloscope ground probe on the IC signal ground. The value must be within 12.5V and 17 V. If it is not so, adjust the supply voltage.

2 . PROBLEM: L6386 outputs don't follow the correspondent logical input.

What to check:

- a) During the commutation, check the L6386 shut down voltage with the oscilloscope ground probe connected to the IC signal ground pin. The driver shut down became active when the voltage is below 1.5 V. Situation like that one can happen in a noisy application, when spurious voltage spikes could shut down the driver .
- b) Check the voltage between the signal ground (Pin nr.7) and the out pin (Pin nr.12). As usual this must be done putting the oscilloscope ground probe close as possible to the IC signal ground pin, and measuring the voltage signal on the IC out pin (50ns as time scale min.). The voltage spikes below the signal ground must be less than **-18 V**, otherwise we have found the problem.

In this case try the following :

Put a resistor on the out pin (R9,R17,R38 see fig.12) with a value between 22 and 220 Ohms. Doing this you can also short the high side turn off resistor, and use the just placed "out resistor" as turn off resistor.

3 . PROBLEM: At startup the high side driver output doesn't work.

What to check:

- a) Check the voltage across the bootstrapp capacitor at startup. This value must be within 12.9 and 17V. The L6386 has an undervoltage lock out on the high side driving section, that lock the device if the bootstrapp capacitor is not well charged. Turning on the low side drive will permit to the bootstrapp capacitor to be charged.

Figure 12.

