DSP Development Board

User's Manual

POWERSIM INC.

DSP Development Board User's Manual

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Chapter 1 - Introduction

Powersim's universal DSP Development Board (DSP board) is designed for product development of power electronics and motor drives that uses TI's C28xxx series DSPs. The DSP board contains all necessary filtering and signal conditioning circuits for digital power supplies, motor control, and other power conversion applications.

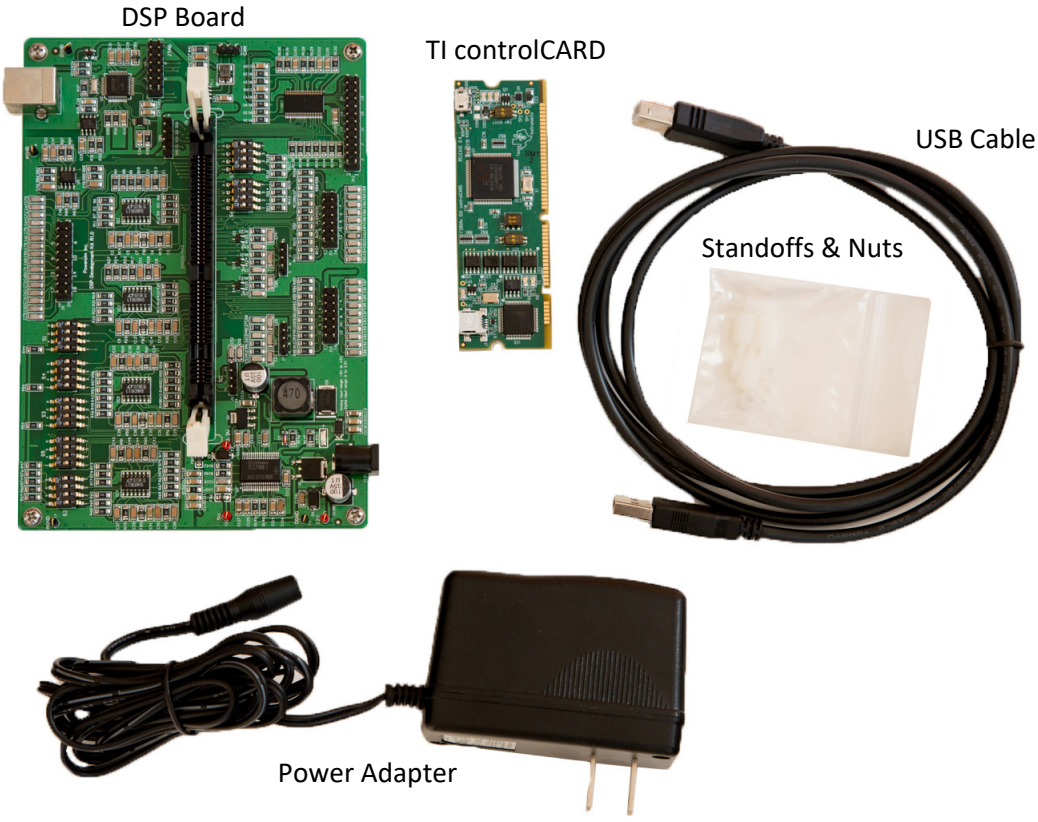
This manual describes the functions of the board, and how to use it.

1.1 What's Included

A DSP board package includes the following items:

- DSP control board
- One of the TI F28335/F28035/F28069/F28069M/F28027 controlCARD
- 12-Vdc power adapter
- USB cable
- 4 sets of standoffs and nuts
- This User Manual (in PDF file)

The picture below shows the items included in the package:



1.2 Applications

The DSP control board is designed for digital control of power converters for various applications, such as digital power supplies, uninterruptible power supplies (UPS), motor drives (including induction motor, PMSM, BLDC, and switched reluctance motor), and other power conversion applications such as utility interface of various energy sources (fuel cell, photovoltaic, turbine-generator, etc.), and power quality control devices.

1.3 Functional Overview

Figure 1 shows pictures of the DSP board. The top picture shows the angle view of the board with the controlCARD. The bottom picture shows the top view with key parts and connectors identified.

Key features of the DSP board are:

- Plug-N-Play universal TI C28xxx family DSP controlCARD interface
- 3-phase voltage sensing circuit with filtering and signal conditioning
- 3-phase current sensing circuit with filtering and signal conditioning
- 10 ADC sensing circuit with filtering and signal conditioning
- PWM signals level shifting for direct IGBT gate driver chip interface
- General-purpose digital I/O
- System communications with CAN, RS-232, and USB
- On-Board DSP emulator for TI C2000 family
- On-Board +12V to +5V and +3.3V power supplies
- Direct interface with the PSIM software

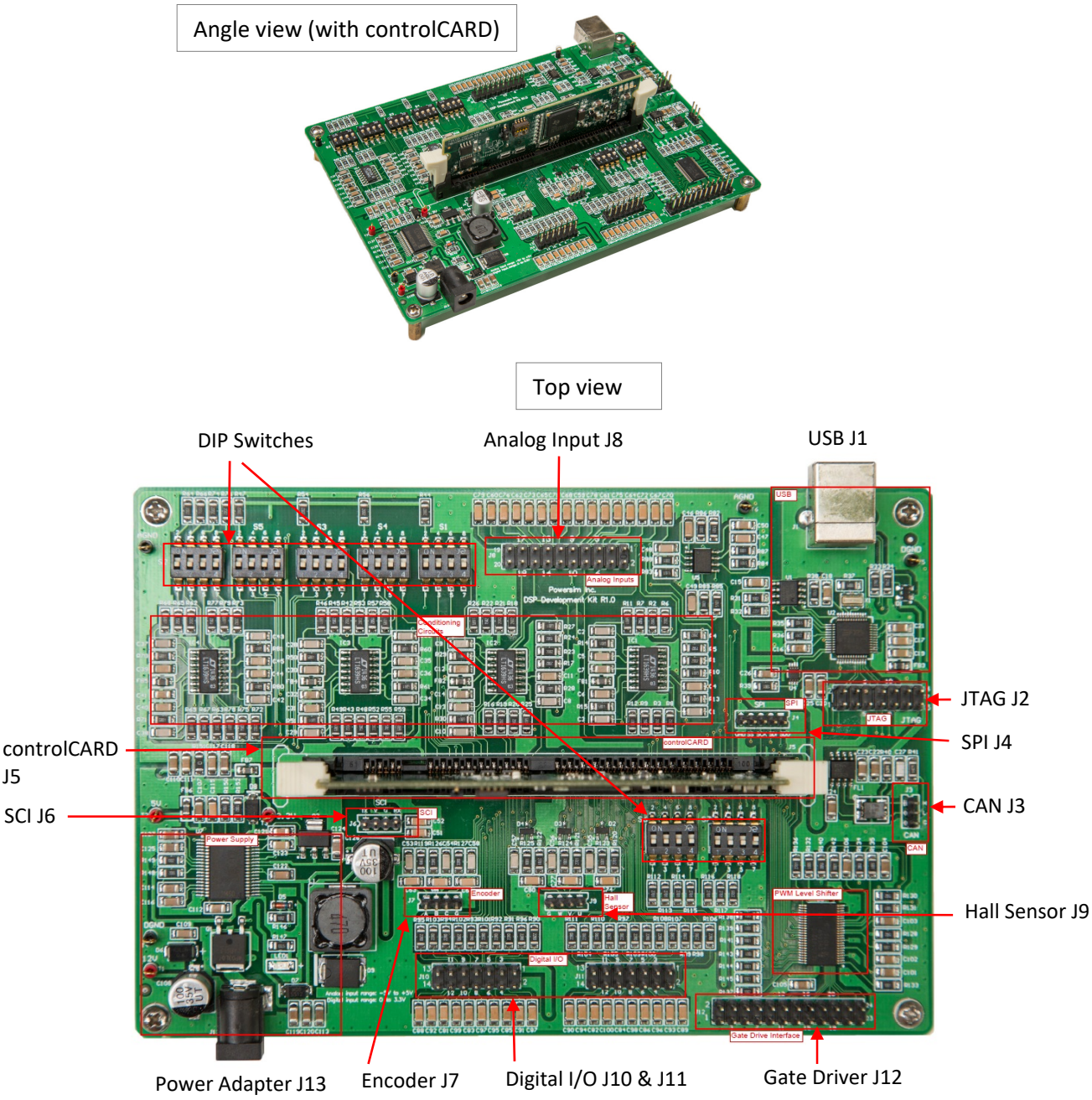


Fig. 1: DSP control board diagram

1.4 Power Supplies

The DSP controlCARD and DSP control board is supplied with an external 12V dc power supply from the power adapter J13. The board uses Infineon TLE7368E power supply IC to convert +12V input power to +5V and +3.3V for all analog and digital circuits in controlCARD and DSP board.

