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User Guide for

FEBFCM8531_B01H300A

Evaluation Board

PMSM/BLDC

Motor Control Board

Featured Fairchild Product:

FCM8531

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

Fairchild Semiconductor.com

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CAUTION!

1. Safety Precautions

Before applying power to the FEBFCM8531_B01H300A evaluation board, it is imperative that all involved personnel read and understand the safety precautions and understand the power on/off procedures.

The FEBFCM8531_B01H300A evaluation board operates at lethal voltages and has bulk capacitors that store significant charge. Accidental contact can lead to lab equipment damage personnel injury, and may be fatal. Please be exceptionally careful when probing and handling this board. Always observe all laboratory precautions, including:

- All connected computers and measurement equipment MUST be isolated from the AC mains before operating voltages are applied to the board. Alternatively, AC/DC power to the board may be isolated.
- When using an oscilloscope with this board, it must be isolated from the AC line. Alternatively, high-voltage (700 V+) isolated probes may be utilized.
- Start with a clean working surface, clear of any conductive material.
- Be careful while turning on the power switch to the AC source.
- Never probe or move a probe on the board while the AC line voltage is present.
- Ensure the bulk capacitors are discharged before disconnecting the AC motor and the MCU. One way to do this is to remove the main power source while the motor is still running with the MCU active. The motor then discharges the output capacitors and the module is safe to disconnect.

Note: Please consider, even when computer is isolated from AC mains through external supply, a connection to earth-potential may exist through LAN, VGA, or other connections to peripherals.

2. Introduction

This user's manual describes how to use the evaluation board for the FCM8531 It should be used in conjunction with the FCM8531 datasheet as well as Fairchild's application notes and technical support team. *Visit Fairchild's website at www.fairchildsemi.com.*

The evaluation board features the FCM8531 brushless DC motor controller and integrates the necessary peripheral circuits, drivers, and power supply. This makes the development and verificataion of a three-phase brushless DC motor application faster and easier. The purpose of this manual is to provide instructions on how to operate and test the evaluation board. *For more information regarding the FCM8531, the MCDS IDE, and the MCDS Programming kit, please visit: http://www.fairchildsemi.com/applications/motor-control/bldc-pmsm-controller.html.*

2.1. Overview

The evaluation board includes the FCM8531 (a brushless DC motor controller), AC-DC rectifier stage, DC-DC converter, control interface, debugging interface, and motor drive circuits, as shown in Figure 1.

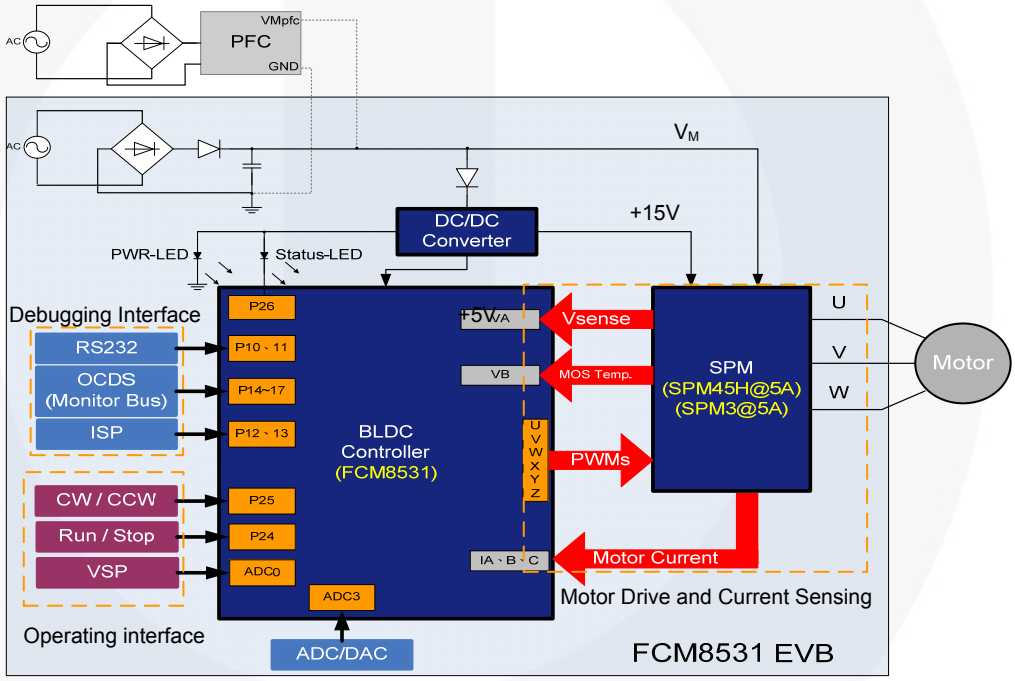

Figure 1. Block Diagram

Power Input

An AC-DC rectifier converts the 220 V_{AC} residential electricity to a DC voltage that powers the motor drive and the system DC-DC converter. The evaluation board can also accommodate an alternate input source through the PFC+ and PFC_GND connectors. For example, if Power Factor Correction (PFC) or a specific regulated DC input voltage is required, connect the output of an external power supply directly to the PFC+ and PFC_GND inputs on the board. When one these alternative powering methods is utilized, the on-board AC-DC rectifier circuits are not used. Nevertheless, it is still galvanically connected to the high-voltage portion of the evaluation board; thus the components of the AC-DC recifier circuit can cause dangerous high-voltage electric shock. It is important to

physically remove the AC input cord of the evaluation board when the AC-DC bridge rectifier is not used.

The DC-DC converter provides the +15 V and +5 V supply voltages for the control and gate drive circuits of the evaluation board. The operation of the bias power supply is indepenent of the input source and can accommodate the input from the AC-DC rectifier or from an external power source.

Motor Drive and Current Sensing

The evaluation board uses a Fairchild Smart Power Module (SPM®), which simplifies the PCB layout and manufacturing by integrating all the motor drive components; e.g. IGBTs/FRFETs, HVICs, LVIC, bootstrap diodes, and NTC thermistor. Note that various SPM modules can meet the requirements of different motor applications; e.g. SPM Series 5, SPM Series 45 H, SPM Series 3, and SPM Series 2. *Please visit the Fairchild website for more information; http://www.fairchildsemi.com/applications/motor-control/bldc-pmsm-controller.html.*

The FCM8531 has three dedicated current-sensing pins and users may connect those pins to three shunt resistors. The current-sense information can be used for over-current protection and for sensorless algorithms.

Operating Interface

Operation of the evaluation board is controlled by three commands: forward / reverse rotation (CW/CCW), run / stop, and speed. The first two commands (FWD/REV and RUN/STOP) are implemented by switches connected to digital I/O pins of the FCM8531. The speed command uses a variable resistor (potentiometer) for adjusting a voltage level connected to the ADC0 input of the FCM8531. Inside the FCM8531, this voltage level is converted to a speed command.

Debugging Interface

The Motor Control Development System (MCDS) programming kit is needed to load the developed firmware into the FCM8531 through the In System Programming (ISP) interface. Verification and debugging are performed with the MCDS programming kit.

2.2. Features

- Bulit-in AC-DC Rectifier
- Bulit-in DC-DC Converter
- Integrated OCDS and ISP Interface
- Sensorless Control Technology
- Sinusoidal Drive
- Programmable Over-Current Protection (OCP)
- Programmable Short-Circuit Protection (SCP)
- Programmable Over-Voltage Protection (OVP)
- Programmable Over-Temperature Protection (OTP)
- A Complete Firmware Example

2.3. Applications

This evaluation board was designed for general-purpose motor applications. It can be used to develop indoor fans, pedestal fans, ceiling fans, bladeless fans, outdoor fans, pumps, oil pumps, refrigerators, e-bikes, range hoods, etc.

This evaluation board reduces the time required for prototyping development boards.

For applications requiring higher output power, the SPM module of this evaluation board can to be replaced. In this case, it might also be necessary to connect an external power supply to match the desired power demand or if different input voltage is required.

3. Specifications

All data in this table was measured at an ambient temperature of T_A=25°C.

Table 1. Evaluation board Specification Table

Symbol	Description	Value	Comments
AC_{IN}	AC Input Voltage	220 V±10%	50~60 Hz
PFC_{IN}	PFC Connector Input Voltage	180~400 V	
DC_{15V}	15 V Voltage	14~16 V	
DC_{5V}	5 V Voltage	5 V	
PWM_{Freq}	PWM Frequency	15 kHz	Programmable
SPM_{OTP}	SPM Over-temperature Protection	100°C	Programmable
$Motor_{OVP}$	Motor Drive Over-Voltage Protection	440 V	Programmable
OCP_{SHORT}	Short-Circuit Current Protection	2 A	Programmable
OCP_{CYCLE}	Cycle-by-Cycle Current Protection	1 A	Programmable
CMD_{RUN}	Motor Run Command Voltage	3.3 V~V_{DD}	V_{DD} = +5 V
CMD_{STOP}	Motor Stop Command Voltage	0~1.8 V	
DIR_{CW}	Motor CW Command Voltage	3.3 V~V_{DD}	V_{DD} = +5 V
DIR_{CCW}	Motor CCW Command Voltage	0~1.8 V	
VSP	Motor Speed Command Voltage Range	0.2~4 V	
	AO Input Voltage	0~V_{DD}	0.2~4 V Readable
	AO Output Voltage	0~V_{DD}	0.2~4 V Output
	Maximum Output Power	300 W	

4. Photographs

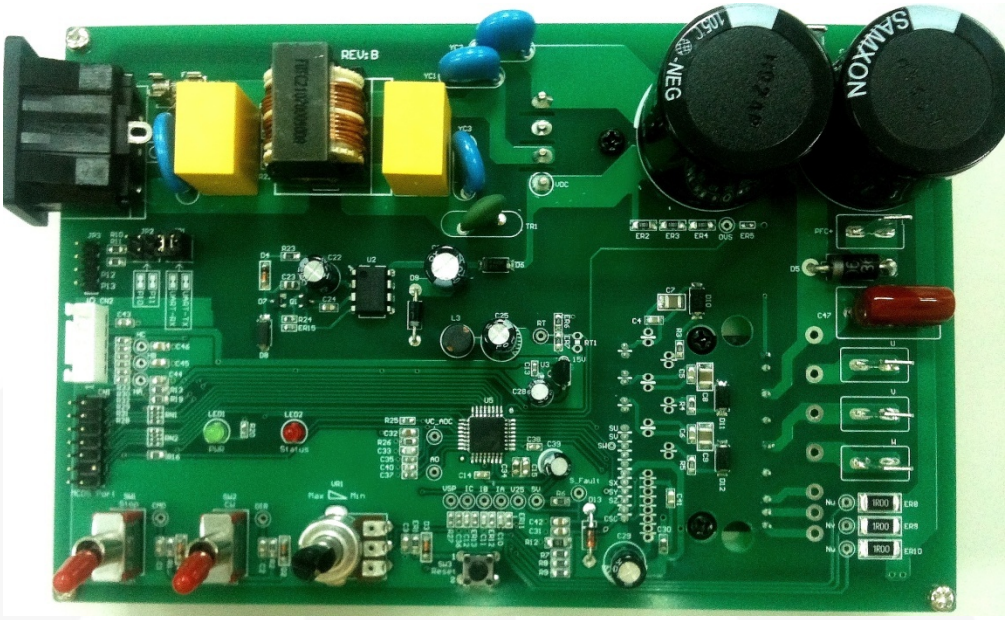

Figure 2. Top (Component Side) View of FCM8531 Evaluation Board

Figure 3. Bottom View of FCM8531 Evaluation Board

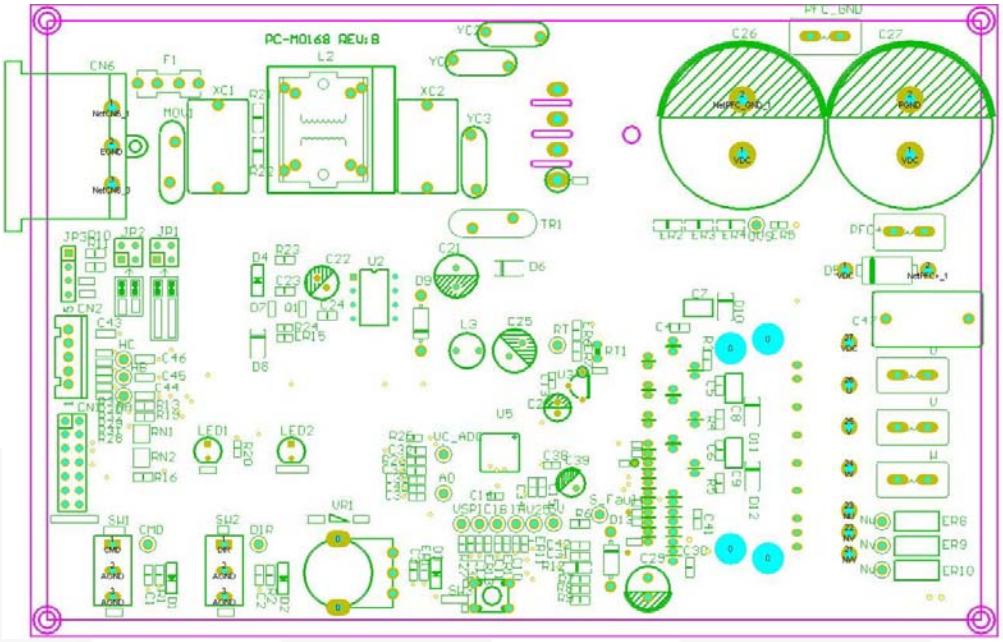

Figure 4. FCM8531 Evaluation Board Silk Screen Plot

Table 2. Connectors/Switches Descriptions

Connectors / Switches	Description
CN6	AC line input (220 V_{AC})
CN1	Connector for MCDS programming kit
U,V,W	Connectors for 3-phase blushless DC motor
SW1	Switch for RUN/STOP command
SW2	Switch for Motor direction CW/CCW command
VR1	Variable resistance for motor speed command
SW3	Reset button to reset the FCM8531
PFC+, PFC_GND	External DC input voltage (**CAUTION**: CN6 must be unused and line cord must be removed!)
JP3-1	P10 / UART RX
JP3-2	P11 / UART TX
JP3-3	P12
JP3-4	P13
JP2	P11, P10
JP1	UART TX, UART RX
CN2-1	Reserved for Hall signal measurement, Hall A input pin with a 4.7 kΩ pull-up to 5 V on evaluation board.
CN2-2	Reserved for Hall signal measurement, Hall B input pin with a 4.7 kΩ pull-up to 5 V on evaluation board.
CN2-3	Reserved for Hall signal measurement, Hall input pin with a 4.7 kΩ pull-up to 5 V on evaluation board.
CN2-4	Reserved for Hall signal measurements, DC15V output.
CN2-5	Reserved for Hall signal measurements, GND.