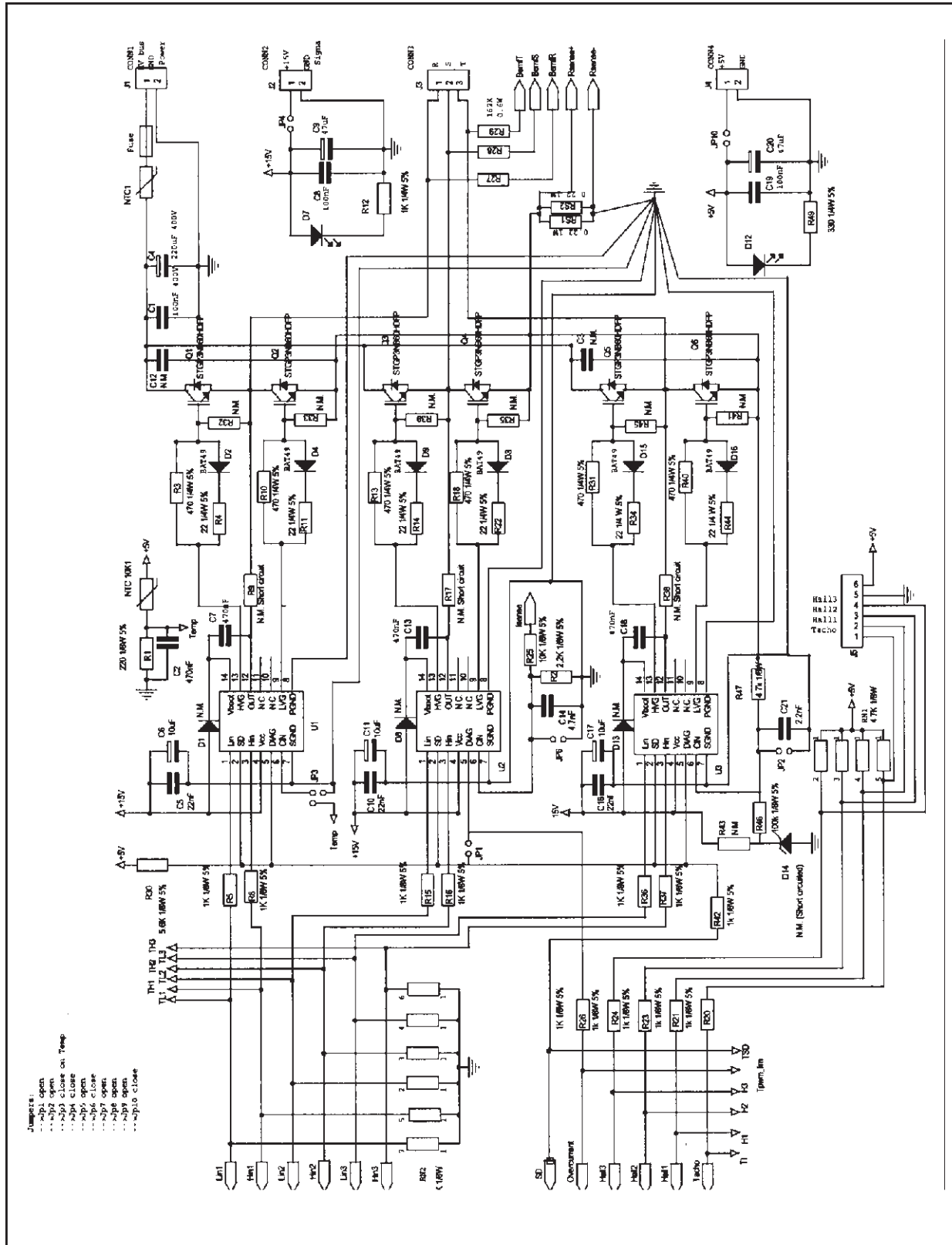


Figure 13.

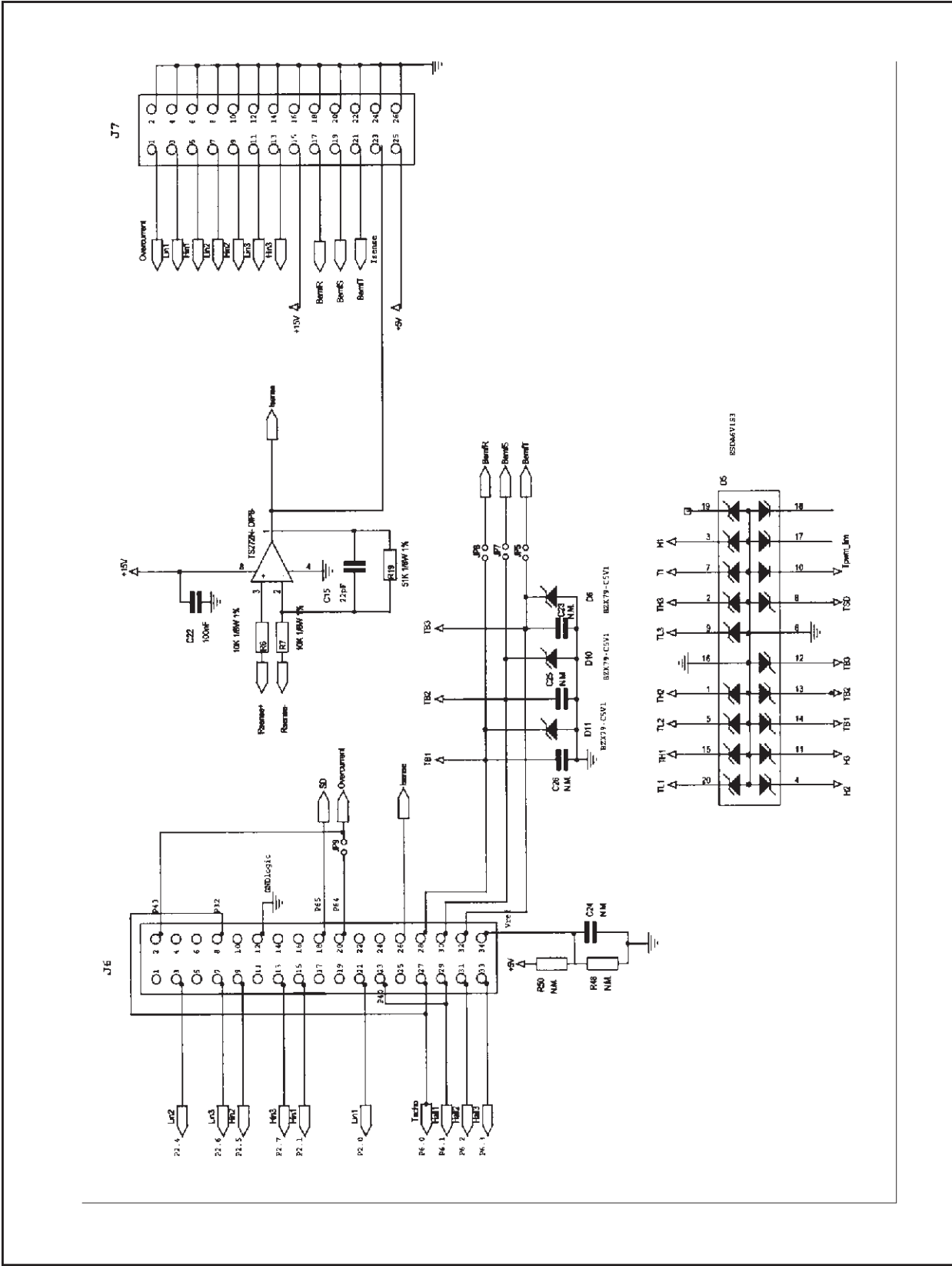


Figure 14.

