Application Guide for the EPC7C006 Evaluation Board

EPC Space (www.epc.space)

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ESD Precaution.

Proper ESD precautions should be employed when handling the EPC7C006 Eval. Board to prevent damage to the components installed on the board.

Introduction.

This document describes the functionality, options and the recommended signal connections to/from the EPC7C006 FBS-GAM02 Three-Phase Motor Driver Eval. Board to power supplies, the motor to be driven and monitoring instruments to observe and evaluate of the performance of EPC Space FBS-GAM02 Modules connected as a three-phase motor driver.

EPC7C006 is a full-featured evaluation board: It can be used as a stand-alone motor driver board using external PWM control inputs for each phase or it may be used in conjunction with the EPC9147A for the motor ramp up/down and rotational speed. The board has dead-time circuitry included for the PWM signals for each phase and various signal (voltage/current) monitor circuitry for each phase and for the VDD supply current.

This document provides a basic block diagram and the descriptions of all input, output and power connectors to/from the board, jumper connection options for the external PWM signals, for the output filtering option, the various power options for the board, the schematic of the evaluation board, the bill of materials (BOM) and the PCB layout of the board in the form of layer-by-layer Gerber rendering of the evaluation printed circuit board.

Please consult schematic included with this document for the connections to/from each FBS-GAM02-P-C50 module and the FBS-GAM02-P-C50 or FBS-GAM02-P-R50 data sheet for further details regarding the specifications and operation of the GAM02 Module.

EPC7C006 Functional Block Diagram.

The functional block diagram is shown in Figure 1.

Evaluation PCB Physical Layout.

Figure 2a shows the top view and Figure 2b shows the bottom view of the EPC7C006 Eval. Board. These pictures illustrate the component placements, connector and jumper locations, power, load and input signal connections and the numerous test points available for monitoring by the end-user. The printing on the PCB is shown as black for clarity – the physical board has white printing:

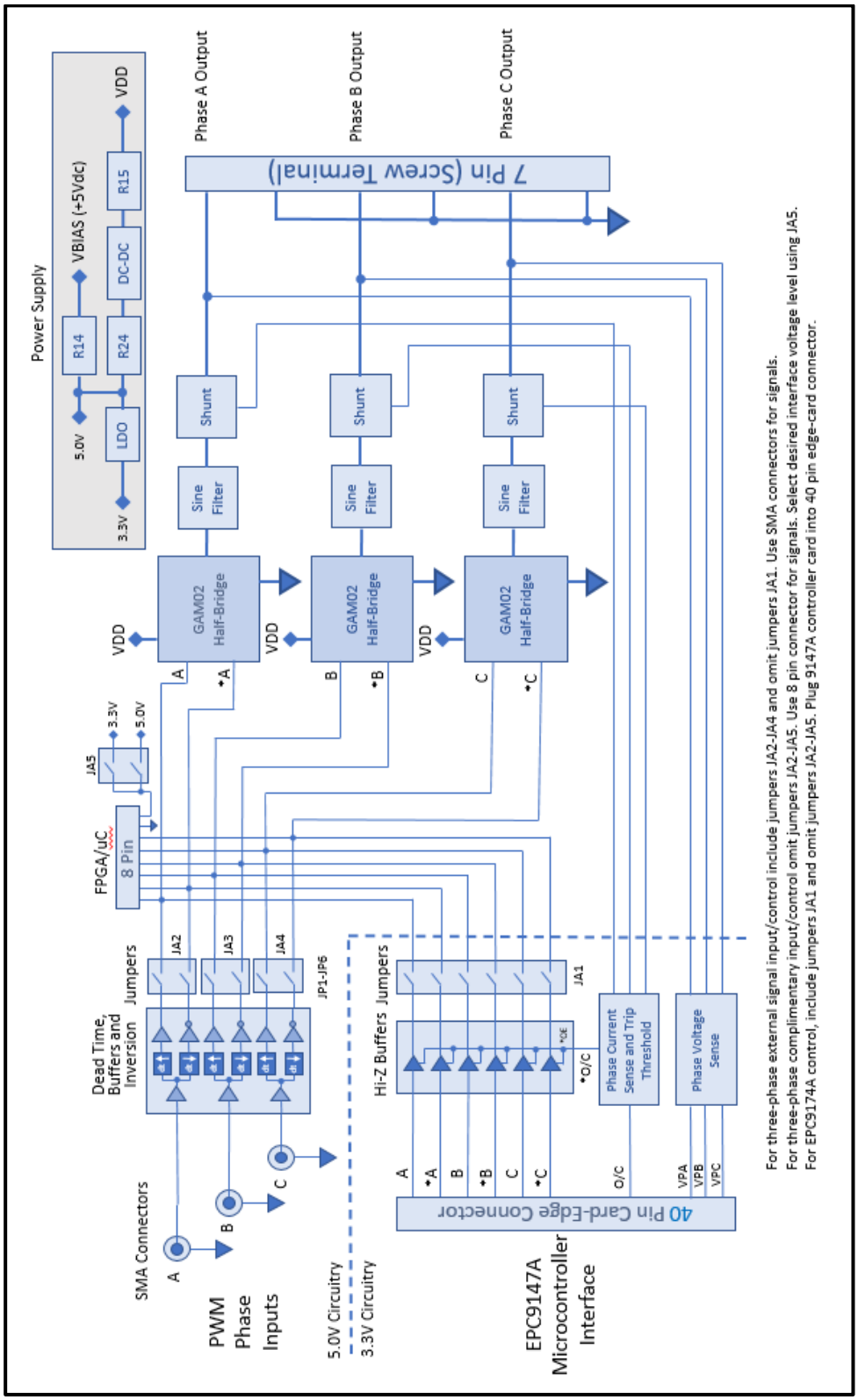


Figure 1. *EPC7C006 Eval. Board Functional Block Diagram.*

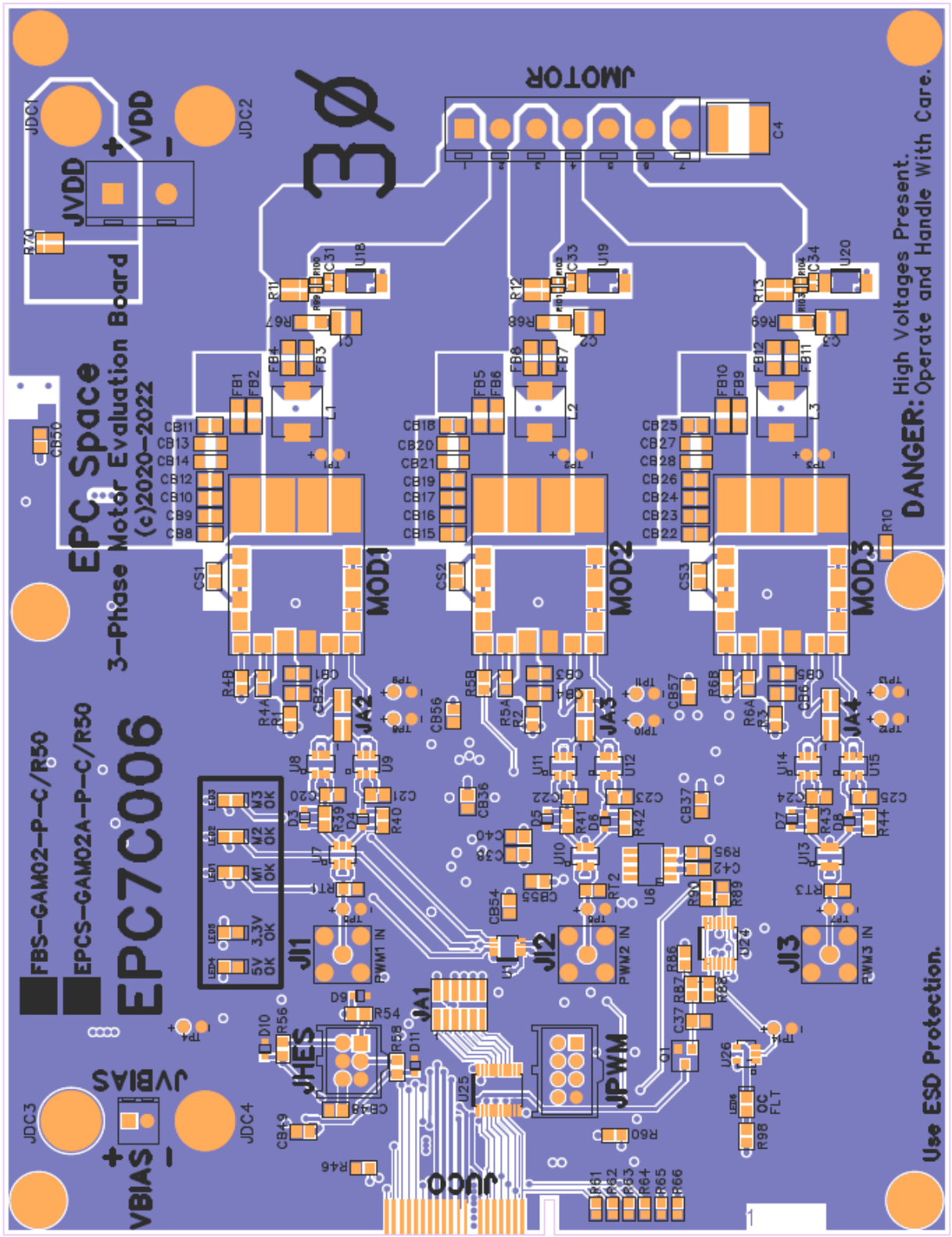


Figure 2a. *EPC7C006 Eval. Board (Top View).*

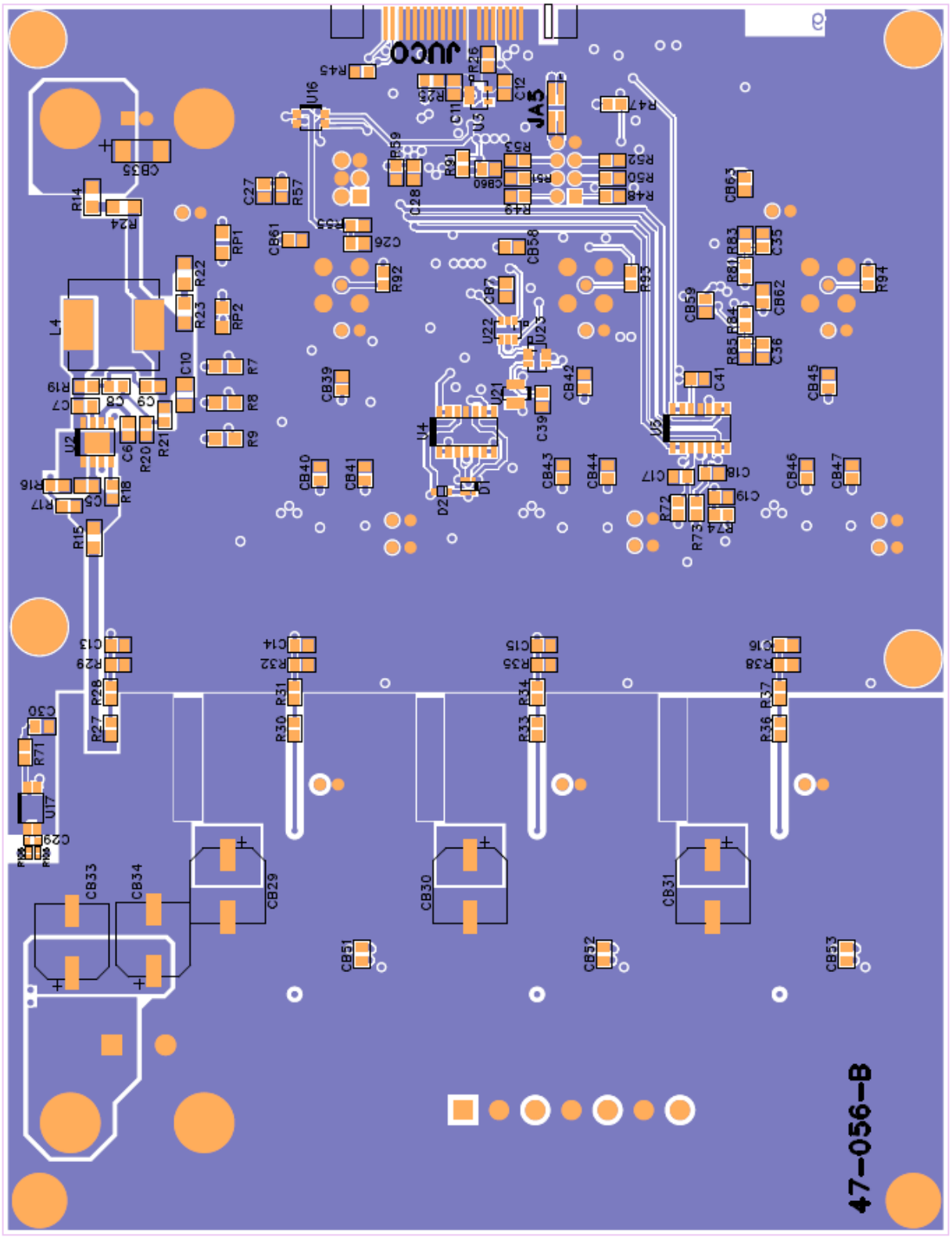


Figure 2b. *EPC7C006 Eval. Board (Bottom View).*

Powering the EPC7C006 Evaluation Board.

The EPC7C006 board is configured to provide flexibility to end-user for providing the 5V (VBIAS) power to the board. Referring to Figure 1, the 5V power may be derived from the VDD power supply via an onboard DC-DC converter (U2); it may be derived from the banana jacks JDC3 and JDC4 or screw terminal connector JVBIAS (with U2 disabled via resistor jumpers) or; from connector JPWM, pin 8 and with the pin 2-3 jumper installed on connector JA5. Table I identifies the three VBIAS power situations and the required configuration of jumpers and resistor placements that are required to implement each, as well as where 5V power must be applied.

TABLE I. EPC7C006 Evaluation Board 5Vdc (VBIAS) Options.

5V (VBIAS) Power Provided By	Connectors Used	Resistors			Jumper
		R14	R15	R24	JA5, Pins 2 and 3
VDD	JDC1, JDC2 or JVDD	Omitted	Present	Present	Note 1
External 5V Power Supply	JDC3, JDC4 or JVBIAS	Present	Omitted	Omitted	Note 1
External 5V Power Supply	JPWM	Omitted	Omitted	Omitted	Present
Note 1: The JA5 Pins 2 and 3 jumper may be present if JPWM, pin 8 is used and 5Vdc power is to be drawn from the EPC7C006 board to power external circuitry. The maximum current that may be drawn from JPWM, pin 8 is 20mAdc.					