5. Usage Procedures

5.1. Contents of FCM8531 Evaluation Board

Figure 5. Evaluation Board

The actual package content may be different from the pictured original version. Fairchild reserves the right to make changes.

5.2. FCM8531 Evaluation Board Installation

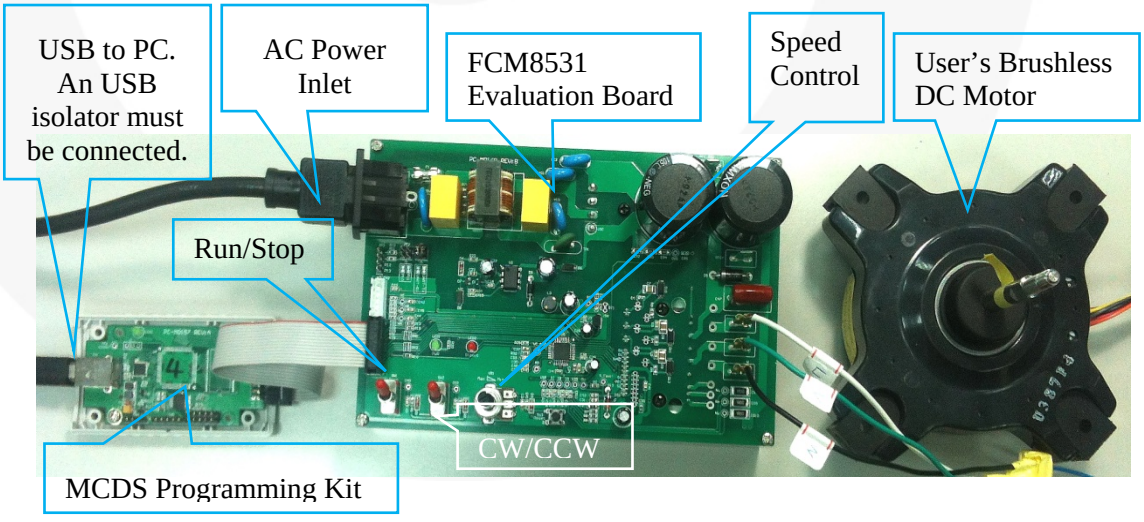

Figure 6. Interface Set-up for Testing the FCM8531 Development System

6. Introduction of Functions

6.1. Power Supply

Three DC voltages are generated from the AC input:

1. Supply voltage of the brushless DC motor, V_M +310 V_{DC};
2. System voltage +15 V;
3. System voltage +5 V.

The supply voltage for the motor, V_M, is provided from a residential AC outlet by rectifying the AC line voltage using the full-bridge rectifier circuits. An EMI filter circuit is included on the board to minimize EMI noise. The PFC+ and PFC_GND terminals enable connection to an external power source when the power requirements exceed the rating of the board's input rectifier. In this case, it is possible to use an external voltage source according to power requirements.

The board DC-DC converter is the FSL206MR, a Green Mode Fairchild Power Switch (FPS™), to convert the V_M voltage to 15 V for the SPM module on the evaluation board. An additional regulator is used to generate the 5 V bias source for the FCM8531 and other control circuits. The power delivery block diagram is shown in Figure 7.

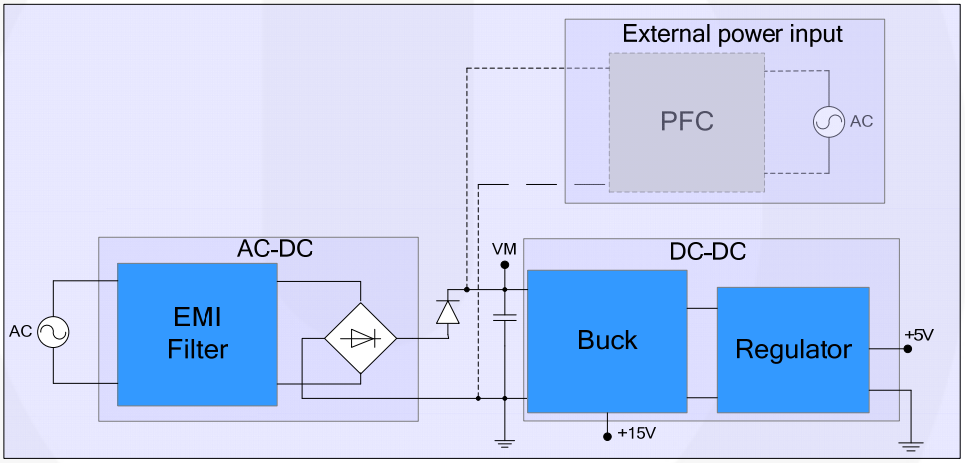

Figure 7. Block Diagram

6.2. Motor Driving and Current Sensing

The FCM8531 is a configurable three-phase PMSP/BLDC motor controller with an embedded MicroController Unit (MCU) with parallel processing cores and a configurable Advanced Motor Controller (AMC). The AMC is specifically designed for motor control and can be configured to perform sensorless motor control using the sensorless AMC libraries. The controller senses the current from the three shunt resistors through the IA, IB, and IC pins and performs the calculations to obtain the rotor position. It then outputs the required PWM signals to the SPM control inputs to drive the motor. Beside the sensorless calculations, the current signals also provide current information to the current-protection circuits, such as the OCH, OCL, and short-circuit protections. Visit *http://www.fairchildsemi.com/applications/motor-control/bldc-pmsm-controller.html*.

6.3. Applicable Power Range

The evaluation board and pre-programmed firmware are designed for a specific power range. If different power rating is needed, a few components and the firmware may need to be changed. In addition, the power capabilities of the AC-DC rectifier (including the EMI filter), the SPM module, and the motor need to be reconsidered.

AC-DC: The maximum power this evaluation board can deliver for the motor is 300 W at 220 V_{AC} input (measured at the three-phase output terminals of the evaluation board). This evaluation board is applicable for implementations below 300 W. For higher power, use of an external power source must be considered to avoid damage to the on-board AC-DC rectifier.

SPM®: The default SPM on this evaluation board is the FNB41060. In conjunction with the example source code delivered with the evaluation board, it is able to drive a brushless DC motor with power consumption below 300 W at 310 V_{DC}. If higher power is needed, the SPM, R_{SHUNT}, and the firmware may need to be changed to meet the power rating. Two SPM packages are compatible with the FCM8531 evaluation board: the SPM26L and SPM27L. Follow the link below for more information on applicable SPM modules: *http://www.fairchildsemi.com/applications/motor-control/integrated-motor-driver-devices.html*.

The following link may be useful to simulate and determine which SPM module meets specific power requirements:

http://www.fairchildsemi.com/design_tools/motion_control_design_tool/index.html

Motor: The power rating of the motor in the evaluation board kit is about 70 W at 310 V_{DC}. If a smaller motor is conncected to the board, pay attention to whether the starting current or stall current may damage the motor windings. If necessary, the parameters of current protections should be revised to fit the requirements.

6.4. Firmware Programming

To program the firmware into the FCM8531, users must have the Motor Control Development System (MCDS) Integrated Development Environment (IDE) and the MCDS programming kit. *For more detailed information about programming, please refer to the AN-8207 — User Guide for MCDS IDE.*

7. Operation

7.1. Parameter Setting for Sensorless

The firmware matching the properties of the motor included in the evaluation kit have been programmed into the FCM8531 on the board. In the following two situations, the motor parameters or MCU programs must be re-written or changed.

- When different motors are used
- When using the incuded motor but with a different load

This evaluation board with pre-programmed firmware provides the following functionality: run/stop, forward/reverse rotation, speed control, and current protections. If additional functions are required, the corresponding program (code) can be developed based on the included firmware example.

For the details of parameters and AMC libraries, please visit the Fairchild website for more information: http://www.fairchildsemi.com/applications/motor-control/bldc-pmsm-controller.html.

7.2. Run / Stop

The SW1 switch controls whether the voltage level is HIGH or LOW at the input P24 (pin 24) of the FCM8531. When SW1 is in ON position, the motor is started. The rotation speed is controlled by the VR1 variable resistor. When SW1 is in OFF position, all three phases of the motor drive circuit are disabled, the high- and low-side drivers are turned off, and the motor is not driven. Note that the rotor might continue to rotate for a while based on its inertia, depending on its state at the assertion of the OFF command.

7.3. Forward Rotation / Reverse Rotation

The SW2 switch controls whether the voltage level is HIGH or LOW at the P25 input pin of the FCM8531. A HIGH voltage level at P25 sets clockwise (CW) rotation, while a LOW voltage level causes the rotor to spin in a counterclockwise (CCW) direction. The direction of the rotation is related to the order in which the motor's three-phase wires connect to the board's connector. In forward (CW) rotation mode, the evaluation board drives the PWM signals following the order of U, V, W. In reverse (CCW) rotation mode, the evaluation board drives the PWM signals following the order of W, V, U. The actual direction of the motor's rotation depends on the motor winding and the connection to the evaluation board.

7.4. Speed Control

The VR1 variable resistor is used to adjust the voltage level connected to the ADC0 input of the FCM8531. The internal ADC of the FCM8351 converts this voltage into a speed command and controls the duty ratio. Turning VR1 clockwise; the voltage is increased and the duty ratio become larger, causing the motor speed to increase. Turning VR1 counterclockwise; the voltage is decreased, the duty ratio become smaller, and the coresponding motor speed is slower.

7.5. Troubleshooting

Q: The motor doesn't rotate when it is connected to the evaluation board.

A: Check the input voltage, SW1 (CMD), VR1 (VSP), and the motor connection.

Q: When using Speed Integral library, the rotation speed is too high or the rotor stops turning after the speed is further increased.

A: It may be caused by the AS angle not being adjusted properly. Refer to the application note *AN-8204 – FCM8531 AMC Library, Speed Integral* to adjust AS.

8. Function Test Report

8.1. Specifications

Parameter	Specifications/Conditions
Input Voltage	176 ~ 264 V_{AC}, 50/60 Hz
Maximum Output Power	300 W at 220 V_{AC}
VSP Input Voltage	0 ~ 4.0 V,
DIR Input Voltage	Toggle Switch Input Level: HIGH = Phase Order: U→V→W LOW = Phase Order: W→V→U
Threshold Voltage of OVP	> 440 V_{DC} Typical
Release Voltage of OVP	< 380 V Typical
Threshold Current of Short-Circuit Protection	2.0 A Typical
Threshold Current of Cycle-by-Cycle Current Protection	1.5 A Typical
SPM Over-Temperature Protection	100°C

8.2. DC Characteristics Test

Input Voltage = 220 V_{AC} / 60 Hz and T_A = 25°C unless otherwise noted.