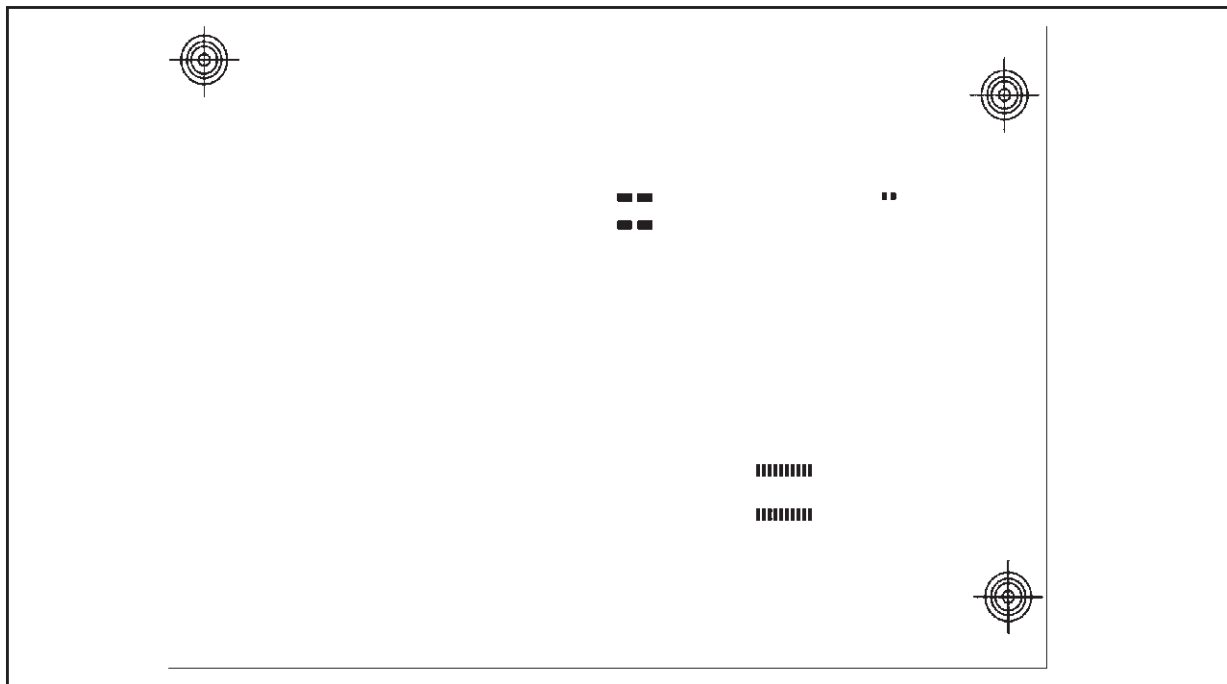


Figure 15.

