TI Designs

VF Compressor Driving System

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

TIDM-VF-COMPRESSOR-DRIVING-SYSTEM	Design Folder
TMS320F28034	Product Folder
TMS320F28027	Product Folder
controlSUITE	Tool Folder

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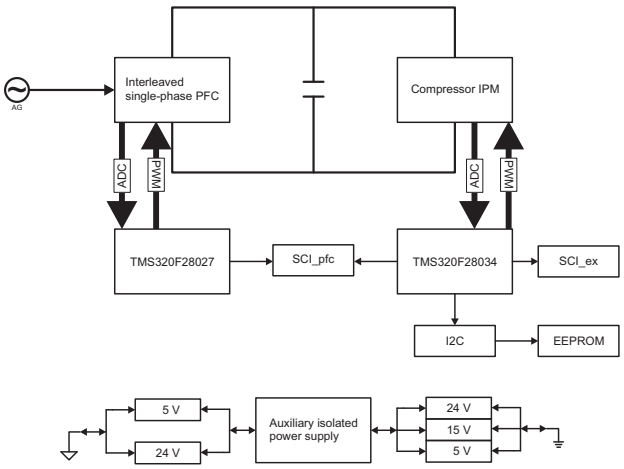
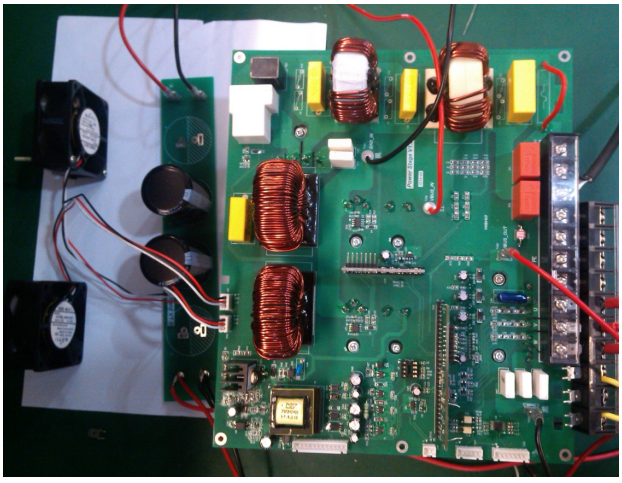
Design Features

- High Frequency Interleaved PFC
- Sensorless PMSM Compressor Control
- SCI Communication PFC and Compressor
- Isolated Auxiliary Power Supply
- Auto Flux Weakening
- Low Speed Compressor Driving

Featured Applications

- Air Conditioning
- Compressor Driving





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WARNING

The VF Compressor driving system is a high voltage system. Follow the instructions and processes strictly to avoid the potential electricity shock and other injuries.

When the system is powered up, *do not touch* anything on the powered board. Keep the working surface dry and clean without any conductive materials.

The operator wear protection such as insulated shoes. When operating the system, at least one accompanier should be in position.

Contact the system developer with any uncertainties about the system.

1 General Description

This reference design is mainly used for demonstrating the key functions of the VF Compressor Driving System and for the reference of a user's own designs. Please do not use this for any other purposes. The system power range is up to 5 kVA. The input voltage range is around 185 to 252 V_{RMS}. The compressor's maximum supporting current is 25 A in peak.

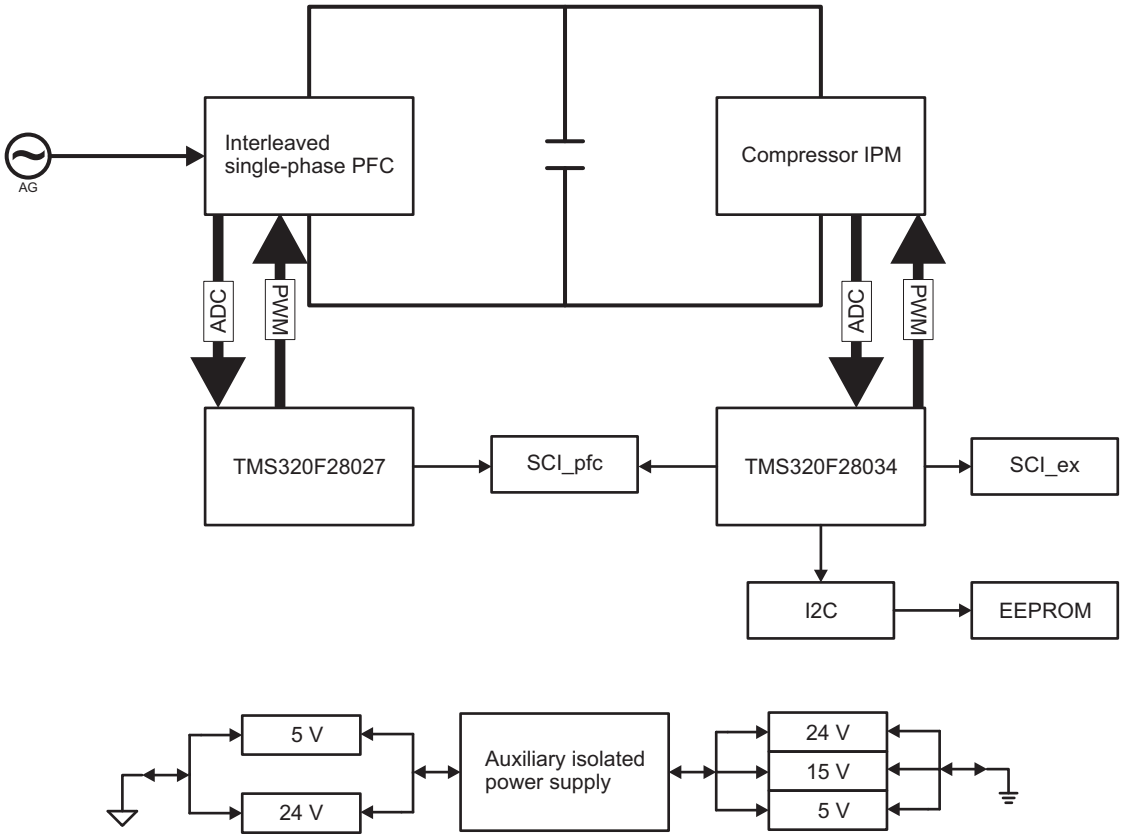

Figure 1. VF Compressor Driving System Block Diagram

The compressor system contains two major parts: an interleaved single-phase PFC and compressor driving. The PFC is controlled by TMS320F28027, and the compressor is controlled by TMS320F28034. The two MCUs were made on two independent control boards connected to the main power board.

