DC 12-24V 30A Three Phase Power Hardware for either PMSM or AC Induction Machines

Literature Number: BPRA071
Texas Instruments Europe
December 1997

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ABSTRACT

Texas Instruments TMS320C24x DSP Controller family is suitable for a wide range of motor drives and power electronics applications. To help the customer with this DSP Controller family and thus to reduce both the development time and the time to market, Texas Instruments offers complete DSP Controller based solutions for driving power applications. As one of these solutions, this report gives details of a 12-24V 30A power board design compatible with the DSP controller control boards.

1. Introduction

This document describes a power electronics board that has been designed as a BLDC drive DSP solution. This solution includes several reports (generic considerations, speed control by means of a sensor and sensorless speed control) and a power hardware. This hardware should be supplied with 12-24V and provides up to 30A. It includes only the power part and is fully compatible with the Portescap control boards based on the TMS320F240 DSP Controller. This report should make it easier to design the power board in a customer’s dedicated application.

2. Hardware Presentation

This two layer power electronics hardware design supports a DC supply of 12-24V at up to 30A. The inverter is suitable as an electrical motor supply for three phase Permanent Magnet Synchronous Machines and for three phase Asynchronous Machines. This power board should be interfaced with an 'C24x DSP Controller based control Board (either EVM board or one of the two Portescap boards (referenced as MCK240 or IMM240). The following chapters describe with the power board schematics and features, with the component implementation and the complete list of material.

2.1 The Electrical Schematics

The figure below shows the electrical schematics of the power board. This board includes several different modules: a reverse polarity protector, an input DC current surge suppressor, a DC link capacitor, a regulated 12V power supply, a three phase MOSFET inverter, a gate driver and an over-current protector.

The feedback interface senses not only the DC bus current and voltage but also the three half-bridge voltages. This is realized by means of non-insulated shunt resistor or resistor bridges. A dedicated connector handles the Hall effect sensors or Incremental encoder outputs. This connector provides not only the sensor power supply but also the necessary pull-up resistors.

As a command interface, seven PWM signals (six PWM signals dedicated to the three phase inverter and one dedicated to the Brake feature) and three control lines (Gate driver ShutDown, Fault and Clearfault) are available.