In any of the three previous VBIAS power situations in Table I the 3.3V DC power required by the board is derived from the on-board 5V supply via an LDO. There may be situations where the end-user may wish to remove power from the on-board 3.3Vdc circuitry or provide 3.3Vdc from an external source via JPWM, pin 8. Table II identifies the possible 3.3Vdc power situations for the EPC7C006 board.

TABLE II. EPC7C006 Evaluation Board 3.3Vdc Options.

3.3V Power Provided By	Connectors Used	Resistors		Jumper
		R25	R26	JA5, Pins 1 and 4
5Vdc (VBIAS)	N/A	Present	Present	Note 2
External 3.3V Power Supply	JPWM	Omitted	Omitted	Present
Disabled	N/A	Omitted	Omitted	Omitted
Note 2: The JA5 Pins 1 and 4 jumper may be present if JPWM, pin 8 is used and 3.3Vdc power is to be drawn from the EPC7C006 board to power external circuitry. The maximum current that may be drawn from JPWM, pin 8 is 15mAdc.				

The maximum current drawn by the 5Vdc (VBIAS) on-board circuitry is 75mA, including the 3.3Vdc current drain. The maximum current drawn by the 3.3Vdc on-board circuitry is 25mA.

The 3.3Vdc supply is capable of providing the 150mA current drain required by the EPC9147A controller daughtercard when it is connected to the EPC7C006 board via connector JUCO.

VBIAS Power Supply Resistor and Jumper Locations.

The resistors in question in Table I are located on the bottom side of the EPC7C006 board, in the upper right-hand corner, as shown in Figure 3.

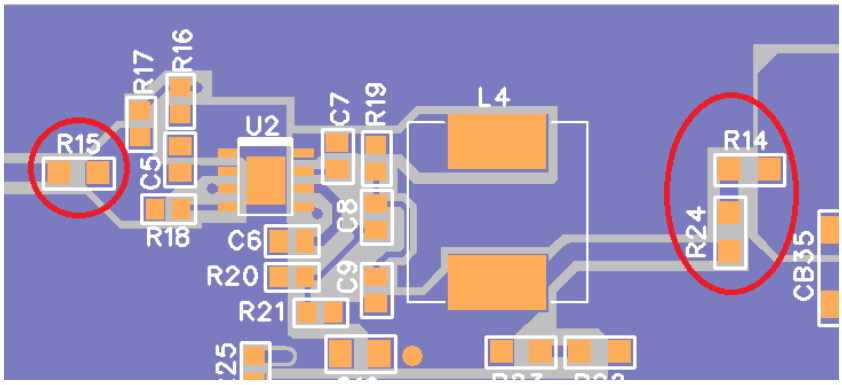


Figure 3. *Resistors R14, R15 and R24 Locations.*

The resistors in question in Table II are located on the bottom side of the EPC7C006 board, in the far right, middle of the board adjacent to JUCO, as shown in Figure 4.