The PFC is controlled with a 45-kHz PWM signal by sampling the total current of two branches. The topology and detailed circuit are displayed in Figure 2.

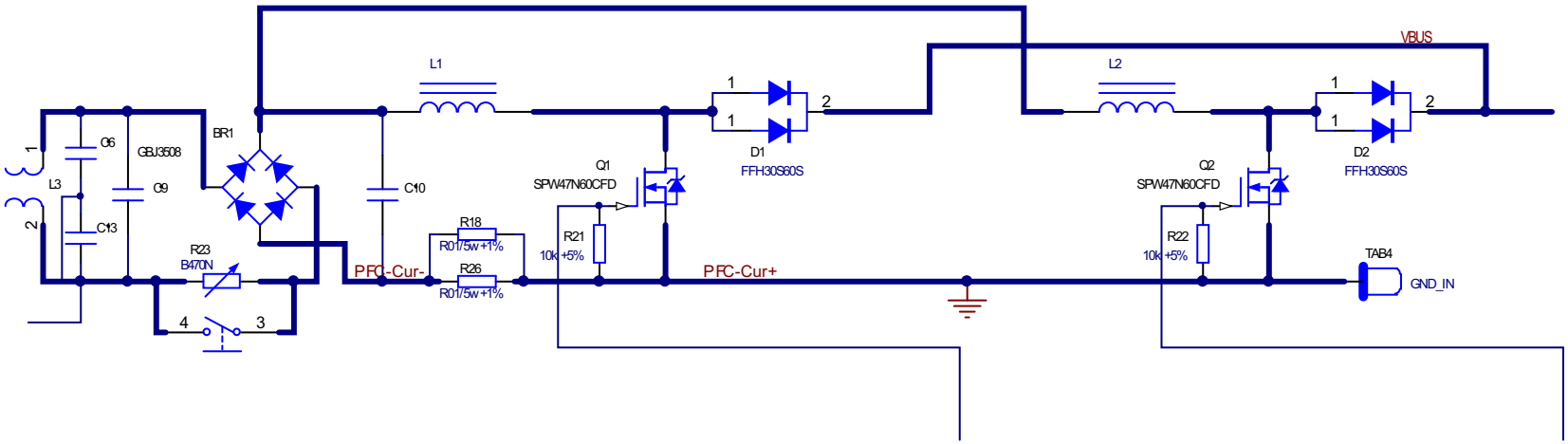

Figure 2. Interleaved PFC Power Circuit

The compressor driving power part has a major IPM module and is controlled with a 5.625-kHz PWM signal by sampling the three-phase current of lower MOSFET. Figure 3 shows the detailed circuit.