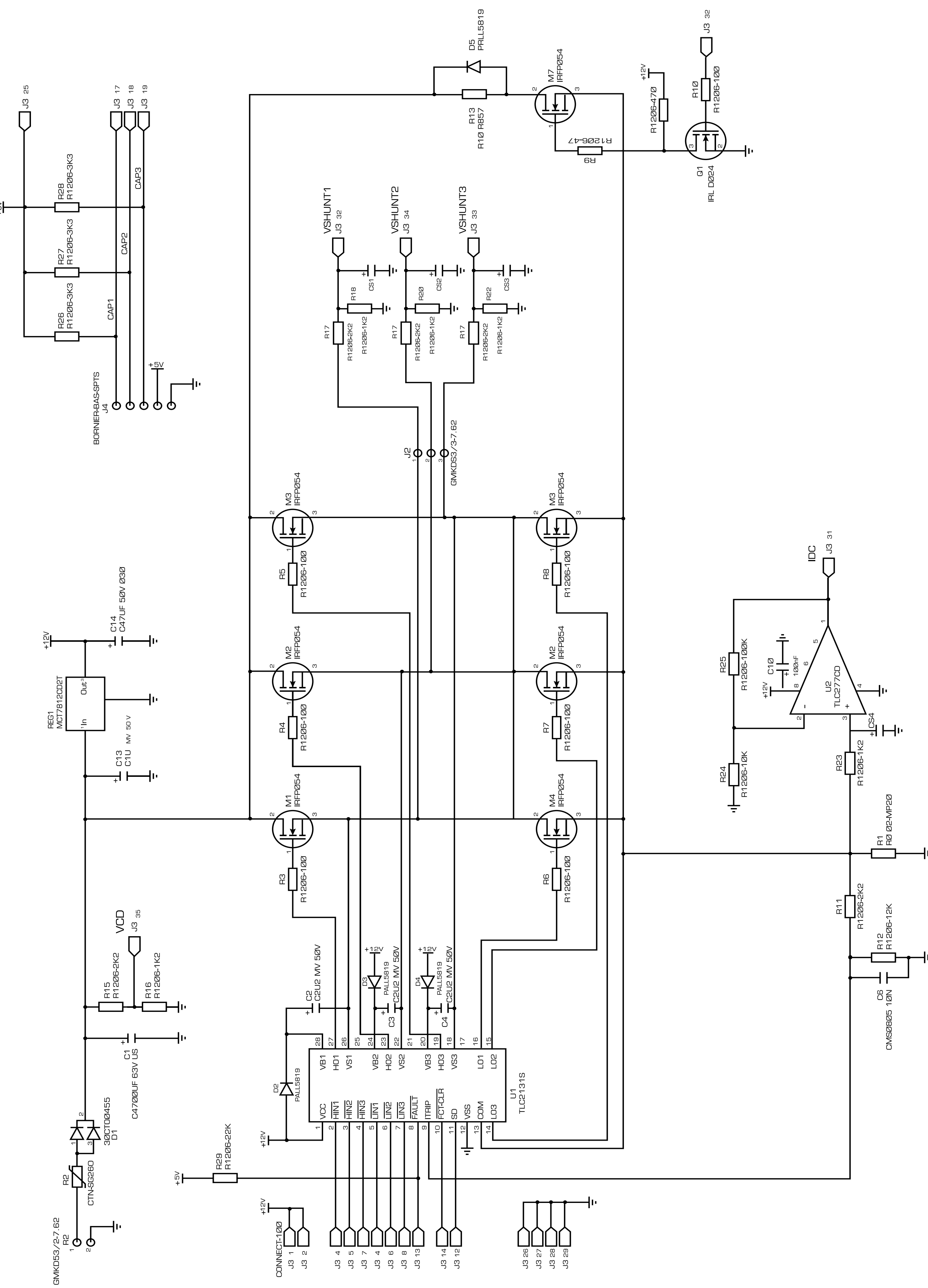
VSHUNT1
VSHUNT2
VSHUNT3
IDC
VCD
IRFP054
U1
TLC2131S
U2
TLC277CD
REG1
MC7812CD2T
BORNIER-BAS-SPTS
CONNECT-100

Figure 1: Power Board Electrical Schematics

For the power interface, this board provides a 30A, 12-24V DC connector and a three slot connector for wiring to the motor phases.

2.2 Component Implementation

The figure below gives the component layout. Every power dissipating component (M1-M7 and R1) is screwed on the heat sink while all other components are mounted directly on the PCB.