Furthermore, a +5V power (analog) is provided through the analog input connector J8 to power external circuits (i.e. current sensor). Also, a +12V power is provided through Pin 1 and 5 of the

gate drive interface connector J12 so that the gate driver board (not included) can generate isolated gate drive power supplies.

1.5 DIP Switches

The DSP board has 7 DIP switches: S1, S2, S3, S4, S5, S6, and S7. These DIP switches provide the ability to configure the DSP board for various applications.

Table 1 summarizes the function of each DIP switch. Each entry in the table gives the DIP switch name, pin number, position, and the resulting function when it is in a given position. Use this table as a reference when configuring the DIP switches.

Switch	Pin	Position	Input	Description
S1	1	on	AC	When AD_A6in = 5*sin(ωt), AD_A6 = 1.5+1.5*sin(ωt)
		off	DC	When AD_A6in = 3.5+3.5*sin(ωt), AD_A6 = 1.5+1.5*sin(ωt)
	2, 3, 4	2, 3 on 4 off	AC	When AD_A4in = 5*sin(ωt), AD_A4 = 1.5+1.5*sin(ωt)
		2, 3 off 4 on	DC	AD_A4 = AD_A4in
S2	1	on	AC	When Iain = 5*sin(ωt), Ia = 1.5+1.5*sin(ωt)
		off	DC	When Iain = 3.5+3.5*sin(ωt), Ia = 1.5+1.5*sin(ωt)
	2	on	AC	When Ibin = 5*sin(ωt), Ib = 1.5+1.5*sin(ωt)
		off	DC	When Ibin = 3.5+3.5*sin(ωt), Ib = 1.5+1.5*sin(ωt)
	3	on	AC	When Icin = 5*sin(ωt), Ic = 1.5+1.5*sin(ωt)
		off	DC	When Icin = 3.5+3.5*sin(ωt), Ic = 1.5+1.5*sin(ωt)
	4	on	AC	When Idcin = 5*sin(ωt), Idc = 1.5+1.5*sin(ωt)
		off	DC	When Idcin = 3.5+3.5*sin(ωt), Idc = 1.5+1.5*sin(ωt)
S3	1	on	AC	When AD_A2in = 5*sin(ωt), AD_A2 = 1.5+1.5*sin(ωt)
		off	DC	When AD_A2in = 1.5+1.5*sin(ωt), AD_A2 = 1.5+1.5*sin(ωt)
	2, 3, 4	2, 3 on 4 off	AC	When AD_A2in = 5*sin(ωt), AD_A2 = 1.5+1.5*sin(ωt)
		2, 3 off 4 on	DC	AD_A2 = AD_A2in
S4	1	on	AC	When AD_B4in = 5*sin(ωt), AD_B4 = 1.5+1.5*sin(ωt)
		off	DC	When AD_B4in = 1.5+1.5*sin(ωt), AD_ B4 = 1.5+1.5*sin(ωt)
	2, 3, 4	2, 3 on 4 off	AC	When AD_B4in = 5*sin(ωt), AD_ B4 = 1.5+1.5*sin(ωt)
		2 ,3 off 4 on	DC	AD_B4 = AD_B4in
S5	1	on	AC	When AD_B2in = 5*sin(ωt), AD_ B2 = 1.5+1.5*sin(ωt)
		off	DC	When AD_B2in = 1.5+1.5*sin(ωt), AD_ B2 = 1.5+1.5*sin(ωt)
	2, 3, 4	2 3 on 4 off	AC	When AD_B2in = 5*sin(ωt), AD_ B2 = 1.5+1.5*sin(ωt)
		2, 3 off 4 on	DC	AD_B2 = AD_B2in
S6	1	on		Boot for F2833x
		off		GPIO 87

	2	on		Boot for F2833x
		off		GPIO 86
	3	on		Boot for F2833x
		off		GPIO 85
	4	on		Boot for F2833x
		off		GPIO 84
S7	1	on		Boot for F280xx
		off		GPIO 34
	2	on		Boot for F280xx
		off		GPIO 29
	3	on		Boot for F280xx
		off		GPIO 18
	4	on		Using USB connector J1 for serial communication
		off		Using SCI connector J6 for serial communication

Table 1: DSP board DIP switches

The figure below shows the circuit of the DIP switches S6 and S7.

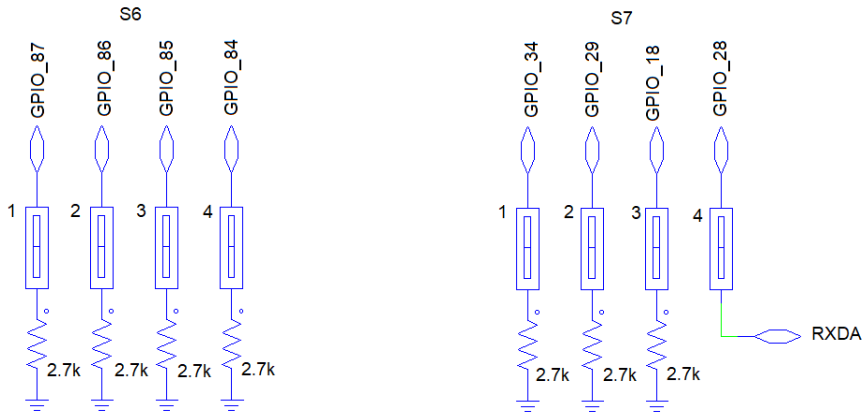


Fig. 2: DIP switches S6 and S7

For further details on how other DIP switches are connected in the circuit, refer to Chapter 2.

Chapter 2 – Analog Input Interface

2.1 Analog Connector J8

The analog input connector J8 provides interface to all analog inputs: power supply to the sensors (VA50), 3-phase voltages (Vain, Vbin, Vcin), dc voltage (Vdcin), 3-phase currents (Iain, Ibin, Icin), dc current (Idcin), 8 general-purpose ADC inputs (AD_A2in, AD_A4in, AD_A6in, AD_A7in, AD_B2in, AD_B4in, AD_B6in, AD_B7in).

Figure 3 and Table 2 show the pin assignment of the connector J8.

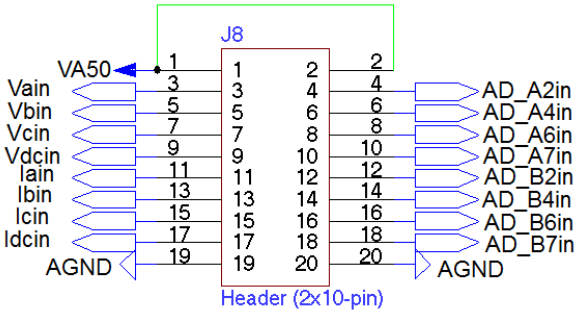


Fig. 3: Analog Connector J8

Pin Number	Pin Name	Type	Description
1	VA50	Supply	+5.0V analog power supply
2	VA50	Supply	+5.0V analog power supply
3	Vain	Analog Input	AC voltage Phase A (range: +/-5V)
4	AD_A2in	Analog Input	Genera- purpose ADC input (range: +/-5V, 0/+7V, or 0/+3V depending on the DIP switch position)
5	Vbin	Analog Input	AC voltage Phase B (range: +/-5V)
6	AD_A4in	Analog Input	General-purpose ADC input (range: +/-5V, 0/+7V, or 0/+3V depending on the DIP switch position)
7	Vcin	Analog Input	AC voltage Phase C (range: +/-5V)
8	AD_A6in	Analog Input	General-purpose ADC input (range: +/-5V or 0/+7V depending on the DIP switch position)
9	Vdcin	Analog Input	DC voltage (range: 0/+3V)
10	AD_A7in	Analog Input	General-purpose ADC input (range: 0/+3V)
11	Iain	Analog Input	AC current Phase A (range: +/-5V or 0/+7V depending on the DIP switch position)
12	AD_B2in	Analog Input	General-purpose ADC input (range: +/-5V, 0/+7V, or 0/+3V depending on the DIP switch position)
13	Ibin	Analog Input	AC current Phase B (range: +/-5V or 0/+7V depending on the DIP switch position)
14	AD_B4in	Analog Input	General-purpose ADC input (range: +/-5V, 0/+7V, or 0/+3V depending on the DIP switch position)
15	Icin	Analog Input	AC current Phase C (range: +/-5V or 0/+7V depending on the DIP switch position)
16	AD_B6in	Analog Input	General-purpose ADC input (range: +/-5V)

17	Idcin	Analog Input	DC current (range: +/-5V or 0/+7V depending on the DIP switch position)
18	AD_B7in	Analog Input	General-purpose ADC input (range: +/-5V)
19	AGND	Supply	Analog ground
20	AGND	Supply	Analog ground

Table 2: Analog Input Connector Pin Assignment

The DSP board has four types of interface circuits for ADC channels:

- AC voltages
- Currents
- General voltage/currents
- DC voltages

They are described in the sections below.