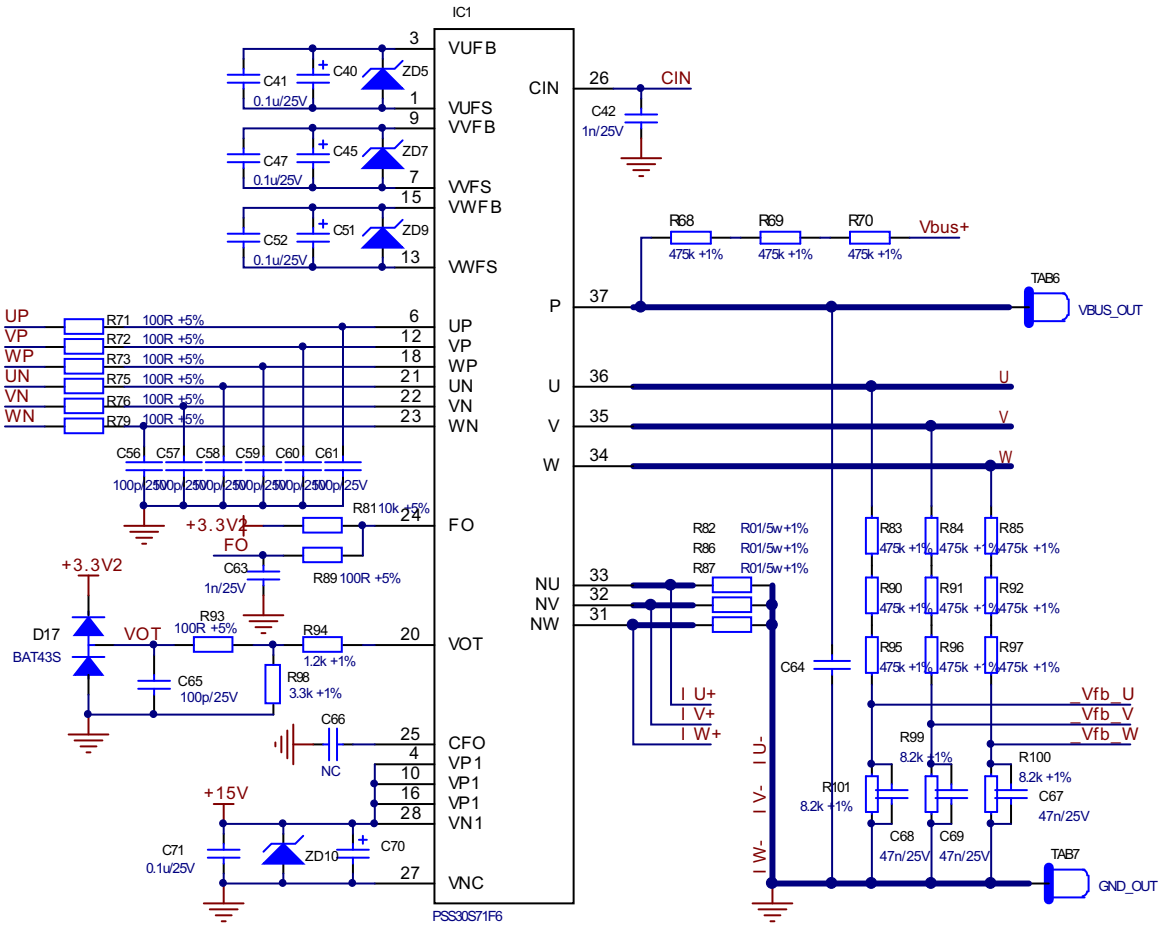

Figure 3. Compressor Driving IPM Circuit

The PFC and compressor control board are communicated through the SCI port. The data exchange between the two are PFC On/Off, PFC target DC-bus voltage command, PFC status, and the PFC fault flags. So, the compressor part is working as a dummy master in the communication system.

There are two series of power output from the auxiliary power supply module. The lower voltage supplied by an isolated auxiliary power supply which could generate 5, 15, and 24 V with the ground named GND. Also, it generates another 5 or 24 V with the ground named COM.

The 5 or 24 V to the COM is used for the user communication interface reserve.

2 Hardware

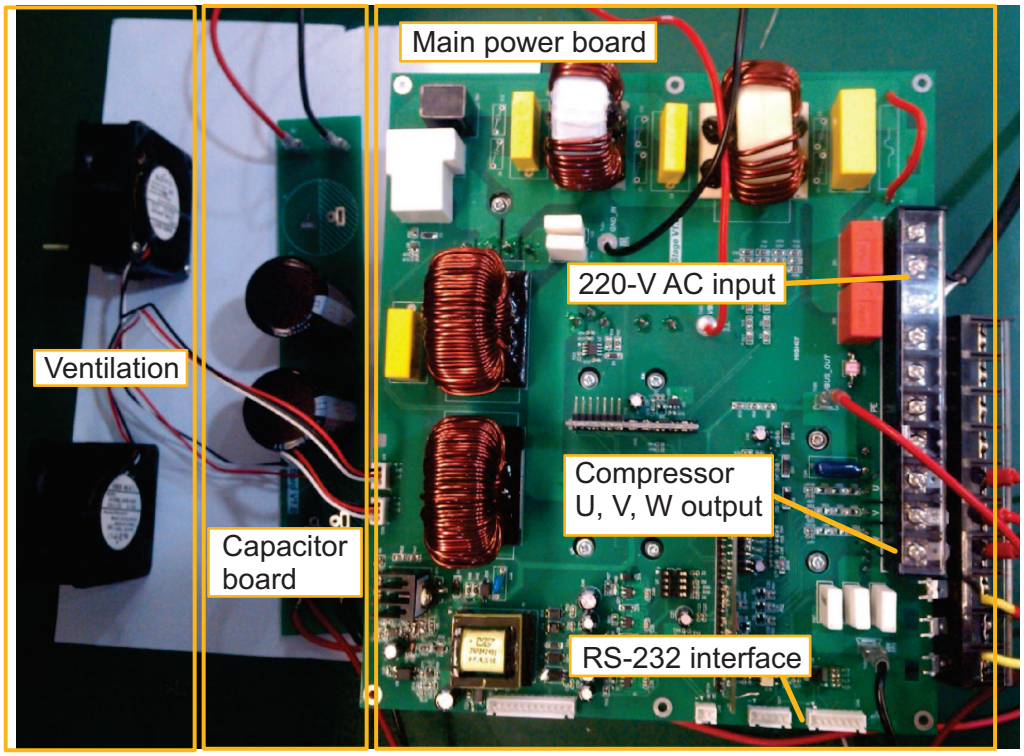

Figure 4. VF Compressor Driving System Board

2.1 I/O Wires Connection

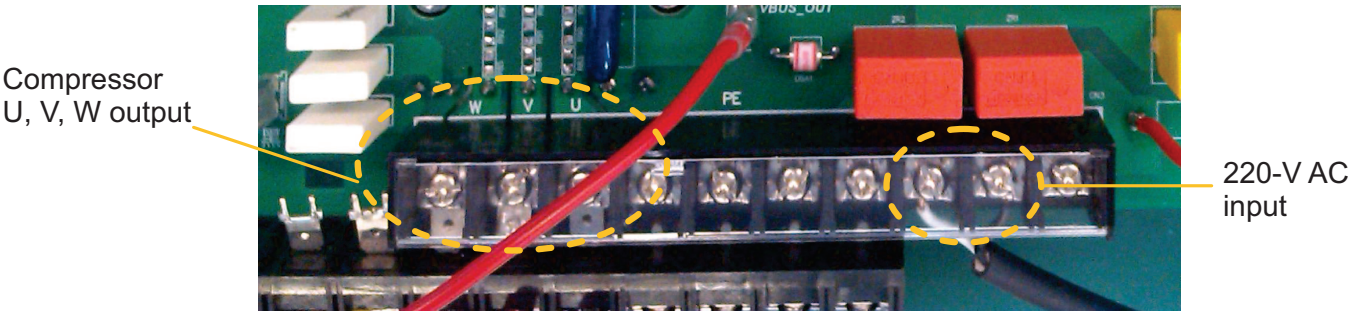

Figure 5. Input and Output Post Heads

Before powering up, connect the 220-V AC 'L' and 'N' wire to input post heads, as indicated in Figure 5. Also, the mark 'L', 'N' could be found on the board. Connect the compressor U, V, W line correspondingly.

NOTE: L, N wires could be connected randomly. But the U, V, W wires should be connected correctly according to compressor's U, V, W marks.

2.2 Capacitor Board

The system's capacitor board is made separate from main power board. Connect the positive line (red) and negative line (black) correspondingly from the main board to the capacitor board according to the marks on the boards.