Parameter	Test Condition	Specification	Value	Unit
Input Power of System Standby	System Standby		0.8	W
V_M RMS Voltage	Load = 150 W	290 ~ 310	306	V
V_M Ripple Voltage	Load = 150 W	< 30	12	V
+15 V Voltage	Load = 150 W	13 ~ 15	14.5	V
+5 V Voltage	Load = 150 W	4.5 ~ 5.5	5.1	V
VSEN Voltage	System Standby		2.83	V
RT Voltage	System Standby		1.2	V
Motor Run Threshold Voltage of VSP			0.4	V
DIR Input High Voltage			5	V
DIR Input Low Voltage			0	V

8.3. AC Characteristics Test

8.3.1. PWM Frequency

- Test Condition: Input Voltage = 220 V_{AC}
- Test Condition: 15 ~ 16 kHz

CH1: Theta	CH2: SU	CH3: SV	CH4: SW

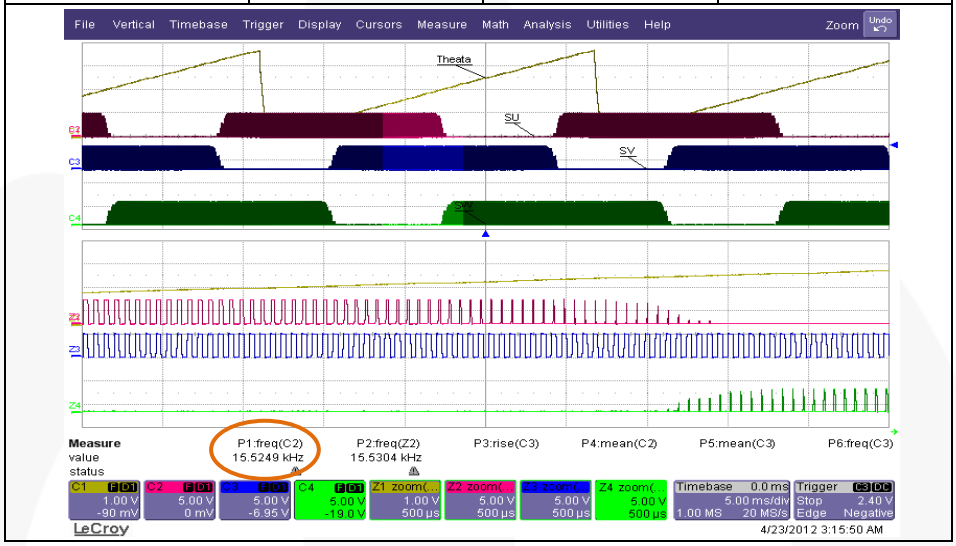

Figure 8. PWM Frequency

8.3.2. PWM Dead Time

- Test Condition: Input Voltage = 220 V_{AC}, Speed = 1500 rpm
- Specification: 2 µs +/- 0.5 µs

CH1: Output of U-Phase	CH2: Gate of SPM High Side	CH3: Gate of SPM Low Side

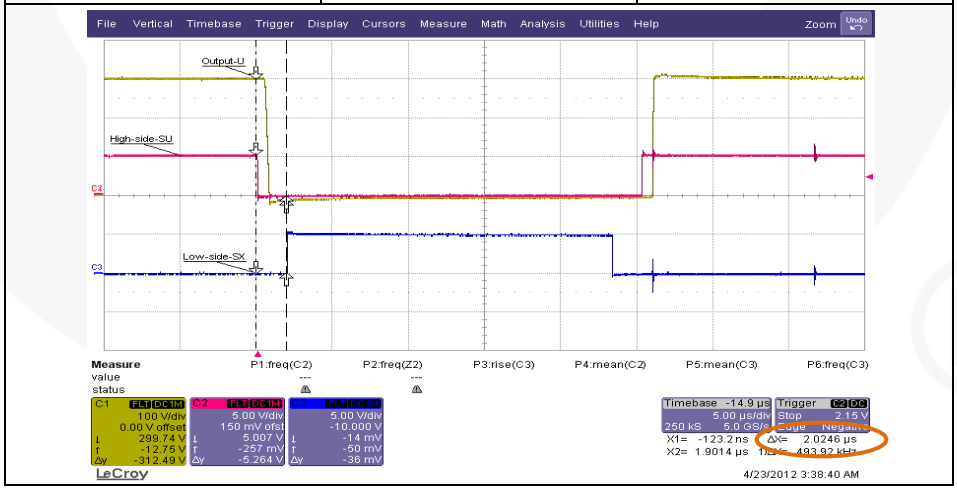

Figure 9. PWM Dead Time Falling Edge of U-Phase; from High-Side Off to Low-Side On

CH1: Output of U-Phase	CH2: Gate of SPM High Side	CH3: Gate of SPM Low Side

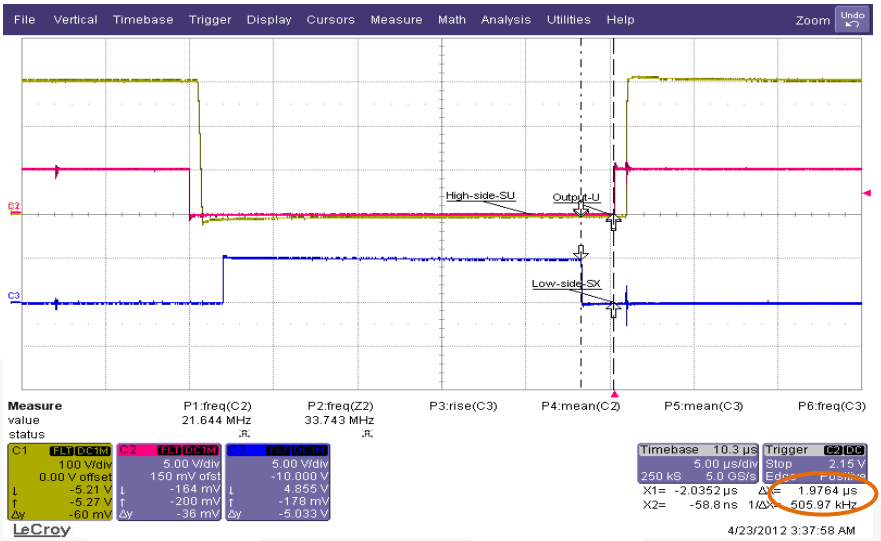

Figure 10. PWM Dead Time Rising Edge of U-Phase; from Low-Side Off to High-Side On

8.3.3. Falling Edge of U-Phase

- Test Condition: Input Voltage = 220 V_{AC}, Speed = 1500 rpm

CH1: Output of U-Phase	CH2: Gate of SPM High Side	CH3: Gate of SPM Low Side

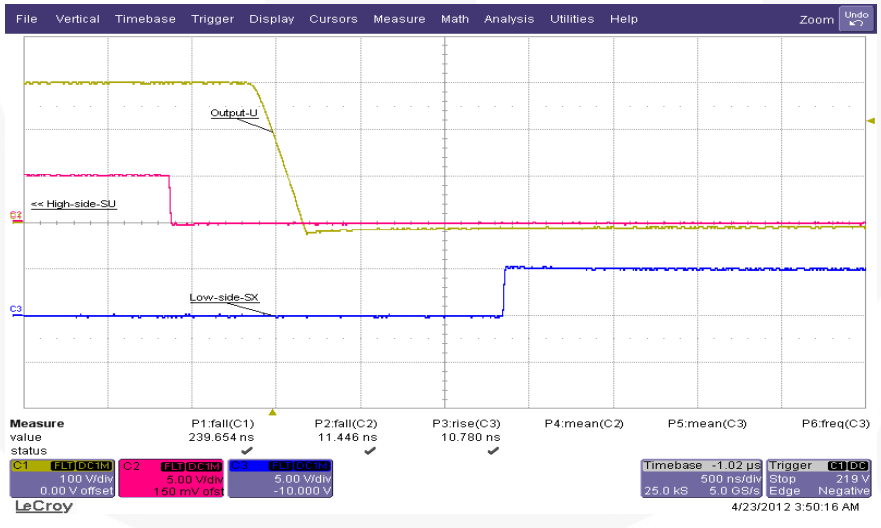

Figure 11. Falling Edge of U-Phase

8.3.4. Rising Edge of U-Phase

CH1: Output of U-Phase	CH2: Gate of SPM High Side	CH3: Gate of SPM Low Side

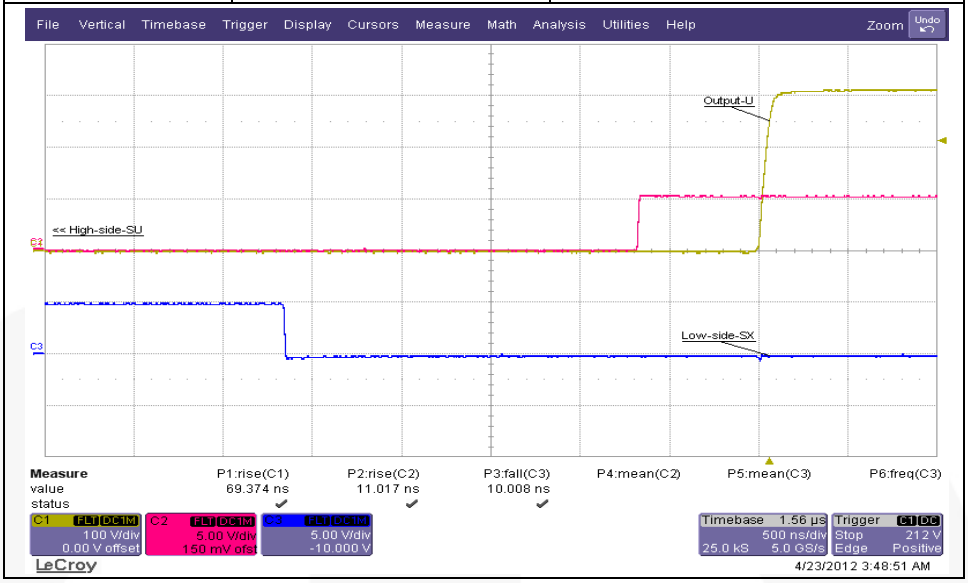

Figure 12. Rising Edge of U-Phase

8.3.5. U-Phase Current

- Test Condition: Input Voltage = 220 V_{AC}, Speed = 1500 rpm

CH1: Theta	CH2: SU	CH3: HA	CH4: U-Phase Current

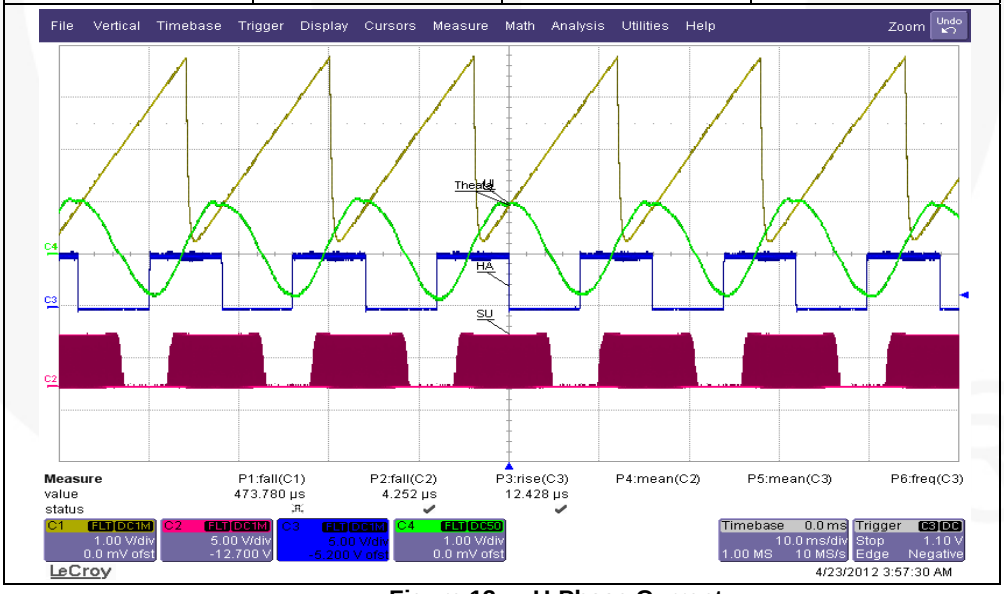

Figure 13. U-Phase Current

8.3.6. V-Phase Current

CH1: Theta	CH2: SV	CH3: HB	CH4: V-Phase Current

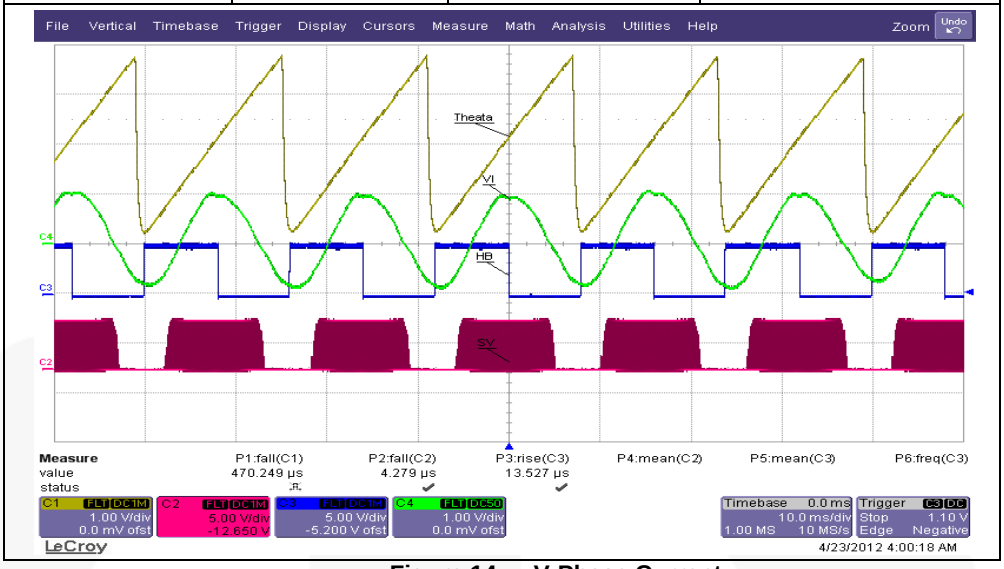

Figure 14. V-Phase Current

8.3.7. W-Phase Current

CH1: Theta	CH2: SW	CH3: HC	CH4: W-Phase Current

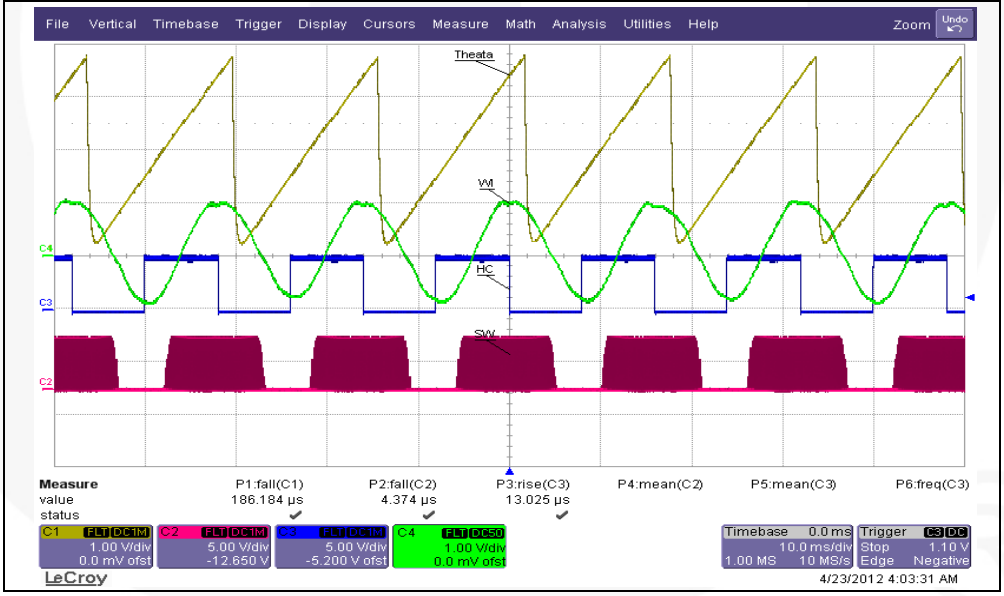

Figure 15. W-Phase Current

8.4. Protection Functions Tests

- Test Condition: Input Voltage = 220 V_{AC}, 60 Hz
- Specification: Over-voltage protection threshold is 440 V_{DC}; reset is at 380 V_{DC}