2.2 AC Voltage Interface Circuit

The ac voltage interface circuit is for ac voltage sensing ADCs (Va, Vb, Vc, AD_B6, AD_B7). The amplitudes of the input signals of the interface circuit (Vain, Vbin, Vcin, AD_B6in, AD_B7in) must be in the range of +/-5V.

Figure 4 shows the ac voltage analog interface circuit. It shifts an input signal from +/-5V to 0/+3V (for example, from Vain=5*sin(ωt) to Va=1.5+1.5*sin(ωt)), and then feeds it to DSP ADC. This circuit also has a 2nd-order filter with a cut-off frequency of 3kHz.

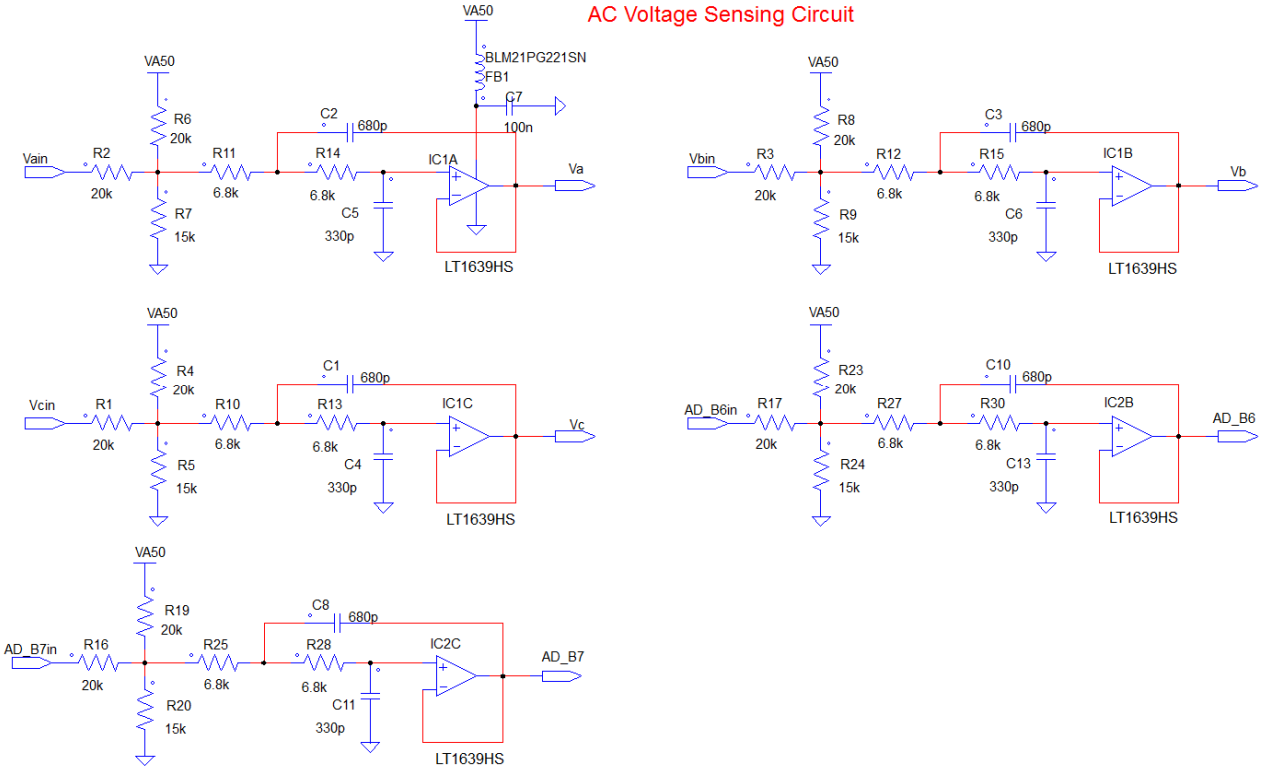


Fig. 4: AC voltage interface circuit

2.3 Current Interface Circuit

The current analog interface circuit is for current sensing ADCs (Ia, Ib, Ic, Idc, AD_A6). The amplitudes of the input signals of the interface circuit (Iain, Ibin, Icin, Idcin, AD_A6in) must be in the range of +/-5V when it is ac or 0/+7V when it is dc.

Figure 5 shows the current analog interface circuit.

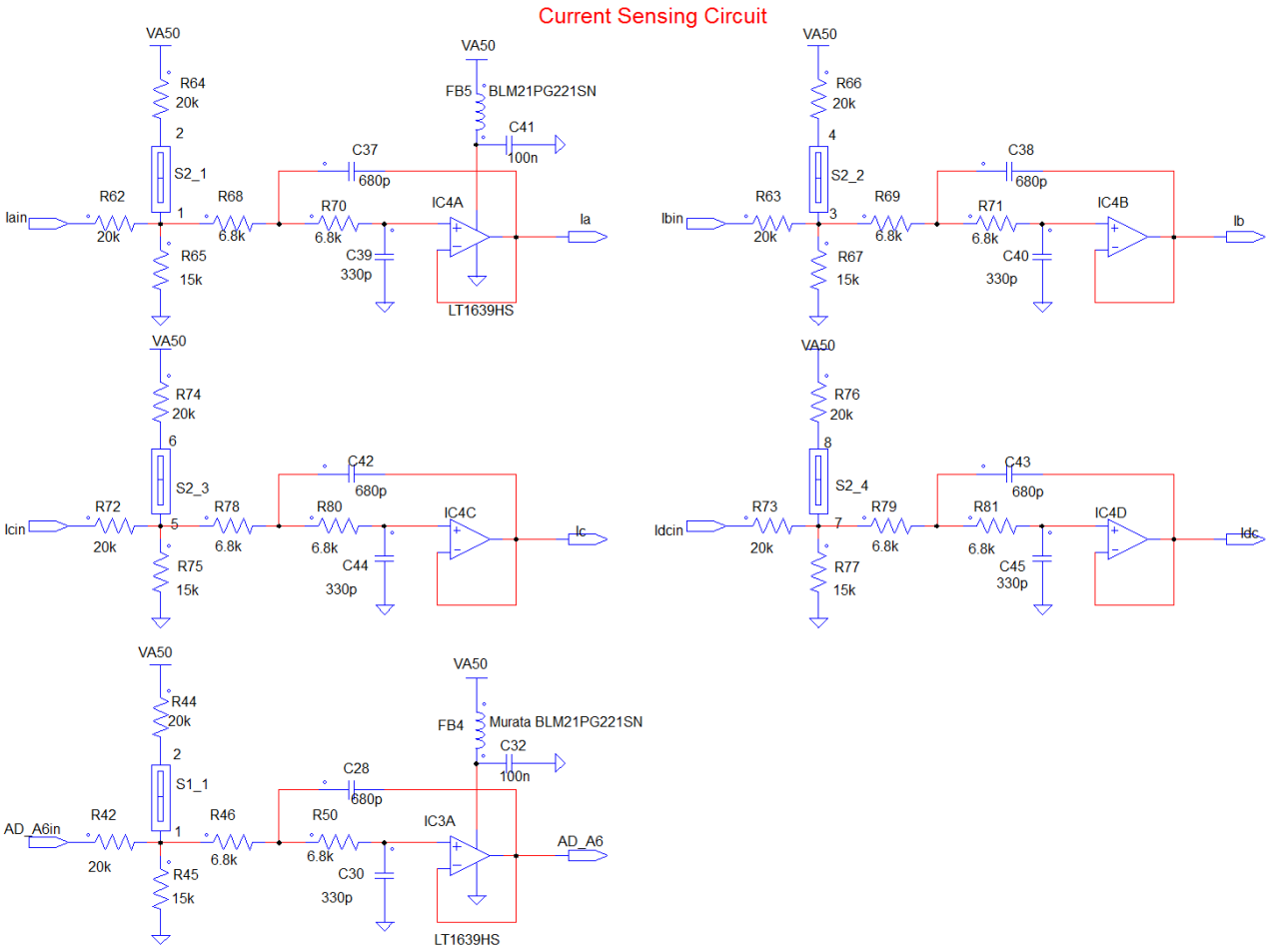


Fig. 5: AC/dc current interface circuit

When input signals are +/-5V, the switch S2_1 (or S2_2, S2_3, S2_4, S1_1) must be in the **ON** position. The interface circuit will shift the input signal from +/-5V to 0/+3V (for example, from Iain=5*sin(ωt) to Ia=1.5+1.5*sin(ωt)) before feeding it to DSP ADC.