NOTE: Positive and Negative wires should absolutely not mistaken, otherwise, when powered up, the capacitors will explode immediately.

2.3 RS-232 Interface

The RS-232 interface is marked as CN7 on the main power board. The pin definition is shown in Figure 6. The mark 'COM' is understood as ground.

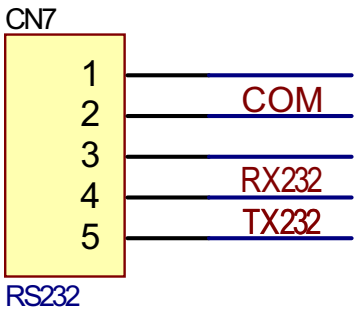

Figure 6. Input and Output Post Heads Schematic

3 Software

3.1 Software Global Structure

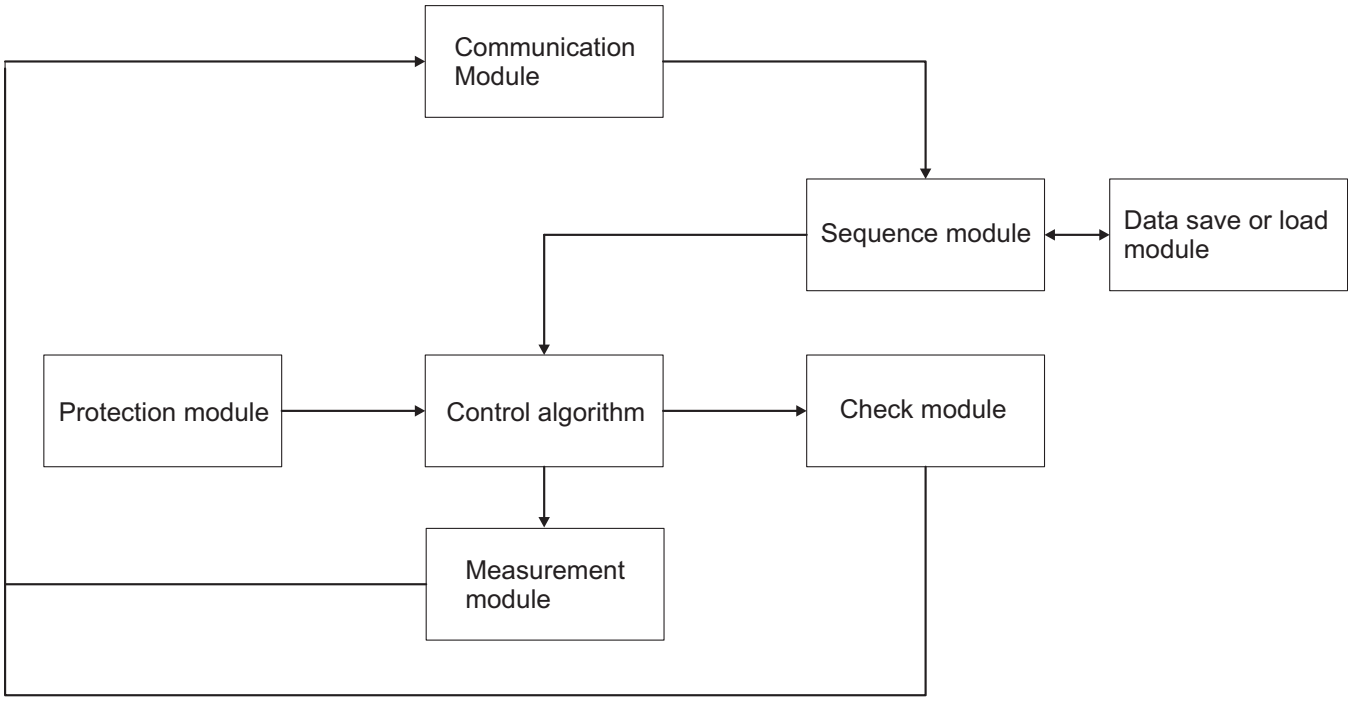

Figure 7. Software Global Structure

Figure 7 shows the global structure of the system software. All the software function modules are shown in the figure. The communication module to get the command and feedback the status through RS-232 interface with PC terminal.

3.2 Run the Compressor

To run the compressor, connect the PC and main board through RS-232 interface. In using the series communication tools to send the start command, stop command and the speed reference command.

The command code is listed in Table 1:

Table 1. SCI Control Command Data Format

SPEEDREF	A100:0.2B
Disable	A000:0B
Enable	A001:0B

The speed reference value unit is in Hz, and the base speed reference is 240 Hz.

So, the actual speed reference will be "setting value × 240 Hz". For example, setting A100:0.2B though series communication tool, the actual speed reference will be 0.2 × 240 Hz = 48 Hz electrical frequency.

3.3 Compressor Parameter

Currently, the example program and demo system only support the compressor ASD102SF-A7JT from Shanghai Hitachi compressor manufactory. The compressor parameters are as following.

Table 2. Motor Parameters

ITEM	PARAM	DESCRIPTION
Motor Pole Number	4	Four poles
Operation Frequency Range (Hz)	33-240	Electrical frequency
Demagnetization Current (A)	18.5	Peak current under 120℃ temperature condition Execute two seconds, demagnetization rate < 5%
Induction Ld (mH)	See Table 3	Induction value changes with current
Induction Lq (mH)	See Table 3	Induction value changes with current
Stator Resistance (Ω) (20℃)	1.79	Line-to-line
Back EMF coefficient (V_{RMS} / krpm)	45.20 V / krpm	Line-to-line
Torque Coefficient (N × m/ A_{RMS})	0.62	Torque / current
Inertia (Kg × m2)	0.000311	
Φa (Wb)	0.1764	φ (One phase peak value)
Type of Magneticiron	NdFeB	

Table 3. Induction Variation (Test Frequency = 100 Hz)

CURRENT (A_{RMS})	1	1.5	2	2.5	3	3.5	4	5	7
Lq (mH)	19.18	18.71	18.13	17.57	17.03	16.56	16.12	15.39	14.17
Ld (mH)	15.79	15.74	15.56	15.29	14.98	14.65	14.27	13.56	12.44

3.4 System Performance

The compressor running frequency range is 10Hz to 90Hz mechanical frequency. With the torque compensation from 20- to 30-Hz range. And the flux weakening range from 80 to 90 Hz. Maximum power could run to 5 kW.