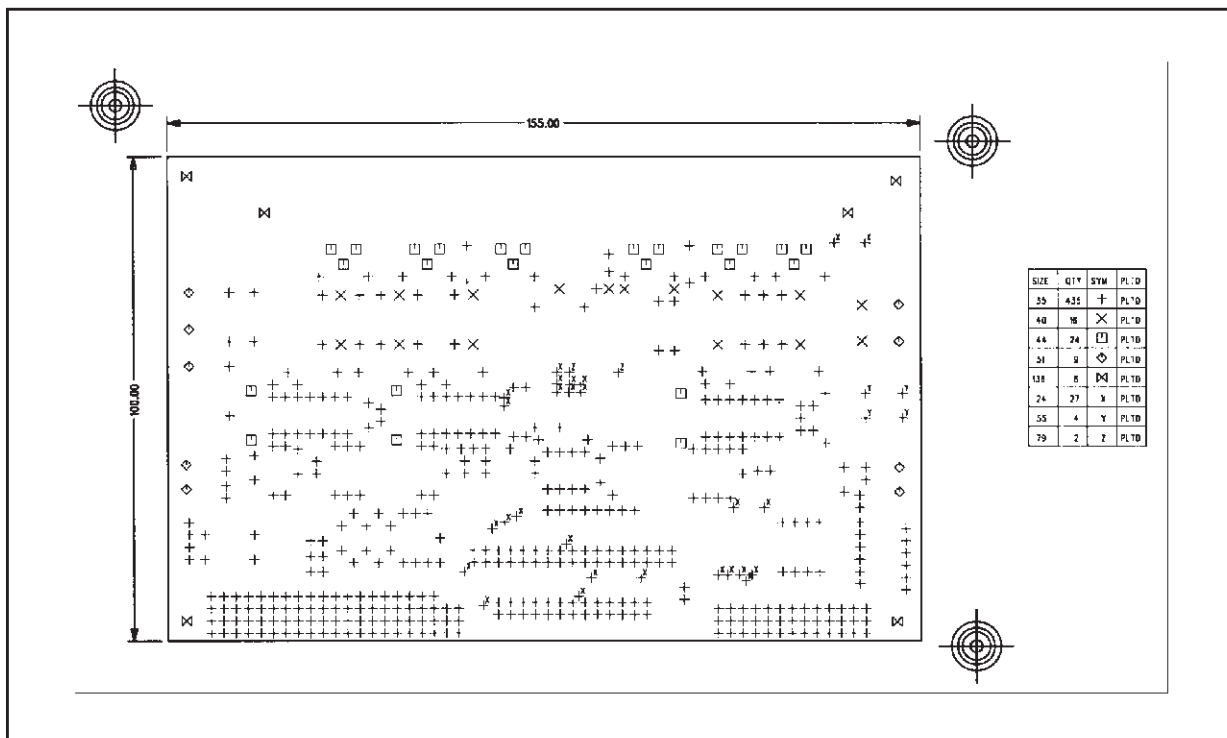


Figure 16.

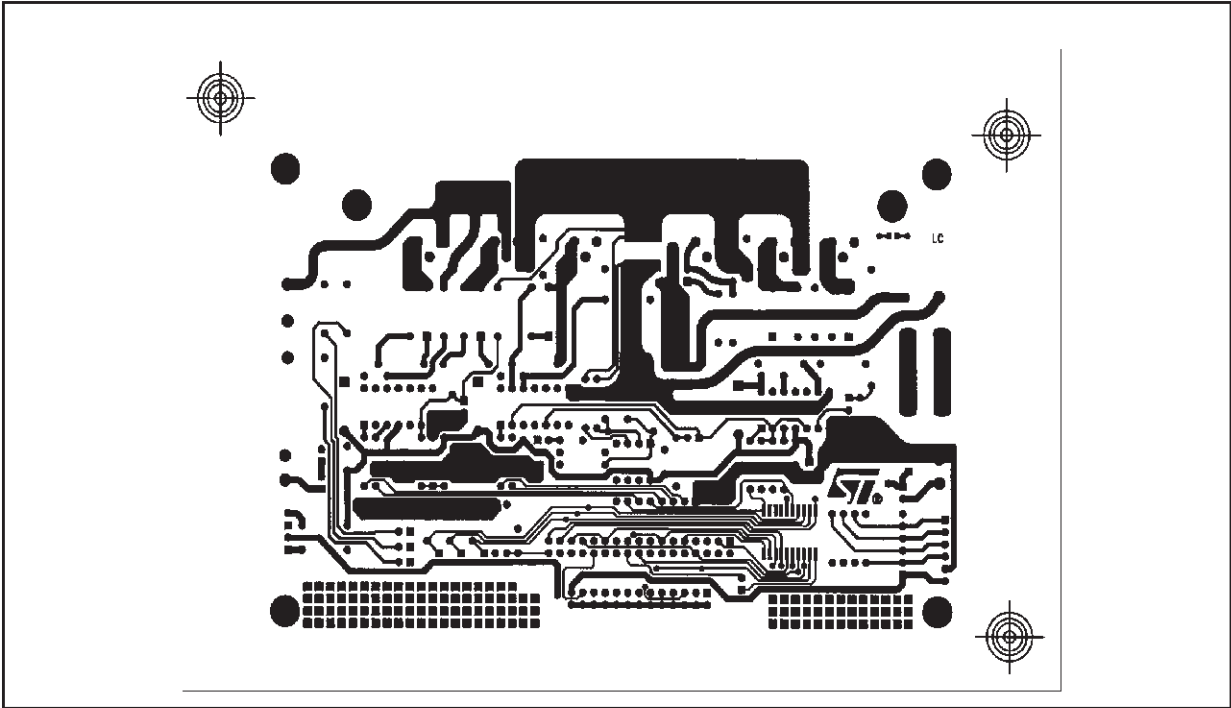


Figure 17.