When input signals are 0/+7V, the switch S2_1 (or S2_2, S2_3, S2_4, S1_1) must be in the **OFF** position. The interface circuit will shift the input signal from 0/+7V to 0/+3V (for example, from Iain=3.5+3.5*sin(ωt) to Ia=1.5+1.5*sin(ωt)) before feeding it to DSP ADC.

This circuit has a 2nd-order filter with a cut-off frequency of 3kHz.

2.4 Voltage/Current Interface Circuit

The voltage/current analog interface circuit is for voltage and/or current sensing ADCs (AD_B2, AD_B4, AD_A2, AD_A4). The amplitudes of the input signals of the interface circuit (AD_B2in, AD_B4in, AD_A2in, AD_A4in) must be in the range of +/-5V for ac signals, or 0/+7V or 0/+3V for dc signals.

The figure below shows the voltage/current analog interface circuit.

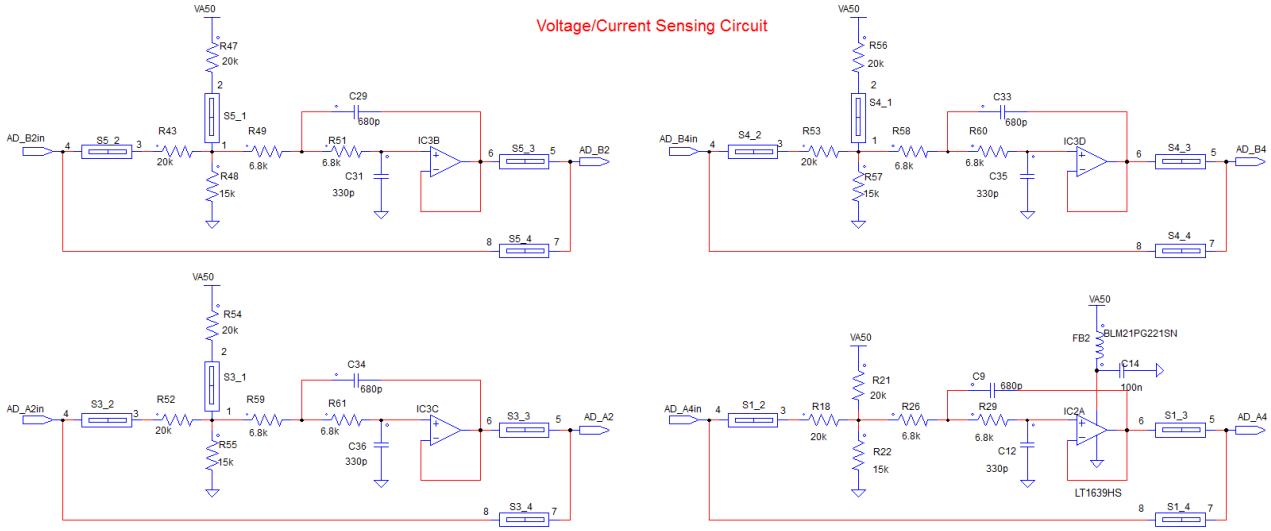


Fig. 6: Voltage/current sense type interface circuit

When the input signals AD_B2in, AD_B4in, AD_A2in, and AD_A4in are +/-5V, the DIP switch positions must be set as follows:

S5_1, S5_2, S5_3:	ON
S5_4:	OFF
S4_1, S4_2, S4_3:	ON
S4_4:	OFF
S3_1, S3_2, S3_3:	ON
S3_4:	OFF
S1_2, S1_3:	ON
S1_4:	OFF

The interface circuit will shift the input signal from +/-5V to 0/+3V (for example, from 5*sin(ωt) to 1.5+1.5*sin(ωt)) before feeding it to DSP ADC.

When the input signals AD_B2in, AD_B4in, and AD_A2in are 0/+7V, the DIP switch positions must be set as follows:

S5_2, S5_3:	ON
S5_1, S5_4:	OFF
S4_2, S4_3:	ON
S4_1, S4_4:	OFF
S3_2, S3_3:	ON
S3_1, S3_4:	OFF

The interface circuit will shift the input signal from 0/+7V to 0/+3V (for example, from 3.5+3.5*sin(ωt) to 1.5+1.5*sin(ωt)) before feeding it to DSP ADC. Note that AD_A4in cannot operate in this type of input.

When the input signals AD_B2in, AD_B4in, AD_A2in, and AD_A4in are 0/+3V (i.e. 1.5+1.5*sin(ωt)), the DIP switch positions must be set as follows:

S5_4:	ON
S5_1, S5_2, S5_3:	OFF
S4_4:	ON
S4_1, S4_2, S4_3:	OFF
S3_4:	ON
S3_1, S3_2, S3_3:	OFF
S1_4:	ON
S1_2, S1_3:	OFF

The interface circuit directly feeds input to DSP ADC.

This circuit has a 2nd-order filter with a cut-off frequency of 3kHz.

2.5 DC Voltage Interface Circuit

The dc voltage analog interface circuit is for dc voltage sensing ADCs (Vdc, AD_A7). The amplitudes of the input signals of the interface circuit (Vdcin, AD_A7in) must be in the range of 0/+3V.

The figure below shows the dc voltage analog interface circuit. It scales the input signal Vdcin from 0/+3V to Vdc of 0/+1.8V, and then feeds it to DSP ADC.

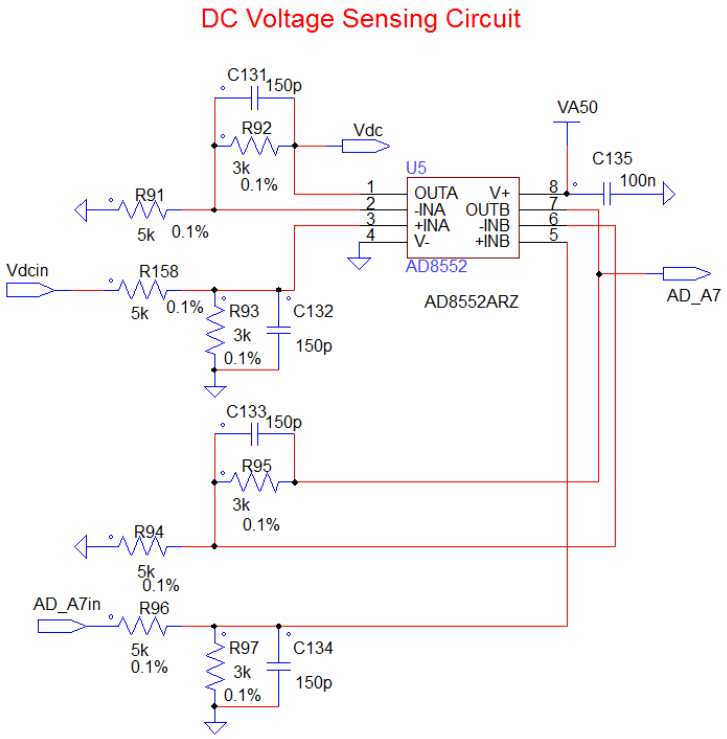


Fig. 7: DC voltage interface circuit

2.6 Digital I/O Connectors J10 and J11

The digital connectors J10 and J11 provide I/O interfaces to outside circuits. Their pin assignments are shown below.

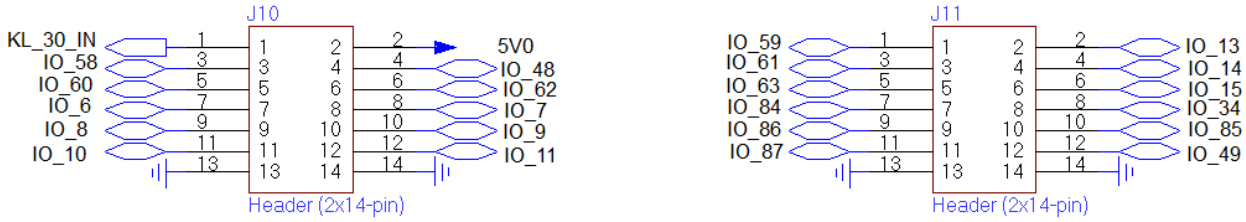


Fig. 8: Digital I/O connectors J10, J11

There is a series connected resistor (22Ω) between each the GPIO port and connector pin for each digital I/O port in order to limit the I/O current. Please refer to TI's TMS320F2833x Data Manual (tms320f28335.pdf) for detailed electrical specification of GPIO.