Input PF value is > 0.99 with more than a 75% load. THDI < 5% with input THDU < 2%.

The DC-bus reference target could be adjusted by the user or according to the AC input voltage. The range is 330 to 380 V. The real system performance test wave is shown in Figure 8.

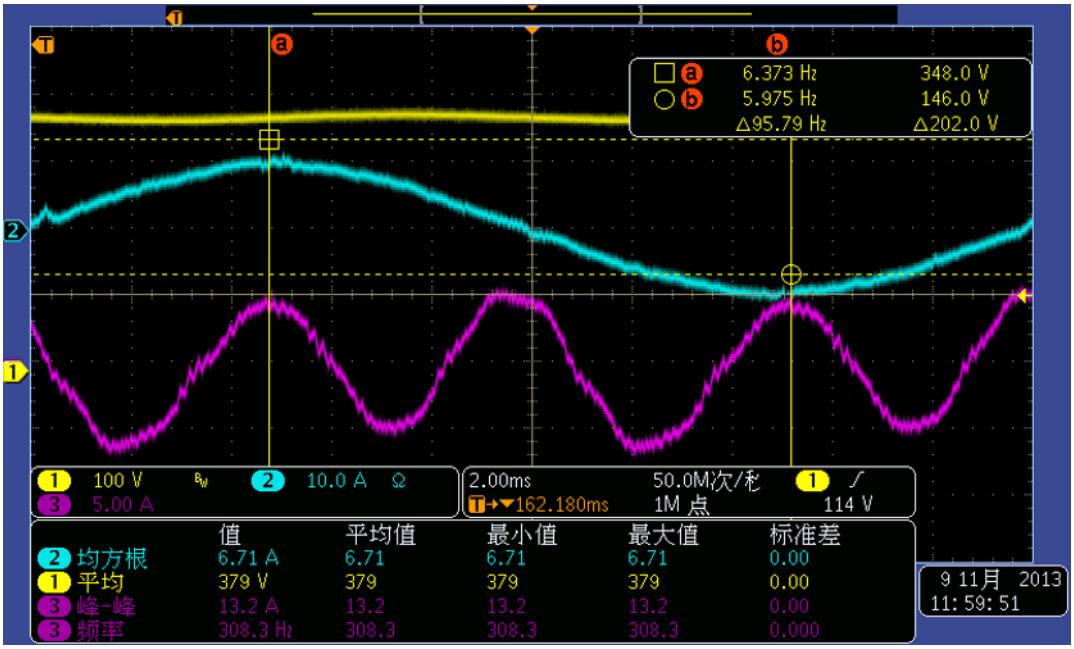

Figure 8. System Performance Test Waves

NOTE: Ch1 (Yellow): DC Bus Voltage
Ch2 (Blue): PFC current
Ch3 (Red): Compressor U phase current

Test condition is the medium cooling condition. The target compressor speed is 96 Hz mechanical. The load rate is about 30% of the full load.

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDM-VF-COMPRESSOR-DRIVING-SYSTEM.