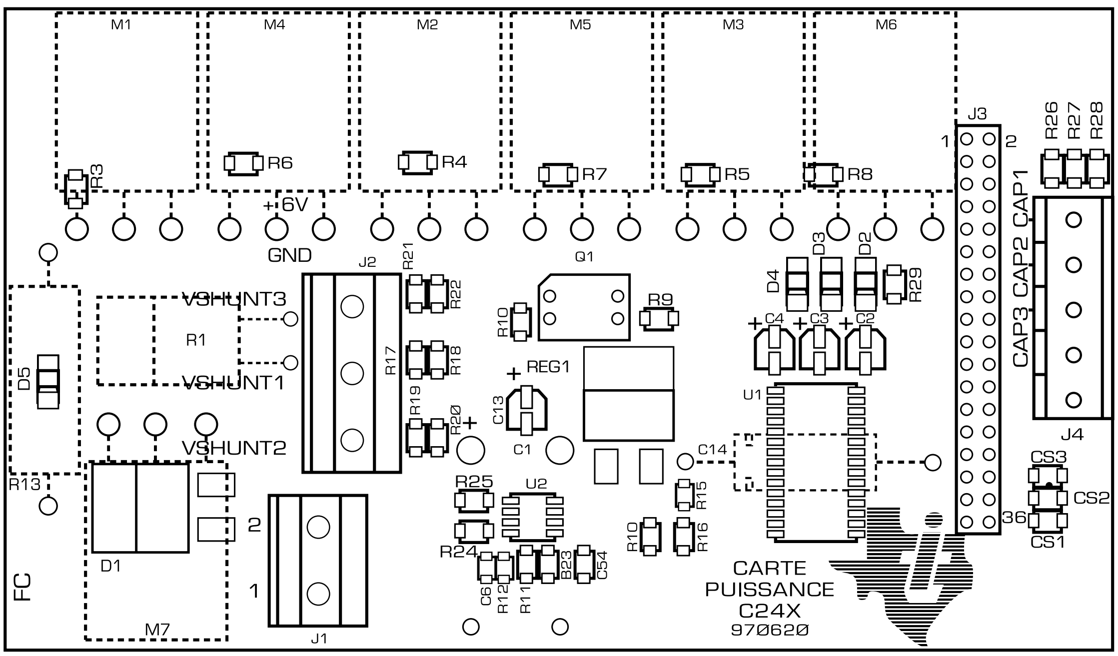

Figure 2: Components Implementation

2.3 Bill of Material

The complete list of required material is as follows.

Table 1: Bill of Material

REF	QTY	DESCRIPTION	SUPPLIER
	1	PRINTED CIRCUIT	
C1	1	CAPACITOR ELECTRO SERIE US 4700uF 63V	
C2-4	3	CAPACITOR ALU CMS 2,2uF serie MV 50V	
C13	1	CAPACITOR ALU CMS 1µF serie MV 50V	
C14	1	CAPACITOR AX. 47uF 50V Serie 030	
C6	1	CAPACITOR CMS0805 10nF	
C10	1	CAPACITOR CMS1206 100nF	
CS1 à CS4	4	CAPACITOR CMS 1206 (Not mounted)	
D1	1	DIODE SCHOTTKY 30A 60V 30CTQ060S	
D2-5	4	DIODE PRLL5819	PHILIPS
J1	1	CONNECTOR GMKDS3/2 au pas de 7.62	PHOENIX
J2	1	CONNECTOR GMKDS3/3 au pas de 7.62	PHOENIX
J4	1	CONNECTOR LOW PROFIL Type Standard 3 points	CAMDEM
M1-7	7	MOSFET 60V CANAL N IRFP054	IR
Q1	1	MOSFET 60V CANAL N IRLD024	IR
R1	1	RESISTOR 20W MP820 20mΩ	C.HADDOCK
R2	1	CTN SG260 30A	RHOPOINT
R3-8 , R10	7	RESISTOR CMS1206 100Ω	
R9	1	RESISTOR CMS1206 47Ω	
R11,R15	2	RESISTOR CMS1206 2.2KΩ	
R17,R19,			
R21	3	RESISTOR CMS1206 3,3KΩ	
R12	1	RESISTOR CMS1206 12KΩ	
R13	1	RESISTOR RB57 10Ω 5% 6W	WELWYN
R16 , R18	5	RESISTOR CMS1206 1.2KΩ	
R20 , R22-23			
R24	1	RESISTOR CMS1206 10KΩ	
R25	1	RESISTOR CMS1206 100KΩ	
R26-28	3	RESISTOR CMS1206 3.3KΩ	
R29	1	RESISTOR CMS1206 22KΩ	
REG1	1	REGULATOR u7812KTE 1,5A CMS	TEXAS
U1	1	CIRCUIT IR2131S	
U2	1	AOP TLC277CD	TEXAS

3. Power Board Characteristics

3.1 Power Switches

The six power switches used for the three phase inverter and the power switch which performs the break feature are IRFP054 power MOSFETs from International Rectifier. Their Drain Source breakdown voltage is 60V, the maximum Drain current is 70A (at 25ºC) and their rated On resistor is 14mΩ. The corresponding data sheet can be found on the Internet at the following location:

http://www.irf.com/product-info/datasheets/hexfet.htm

3.2 Power Supplies

The main power supply provides and supports a voltage range of 12-24V and a DC current of up to 30A. In fact, every power component can support a voltage up to 60V. This board could thus be used at voltages higher than 24V but the resistor bridges (used as control feedback) should be resized in order to address the 0-5V maximum 'C24x DSP Controller ADC input range. Make sure, also, that the 12V regulator accepts up to 60V as an input voltage. The power part of this three phase inverter has been designed to support up to 30A. This applies not only to the power components but also the PCB itself and the heat sink dimensions.