> WARNING: When making connection or measurement to the connector J10, please handle with extreme care. DO NOT short circuit the power supply pins (Pins 1 and 2) with any other pins. Short-circuit will damage the board!

Chapter 3 – Motor Control Interface

3.1 Encoder Interface Connector J8

Connector J8 provides the interface to an encoder for motor position/speed sensing.

Phase A of the encoder should be connected to Pin 1; Phase B should be connected to Pin 2; and Phase Z (index or zero marker) should be connected to Pin 3 as shown below.

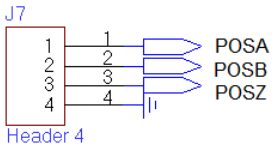


Fig. 9: Encoder Interface connector J8 pin assignment

3.2 Encoder Interface Circuit

The encoder interface circuit is shown below.

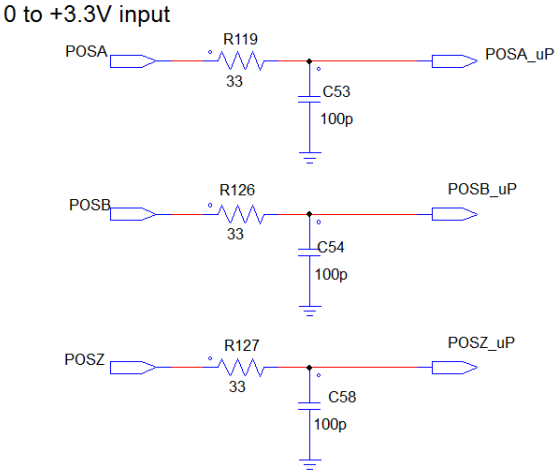


Fig. 10: Encoder interface circuit

The circuit uses a 1st-order low-pass filter with R=33Ω and C=100pf. Please note that input signals POSA, POSB, POSZ must be scaled to 0/+3.3V because these signals are fed into DSP I/O directly.

3.3 Hall Sensor Interface Connector J9

Connector J9 provides the interface to a hall sensor for motor position/speed sensing.

Phase U of the hall sensor should be connected to Pin 1; Phase V should be connected to Pin 2; and Phase W should be connected to Pin 3, as shown below.

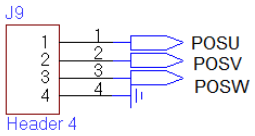


Fig. 11: Hall sensor interface connector J9 pin assignment

3.4 Hall Sensor Interface Circuit

The hall sensor interface circuit is shown below.

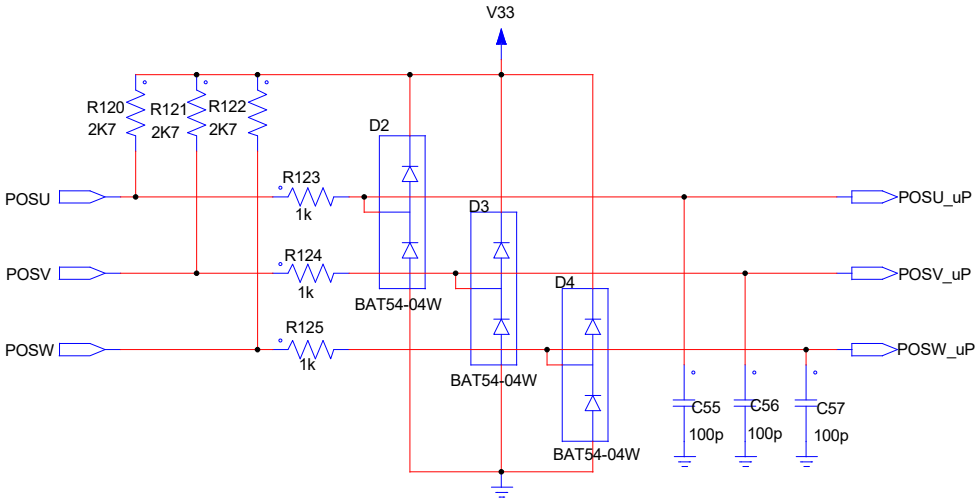


Fig. 12: Hall sensor interface circuit

The circuit uses a 1st-order low-pass filter with R=1kΩ and C=100pf. Please note that input signals POSU, POSV, POSW are clamped to 0/+3.3V by the interface circuit before these signals are fed into DSP I/O.

Chapter 4 – PWM/Digital Signals and Fault Signals

4.1 PWM Signal Connector J12

Figure 13 and Table 3 show the pin assignment of the PWM signal connector J12.

As shown in the figure, pins 1 to 8 provide the power supply.

Pins 1, 2 and 3 are connected to the external 12V dc power supply KL_30.

Pins 4, 5 and 8 provide the digital ground and Pin 7 supplies the analog ground.

Pins 14 (phase W, top switch), 16 (phase W, bottom switch), 18 (phase V, top switch), 20 (phase V, bottom switch), 22 (phase U, top switch) and 24 (phase U, bottom switch) are PWM logic signals for 6 IGBT/MOSFET gate drivers. These PWM signals are generated by TI controlCARD.

Pin 12 is a reset signal to control the gate drivers.

Pins 13, 17, 21 and 23 are fault detection signals - one for each phase and one as logical "AND" combination of 3 phase fault detection signals.

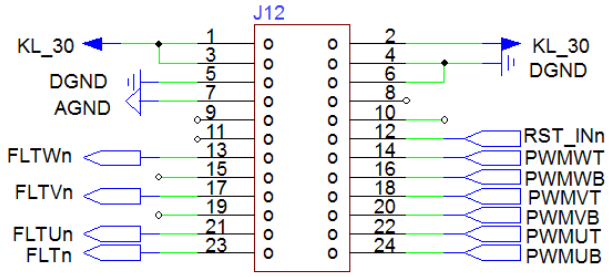


Fig. 13: PWM Signal Connector J12 Pin Assignments

WARNING: When making connection or measurement to the connector J12, please handle with extreme care. DO NOT short circuit the power supply pins (Pins 1, 2, and 3) with any other pins. Short-circuit will damage the board!

Pin Number	Pin Name	Type	Description
1	KL_30	Supply	+12V power supply
2	KL_30	Supply	+12V power supply
3	KL_30	Supply	+12V power supply
4	DGND	Supply	Digital ground
5	DGND	Supply	Digital ground
6	DGND	Supply	Digital ground
7	AGND	Supply	Analog ground
8	NC		
9	NC		
10	NC		
11	NC		
12	RST_INn	Digital Output	Gate driver reset (to the gate driver)

13	FLTWn	Digital Input	Gate driver fault from Phase C (from the gate driver)
14	PWMWT	PWM Output	PWM signal for Phase C (top) (to the gate drive)
15	NC		
16	PWMWB	PWM Output	PWM signal for Phase C (bottom)
17	FLTVn	Digital Input	Gate driver fault from Phase B
18	PWMVT	PWM Output	PWM signal Phase B (top)
19	NC		
20	PWMVB	PWM Output	PWM signal for Phase B (bottom)
21	FLTUn	Digital Input	Gate driver fault from Phase A
22	PWMUT	PWM Output	PWM signal for Phase A (top)
23	FLTn	Digital Input	Gate driver fault
24	PWMUB	PWM Output	PWM signal for Phase A (bottom)

Table 3: PWM signal connector J12 pin assignment

4.2 Gate Drive Interface Signals

The figure below shows the interface circuit between DSP (0 to +3.3V) and IGBT/MOSFET gate drivers (0 to +5V). This is a level shift circuit with a 16-bit dual supply translating transceiver IC 74ALVC164245. The 0/+3.3V PWM control signals G1, G2, G3, G4, G5, G6 from DSP are converted to 0/+5V signals PWMUT, PWMUB, PWMVT, PWMVB, PWMWT, PWMWB for gate drivers. The 0/+5V fault signals FLTUn, FLTVn, FLTWn, and FLTn are level shifted to 0/+3.3V for DSP.