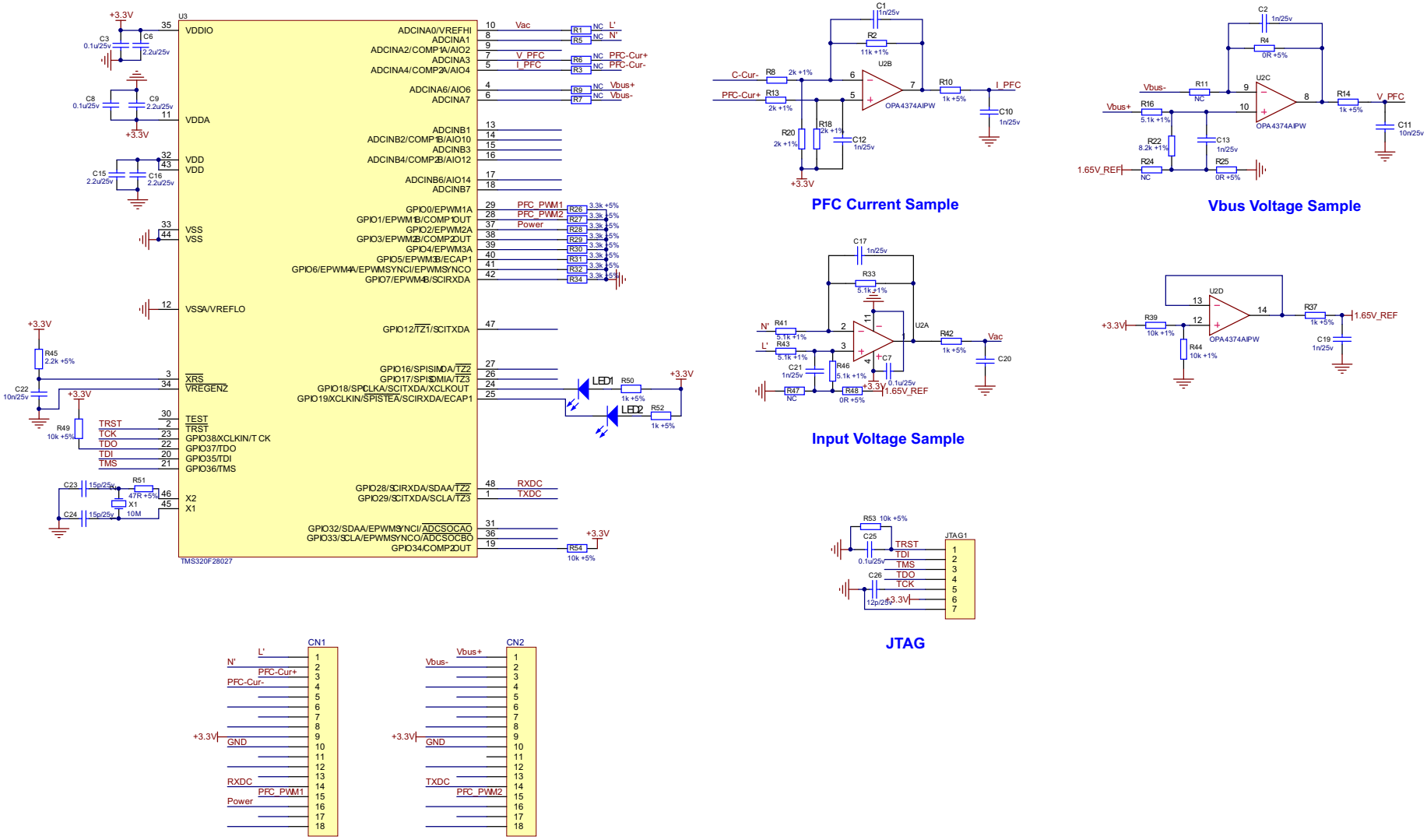

Figure 9. PFC Control MCU and ADC Circuit Schematic

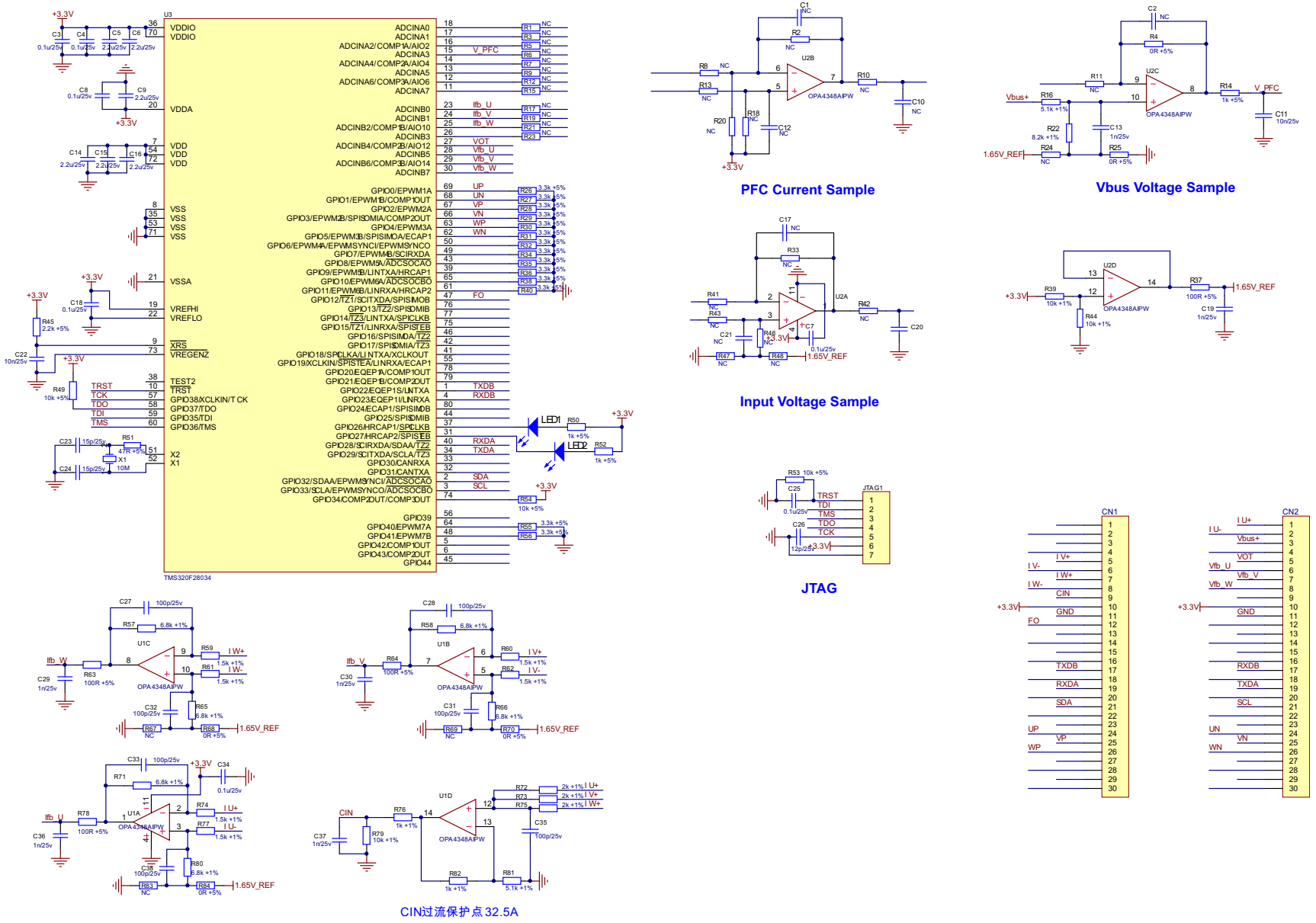

Figure 10. Compressor Control MCU and ADC Circuit

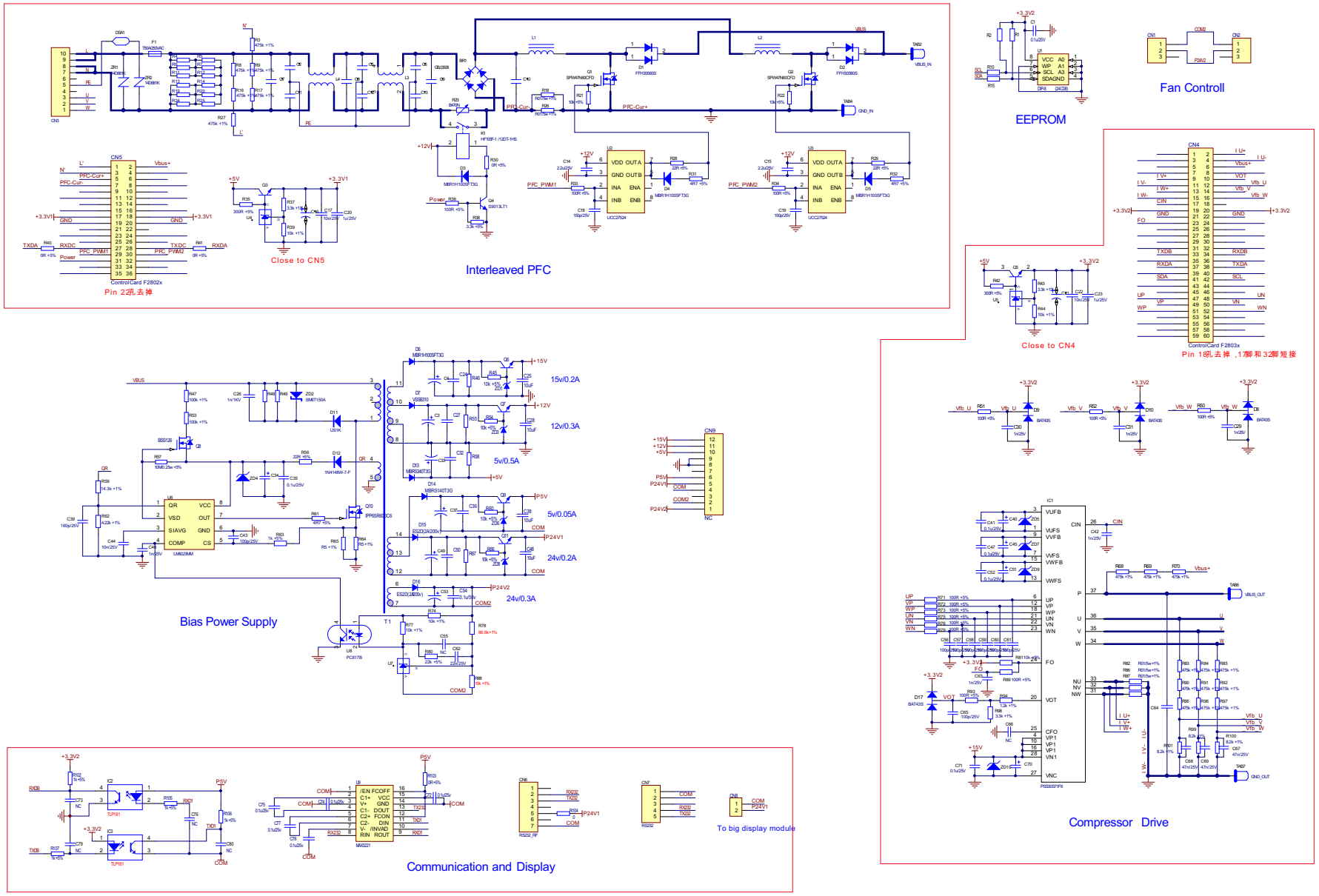

Figure 11. Power Module Schematic

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDM-VF-COMPRESSOR-DRIVING-SYSTEM.

Table 4. BOM

DESIGNATOR	DESCRIPTION	QTY
BR1	GBJ3508	1
C1, C2, C7, C9, C10, C13, C14, C17, C34, C40, C51, C52, C58, C59, C89, C90, C91, C102, C106, C123	1 n/25 V	20
C3, C6, C11, C12, C25, C26, C30, C35, C36, C37, C72, C73	2.2 µ/25 V	12
C4, C5, C15, C21, C27, C28, C29, C39, C41, C47, C56, C61, C82, C87, C92, C95, C96, C101, C107, C112, C131, C132, C134, C135, C137, C138	0.1 µ/25 V	26
C8, C16, C18, C32, C44, C75, C80, C104	10 n/25 V	8
C19, C20, C45, C46	15 p/25 V	4
C22, C48	12 p/25 V	2
C23, C24, C31, C33, C38, C42, C43, C115, C126, C133, C136, C139, C140	NC	13