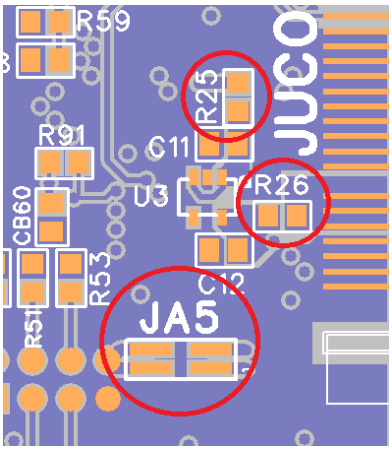


Figure 4. *Resistors R25, R26 and JA5 Locations.*

Indicator LEDs: LED1, LED2, LED3, LED5 and LED6.

The EPC7C006 evaluation board is provided with visual indication that the "Power Good" outputs for GAM02 modules MOD1, MOD2 and MOD3. The high logic state (indicating that the modules are undamaged) indicates that the modules are undamaged and that their respective VBIAS inputs are above the UVLO+ threshold, and this condition is indicated by LED1, LED2and LED3, respectively. These three indicators glow **GREEN** when the modules have VBIAS applied and are ready to have VDD applied.

Indicator LED4 glows **GREEN** when VBIAS power is properly applied to the board.

Indicator LED5 glows **GREEN** when +3.3V power is properly applied to the board.

IMPORTANT NOTE: In order to prevent damage to the EPC7C006 board, it is recommended that prior to the application of VDD to the board that VBIAS is applied and all five indicator LEDs are observed to be glowing. The locations of Indicators LED1 through LED5 are shown in Figure 5.

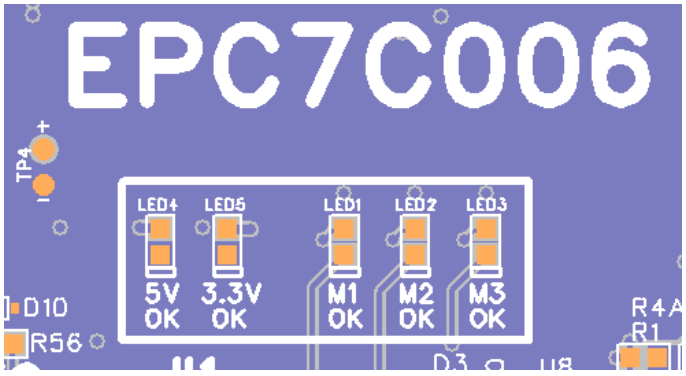


Figure 5. *Indicator LED1 through LED5 Locations.*

Indicator LED6 glows **RED** when an output over-current (O/C) condition exists in the main motor power supply (VDD) or any of the three phase outputs. The O/C threshold may be varied by adjusting R84 for the VDD supply and by adjusting R81 for the three phase outputs. The location of indicator LED6 is shown in Figure 6.

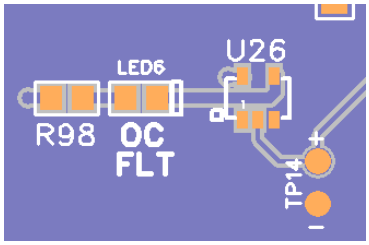


Figure 6. *Indicator LED6 Location.*

Description of Test Points.

The description of each test point on the EPC7C006 Evaluation Board is found in Table III.

TABLE III. EPC7C006 Evaluation Board Test Point Identification.

Test Point	+/- Spacing (in.)	Parametric Measurement Location
TP1	0.100	Phase 1 Switching Node Monitor.
TP2	0.100	Phase 2 Switching Node Monitor.
TP3	0.100	Phase 3 Switching Node Monitor.
TP4	0.100	VBIAS (+5V) Monitor.
TP5	0.100	Phase 1 External PWM Signal Monitor.
TP6	0.100	Phase 2 External PWM Signal Monitor.
TP7	0.100	Phase 3 External PWM Signal Monitor.
TP8	0.100	Phase 1 TIN PWM Signal Monitor.
TP9	0.100	Phase 1 BIN PWM Signal Monitor.
TP10	0.100	Phase 2 TIN PWM Signal Monitor.
TP11	0.100	Phase 2 BIN PWM Signal Monitor.
TP12	0.100	Phase 3 TIN PWM Signal Monitor.
TP13	0.100	Phase 3 BIN PWM Signal Monitor.

Each set of test points (signal to be measured as indicated by "+", and ground as indicated by "-") have the physical spacings shown in Table I so as to facilitate easy oscilloscope probing by the end-user.

IMPORTANT NOTE: The "-" side of each test point is connected to the ground potential (i.e., 0Vdc) of the Evaluation Board. ALWAYS make sure that the ground connection to the oscilloscope is connected to this point when power is applied to the board as damage may occur to the oscilloscope, the Eval. Board or BOTH.

Description of Selection Jumpers.

There are five (5) jumper arrays provided on the EPC7C006 Eval. Board. Jumper array JA1 provides the connection of the PWM signals to the three phases from the optional EPC9147A motor controller board, accessible via connector JUCO. Jumper arrays JA2-JA4 provides the connection of the PWM signals to the three phases from the SMA connectors JI1, JI2 and JI3. Jumper array JA5 provides selection capability for the interface voltage provided to connector JPWM. This voltage may be used to drive interface buffers or other level shifting circuitry on the customer's end-use application board.

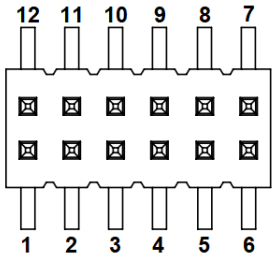


Figure 7. *JA1 Pinout.*

TABLE IV. Jumper Array JA1 Pin Jumping Guide and Functionality.