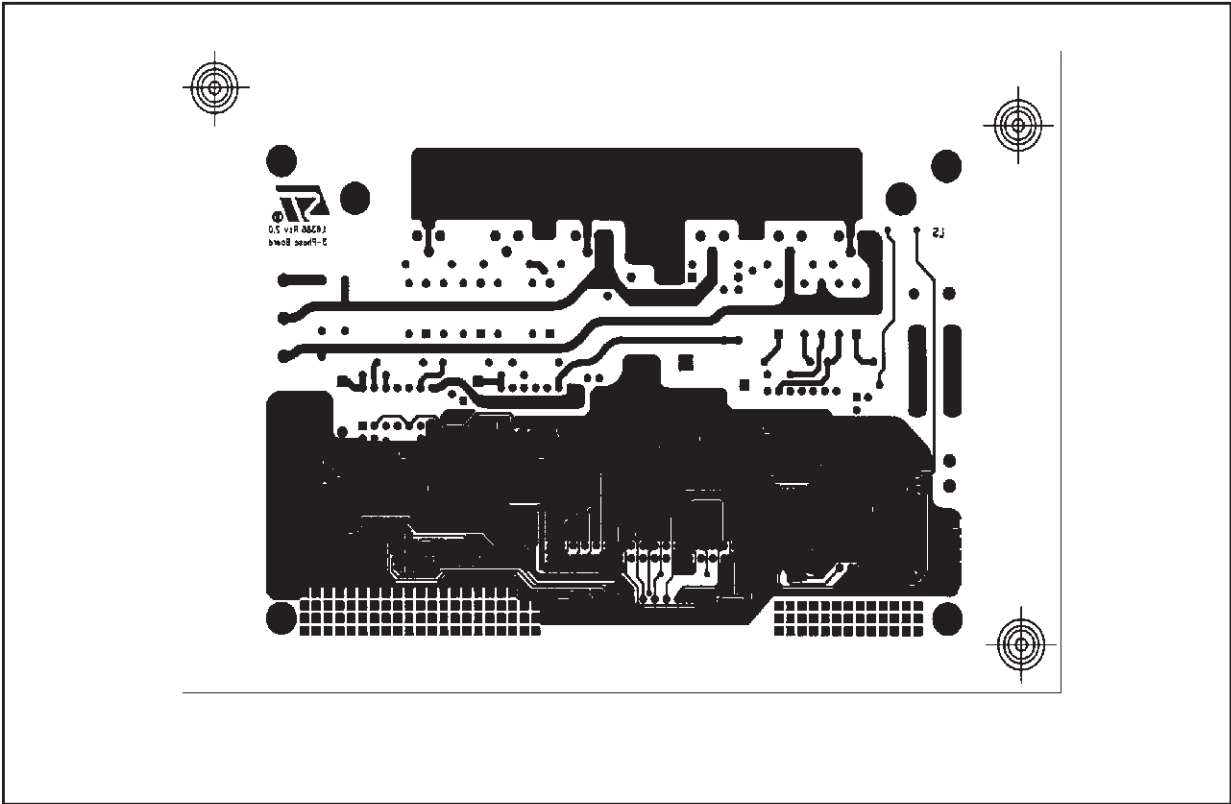


Figure 18.