C49, C50, C53, C54, C55, C57, C60, C103, C116, C117, C118, C119, C120, C121, C125	100 p/25 V	15
C62, C69	2220JA250471KXTB16	2
C63, C64, C70, C71	2220JA250472KXTB16	4
C65	C42Q2225KBSC000 (2.2 µF/305-V AC)	1
C66, C67	C42Q2105KBSC000 (1 µF/305-V AC)	2
C68	C352J474KB0C000 (0.47 µF/630-V DC)	1
C74, C79, C93, C97	UPW0J331MED6 (330 V/6.3 V)	4
C76, C77	150 p/25 V	2
C78, C81	1 µ/25 V	2
C83, C88, C98, C108	10 µ/25 V	4
C84, C86	UPW1E331MPD6 (330 µF/25 V)	2
C85	1 n/1 KV	1
C94, C100, C105, C111	UPW1V220MDD (22 µ/35 V)	4
C99	160 p/25 V	1
C109, C113	UPW1V331MPD6 (330 µF/35 V)	2
C110, C114	0.1 µ/50 V	2
C122	22 n/25 V	1
C124	C822J104K60C000 (0.1 µ/630-V DC)	1
C127, C128, C129	47 n/25 V	3
C130	UPW1V470MED (47 µ/35 V)	1
CN1, CN2	18-pin, 2.54 mm	2
CN3, CN4		2
CN5, CN6	Header 3	2
CN7	TB1300-03-10P-C	1
CN8	Control Card F2803x	1
CN9	Control Card F2802x	1
CN10	NC	1
CN11	RS232_RF	1
CN12	RS232	1
CN13	CON2	1
D1, D2	FFH30S60S	2
D3, D4, D5	MBR1H100SFT3G	3
D6	MBR1H100SFT3G	1
D7	VSSB310	1

Table 4. BOM (continued)