In order to minimize the interference between the 20MHz low current section and the high power section running at several tens of kHz, particular attention has been paid to the separation of these two signal types. The low power section (also called the control section) has been laid out in the bottom right hand corner of the board, while the high power part (including both the input power supply and the motor phase connectors) has been designed within the left hand space to minimize the current path loops (from ground via the DC link capacitor, through the power switches, the motor phases and then back to ground).

Another power supply is the 12V regulator. The regulator used on this board is the µA7812KTE from Texas Instruments. The complete data sheet can be found at the following Internet location:

http://www-s.ti.com/cgi-bin/sc/family3.cgi

This 12V regulated output is used to supply the gate driver, the single operational amplifier and the control daughter board. Depending on the daughter board consumption (DSP Controller external memory, serial link supply, CPU and Peripheral load, Digital to Analog Converters) the maximum output current of the regulator can vary between 300 and 500mA. The regulator output capacitor has been oversized to ensure a software low voltage detection and a thus a software handling of the default (gate driver shutdown, output the supply low voltage via the DSP Controller I/O).

Both the main supply and the regulated 12V supply contribute to the following specification for this power board - which does not support any negative voltages.

The last power supply input of the power board is the regulated logical +5V. This voltage is not created on board. It should be supplied via the control connector. As this board has been designed to support the Portescap control boards (both the MCK240 and the IMM240) the +5V supply is obtained from these daughter boards when supplied via the control connector with regulated 12V. On the power board, the 5V power supply is responsible for the gate driver Fault signal pull up and for the position sensor supply. Typically the maximum current requirement on this 5V pin is below 50mA as three Hall effect sensors require less than 45mA and an incremental encoder requires less than 25mA.

3.3 Shunt Resistor

This power board has been designed to support line current measurement. This is achieved by means of a shunt resistor placed between the lower transistor source and the power ground.

This type of current sensing only gives over-current protection. This over-current may be due to either a vertical conduction of the power switches or simply too high a phase current. The over-current protection is activated only in the latter case so line to ground, vertical conduction and phase to phase current faults cannot be detected.

The shunt resistor has been sized so that its voltage drop is equal to 0.5V when the maximum desired current flowing through the shunt is reached. This 0.5V is the threshold to cross before the gate driver integrated over- current protection becomes active. In this configuration the shunt voltage drop range is 0-0.5V. In order to utilize the whole DSP Controller ADC input range, the shunt voltage drop should be amplified. If the ADC unit is supplied with 0-5V then the gain in the current measurement path should be 10. The shunt sizing should be understood as a compromise between current measurement precision (the higher the shunt value the better the precision) and power dissipation (Joule losses).

Depending on the desired current rating, the shunt resistor can be sized differently. As precise current measurement might be wanted and as the shunt might not continuously see the phase current, a fast and precise - and single voltage - operational amplifier should be chosen. The device selected in this application is the TLC277CD. The data sheet can be found at the following Internet location:

http://www.ti.com/sc/docs/psheets/abstract/datasht/slos091b.htm

3.4 Control Connector Characteristics

The feedback and command signal voltage range is 0-5V. These signals can be either TTL logic or analog voltages. Regarding the ADC inputs, they should be within the ADC supply range. This can be ensured either with clamp diodes placed between ground and conversion line and between conversion line and ADC supply or, of course, by correctly sizing the resistor bridges on the conversion line. In this application, where the maximum output voltage is 18V, the resistor bridge is made of 3.3kΩ and 1.2kΩ resistors. The maximum ADC input current is 2.5mA.

The PWM, Fault, Clearfault and Shutdown signals require 0.2mA at high level and less than 0.06mA at low level. When interfaced with the Portescap control boards this power does not require any buffering (or conditioning) of the gate drive input signals.

4. Mechanical Constraints and Interfaces

This chapter describes the mechanical requirements to use this 12-24V 30A power board in another application.

4.1 Mechanical Constraints

This chapter presents the different mechanical aspects of the power board. It deals with the available connectors and with the board mechanical data.