8.4.1. Over-Voltage Protection Triggered

CH1: VDC	CH2: SU	CH3: VSENSE	CH4: Fault

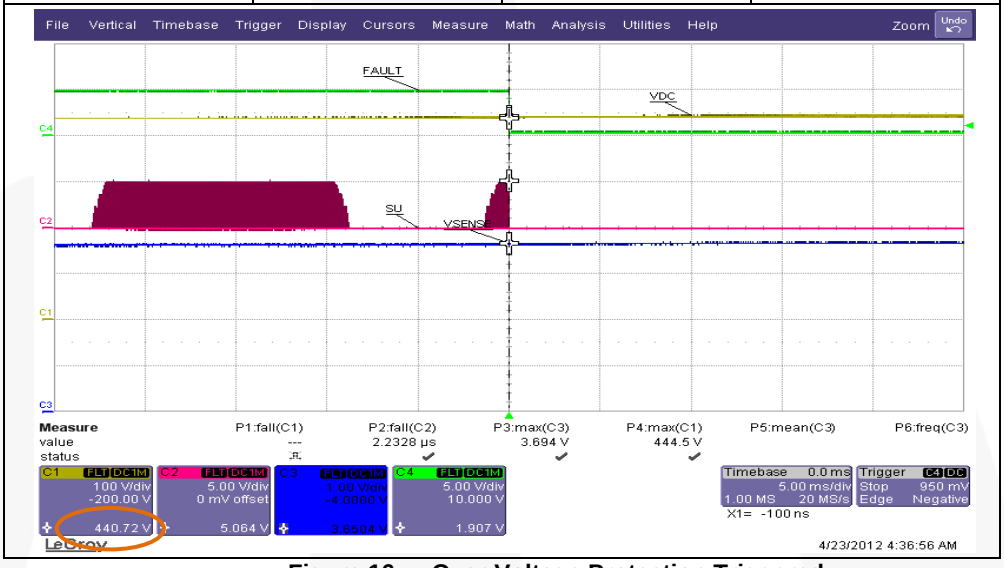

Figure 16. Over-Voltage Protection Triggered

8.4.2. Over-Voltage Protection Released

CH1: VDC	CH2: SU	CH3: VSENSE	CH4: Fault

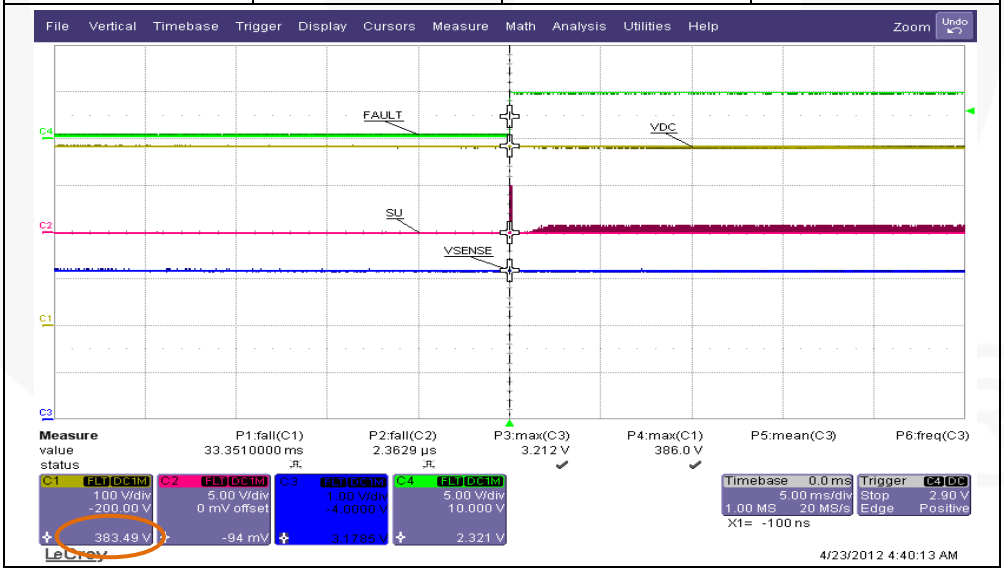

Figure 17. Over-Voltage Protection Released

8.4.3. Short-Circuit Protection

- Test Condition: Input Voltage = 220 V_{AC}, 60 Hz

CH1: Fault	CH2: SU	CH3: SV	CH4: IC

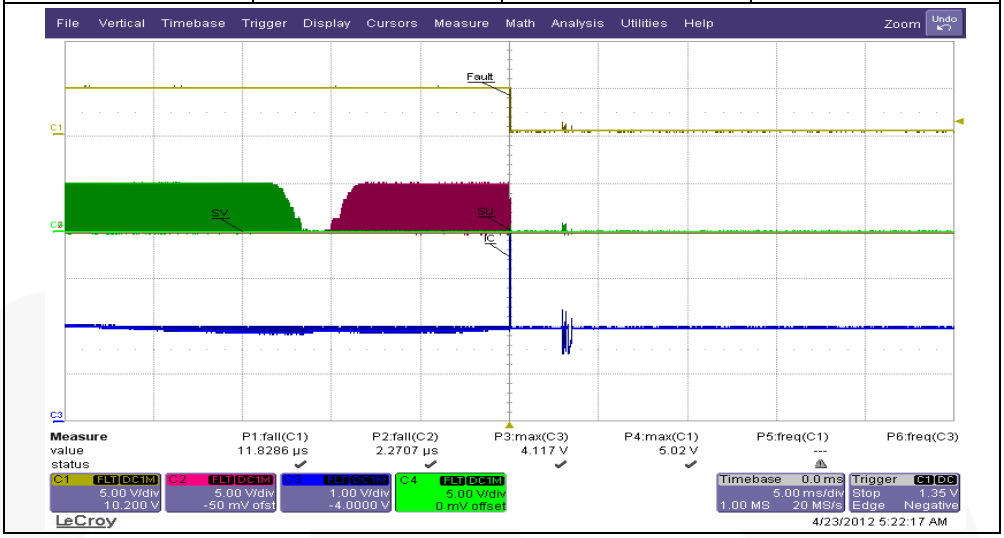

Figure 18. Short-Circuit Protection

8.4.4. Cycle-by-Cycle Current Protection

- Test Condition: Input Voltage = 220 V_{AC}, 50 Hz

CH1: SU	CH2: SV	CH3: SW	CH4: I_IN

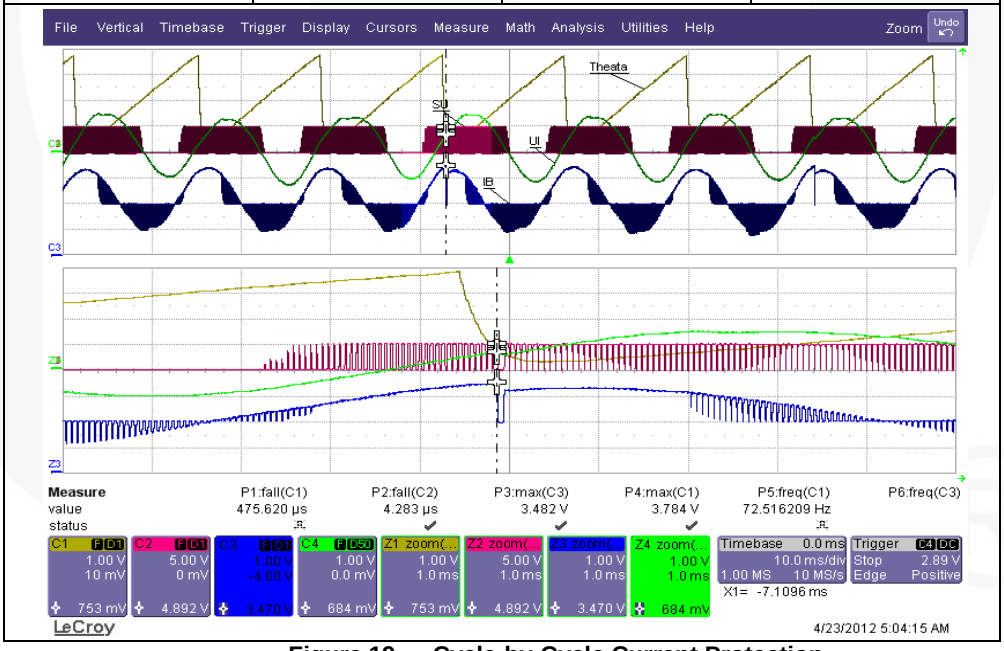

Figure 19. Cycle-by-Cycle Current Protection

8.4.5. SPM Over-Temperature Protection

- Test Condition: Input Voltage = 220 V_{AC}, 60 Hz

CH1: SU	CH2: SV	CH3: SW	CH4: I_IN

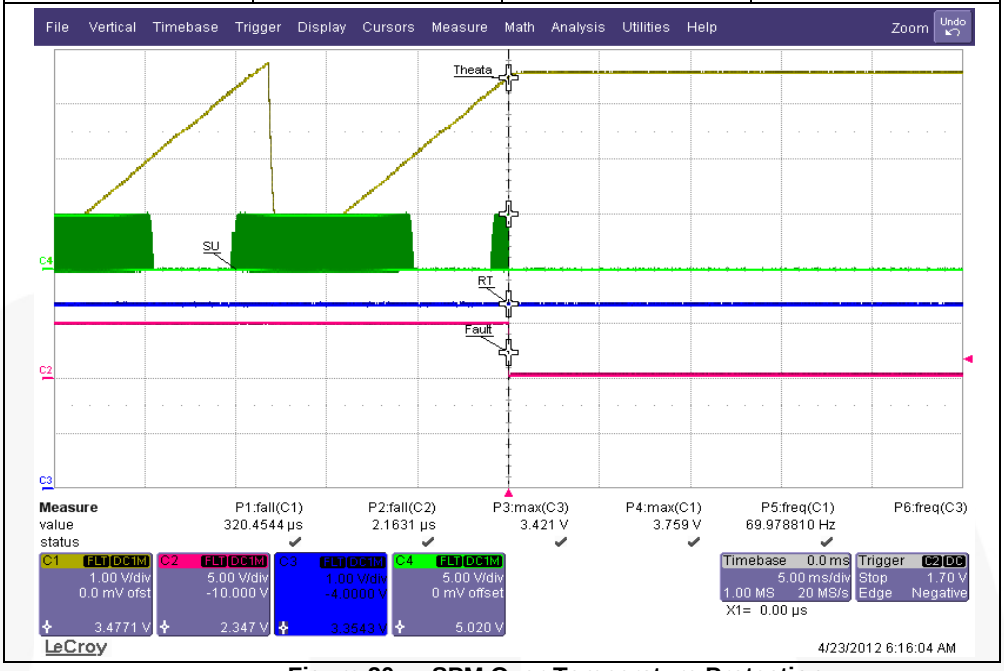

Figure 20. SPM Over-Temperature Protection

8.5. Startup Function (Waveform Sample)

8.5.1. Static Startup

CH1: Theta	CH2: HA	CH3: SX	CH4: HB

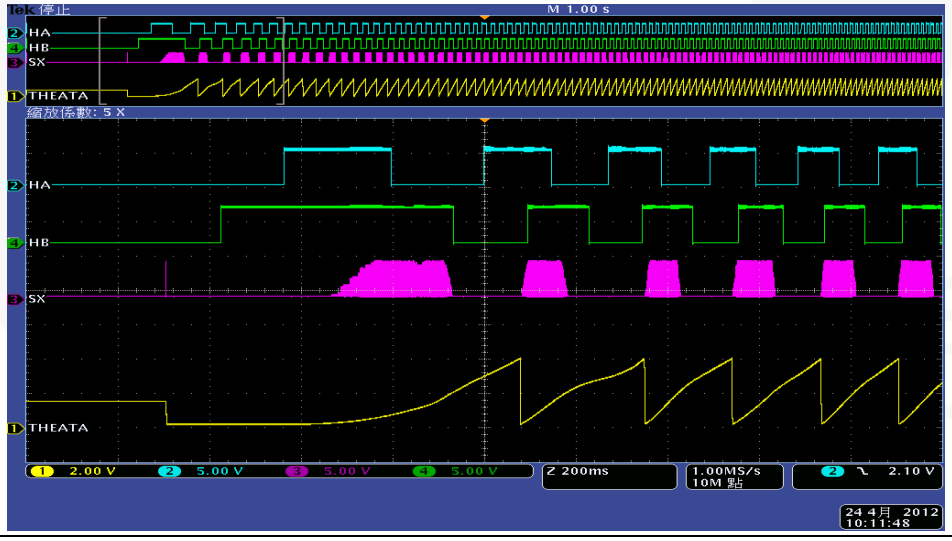

Figure 21. Static Startup

8.6. Thermal Test

- Test Condition: Input Voltage = 220 V_{AC} ±20% / 50 Hz
- Result: 100°C protection without heat sink