DESIGNATOR	DESCRIPTION	QTY
D8, D9, D10, D17	BAT43S	4
D11	US1K	1
D12	1N4148W-7-F	1
D13	MBRS340T3G	1
D14	MBRS140T3G	1
D15, D16	ES2D(2A/200v)	2
DSA1	EM3600XS-X4241	1
F1	T50A/250VAC	1
IC1	PSS30S71F6	1
IC2, IC3	TLP181	2
JTAG1	7-pin, 2.54 mm	1
JTAG2	JTAG	1
K1	HF105F-1/12DT-1HS	1
L1, L2	RC12A057RL (574 µH/15 A)	2
L3	CM30T13L	1
L4	LT38-4P-014	1
LED1, LED3	蓝	2
LED2, LED4	白	2
Q1, Q2	SPW47N60CFD	2
Q3, Q5, Q6, Q7, Q9, Q11	BCX 55-16 E6327	6
Q4	S9013LT1	1
Q8	BSS126	1
Q10	IPP65R600C6	1
R1, R3, R5, R6, R9, R10, R13, R18, R38, R45, R46, R47, R49, R50, R51, R52, R53, R54, R55, R56, R57, R59, R61, R62, R63, R64, R65, R67, R68, R77, R85, R86, R87, R90, R91, R92, R111, R113, R127	NC	39
R2	11 k +1%	1
R4, R19, R39, R48, R69, R112, R114, R128, R168, R169, R231	0 R +5%	11
R7, R11, R15, R16, R116, R117, R119	2 k +1%	7
R8, R12, R29, R32, R37, R40, R58, R94, R96, R191, R230, R232, R234, R235	1 k +5%	14
R14, R27, R31, R33, R36, R60, R125	5.1 k +1%	7
R17, R66	8.2 k +1%	2
R20, R21, R22, R23, R24, R25, R26, R28, R70, R71, R72, R73, R74, R75, R76, R78, R79, R80, R82, R84, R99, R100, R166	3.3 k +5%	23
R30, R34, R83, R88, R123, R167, R172, R202, R205, R216	10 k +1%	10
R35, R89	2.2 k +5%	2
R41, R43, R44, R93, R97, R98, R129, R130, R149, R150, R209	10 k +5%	11
R42, R95	47 R +5%	2
R81, R105, R108, R121, R138, R143, R161, R162, R164, R178, R179, R180, R217, R221	100 R +5%	14
R101, R102, R109, R110, R115, R124	6.8 k +1%	6
R103, R104, R106, R107, R118, R122	1.5 k +1%	6
R120, R126	1 k +1%	2
R131, R136, R137, R144, R145, R155, R196, R197, R198, R211, R212, R213, R218, R219, R220, R223, R224, R225	475 k +1%	18
R132, R139, R140	360 k +5%	3
R133, R134, R135, R141, R142, R147, R148, R152, R153	360 k	9
R146, R154, R210, R214, R215	R01/5 W +1%	5
R151	B470N	1

Table 4. BOM (continued)

DESIGNATOR	DESCRIPTION	QTY
R156, R157	22 R +5%	2
R158	0 R +5%	1
R159, R160	4R7 +5%	2
R163, R170	300 R +5%	2
R165, R171, R226	3.3 k +1%	3
R173, R174, R182, R183, R186, R188, R194	10 k +5%	7
R175, R181	100 k +1%	2
R176, R177	300 k +1%	2
R184	22 R +5%	1
R185	10 M/0.25 W +5%	1
R187	14.3 k +1%	1
R189	4R7 +5%	1
R190	4.22 k +1%	1
R192, R193	R5 +1%	2
R195	10 k +5%	1
R199, R200, R201, R203, R204, R207	100 R +5%	6
R206	86.6 k +1%	1
R208	22 k +5%	1
R222	1.2 k +1%	1
R227, R228, R229	8.2 k +1%	3
R233	ZERO	1
T1	EE25/13/7	1
TAB1	VBUS_IN	1
TAB2	GND_IN	1
TAB3	VBUS_OUT	1
TAB4	GND_OUT	1
U1	TMS320F28027	1
U2	OPA4374AIPW	1
U3	TMS320F28034	1
U4, U5	OPA4348AIPW	2
U6	DIP-8 座子(24C08)	1
U7, U8	UCC27524	2
U9, U10, U13	TL431AQDBZ	3
U11	LM5023MM	1
U12	PC817B	1
U14	MAX3221	1
X1, X2	10 M	2
ZD1	MMSZ5246B (16 V/0.5 W)	1
ZD2	SM6T150A	1
ZD3	MMSZ5242B (12 V/0.5 W)	1
ZD4	MMSZ5245B (15 V/0.5 W)	1
ZD5, ZD7, ZD9	SMAZ24-13-F (24 V/1 W)	3
ZD6	MMSZ5231B (5.1 V/0.5 W)	1
ZD8	MMSZ5252B (24 V/0.5 W)	1
ZD10	MMSZ5248B (18 V/0.5 W)	1
ZR1, ZR2	14D681K	2

4.3 Layer Plots

To download the layer plots, see the design files at TIDM-VF-COMPRESSOR-DRIVING-SYSTEM.

4.4 Gerber Files

To download the Gerber files, see the design files at TIDM-VF-COMPRESSOR-DRIVING-SYSTEM.

4.5 Firmware Files

To download the firmware files, see the design files at TIDM-VF-COMPRESSOR-DRIVING-SYSTEM.

5 References

1. Texas Instruments, *TMS320F240 DSP Solution for Obtaining Resolver Angular Position and Speed*, TMS320F240 Application Report (SPRA605)
2. Texas Instruments, *TMS320F2803x Piccolo™ MCUs*, Data Manual (SPRS584)
3. Texas Instruments, *TMS320F2802x, TMS320F2802xx (Piccolo) MCUs*, Data Manual (SPRS523)

6 About the Author

IGOR AN is the system application engineer at Texas Instruments' Shanghai Site, mainly focusing on TI C2000™ series MCU application of digital power and motor control domain of industrial segment. Igor received his education of engineering from Supélec of France and earned his bachelor master degree of automatic from Nanjing University of Aeronautics and Astronautics.

This system's firmware is developed by **IGOR AN**. The hardware part is developed by **JASON TAO**.

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