The board volume is L*l*h = 124.49in * 74.9in * 65in. Viewed from the top the mechanical connector constraints are as depicted below (dimension given in mm):

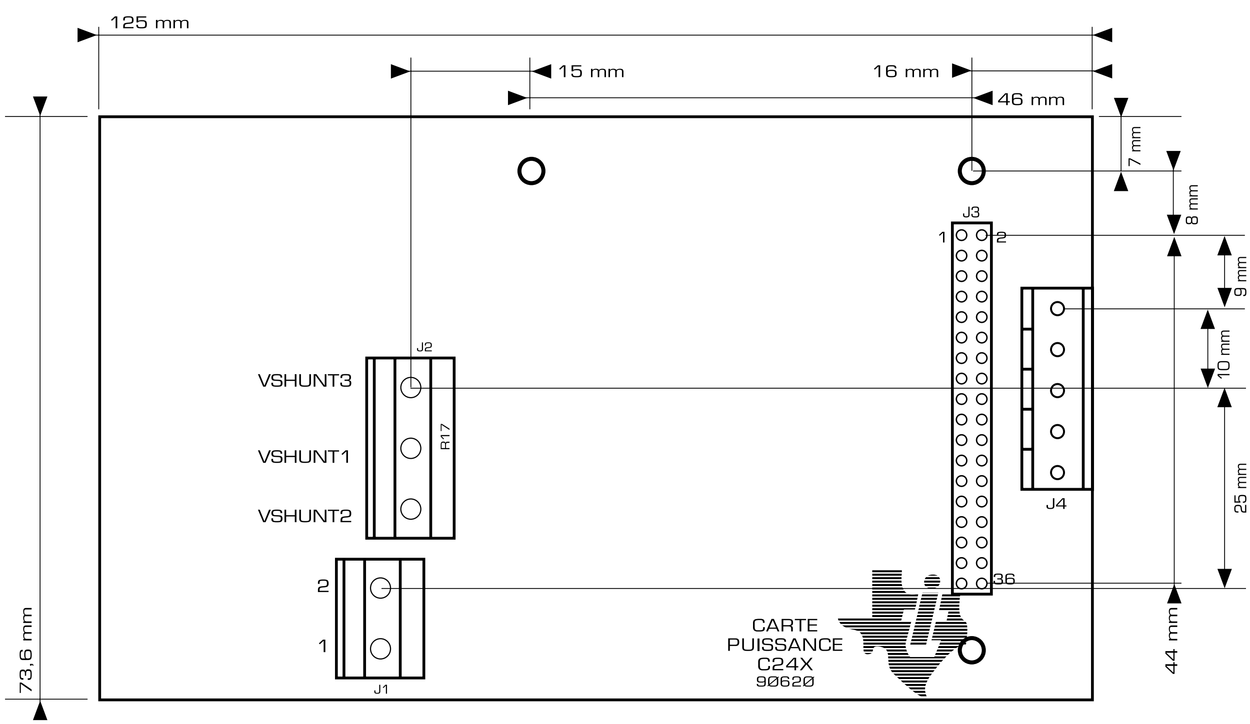

Figure 3: Power Board Upside Mechanical Data

The following figures show how the power components are mounted on the heat sink, how the heat sink is screwed to the board and the heat sink mechanical data.