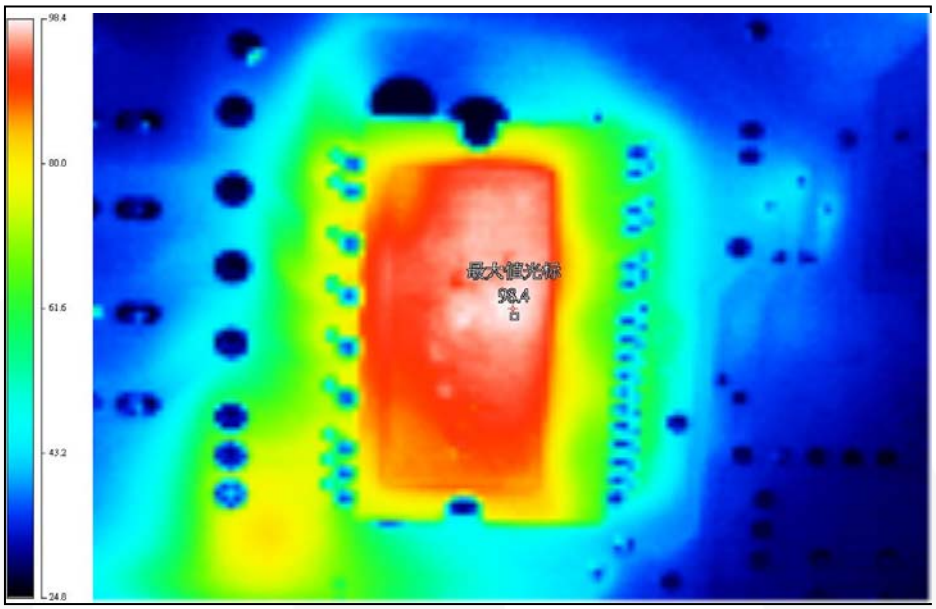

Figure 22. SPM Thermal Image

8.7. Electromagnetic Interference Test (Conduction Only)

- Test Condition: 220 V_{AC}/60Hz, 300 rpm

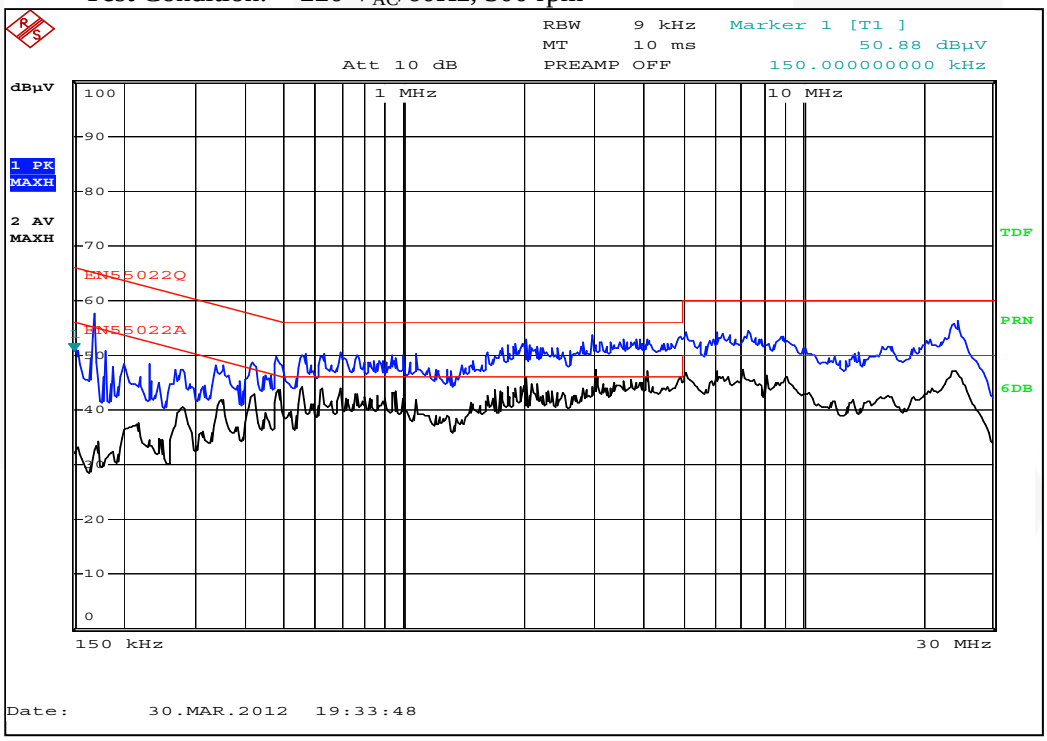

Figure 23. Line Mode

9. Appendix

9.1. Circuit Diagrams

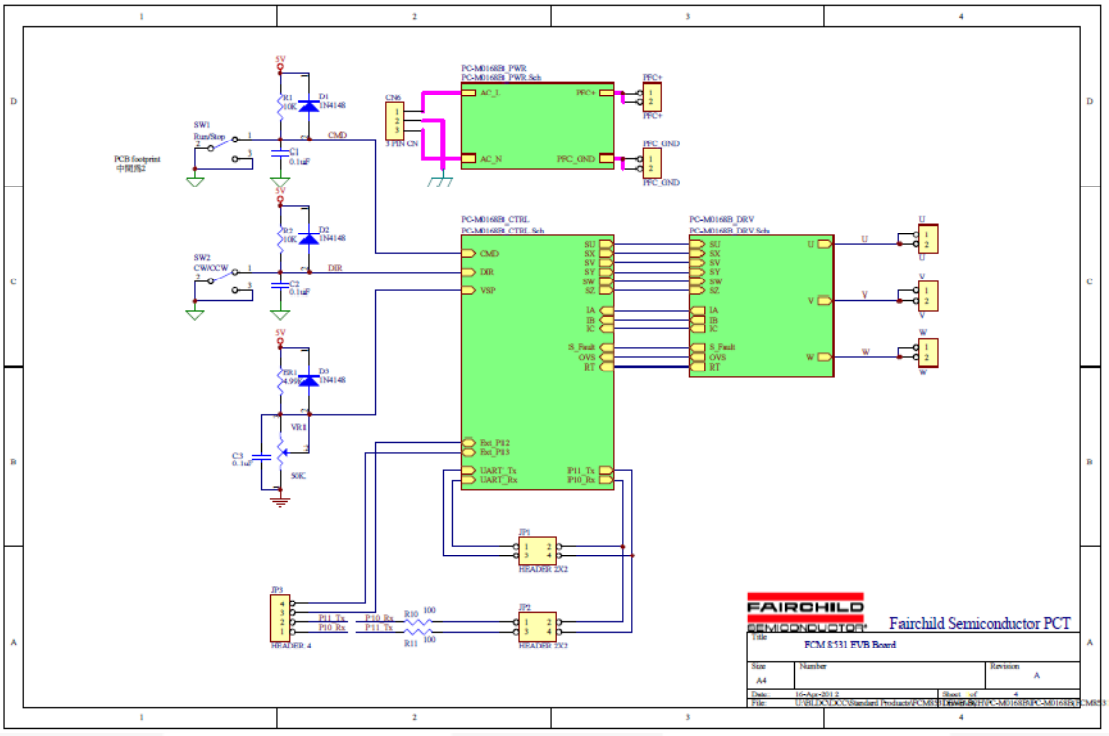

Figure 24. Top Level Schematic

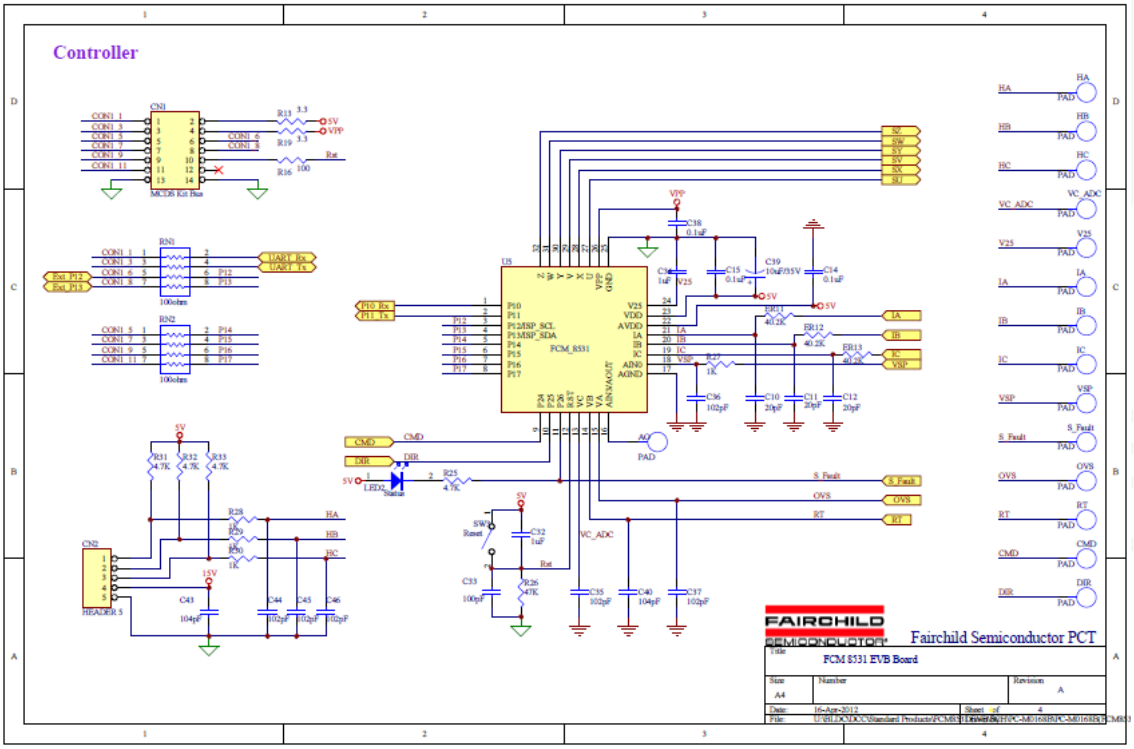

Figure 25. Controller Schematic Diagram

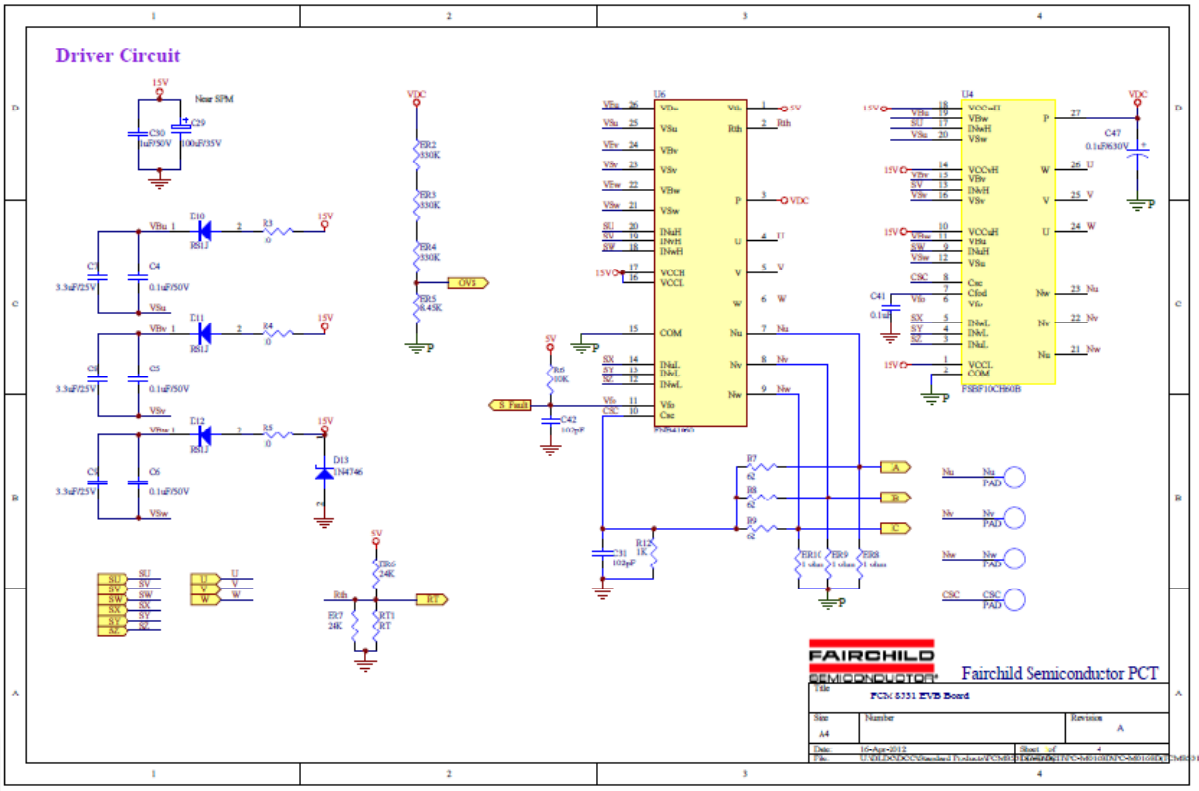

Figure 26. Detailed Driver Circuit Schematic

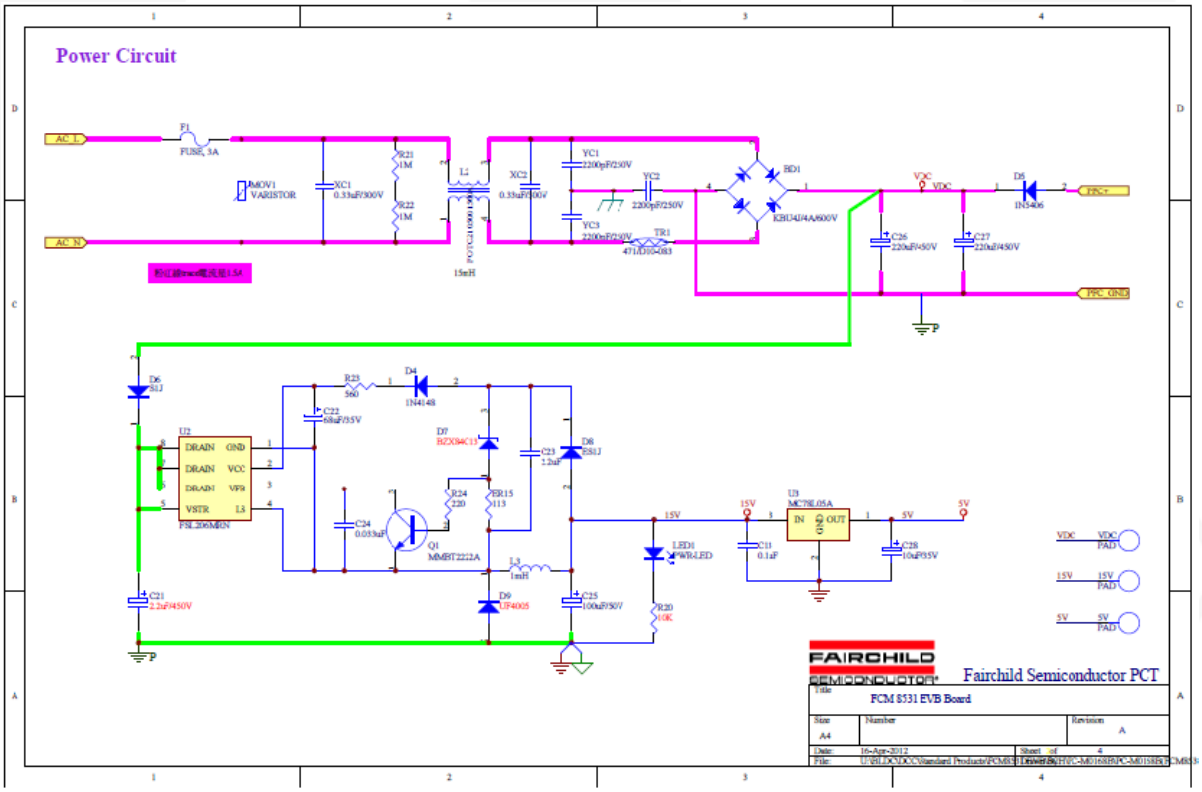

Figure 27. AC-DC Rectifier and System DC-DC Converter Schematic Diagrams

9.2. PCB Layout

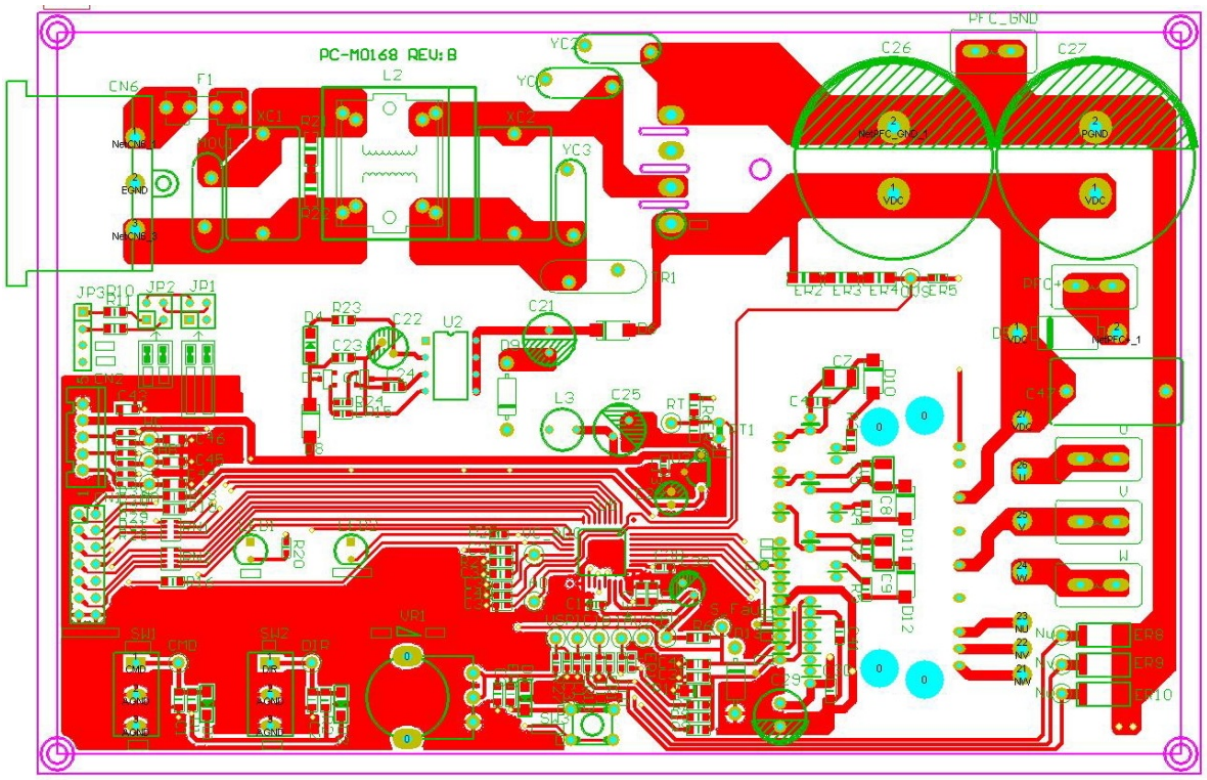

Figure 28. Printed Circuit Board, Top Layer, Component Side

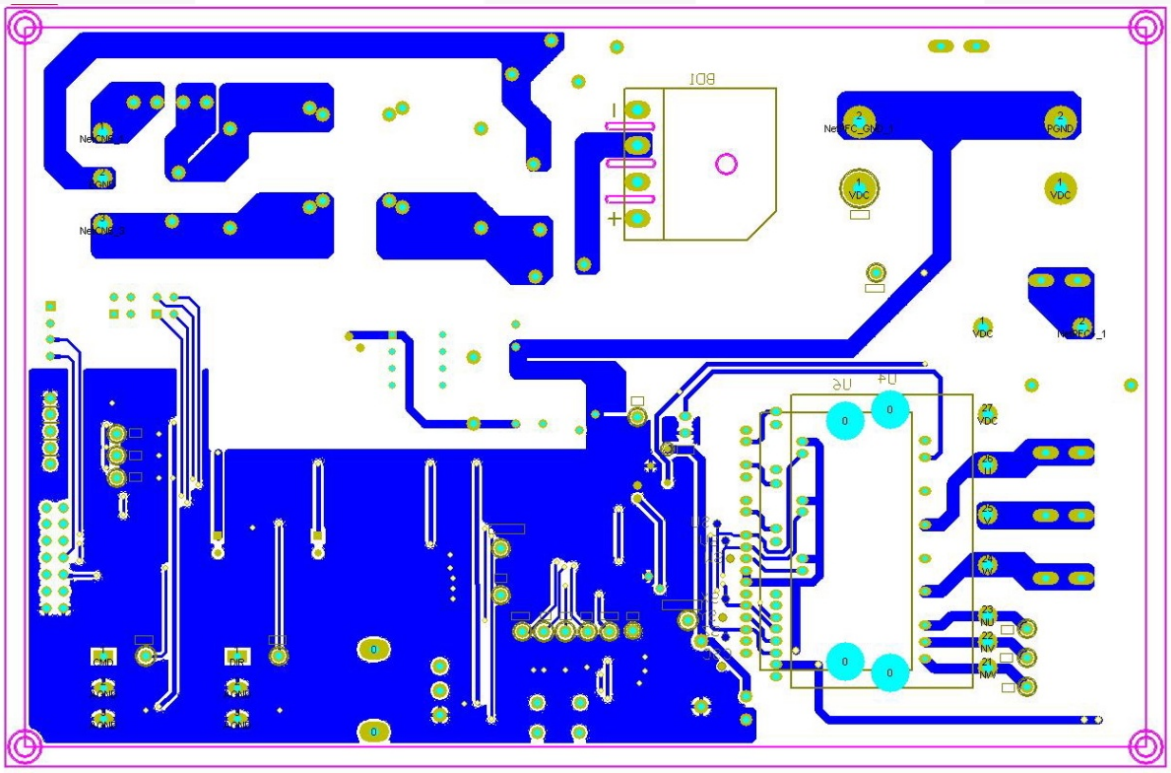

Figure 29. Printed Circuit Board, Bottom Layer, Solder Side

9.3. Bill of Materials

Item	Description	Vendor	Part #	Package	Qty.	Designator
1	Chip Resistor, 113 Ω ±1%, 1/10 W			0603	1	ER15
2	Chip Resistor, 220 Ω ±5%, 1/10 W			0603	1	R24
3	Chip Resistor, 1 kΩ ±5%, 1/10 W			0603	4	R27 ,R28, R29, R30
4	Chip Resistor, 4.7 kΩ ±5%, 1/10 W			0603	3	R31, R32, R33
5	Chip Resistor, 8.45 kΩ ±1%, 1/10 W			0603	1	ER5
6	Chip Resistor, 10 kΩ ±5%, 1/10 W			0603	1	R20
7	Chip Resistor, 40.2 kΩ ±1%, 1/10 W			0603	3	ER11~13
8	Chip Resistor, 3.3 Ω ±5%, 1/8 W			0805	2	R13, R19
9	Chip Resistor, 10 Ω ±5%, 1/8 W			0805	3	R3~5
10	Chip Resistor, 62 Ω ±5%, 1/8 W			0805	3	R7~9
11	Chip Resistor, 100 Ω ±5%, 1/8 W			0805	3	R10~11, R16