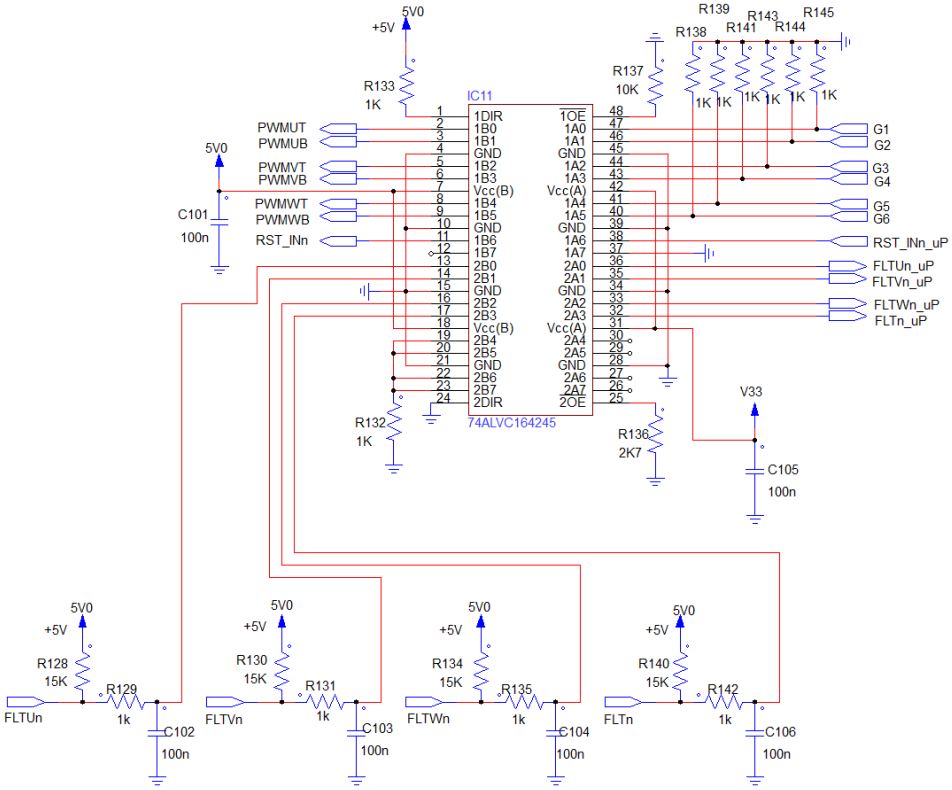


Fig. 14: Gate drive interface circuit

Chapter 5 – DSP Control Card Interface

5.1 TI controlCARD Interface Connector J5

TI controlCARD Interface Connector J5 (DIMM 100) provides the interface to various DSP controlCARDS from TI C2000 DSP family: 28335, 28035, 28027, and 28069. It offers a Plug-N-Play platform for users to quickly and easily develop a power converter system with any TI C2000 DSP (fixed point or floating point).

Figure 15 and Table 4 show the pin assignment of the connector J5.

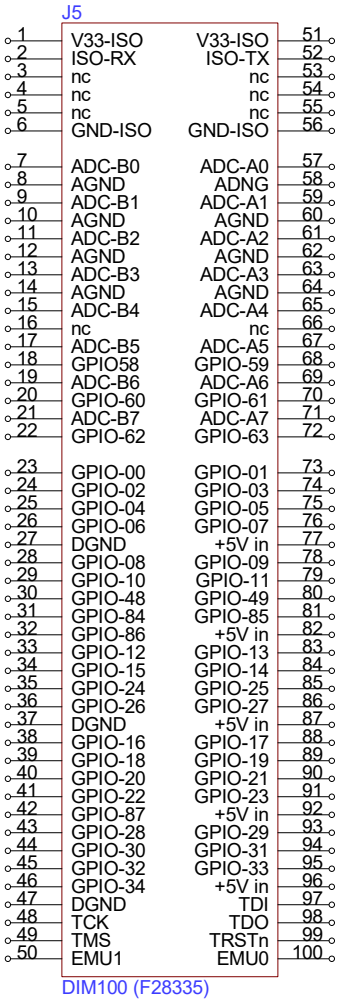


Fig. 15: DSP Interface Connector J5 Pin Assignment

Note that, depending on the specific controlCARD, not all pins are available. Please check the datasheet of the corresponding controlCARD for details.

Pin Number	Pin Name (Name used)	Type	Description (Location in the figure)
1	V33-ISO	Supply	Isolated RS-232 +3.3V power supply
2	RX-ISO	RS-232 I/O	Isolated RS-232 receive input
3	NC		
4	NC		
5	NC		
6	GND-ISO	Supply	Isolated RS-232 ground
7	ADC-B0 (Ia)	Analog Input	Current Phase A (Fig. 5)
8	AGND	Supply	Analog ground
9	ADC-B1 (Ib)	Analog Input	Current Phase B (Fig. 5)
10	AGND	Supply	Analog ground
11	ADC-B2 (AD_B2)	Analog Input	General ADC input (Fig. 6)
12	AGND	Supply	Analog ground
13	ADC-B3 (Ic)	Analog Input	Current Phase C (Fig. 5)
14	AGND	Supply	Analog ground
15	ADC-B4 (AD_B4)	Analog Input	General ADC input (Fig. 6)
16	NC		
17	ADC-B5 (Idc)	Analog Input	DC current (Fig. 5)
18	GPIO-58	Digital I/O	General-purpose digital I/O (Fig. 8)
19	ADC-B6 (AD_B6)	Analog Input	General ADC input (Fig. 4)
20	GPIO-60	Digital I/O	General-purpose digital I/O (Fig. 8)
21	ADC-B7 (AD_B7)	Analog Input	General ADC (Fig. 4)
22	GPIO-62	Digital I/O	General-purpose digital I/O (Fig. 8)
23	GPIO-00 (G1)	PWM I/O	PWM signal for Phase A (top) (Fig. 14)
24	GPIO-02 (G3)	PWM I/O	PWM signal for Phase B (bottom) (Fig. 14)
25	GPIO-04 (G5)	PWM I/O	PWM signal for Phase C (top) (Fig. 14)
26	GPIO-6	Digital I/O	General-purpose digital I/O (Fig. 8)
27	DGND	Supply	Digital ground
28	GPIO-8	Digital I/O	General-purpose digital I/O (Fig. 8)
29	GPIO-10	Digital I/O	General-purpose digital I/O (Fig. 8)
30	GPIO-48	Digital I/O	General-purpose digital I/O (Fig. 8)
31	GPIO-84	Digital I/O	General-purpose digital I/O (Fig. 8)
32	GPIO-86	Digital I/O	General-purpose digital I/O (Fig. 8)
33	GPIO-12 (RST_INn_uP)	Digital I/O	Gate driver Reset (Fig. 14)
34	GPIO-15	Digital I/O	General-purpose digital I/O (Fig. 8)
35	GPIO-24 (POSZ_uP)	Digital I/O	Encoder Phase Z (Fig. 10)
36	GPIO-26 (FLTWn_uP)	Digital I/O	Gate driver fault Phase C (Fig. 14)
37	DGND	Supply	Digital ground
38	GPIO-16 (SDO)	Digital I/O	SPI Data Out (Fig. 20)
39	GPIO-18 (SCK)	Digital I/O	SPI Clock (Fig. 20)
40	GPIO-20 (POSV_uP)	Digital I/O	Hall sensor Phase V (Fig. 12)
41	GPIO-22 (POSA_uP)	Digital I/O	Encoder Phase A (Fig. 10)
42	GPIO-87	Digital I/O	General-purpose digital I/O (Fig. 8)
43	GPIO-28 (RXDA)	RS-232 I/O	Non-Isolated RS-232 Receive Input (Fig. 2)
44	GPIO-30 (CANRXA)	CAN I/O	CAN Receive Signal