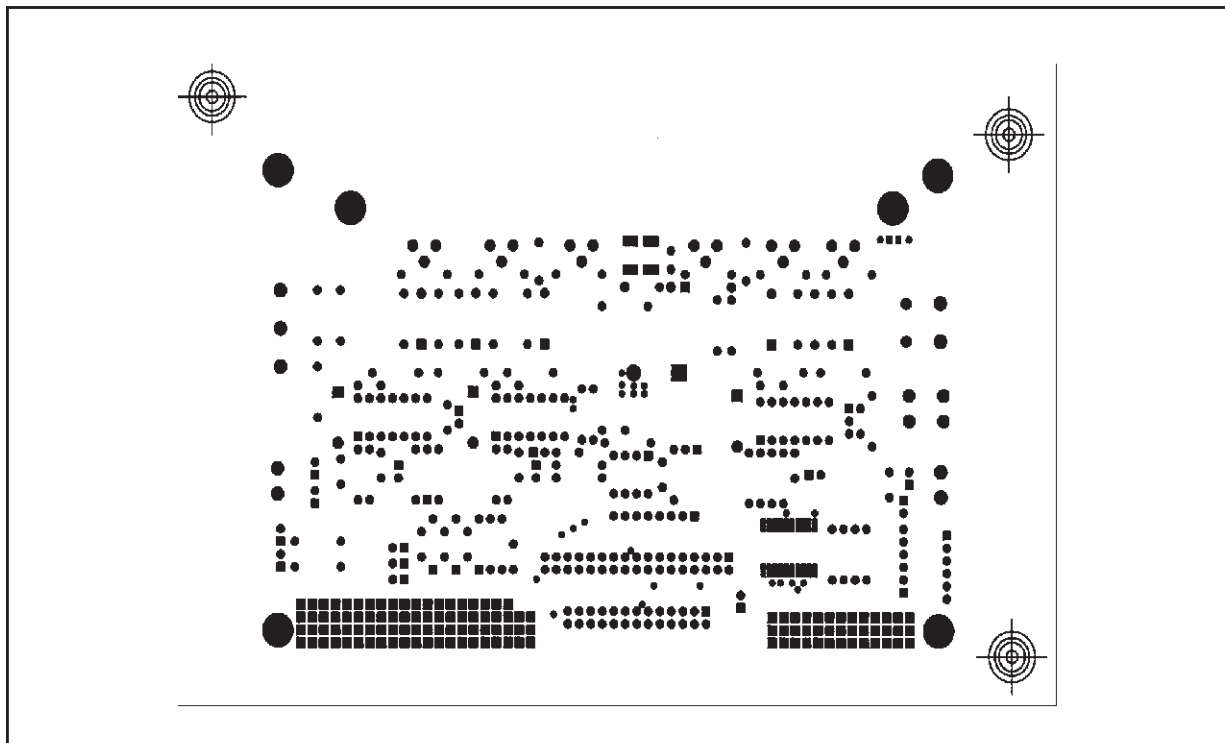


Figure 19.