JA1 Pin # Shorted to	JA1 Pin #	Description/Functionality
1	12	Low-side PWM drive signal to Module 3 from JUCO.
2	11	High-side PWM drive signal to Module 3 from JUCO.
3	10	Low-side PWM drive signal to Module 2 from JUCO.
4	9	High-side PWM drive signal to Module 2 from JUCO.
5	8	Low-side PWM drive signal to Module 1 from JUCO.
6	7	High-side PWM drive signal to Module 1 from JUCO.

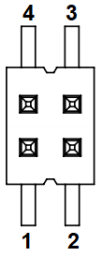


Figure 8. *JA2-JA5 Pinouts.*

TABLE V. Jumper Array JA2 Pin Jumping Guide and Functionality.

JA2 Pin # Shorted to	JA2 Pin #	Description/Functionality
1	4	High-side PWM drive signal to Module 1 from JI1.
2	3	Low-side PWM drive signal to Module 1 from JI1.

TABLE VI. Jumper Array JA3 Pin Jumping Guide and Functionality.

JA3 Pin # Shorted to	JA3 Pin #	Description/Functionality
1	4	High-side PWM drive signal to Module 2 from JI2.
2	3	Low-side PWM drive signal to Module 2 from JI2.

TABLE VII. Jumper Array JA4 Pin Jumping Guide and Functionality.

JA4 Pin # Shorted to	JA4 Pin #	Description/Functionality
1	4	High-side PWM drive signal to Module 3 from JI3.
2	3	Low-side PWM drive signal to Module 3 from JI3.

TABLE VIII. Jumper Array JA5 Pin Jumping Guide and Functionality.

JA5 Pin # Shorted to	JA5 Pin #	Description/Functionality
1	4	+5V connected to JPWM pin 8.
2	3	+3.3V connected to JPWM pin 8.

Figure 9. *Jumper for JA1-JA5.*

All jumpers for JA1 through JA5 are Harwin P/N M50-2000005.

NOTE: Jumpers should be present in JA1 or JA2-JA4, NEVER in both sets of jumpers. If JPWM is used a jumper should be present on JA5 pin1 to pin 4 or pin2 to pin 3, NEVER in both positions.

Description of Connectors.

There are thirteen (13) connectors provided on the EPC7C006 Eval. Board. There are three (3) connectors to provide 5V bias power to the board, three (3) connectors to provide motor VDD power to the board, four (4) connectors to provide PWM signals to the board, one (1) connector to interface to the motor, and two (2) connectors to interface to the optional EPC9147A motor controller daughter board.

The description of the functionality of each connector is shown in Table IX.

TABLE IX. EPC7C006 Evaluation Board Connector Description and Functionality.

Connector	Description/Functionality
JVDD	Motor VDD power.
JDC1(+), JDC2(-)	Motor VDD power.
JVBIAS	External VBIAS power.
JDC3(+), JDC4(-)	External VBIAS power.
JPWM	External user-provided three-phase PWM controller input signals.
JI1	Phase 1 external PWM input.
JI2	Phase 2 external PWM input.
JI3	Phase 3 external PWM input.
JHES	Hall-effect position sensor input signals to optional EPC9147A controller daughtercard.
JUCO	Analog/digital interface signals to optional EPC9147A controller daughtercard.
JMOTOR	Three-phase motor drive power signals.

JVDD, JDC1 and JDC2 "VDD" Connector Details.

The VDD power connectors offer the end-user the ability to provide power via standard banana cables via JDC1 (+) and JDC2 (-) or by wires to terminal block connector JVDD. It is recommended that if wires are used to connect VDD to the board via JVDD that 14AWG or greater diameter wires be used and that the +/- wires be twisted to avoid noise – radiated or conducted.

JVBIAS, JDC3 and JDC4 "VBIAS" Connector Details.

The VBIAS power connectors also offer the end-user the ability to provide power via standard banana cables via JDC3 (+) and JDC4 (-) or by wires to terminal block connector JVBIAS. It is recommended that if wires are used to connect VBIAS to the board via JVBIAS that 22AWG or greater diameter wires be used and that the +/- wires be twisted to avoid noise – either radiated or conducted.

JPWM Connector Details.

Connector JPWM is provided such that the end-user of the EPC7C006 Eval. Board can provide three-phase input logic signals to the board with VBIAS power and ground signals. This connector is a Molex 90136-1208 CGRID III-style, 8 pin connector. The pinout for this connector is shown in Figure 10, looking into the pins, and the functionality of each pin is described in Table X.

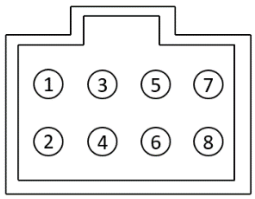


Figure 10. *JPWM Pinout.*

TABLE X. Connector JPWM Pin Functional Descriptions.

JPWM Pin #	Signal Name	Description/Functionality
1	PWM1H	Phase 1 high-side driver PWM signal.
2	PWM1L	Phase 1 low-side driver PWM signal.
3	PWM2H	Phase 2 high-side driver PWM signal.
4	PWM2L	Phase 2 low-side driver PWM signal.
5	PWM3H	Phase 3 high-side driver PWM signal.
6	PWM3L	Phase 3 low-side driver PWM signal.
7	Ground	Signal Ground Return.
8	VBIAS	+5V to external circuitry (10mA, max).

The PWM signals provided to the PWM1H/L, PWM2H/L and PWM3H/L inputs must be the same frequency and they should be 0 to +3V, minimum, to a maximum of +5V, in amplitude. The minimum duty cycle for these inputs is 0% and the maximum is 95%. The maximum input frequency is 500kHz.

JI1, JI2 and JI3 Connector Details.