12	Chip Resistor, 560 Ω ±5%, 1/8 W			0805	1	R23
13	Chip Resistor, 4.7 kΩ ±5%, 1/8 W			0805	1	R25
14	Chip Resistor, 5.1 kΩ ±1%, 1/8 W			0805	1	ER1
15	Chip Resistor, 10 kΩ +/-1%, 1/8W			0805	3	R1~2,R6
16	Chip Resistor, 24 kΩ ±1%, 1/8 W			0805	2	ER6~7
17	Chip Resistor, 47 kΩ ±%, 1/8 W			0805	1	R26
18	Chip Resistor, 1 kΩ ±5%, 1/4 W			1206	1	R12
19	Chip Resistor, 330 kΩ ±1%, 1/4 W			1206	3	ER2~4
20	Chip Resistor, 1 MΩ±5%, 1/4 W			1206	2	R21~22
21	Chip Resistor, 1 Ω ±1%, 1 W			2512	3	ER8~10
22	Variable Resistor 50 kΩ			VR9	1	VR1
23	SMD Resistor Networks YC16 8-PIN 100 Ω ±5%			RN-YC16	2	RN1~2
24	Chip Capacitor X7R ±10% 20 pF 50 V			0603	3	C10~12
25	Chip Capacitor X7R ±10% 1 nF 50 V			0603	6	C35~C37, C44, C45, C46
26	Chip Capacitor X7R ±10% 0.1 µF 50 V			0603	5	C13~14, C38, C40, C43
27	Chip Capacitor NP0 ±5% 100 pF 50 V			0805	1	C33
28	Chip Capacitor X7R ±10% 1 nF 50 V			0805	2	C31, C42
29	Chip Capacitor X7R ±10% 33 nF 50 V			0805	1	C24
30	Chip Capacitor X5R ±10% 100 nFP 50 V			0805	8	C1~6, C15, C41
31	Chip Capacitor X5R ±10% 1 µF 50 V			0805	3	C30, C32, C34
32	Chip Capacitor X5R ± 10% 2.2 µF 10 V			0805	1	C23
33	Y1 Capacitor 3.3 nF 250 V ±20%				3	YC1~3
34	Electrolytic Capacitor 10 µF 50 V 105°C			EC5D	2	C28, C39
35	Radial Lead Aluminum Electrolytic Capacitor, 47 µF 50 V ±20% 105°C			EC6D3	1	C22
36	Electrolytic Capacitor 100 µF 35 V 105°C			CEA8	2	C25, C29
37	Electrolytic Capacitor 220 µF / 450 V			CEA30A	2	C26~27
38	Radial Lead Aluminum Electrolytic Capacitor, 2.2 µF 450 V ±20% 105°C			EC12D5	1	C21