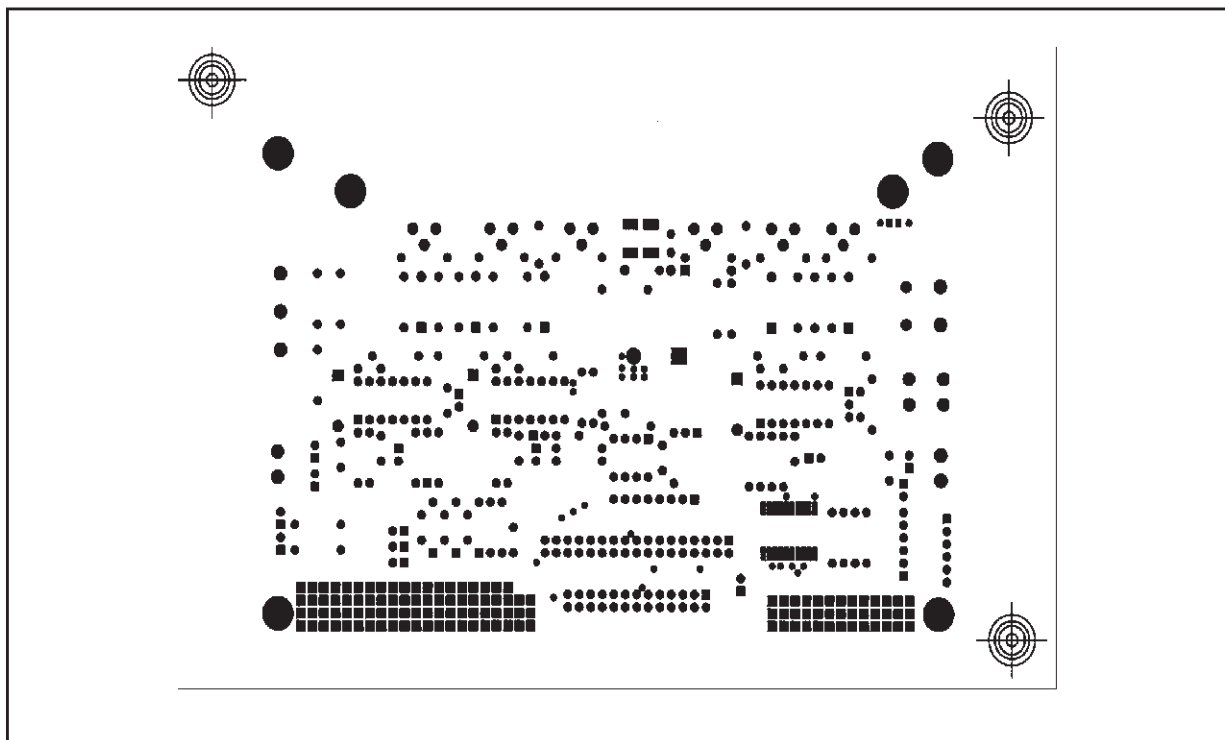
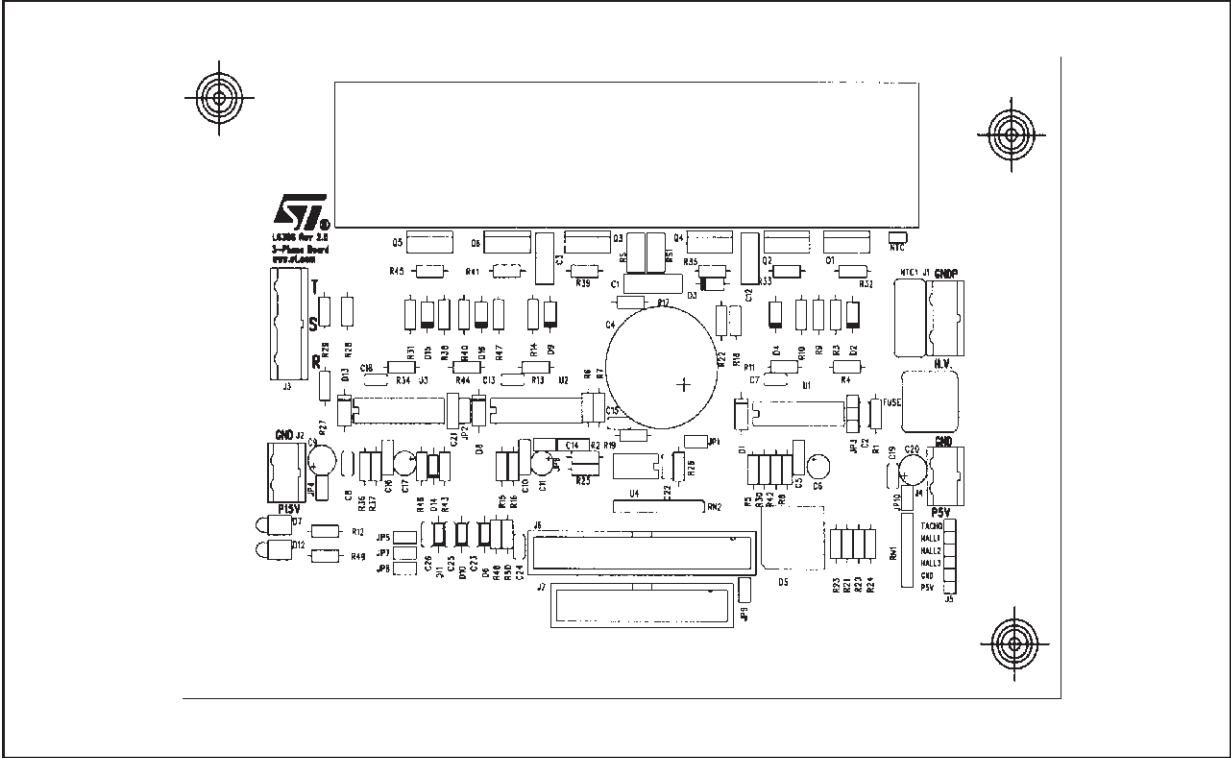


Figure 20.



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