Connectors JI1, JI2 and JI3 are SMA style coaxial connectors. JI1 through JI3 connect external PWM signals for each phase (Phase 1, 2 and 3, respectively) to the board. These three signals, which are provided to the board with 120 degrees phase difference between phases 1 and 2 and between phases 2 and 3, are then converted to complimentary signals with added dead times to drive the low- and high-side logic inputs for each FBS-GAM02-P-C50 module for each motor phase.

The PWM signals provided to the JI1, JI2 and JI3 inputs must be the same frequency and they should be 0 to +3V, to a maximum of +5.5V, in amplitude. The minimum duty cycle for these inputs is 0% and the maximum is 95%. The maximum input frequency is 500kHz.

JHES Connector Details.

Connector JHES is provided such that the end-user of the EPC7C006 Eval. Board can provide optional three-phase Hall-effect position logic signals from the motor being driven to the EPC7C006 board along with +3.3V power and ground signals. This connector is a Molex 90136-1206 CGRID III-style, 6 pin connector. The pinout for this connector is shown in Figure 11, looking into the pins, and the functionality of each pin is described in Table XI.

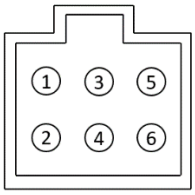


Figure 11. *JHES Pinout.*

TABLE XI. Connector JHES Pin Functional Descriptions.

JHES Pin #	Signal Name	Description/Functionality
1	HES1	Phase 1 Hall effect sensor output signal.
2	HES2	Phase 2 Hall effect sensor output signal.
3	HES3	Phase 3 Hall effect sensor output signal.
4	Ground	Signal Ground Return.
5	Ground	Signal Ground Return.
6	+3.3VDC	+3.3V to external circuitry (5mA, max).

The Hall effect sensor output signals provided to the HES1, HES2 and HES3 inputs should be 0 to +3.0V, minimum, to a maximum of +12V, in amplitude.

JUCO Connector Details.

Connector JUCO is provided such that the end-user of the EPC7C006 Eval. Board can interface the board to the optional EPC9147A motor control daughterboard. This connector is a Samtec MEC1-120-02-F-D-EM2 1.00mm Mini Card Edge Socket, 40 pin connector. The pinout for this connector is shown in Figure 12, looking into the pins, and the functionality of each pin is described in Table XII.

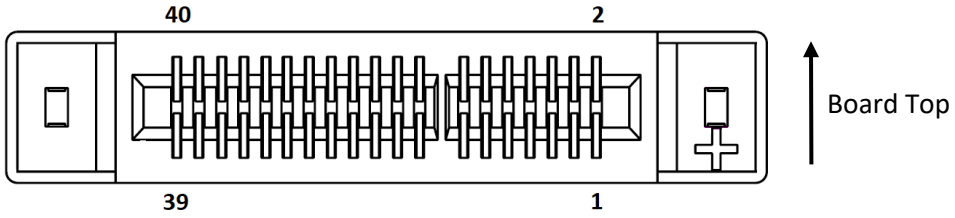


Figure 12. *JUCO Pinout.*

Please note the empty positions at pin locations 15 and 16.

Although this connector is intended to interface to the optional EPC9147A controller daughterboard, it may also be used as a convenient contact point for the end-user to monitor/measure the key motor operating parameters such as phase voltage, phase current, VDD current, the VBIAS and +3.3V power supply and the GAM02 MOD1-MOD3 “Power Good” signal status and the board temperature in the absence of the optional controller.

A useful interface board for the JUCO connector is the EPC9147E Interface Board, as shown in Figure 13. It provides a break-out connection for each of the signals that terminate on the JUCO connector. This makes monitoring the phase voltages and currents accessible and convenient.

More information regarding this interface board may be found at: https://epc-co.com/epc/Portals/0/epc/documents/guides/EPC9147E_qsg.pdf.

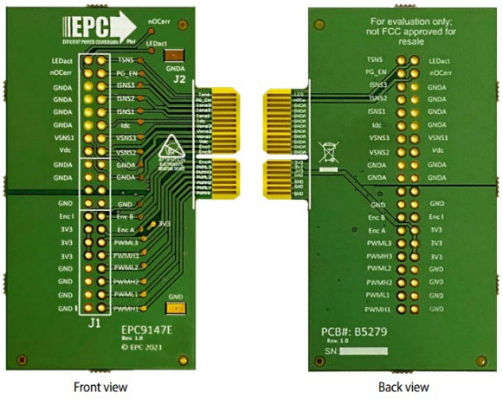


Figure 13. *EPC9147E Interface Board.*

TABLE XII. Connector JUCO Pin Functional Descriptions.

JUCO Pin #(s)	Signal Name	I/O*	(A)nalog/ (Digital)	Description/Functionality
2	PWM1H	I	D	Phase 1 high-side driver PWM signal.
4	PWM1L	I	D	Phase 1 low-side driver PWM signal.
6	PWM2H	I	D	Phase 2 high-side driver PWM signal.
8	PWM2L	I	D	Phase 2 low-side driver PWM signal.
10	PWM3H	I	D	Phase 3 high-side driver PWM signal.
12	PWM3L	I	D	Phase 3 low-side driver PWM signal.
14	HES1	O	D	Phase 1 Hall effect sensor output.
18	HES2	O	D	Phase 2 Hall effect sensor output.
20	HES3	O	D	Phase 3 Hall effect sensor output.
22	VDDM	O	A	VDD supply monitor. VDDM = VDD/24.65
24	VPH1	O	A	Phase 1 voltage monitor. VPH1 = PH1/24.65
26	VPH2	O	A	Phase 2 voltage monitor. VPH2 = PH2/24.65
28	VPH3	O	A	Phase 3 voltage monitor. VPH3 = PH3/24.65
30	IDDM	O	A	VDD supply current monitor. IDDM = IDD*0.1
32	VIPH1	O	A	Phase 1 current monitor. VIPH1 = IPH1*0.1
34	VIPH2	O	A	Phase 2 current monitor. VIPH2 = IPH2*0.1
36	VIPH3	O	A	Phase 3 current monitor. VIPH3 = IPH3*0.1
38	PGOOD	O	D	PGOOD = logic high (“1”) when +5V > 4.5Vdc, +3.3V > 3.0Vdc and MOD1-MOD3 “Power Good” signals are logic high. PGOOD = logic low (“0”) otherwise.
40	TEMP	O	A	TEMP is the output of a TI TMP236A temperature sensor IC.
9,11,13	+3.3VDC	O	--	+3.3Vdc to EPC9147A Daughterboard
1,3,5,7,17,19, 21,23,25,27, 29,31,33,35	Ground	--	--	Power and signal ground return.
37,39	Reserved	--	--	Reserved for EPC9147A. No connect otherwise.