Item	Description	Vendor	Part #	Package	Qty.	Designator
39	Chip Capacitor X5R 3.3 µF / 25 V			1210	3	C7~9
40	X2 Capacitor 0.68 µF 275 V ±10%			11.5*19.5*17.5P:15 HQX684KS27I	2	XC1~2
41	MPE Capacitor 0.1 µF 630 V ±10%			W18*H13.5*T7 P=15 mm	1	C47
42	SMD Switching Diode		1N4148	LL-34	4	D1~4
43	600 V, 3 A, Rectifier		1N5406	DIODE-0.5	1	D5
44	18 V Zener Diode		1N4746	DO-41	1	D13
45	600 V, 4 A, Bridge Rectifiers		KBU4J	4 A / 600 V	1	BD1
46	600 V, 1 A, Fast Switching Rectifiers		RS1J	DO-214AC	3	D10~12
47	600 V, 1 A, General-Purpose Rectifiers		S1J	DO-214AC	1	D6
48	600V, 1 A, Fast Rectifiers		ES1J	DO-214AC	1	D8
49	SMD 13 V Zener		BZX84C13	SOT-23	1	D7
50	Inductance 15 mH	YUJING	VFOTC210 5001500A	OTC21 14*18 mm	1	L2
51	Radial Choke Inductors, 1 mH	GANG SONG	GSRB0605-102M	6.5 x 5.5 mm	1	L3
52	NTC Thermal Resistor 10ψ 8 Ω		SCK083	SCK10083MSY	1	TR1
53	Tact Switch			*see following*	1	SW3
54	Miniature Toggle Switch	Dailywell	1MS1T1B2M 2QES		2	SW1,SW2
55	PMSM Motor Controller	Fairchild Semiconductor	FCM8531	LQFP32	1	U5
56	Power Switch	Fairchild Semiconductor	FSL206MR N	DIP8	1	U2
57	600 V, 10 A Motion SPM	Fairchild Semiconductor	FNB41060	SPM26	1	U6
58	FUSE MICRO 250 V / 3.15 A SLOW			3.6*10 mm 36ESR (NONE LEAD)	1	F1
59	FUSE CLIP 3.6ψ			Type SL001	2	F1
60	AC INLET 3P 90°			AC-IN7	1	CN6
61	Header 2X2, pitch 2.54 mm				2	JP1~2
62	Header 1*4, Header 2.54 mm				1	JP3
63	3 Terminal, 0.1 A, 5 V Positive Voltage Regulator	Fairchild Semiconductor	MC78L05A	TO-92 (DGS)W	1	U3
64	2.54 mm Box Header 2X7P 180 DIP	Most Well		CON7X2A	1	CN1
65	Wafer Connector, 5P 2.5 mm 180°				1	CN2
66	SMD NPN Swtiching Transistor	Fairchild Semiconductor	MMBT2222 A	SOT-23 (EBC)	1	Q1
67	LED			5 mm	1	LED1
68	LED			5 mm	1	LED2
69	10 kΩ NTC Thermal Resistor		TTF3A103H 34D3AY	W2.5	1	RT1(with SPM3 pkg)
70	600 V, 1.0 A Ultra-Fast Recovery Rectifiers		UF4005	DO-214AC	1	D9
70	VDR 14ψ470 V				1	MOV1
71	PCB 176*115 mm, 2-Layer, 1.6 T, Copper 2 oz		PC-M0168B			
72	Male Terminal				5	CN1~3,CN8~9

10. Component Specification

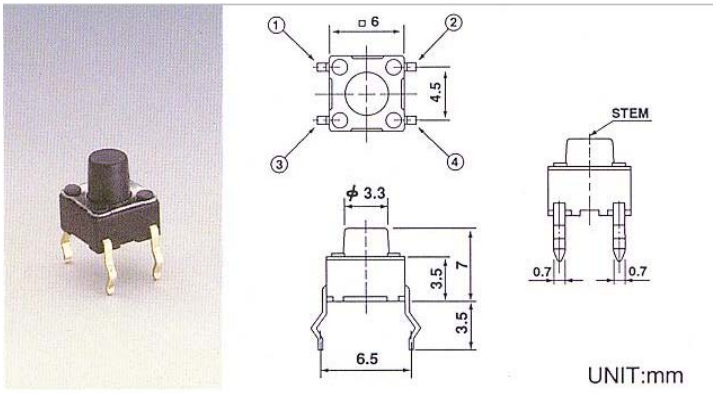

Figure 30. Tact Switch

R -T TABLE

PART NO. : TTF3A104H34D3AY

R25 =100 KOhm ±3%
B25/85 = 3435 K ± 3%

Temperature (℃)	Rmax. (KΩ)	Rnor. (KΩ)	Rmin. (KΩ)	Temperature Tol. (℃)	
-40	2,219.2298	1,970.2856	1,747.6925	-2.15	1.93
-39	2,093.7971	1,862.0762	1,654.5095	-2.14	1.92
-38	1,976.3461	1,760.5814	1,566.9609	-2.12	1.91
-37	1,866.3124	1,665.3367	1,484.6659	-2.11	1.89
-36	1,763.1756	1,575.9135	1,407.2723	-2.09	1.88
-35	1,666.4554	1,491.9152	1,334.4539	-2.07	1.87
-34	1,575.7083	1,412.9753	1,265.9083	-2.06	1.86
-33	1,490.5244	1,338.7542	1,201.3556	-2.04	1.85
-32	1,410.5250	1,268.9378	1,140.5356	-2.02	1.84
-31	1,335.3593	1,203.2348	1,083.2074	-2.01	1.82
-30	1,264.7030	1,141.3753	1,029.1469	-1.99	1.81
-29	1,198.2556	1,083.1088	978.1459	-1.97	1.80
-28	1,135.7385	1,028.2027	930.0111	-1.96	1.79
-27	1,076.8935	976.4413	884.5624	-1.94	1.77
-26	1,021.4810	927.6238	841.6324	-1.92	1.76
-25	969.2785	881.5638	801.0652	-1.90	1.75
-24	920.0796	838.0877	762.7154	-1.88	1.73
-23	873.6922	797.0342	726.4477	-1.87	1.72
-22	829.9380	758.2528	692.1358	-1.85	1.70
-21	788.6508	721.6034	659.6618	-1.83	1.69
-20	749.6762	686.9556	628.9158	-1.81	1.68
-19	712.8704	654.1875	599.7951	-1.79	1.66
-18	678.0991	623.1857	572.2037	-1.77	1.65
-17	645.2377	593.8439	546.0519	-1.75	1.63
-16	614.1695	566.0634	521.2557	-1.73	1.61
-15	584.7858	539.7514	497.7367	-1.71	1.60
-14	556.9853	514.8216	475.4215	-1.69	1.58
-13	530.6731	491.1931	454.2411	-1.67	1.57
-12	505.7608	468.7903	434.1312	-1.65	1.55
-11	482.1657	447.5423	415.0312	-1.63	1.53
-10	459.8104	427.3828	396.8846	-1.61	1.52
-9	438.6226	408.2498	379.6382	-1.59	1.50
-8	418.5345	390.0850	363.2421	-1.57	1.48
-7	399.4828	372.8339	347.6496	-1.55	1.47
-6	381.4081	356.4453	332.8165	-1.53	1.45
-5	364.2547	340.8711	318.7016	-1.51	1.43
-4	347.9705	326.0663	305.2661	-1.49	1.41
-3	332.5065	311.9886	292.4734	-1.47	1.39
-2	317.8169	298.5982	280.2891	-1.44	1.38
-1	303.8586	285.8577	268.6811	-1.42	1.36

R -T TABLE

PART NO.:TTF3A104H34D3AY

R25 =100 KOhm ± 3%
B25/85 = 3435 K ±3%

Temperature (℃)	Rmax. (KΩ)	Rnor. (KΩ)	Rmin. (KΩ)	Temperature Tol. (℃)	
0	290.5912	273.7319	257.6187	-1.40	1.34
1	277.9767	262.1880	247.0735	-1.38	1.32
2	265.9793	251.1946	237.0183	-1.36	1.30
3	254.5657	240.7227	227.4277	-1.33	1.28
4	243.7042	230.7447	218.2778	-1.31	1.26
5	233.3651	221.2346	209.5459	-1.29	1.24
6	223.5205	212.1680	201.2107	-1.27	1.22
7	214.1443	203.5218	193.2521	-1.24	1.20
8	205.2115	195.2743	185.6511	-1.22	1.18
9	196.6990	187.4051	178.3897	-1.20	1.16
10	188.5847	179.8949	171.4510	-1.17	1.14
11	180.8480	172.7253	164.8189	-1.15	1.12
12	173.4694	165.8792	158.4783	-1.12	1.10
13	166.4304	159.3403	152.4149	-1.10	1.07
14	159.7136	153.0933	146.6152	-1.08	1.05
15	153.3027	147.1236	141.0664	-1.05	1.03
16	147.1823	141.4175	135.7562	-1.03	1.01
17	141.3376	135.9621	130.6734	-1.00	0.99
18	135.7549	130.7451	125.8069	-0.98	0.96
19	130.4211	125.7549	121.1465	-0.95	0.94
20	125.3239	120.9804	116.6824	-0.93	0.92
21	120.4516	116.4114	112.4055	-0.90	0.89
22	115.7933	112.0379	108.3069	-0.88	0.87
23	111.3384	107.8507	104.3783	-0.85	0.85
24	107.0771	103.8408	100.6118	-0.82	0.82
25	103.000	100.000	97.000	-0.82	0.82
26	99.3339	96.3326	93.3380	-0.84	0.83
27	95.8163	92.8178	89.8322	-0.87	0.87
28	92.4407	89.4485	86.4753	-0.91	0.90
29	89.2007	86.2182	83.2605	-0.95	0.94
30	86.0903	83.1205	80.1810	-0.98	0.97
31	83.1038	80.1494	77.2306	-1.02	1.01
32	80.2356	77.2992	74.4033	-1.06	1.04
33	77.4806	74.5645	71.6935	-1.09	1.08
34	74.8339	71.9400	69.0957	-1.13	1.11
35	72.2907	69.4209	66.6050	-1.17	1.15
36	69.8466	67.0025	64.2163	-1.21	1.18
37	67.4973	64.6803	61.9251	-1.25	1.22
38	65.2386	62.4501	59.7270	-1.29	1.26
39	63.0667	60.3079	57.6178	-1.33	1.29

R -T TABLE

PART NO.:TTF3A104H34D3AY

R25 =100 KOhm ±3%
B25/85 = 3435 K ± 3%

Temperature (℃)	Rmax. (KΩ)	Rnor. (KΩ)	Rmin. (KΩ)	Temperature Tol. (℃)	
40	60.9779	58.2497	55.5936	-1.37	1.33
41	58.9686	56.2720	53.6504	-1.41	1.37
42	57.0356	54.3713	51.7848	-1.45	1.40
43	55.1755	52.5442	49.9933	-1.49	1.44
44	53.3853	50.7875	48.2727	-1.53	1.48
45	51.6621	49.0983	46.6198	-1.57	1.51
46	50.0030	47.4737	45.0317	-1.61	1.55
47	48.4055	45.9108	43.5055	-1.65	1.59
48	46.8670	44.4072	42.0386	-1.69	1.63
49	45.3849	42.9602	40.6285	-1.73	1.67
50	43.9571	41.5676	39.2726	-1.77	1.70
51	42.5814	40.2270	37.9686	-1.82	1.74
52	41.2554	38.9363	36.7144	-1.86	1.78
53	39.9774	37.6934	35.5079	-1.90	1.82
54	38.7453	36.4963	34.3469	-1.95	1.86
55	37.5572	35.3432	33.2297	-1.99	1.90
56	36.4115	34.2321	32.1543	-2.03	1.94
57	35.3064	33.1616	31.1190	-2.08	1.98
58	34.2403	32.1297	30.1222	-2.12	2.02
59	33.2116	31.1351	29.1622	-2.16	2.06
60	32.2190	30.1762	28.2375	-2.21	2.10
61	31.2609	29.2515	27.3467	-2.25	2.14
62	30.3360	28.3598	26.4884	-2.30	2.18
63	29.4431	27.4996	25.6612	-2.35	2.22
64	28.5809	26.6697	24.8640	-2.39	2.26
65	27.7481	25.8690	24.0954	-2.44	2.30
66	26.9437	25.0962	23.3544	-2.48	2.34
67	26.1666	24.3504	22.6398	-2.53	2.38
68	25.4157	23.6303	21.9506	-2.58	2.42
69	24.6901	22.9351	21.2857	-2.62	2.47
70	23.9888	22.2638	20.6442	-2.67	2.51
71	23.3108	21.6153	20.0252	-2.72	2.55
72	22.6553	20.9890	19.4278	-2.77	2.59
73	22.0214	20.3839	18.8511	-2.81	2.63
74	21.4084	19.7991	18.2944	-2.86	2.68
75	20.8154	19.2340	17.7568	-2.91	2.72
76	20.2418	18.6878	17.2376	-2.96	2.76
77	19.6867	18.1598	16.7361	-3.01	2.81
78	19.1496	17.6492	16.2517	-3.06	2.85
79	18.6298	17.1555	15.7836	-3.11	2.89

R -T TABLE

PART NO.:TTF3A104H34D3AY

R25 =100 KOhm ±3%
B25/85 = 3435 K ±3%

Temperature (℃)	Rmax. (KΩ)	Rnor. (KΩ)	Rmin. (KΩ)	Temperature Tol. (℃)	
80	18.1266	16.6780	15.3313	-3.16	2.94
81	17.6395	16.2161	14.8942	-3.21	2.98
82	17.1678	15.7693	14.4716	-3.26	3.02
83	16.7110	15.3369	14.0631	-3.31	3.07
84	16.2686	14.9185	13.6681	-3.36	3.11
85	15.8400	14.5135	13.2861	-3.41	3.16
86	15.4248	14.1214	12.9166	-3.46	3.20
87	15.0225	13.7419	12.5591	-3.52	3.25
88	14.6326	13.3744	12.2133	-3.57	3.29
89	14.2548	13.0185	11.8787	-3.62	3.34
90	13.8885	12.6737	11.5548	-3.67	3.38
91	13.5333	12.3398	11.2413	-3.73	3.43
92	13.1890	12.0162	10.9379	-3.78	3.48
93	12.8551	11.7027	10.6441	-3.83	3.52
94	12.5312	11.3989	10.3595	-3.89	3.57
95	12.2171	11.1044	10.0840	-3.94	3.61
96	11.9123	10.8189	9.8171	-3.99	3.66
97	11.6166	10.5422	9.5585	-4.05	3.71
98	11.3297	10.2738	9.3080	-4.10	3.75
99	11.0512	10.0136	9.0652	-4.16	3.80
100	10.7808	9.7611	8.8299	-4.21	3.85