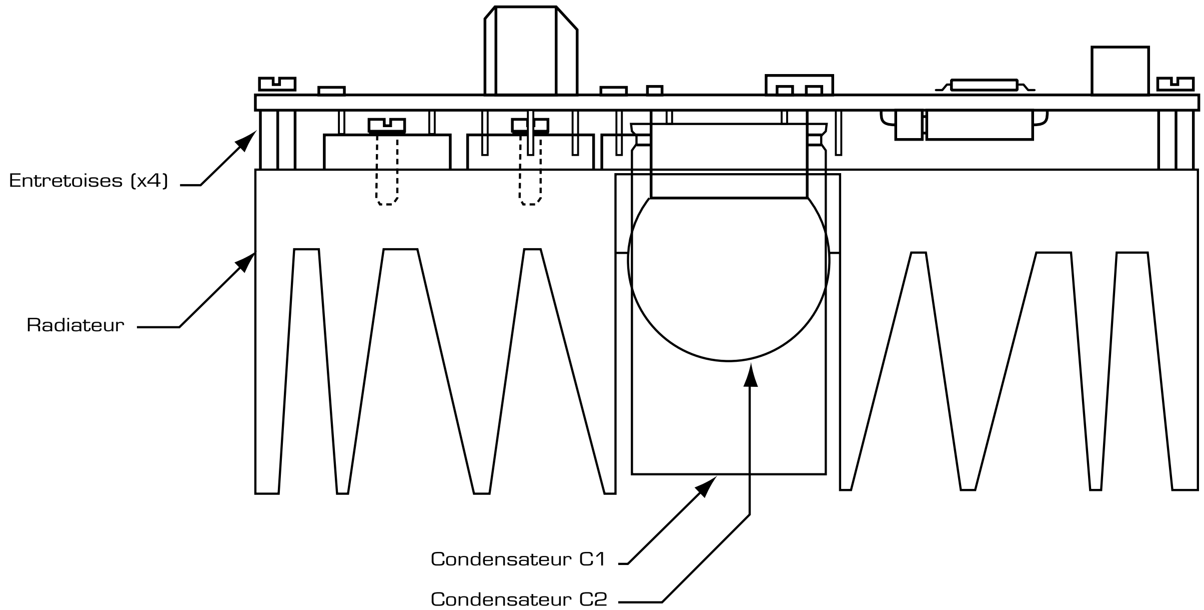

Figure 4: Lateral View of the Power Board Mounting

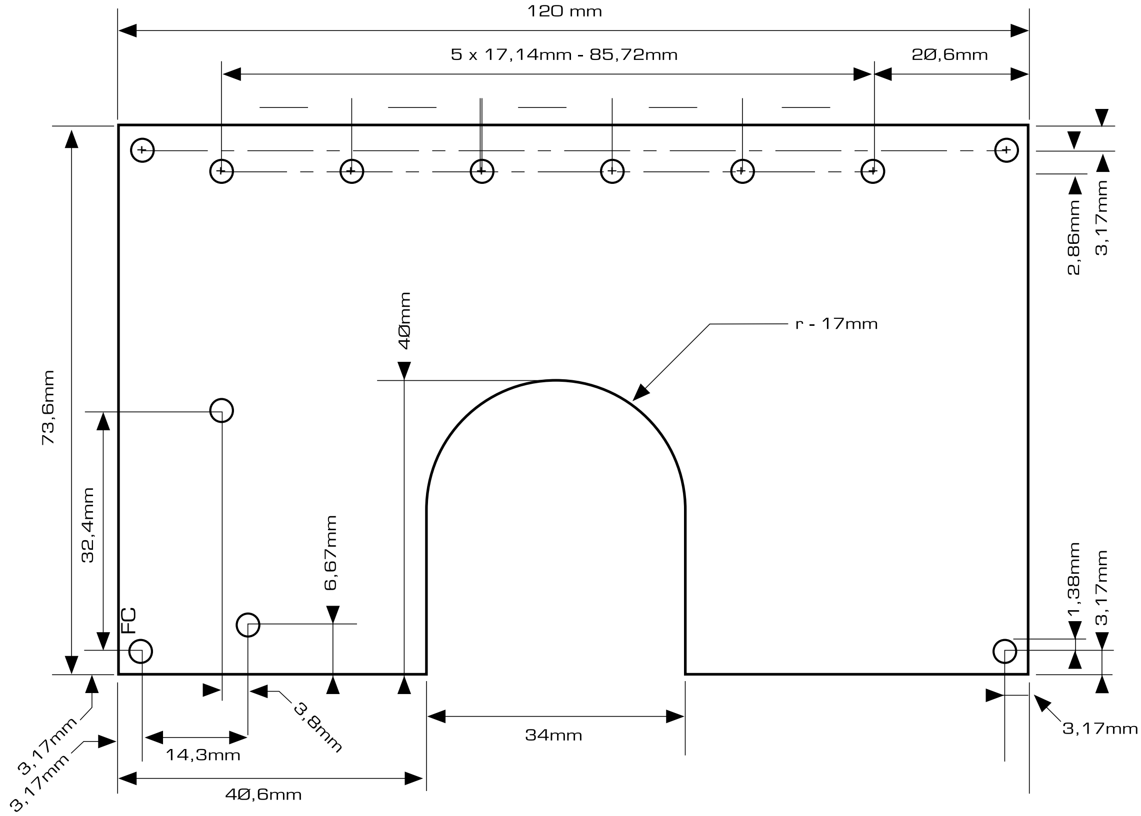

Figure 5: Heat Sink Mechanical Data

4.2 Power Board Interface

This power board has been designed to support either the MCK240 or the IMM240 control boards from Portescap. These boards are based on the 'C24x DSP Controller family and offer on their connectors all the necessary signals to control an electrical motor. One of the connectors (J3) delivers all the basic signals required for interfacing. This connector is then the interface between these control boards and the power electronics board shown here. The connector pin assignment is given in the table below.