* “I” indicates an input to the EPC7C006 board from the EPC9147A daughtercard and “O” indicates an output to the EPC9147A or an end-user monitor point absent the EPC9147A.

JMOTOR Connector Details.

The connection from the EPC7C006 board to the motor is provided via the 7-place terminal block connector JMOTOR. The pinout for this connector is shown in Figure 14, as a top view, and the functionality of each pin is described in Table XIII.

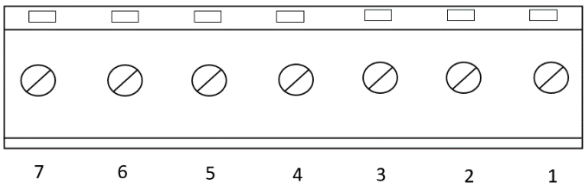


Figure 14. JMOTOR Pinout.

TABLE XIII. Connector JMOTOR Pin Functional Descriptions.

JMOTOR Pin #	Signal Name	Description/Functionality
1	PH1	Motor Phase 1.
2	Ground	Power Ground Return.
3	PH2	Motor Phase 2.
4	Ground	Power Ground Return.
5	PH3	Motor Phase 3.
6	Ground	Power Ground Return.
7	Chassis	Motor/Equipment Chassis

PWM Drive Options.

The EPC7C006 evaluation board is provided with three different ways of providing PWM drive signals to the GAM02 phase driver modules:

1.) The first option is using signals applied to SMA connectors JI1, JI2 and JI3. The signal applied to each of these inputs then has a dead time added between the low- and high-side drive signals for each module as well as a phase inversion for the low-side driver. These processed signals are then applied to the GAM02 modules for each phase.

This PWM drive option is selected and enabled with all jumpers omitted in jumper array JA1 and all jumpers present on jumper arrays JA2 through JA4.

NOTE: The EPC7C006 board is shipped standard with this (previous) PWM drive option.

2.) The second drive option is using signals applied to connector JPWM. The signals to this connector may be obtained from the end-user's hardware test set-up (Labview, etc.) or from an FPGA, gate array or microcontroller.

This PWM drive option is selected and enabled with all jumpers omitted in jumper arrays JA1 through JA4.

3.) The third drive option is employed when the optional EPC9147A controller daughtercard is utilized. The PWM drive signals will be applied to the GAM02 phase drive modules with some on-card buffering and conditioning from the connector JUCO. The low- and high-side signals for each GAM02 module, including dead times and operating frequencies are provided by the EPC9147A daughtercard.

This PWM drive option is selected and enabled with all jumpers present in jumper array JA1 and all jumpers omitted on jumper arrays JA2 through JA4.

BIN-TIN and TIN-BIN Logic Input Dead Times.

The EPC7C006 Evaluation Board is shipped with a fixed, approximate 100ns dead time between the BIN and TIN and TIN and BIN logic inputs of each of the three GAM02 phase drivers being asserted to prevent the possibility of cross-conduction/shoot-through occurring during the evaluation board's operation. To improve high-frequency efficiency, the dead time may be decreased to 75ns, minimum, by replacing the 100pF capacitors in reference designations C20 through C25 with 75pF values (75pF, COG, 5%, 0805).

IMPORTANT NOTE: The dead time should **NEVER** be reduced below 75ns. It is also recommended that prior to the application of VDD for testing the evaluation board that the BIN-TIN and TIN-BIN dead times are verified by applying VBIAS to the circuit and monitoring the appropriate test points (see Table I) to ensure that the resultant dead times for each GAM02 module are either 100ns (default as shipped) or the desired value set by the end-user.

Operation at Lower PWM Switching Frequencies.

Three non-populated component shapes, CS1, CS2 and CS3, have been provided just adjacent to the three GAM02/GAM02A phase driver modules for additional high-side driver bootstrap capacitance for operation of the evaluation board at PWM switching frequencies lower than 200kHz. A capacitance of 0.15uF is recommended if switching frequencies below 200kHz down to a minimum of 75kHz, are desired. The capacitor is 0805 size and should be rated for 25Vdc.

VDD and Motor Phase Voltage Feedback Signals (VDDM, VPH1, VPH2 and VPH3).

Four voltage signals are provided to connector JUCO that are voltage divided replicas of VDD and the voltage at each motor phase output, VPH1, VPH2 and VPH3. Each voltage is divided by 24.65, and each is clamped to a maximum value of ~3.3Vdc.

VDD and Motor Phase Current Feedback Signals (IDDM, VIPH1, VIPH2 and VIPH3).

Four voltage signals are provided to connector JUCO that are aggregate VDD current, IDDM, and the sensed current at each motor phase output, VIPH1, VIPH2 and VIPH3. Each voltage is the current multiplied by 0.075, each current signal is inverted in phase such that the when the current is at a maximum, the voltage is at a minimum, and the zero-level current is offset to 1.65V, with a maximum value of 3.3Vdc. For example, when 10A peak current is sourced by VDD or a phase output, the voltage at IDDM, VIPH1-VIPH39 is 1.65 – (10 * 0.75) = 0.9V. Similarly, when 10A peak current is sunk by VDD or a phase current, the voltage at IDDM, VIPH1-VIPH3 is 1.65 + (10 * 0.75) = 2.4V.