45	GPIO-32 (FLTUn_uP)	Digital I/O	Gate driver fault Phase A (Fig. 14)
46	GPIO-34	Digital I/O	General-purpose digital I/O (Fig. 8)
47	DGND	Supply	Digital Ground
48	TCK	Digital I/O	JTAG Test Clock (Fig. 21)
49	TMS	Digital I/O	JTAG Test Mode Select (Fig. 21)
50	NC		
51	V33-ISO	Supply	Isolated RS-232 +3.3V power supply
52	TX-ISO	RS-232 I/O	Isolated RS-232 transmit output
53	NC		
54	NC		
55	NC		
56	GND-ISO		Isolated RS-232 ground
57	ADC-A0 (Va)	Analog Input	AC voltage Phase A (Fig. 4)
58	AGND	Supply	Analog ground
59	ADC-A1 (Vb)	Analog Input	AC voltage Phase B (Fig. 4)
60	AGND	Supply	Analog ground
61	ADC-A2 (AD_A2)	Analog Input	General ADC input (Fig. 6)
62	AGND	Supply	Analog ground
63	ADC-A3 (Vc)	Analog Input	AC voltage Phase C (Fig. 4)
64	AGND	Supply	Analog ground
65	ADC-A4 (AD_A4)	Analog Input	General ADC input (Fig. 6)
66	NC		
67	ADC-A5 (Vdc)	Analog Input	DC voltage (Fig. 7)
68	GPIO-59	Digital I/O	General-purpose digital I/O (Fig. 8)
69	ADC-A6 (AD_A6)	Analog Input	General ADC input (Fig. 5)
70	GPIO-61	Digital I/O	General-purpose digital I/O (Fig. 8)
71	ADC-A7 (AD_A7)	Analog Input	General ADC input (Fig. 7)
72	GPIO-63	Digital I/O	General-purpose digital I/O (Fig. 8)
73	GPIO-01 (G2)	PWM I/O	PWM Gate Low Phase A (Fig. 14)
74	GPIO-03 (G4)	PWM I/O	PWM Gate Low Phase B (Fig. 14)
75	GPIO-05 (G6)	PWM I/O	PWM Gate Low Phase C (Fig. 14)
76	GPIO-7	Digital I/O	General-purpose digital I/O (Fig. 8)
77	+5V In (5V0)	Supply	+5V Digital Power Supply
78	GPIO-9	Digital I/O	General-purpose digital I/O (Fig. 8)
79	GPIO-11	Digital I/O	General-purpose digital I/O (Fig. 8)
80	GPIO-49	Digital I/O	General-purpose digital I/O (Fig. 8)
81	GPIO-85	Digital I/O	General-purpose digital I/O (Fig. 8)
82	+5V In (5V0)	Supply	+5V Digital Power Supply
83	GPIO-13	Digital I/O	General-purpose digital I/O (Fig. 8)
84	GPIO-14	Digital I/O	General-purpose digital I/O (Fig. 8)
85	GPIO-25 (POSU_uP)	Digital I/O	Hall sensor Phase U (Fig. 12)
86	GPIO-27 (FLTn_uP)	Digital I/O	Gate driver fault (Fig. 14)
87	+5V In (5V0)	Supply	+5V Digital Power Supply
88	GPIO-17 (SDI)	Digital I/O	SPI Data In (Fig. 20)
89	GPIO-19 (SS)	Digital I/O	SPI Select (Fig. 20)
90	GPIO-21 (POSW_uP)	Digital I/O	Hall sensor Phase W (Fig. 12)

91	GPIO-23 (POSB_uP)	Digital I/O	Encoder Phase B (Fig. 10)
92	+5V In (5V0)	Supply	+5V Digital Power Supply
93	GPIO-29 (TXDA)	RS-232 I/O	Non-Isolated RS-232 Transmit Output
94	GPIO-31 (CANTXA)	CAN I/O	CAN Transmit Signal
95	GPIO-33 (FLTVn_uP)	Digital I/O	Gate driver fault Phase B (Fig. 14)
96	+5V In (5V0)	Supply	+5V digital power supply
97	TDI	Digital I/O	JTAG Test Data Input (Fig. 21)
98	TDO	Digital I/O	JTAG Test Data Output (Fig. 21)
99	TRSTn	Digital I/O	JTAG Test Rest (Fig. 21)
100	NC		

Table 4: DSP Interface Connector DIM100 Pin Assignment

5.2 DSP controlCARD

Figure 16 shows TI C2000 DSP family controlCARDs. They are small 100-pin Dual-In-Line-Memory-Module (DIMM) style vertical plug-in boards that have the necessary support circuitry (clock, supply LDO, decoupling, pull-ups, etc.).

TI offers several pin compatible controlCARDs for evaluating different MCUs available in the C2000 family: Piccolo family controlCARDs that use F28027, F28035 and F28069 fixed-point DSPs, and the Delfino controlCARD that uses the F28335 floating-point DSP.

The controlCARDs offer the following features:

- Small size - 90 mm x 25 mm (3.5" x 1")
- All GPIO, ADC, and other key signals are routed to gold edge connector fingers.
- Extensive supply pin decoupling with L+C close to pins
- Clamping diode protection at ADC input pins
- Anti-aliasing filter (noise filter) at ADC input pins
- Ground plane

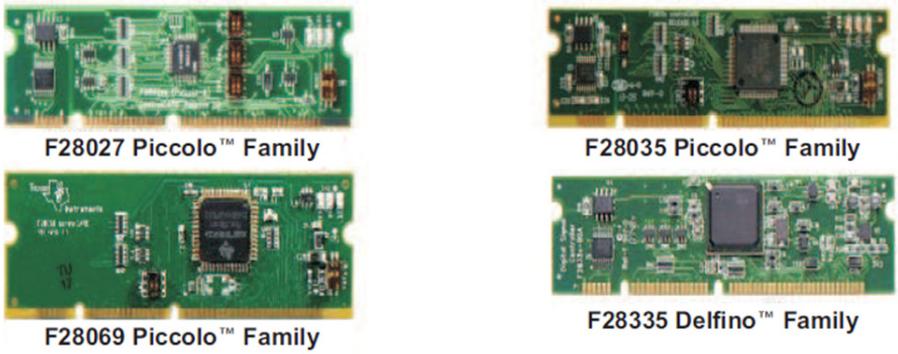


Fig. 16: TI C2000 DSP Family controlCARDs

A brief description of each DSP is given below.

F28335:

The F28335 DSP has the following main features:

- High-performance floating point 32-Bit CPU (TMS320C28x) with 150 MHz (6.67-ns cycle time)
- On-chip memory (256K x 16 Flash, 34K x 16 SARAM, 8K x 16 Boot ROM)
- 6-channel DMA controller (for ADC, McBSP, ePWM, XINTF, and SARAM)
- Enhanced control peripherals
  - Up to 18 PWM outputs
  - Up to 6 HRPWM outputs with 150 ps MEP resolution
  - Up to 6 Event Capture inputs
  - Up to 2 Quadrature Encoder interface
  - Up to 8 32-Bit Timers (6 for eCAPs and 2 for eQEPs)
  - Up to 9 16-Bit Timers (6 for ePWMs and 3 XINTCTRs)
- Three 32-Bit CPU Timers
- Serial port peripherals
  - Up to 2 CAN modules
  - Up to 3 SCI (UART) modules
  - Up to 2 McBSP modules (Configurable as SPI)
  - One SPI module
  - One Inter-Integrated-Circuit (I2C) module
- 12-Bit ADC, 16 channels
  - 80-ns conversion rate
  - x 8 channel input multiplexer
  - Two Sample-and-Hold
  - Single/simultaneous conversions
  - Internal or external reference
- Up to 88 individually programmable, multiplexed GPIO pins with input filtering

F28035:

The F28035 DSP has the following main features:

- High-efficiency fixed point 32-Bit CPU (TMS320C28x) with 60 MHz (16.67-ns cycle time)
- On-chip memory (64K x 16 Flash, 10K x 16 SARAM, 8K x 16 Boot ROM)
- Three 32-Bit CPU Timers
- Independent 16-Bit Timer in each enhanced Pulse Width Modulator (ePWM)
- Serial port peripherals
  - One SCI (UART) module
  - Two SPI modules
  - One Inter-Integrated-Circuit (I^2C) bus
  - One Local Interconnect Network (LIN) bus
  - One enhanced Controller Area Network (eCAN) bus

- Enhanced control peripherals
  - ePWM
  - High-Resolution PWM (HRPWM)
  - Enhanced Capture (eCAP) module
  - High-Resolution Input Capture (HRCAP) module
  - Enhanced Quadrature Encoder Pulse (eQEP) module
  - On-chip temperature sensor
  - Comparator
- 12-Bit ADC, 16 channels
  - 216-ns conversion rate
  - x 8 channel input multiplexer
  - Two Sample-and-Hold
  - Single/simultaneous conversions
- Up to 45 individually programmable, multiplexed GPIO pins with input filtering

F28027:

The F28027 DSP has the following main features:

- High-efficiency fixed point 32-Bit CPU (TMS320C28x) with 60 MHz (16.67-ns cycle time)
- On-chip memory (Flash, SARAM, OTP, Boot ROM available)
- Three 32-Bit CPU Timers
- Independent 16-Bit Timer in each enhanced Pulse Width Modulator (ePWM)
- Serial port peripherals
  - One Serial Communications Interface (SCI) Universal Asynchronous Receiver/Transmitter (UART) module
  - One Serial Peripheral Interface (SPI) module
  - One Inter-Integrated-Circuit (I2C) module
- Enhanced Control Peripherals
  - ePWM
  - High-resolution PWM (HRPWM)
  - Enhanced Capture (eCAP) module
  - On-Chip temperature sensor
  - Comparator
- 12-Bit ADC, 13 channels
  - 216-ns conversion rate
  - Two Sample-and-Hold
  - Single/simultaneous conversions
- Up to 22 individually programmable, multiplexed GPIO pins with input filtering

F28069:

The F28069 DSP has the following main features:

- High-efficiency fixed point 32-Bit CPU (TMS320C28x) with 90 MHz (11.11-ns cycle time)
- On-chip memory (256KB Flash,100KB SARAM, 2KB OTP ROM)

- Six-channel DMA controller
- Three 32-Bit CPU Timers
- Enhanced control peripherals
- Up to 8 enhanced Pulse-Width Modulator (ePWM) Modules
  - 16 PWM channels total (8 HRPWM-capable)
  - Independent 16-Bit Timer in each module
- Three Input enhanced Capture (eCAP) modules
- Up to 4 High-Resolution Capture (HRCAP) modules
- Up to 2 enhanced Quadrature Encoder Pulse (eQEP) modules
- Serial port peripherals
  - One CAN module
  - Up to 2 SCI (UART) modules
  - One McBSP module
  - Two SPI module
  - One Inter-Integrated-Circuit (I2C) module
- 12-Bit ADC, 16 channels
  - 289-ns conversion rate
  - x 8 channel input multiplexer
  - Two Sample-and-Hold
  - Single/simultaneous conversions
  - Internal or external reference
- Up to 54 individually programmable, multiplexed GPIO pins with input filtering

Chapter 6 – Communication Port and Computer Interface

The DSP board provides several communication ports for computer interface and program debugging purposes. These communication interfaces include one CAN bus, one SCI port one SPI port, one USB, and one JTAG.

6.1 CAN BUS Interface J3

The figure below shows the pin assignment of the CAN bus connector J3. Pin 1 is CAN high line and pin 2 is CAN low line. Pin 3 is digital ground.

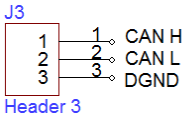


Fig. 17: CAN bus connector J3 pin assignment

6.2 SCI Interface J6

The figure below shows the pin assignment of the SCI connector J6. Pin 1 is the RS-232 transmit output, pin 4 is the RS-232 receive input. Pin 2 is the +3.3V power supply. Pin 43 is ground.

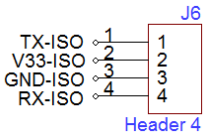


Fig. 18: SCI interface connector J6 pin assignment

Note that to use the SCI connector J6 for serial communication, the DIP switch S7_4 must be in the **OFF** position.

6.3 USB Interface J1

The USB connector J1, shown in the figure below, provides the interface to a computer. The built-in DSP emulator allows users to debug DSP program with TI Code Composer Studio.

Table 5 shows the pin assignment of the connector J5. Pin 2 is data plus and pin 3 is data minus.

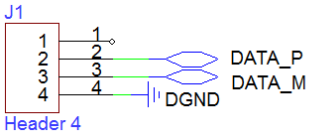


Fig. 19: USB connector J1 pin assignment

Pin Number	Pin Name	Description
1	NC	
2	DATA_P	Data plus
3	DATA_M	Data minus
4	DGND	Digital Ground

Table 5: USB Connector J1 pin assignment

Note that to use the USB connector J1 for serial communication, the DIP switch S7_4 must be in the **ON** position.

6.4 SPI Interface J2

The SPI connector J4 provides the interface to serial peripheral communication (SPI). The figure below shows the pin assignment of SPI connector J4. Pin 1 is SPI data out, pin 2 is SPI data in, pin 3 is SPI clock, pin 4 is SPI select, and pin 5 is digital ground.

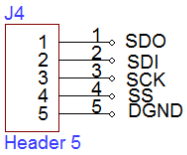


Fig. 20: SPI connector J4 pin assignment

6.5 JTAG Interface J2

The JTAG connector J2 (14-pin) provides the interface to an external TI DSP emulator. Figure 21 and Table 6 show the pin assignment of the connector J2.

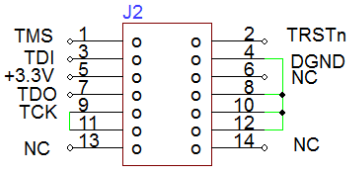


Fig. 21: JTAG connector J2 pin assignment

Pin Number	Pin Name	Description
1	TMS	Test Mode Select
2	TRSTn	Test Rest
3	TDI	Test Data Input
4	DGND	Ground
5	V33	Power
6	NC	
7	TDO	Test Data Output
8	DGND	Ground
9	TCK	Test Clock
10	DGND	Ground
11	TCK	Test Clock
12	DGND	Ground
13	NC	
14	NC	

Table 6: JTAG Connector Pin Assignment

6.6 Interface with PSIM Software

The DSP board works with together the PSIM software to provide an integrated software/hardware solution in the following ways:

- PSIM provides the automatic code generation capability for TI DSP. The auto code generation will generate code that is ready to run on TI F28335/F28035/F28027/F28069 DSP without any change or manual coding. The DSP board provides the convenient platform for running the DSP code and controlling a power converter.
- PSIM provides the Processor-In-the-Loop (PIL) simulation capability for TI DSP. The PIL simulation allows users to validate either PSIM generated code or hand written code by running the code on the actual DSP board, while simulating the power converter in PSIM on a computer. Again, the DSP board provides the platform for running the DSP code for PIL simulation.

For further information, refer to PSIM's SimCoder User Manual and relevant tutorials.

For each TI DSP, various examples are provided in the folder "examples\SimCoder" to illustrate how to use DSP peripherals and functions (such as ADC, PWM, Digital Input/Output, CAN bus). Examples are also provided for sensored and sensorless motor control of BLDC, PMSM, and induction motors.

One PSIM function that is very useful is the DSP Oscilloscope (under the **Utilities** menu). The figure below shows the interface of the DSP Oscilloscope.

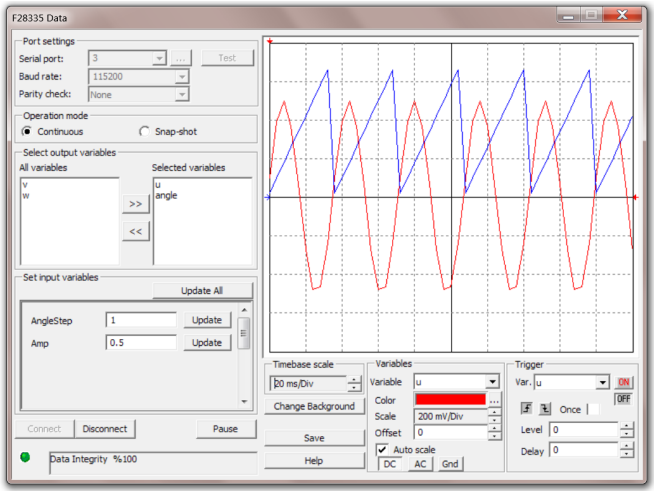


Fig. 22: Interface of the DSP Oscilloscope

The DSP Oscilloscope provides an easy and convenient way of monitoring signals inside the DSP and adjusting parameter values in real time. This is particularly useful in debugging the code.

The following changes are needed to the DSP board and the TI controlCARDs in order for the DSP Oscilloscope to communicate with DSP via the USB cable (the same cable used to program the DSP):

Changes to the Powersim DSP Development Board:

- For F28335/F28035/F28027/F28069 controlCARDs: Set the DIP switch S7 position 4 to **ON**.
- For F28069M controlCARD (InstaSPIN enabled): Set the DIP switch S7 position 4 to **OFF**.

Changes to the TI controlCARDs:

- F28335 controlCARD: Set Switch SW1 to **OFF** (by default, it is on).
- F28035 controlCARD: Set Switch SW1 to **OFF** (by default, it is on).
- F28027 controlCARD: Remove Resistor R10 (by default, R10 is present).
- F28069 or F28069M controlCARD: There is no change.

For more information, refer to the tutorial "Tutorial – Using SCI for Waveform Monitoring.pdf".