Table 2: Power board Control Board Interface Connector Pining

J3 CONNECTOR PIN NO	TMS320F240 PIN NAME	POWER BOARD SIGNAL	ELECTRICAL CHARACTERISTICS
1		+12 V	max current 500mA
2		+12V	max current 500mA
3	CMP1/PWM1 (94)	HIN1	TTL Logic
4	CMP2/PWM2 (95)	LIN1	TTL Logic
5	CMP3/PWM3 (96)	HIN2	TTL Logic
6	CMP4/PWM4 (97)	LIN2	TTL Logic
7	CMP5/PWM5 (98)	HIN3	TTL Logic
8	CMP6/PWM6 (99)	LIN3	TTL Logic
9	CMP7/PWM7/IOPB0 (100)		
10	CMP8/PWM8/IOPB1 (101)		
11	CMP9/PWM9/IOPB2 (102)	Brake	TTL Logic
12	T1CMP/T1PWM/IOPB3 (103)	Shutdown	TTL Logic
13	T2CMP/T2PWM/IOPB4 (105)	Fault	TTL Logic
14	T3CMP/T3PWM/IOPB5 (106)	Clear Fault	TTL Logic
15	TMRDIR/IOPB6 (108)		
16	TMRCLK/IOPB7 (109)		
17	CAP1/QEP1/IOPC4 (67)	CAP1	TTL Logic
18	CAP2/QEP2/IOPC5 (68)	CAP2	TTL Logic
19	CAP3/IOPC6 (69)	CAP3	TTL Logic
20	CAP4/IOPC7 (70)		
21	PDPINT (52)		
22	XINT2/IO (54)		
23	SCIRXD/IO (43)		
24	SCITX/IO (44)		
25	VCC	+5V	
26	VSS	Digital Ground	Power GND connected
27	Power GND	12V supply ground	Digital GND connected
28	Power GND	12V supply ground	
29	VSSA (87)		
30	VREFLO (86)		
31	ADCIN05 (77)	Idc	0-5V, 5mA input range
32	ADCIN13 (82)	Vshunt1	0-5V, 5mA input range
33	ADCIN06 (78)	Vshunt3	0-5V, 5mA input range
34	ADCIN14 (81)	Vshunt2	0-5V, 5mA input range
35	ADCIN07 (79)	Vdc	0-5V, 5mA input range
36	ADCIN15 (80)		

Table 3: Main Power Supply Connector

J1 CONNECTOR PIN NO	POWERBOARD SIGNAL	ELECTRICAL CHARACTERISTICS
1	Power Supply	12-24V 30A
2	Power GND	

Table 4: Motor Phase Supply Connector

J2 CONNECTOR PIN NO	POWER BOARD SIGNAL	ELECTRICAL CHARACTERISTICS
1	Vshunt3	12-24V 30A
2	Vshunt1	12-24V 30A
3	Vshunt2	12-24V 30A

Table 5: Position Sensor Connector

J4 CONNECTOR PIN NO	POWER BOARD SIGNAL	ELECTRICAL CHARACTERISTICS
1	Cap1	30mA
2	Cap2	30mA
3	Cap3	30mA
4	+5V	150mA
5	Digital GND	150mA

References

1. TMS320C24x DSP Controllers - Reference Set: Vol.1, Texas Instruments Inc, 1997.

2. TMS320C24x DSP Controllers - Reference Set: Vol.2 Texas Instruments Inc, 1997.

3. Digital Signal Processor Solutions for BLDC motor, Application Report Texas Instruments part #BPRA055.

4. Implementation of a Speed Controlled Brushless DC Drive using TMS320F240, Application Report Texas Instruments part # BPRA064.

5. Implementation of a Sensorless Speed Controlled BLDC Drive using TMS320F240. Application Report Texas Instruments part # BPRA072