產品名稱: R-301SN-C49

Standard: IEC 60320 C14

Rating: 15A 250V AC / 10A 250V AC

Insulation Resistance: 100MΩ 500V DC/1 minute

Dielectric Strength: 2000V AC/1 minute

Housing Material: Thermoplastic 94V-2~V-0

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Dimensions

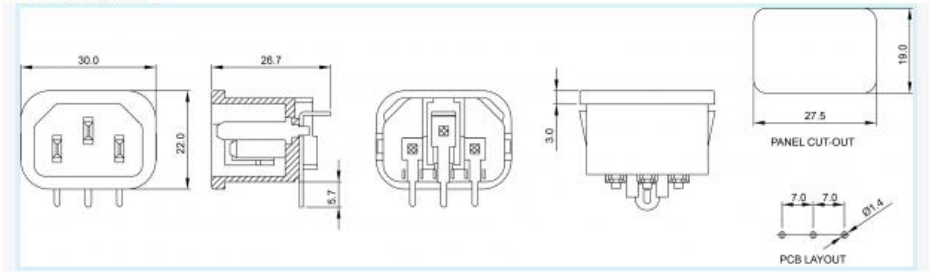


Figure 31. AC Inlet

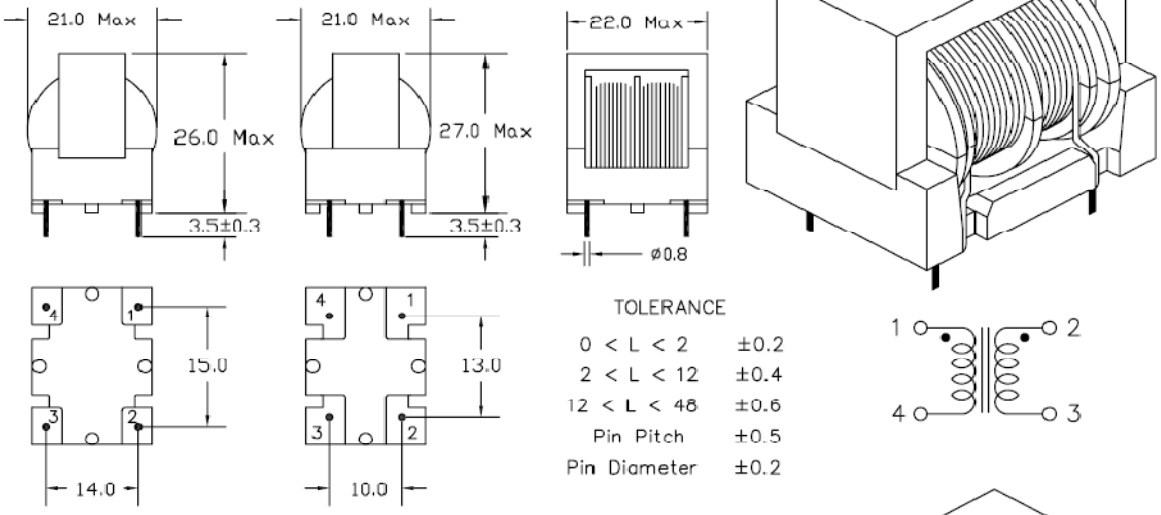
OTC-21 EMI FILTER

Optimum Toroid Chokes

A New Products
For Super Power

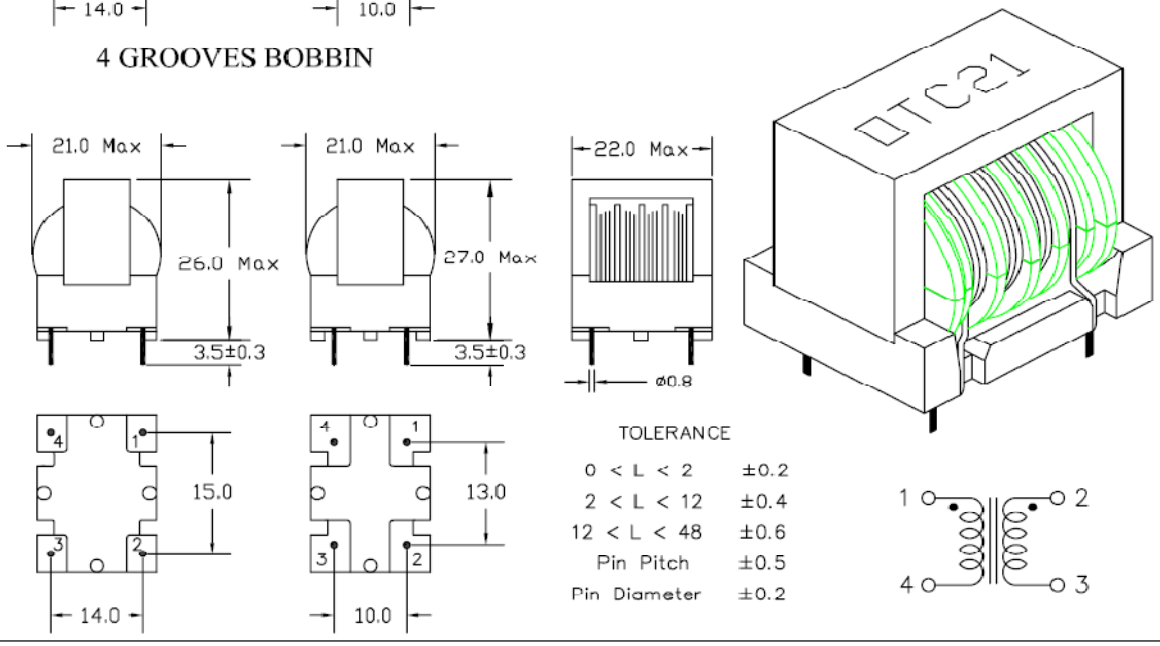
Mechanical Dimension (UNIT: mm)

2 GROOVES BOBBIN



TOLERANCE	
0 < L < 2	±0.2
2 < L < 12	±0.4
12 < L < 48	±0.6
Pin Pitch	±0.5
Pin Diameter	±0.2

4 GROOVES BOBBIN



TOLERANCE	
0 < L < 2	±0.2
2 < L < 12	±0.4
12 < L < 48	±0.6
Pin Pitch	±0.5
Pin Diameter	±0.2

YUJING

PAT. US 6,121,696 / J 3060520 / ZL 98 2 47924.9 / TW164060

昱京科技股份有限公司 YU JING TECHNOLOGY CO., LTD. Tel: 02-2672-3910
昱京國際貿易有限公司 YU JING INTERNATIONAL CO., LTD. Fax: 02-2672-4872

OTC-21 EMI FILTER

Optimum Toroid Chokes

A New Products
For Super Power

DIELECTRIC STRENGTH

TEST FREQUENCY: 20 KHz / 0.1 V
WITHSTANDING VOLTAGE: 1.5KVAC WIND TO CORE, LINE TO LINE

REFERENCE RATING (2 GROOVES BOBBIN)

	INDUCTANCE (L) mH Min.	D.C.R. mOHM Max.	RATE CURRENT Amp (ac) REF.	WIRE DIA. ∅ (mm)	REMARK
VOTC2110000150A	1.5	25	5.80	1.00	
VOTC2109000200A	2.0	30	4.70	0.90	
VOTC2108000400A	4.0	50	3.70	0.80	
VOTC2107000900A	9.0	100	2.80	0.70	
VOTC2106001400A	14.0	170	2.10	0.60	

** Special or Custom-made specification is available by request.

REFERENCE RATING (4 GROOVES BOBBIN)

	INDUCTANCE (L) mH Min.	D.C.R. mOHM Max.	RATE CURRENT Amp (ac) REF.	WIRE DIA. ∅ (mm)	REMARK
VOTC2107000400A	4.0	70	2.80	0.70	
VOTC2106500550A	5.5	90	2.40	0.65	
VOTC2106000700A	7.0	130	2.10	0.60	
VOTC2105501100A	11.0	180	1.70	0.55	
VOTC2105001500A	15.0	240	1.40	0.50	

** Special or Custom-made specification is available by request.

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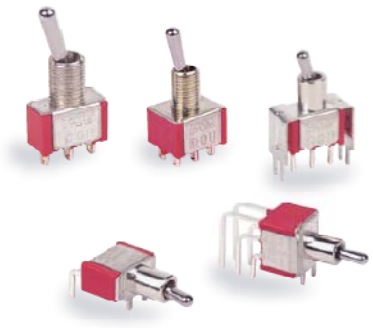
1M SERIES Miniature Toggle Switches

1M Toggle Switches



SPECIFICATIONS

CONTACT RATING: Dependent upon contact material See page 10.
MECHANICAL LIFE: 40,000 make-and-break cycles.
CONTACT RESISTANCE: 10mΩmax. initial @ 2-4VDC
100mA for both silver and gold plated contacts.
INSULATION RESISTANCE: 1,000 MΩ min.
DIELECTRIC STRENGTH: 1,000 Vrms min.@sea level.
OPERATING TEMPERATURE: -30°C to 85°C.

MATERIALS

CASE: Diallyl phthalate (DAP) (UL94v-0).
ACTUATOR: Brass,chrome plated.
BUSHING: Brass, nickel plated.
HOUSING: Stainless steel.
SWITCH SUPPORT: Brass, tin plated.
CONTACT / TERMINALS: Brass, Silver or gold plated.(See Page 10)

HOW TO ORDER

MODEL NO. ACTUATOR BUSHING TERMINATIONS CONTACT MATERIAL SEAL ROHS SOLDERING

MODEL NO.
1MS1 SP On-None-On
1MS2 SP On-None-Mom
1MS3 SP On-Off-On
1MS4 SP Mom-Off-Mom
1MS5 SP On-Off-Mom
1MD1 DP On-None-On
1MD2 DP On-None-Mom
1MD3 DP On-Off-On
1MD4 DP Mom-Off-Mom
1MD5 DP On-Off-Mom
1MD6 DP On-On-On
1MD7 DP MOm-On-Mom
1MD8 DP On-On-Mom
1M31 3P On-None-On
1M32 3P On-None-Mom
1M33 3P On-Off-On
1M34 3P Mom-Off-Mom.
1M35 3P On-Off-Mom
1M41 4P On-None-On
1M42 4P On-None-Mom
1M43 4P On-Off-On
1M44 4P Mom-Off-Mom
1M45 4P On-Off-Mom
1M46 4P On-On-On
1M47 4P MOm-On-Mom
1M48 4P On-On-Mom

ACTUATOR
T1 10.41 high
T2 5.08 high
T3 13.97 high
T4 16.26 high
T5 21.34 high
T6 Flatted,anti-rotation 12.30 high
T61 Flatted,anti-rotation 21.0 high
T62 Lever handle with cap 13.49 high
T63 Flatted,anti-rotation 6.35 high
T7 12.37 high,15/32 bushing
T8 17.56 high,15/32 bushing
T9 Plastic,21.3 high
TA 26.30 high lever handle with cap,15/32 bushing
T11 Plastic,12.2 high
TL1 Locking lever 16.00 high
TL2 Locking lever 16.26 high
TL3 Locking lever 17.28 high

TERMINATIONS
M1 Solder Lug
M2 PC thru-hole
M3 Quick Connect
M5-1 18.70 high, wire wrap
M5-2 24.20 high, wire wrap
M5-3 10.55 high, wire wrap
M5-4 26.97 high, wire wrap
M6 Right angle, PC thru-hole
M6N Right angle, snap-in, PC thru-hole
M7 Vertical right angle, PC thru-hole
VS2 11.68 high, V-bracket
V2N 11.68 high, snap-in V-bracket
VS3 16.00 high, V-bracket
VS4 11.68 high, V-bracket
VS5 16.00 high, V-bracket

BUSHING
B1 8.89 high,keyway (thd std)
B2 8.89 high,keyway (non-thd)
B3 7.10 high,keyway (thd)
B4 7.10 high,keyway (non-thd)
B5 7.52 high,flat (torque)
B6 8.00 high,keyway (torque)
B7 8.89 high,flat (thd std)
B8 8.89 high,keyway (metric thd)
B9 7.52 high,flat (splash proof)
B11 7.55 high,keyway (thd std)
B12 7.55 high,keyway (non-thd)
B13 11.38 high,keyway (15/32 bushing)
B14 11.90 high,flat (splash proof)
B15 7.55 high,flat (thd std)
B16 7.55 high,flat (non-thd)
B17 3.50 high,keyway
B18 11.38 high,keyway (15/32 bushing)
B20 11.38 high,keyway (15/32 bushing)
B25 8.00 high,keyway,locking lever (thd)
B26 8.00 high,keyway,locking lever (non-thd)

CONTACT MATERIAL
Q Silver
R Gold
G Gold,pure-tin
S Silver,pure-tin
C Gold over silver
K Gold over silver,pure-tin

SEAL
E EPOXY (std)
N NO EPOXY

ROHS SOLDERING
☐ Rohs Compliant
S Rohs & Lead Free
F Halogen Free+RoHS

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11. Revision History

Rev.	Date	Description
1.0.0	Dec 2012	Initial Release
1.0.1	Mar 2013	Change photo of EVB contents and motor descriptions in Figure 6.
1.0.2	May 2013	Change the descriptions in section 'Caution' and Figure 6.