Optional Phase Output Filters.

The EPC7C006 board is provided with empty component positions at each phase output such that the end-user can tune the phase output voltage to approximate a sine wave at the motor rotational frequency(ies). As such, a series R-C circuit is provided at each phase output: R67 and C1 for Phase 1, R68 and C2 for Phase 2 and R69 and C3 for Phase 3. Each resistor is a 1206 case size and each capacitor is a 0805 case size.

Board Temperature Sensor Output (TEMP).

The EPC7C006 board is equipped with an on-board temperature sensor based on the Analog Devices AD590 temperature sensor IC. The voltage at the TEMP pin of JUCO, pin 40, is 2.35V for T_{board} = 25^{o}C, 1.72V for T_{board} = -55^{o}C and 3.32V for T_{board} = 150^{o}C. The sensed temperature accuracy is +/-1^{o}C.

Optional EPC9147A Motor Control Daughtercard.

The EPC Space EPC7C006 Evaluation Board is completely compatible with the EPC9147A daughtercard.

The technical description and operation of the EPC9147A motor control daughtercard are beyond the scope of this application guide. It is suggested that if the end-user desires to use this daughtercard that they visit the EPC website and obtain the technical information for this board at: https://epc-co.com/epc/Products/DemoBoards/EPC9147A.aspx. Complete information for the circuit and its operation are contained at that link.

IMPORTANT NOTE: If the EPC9147A board is utilized, it should be special-ordered from EPC Corp. with 100ns dead times. The standard EPC9147A board is shipped with 25ns, which would damage or destroy the FBS-GAM02 modules on the EPC7C006 board.

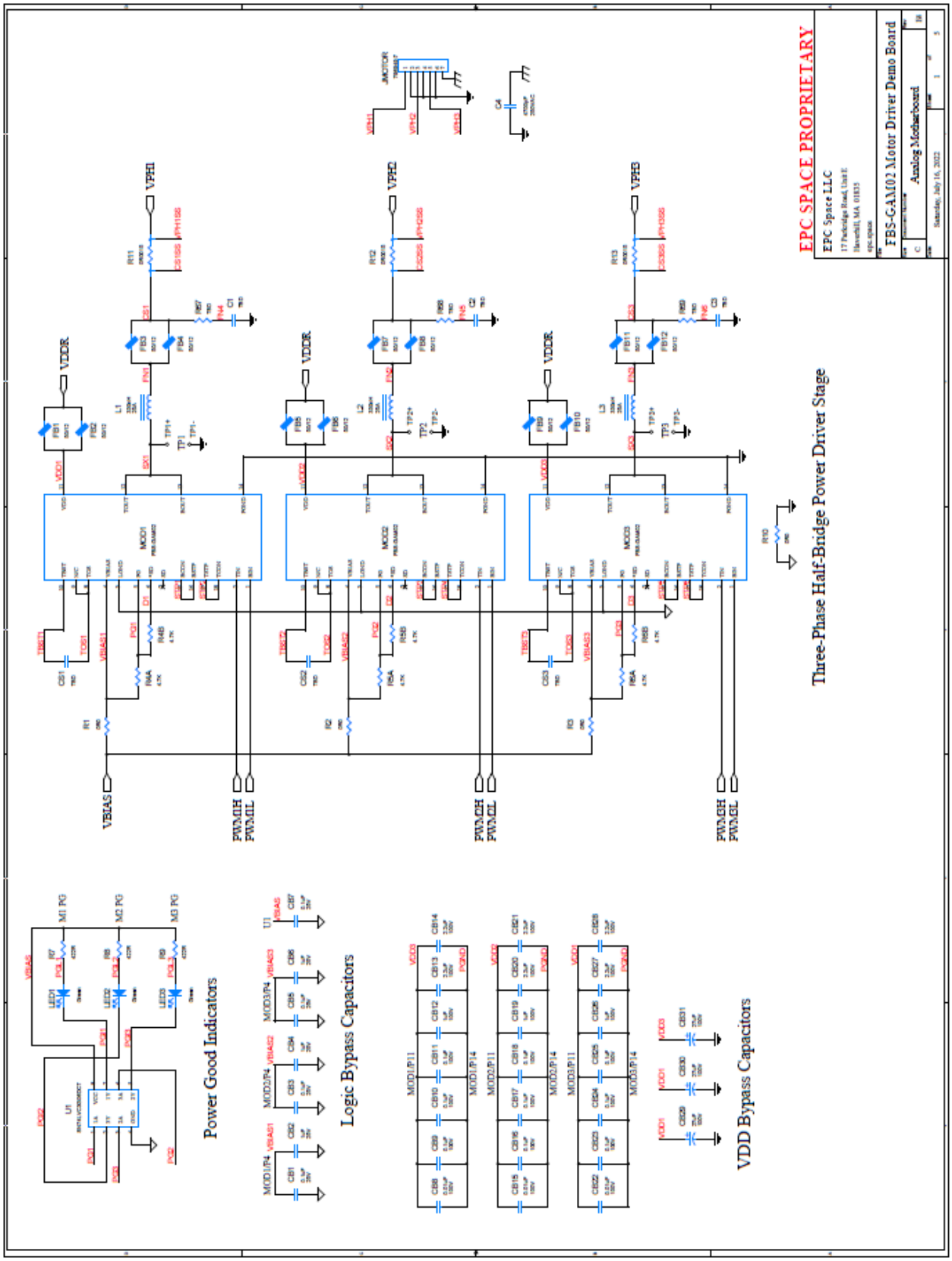


Figure 15. *EPC7C006/FBS-GAM02 3-Phase Motor Control Board Schematic Diagram.*

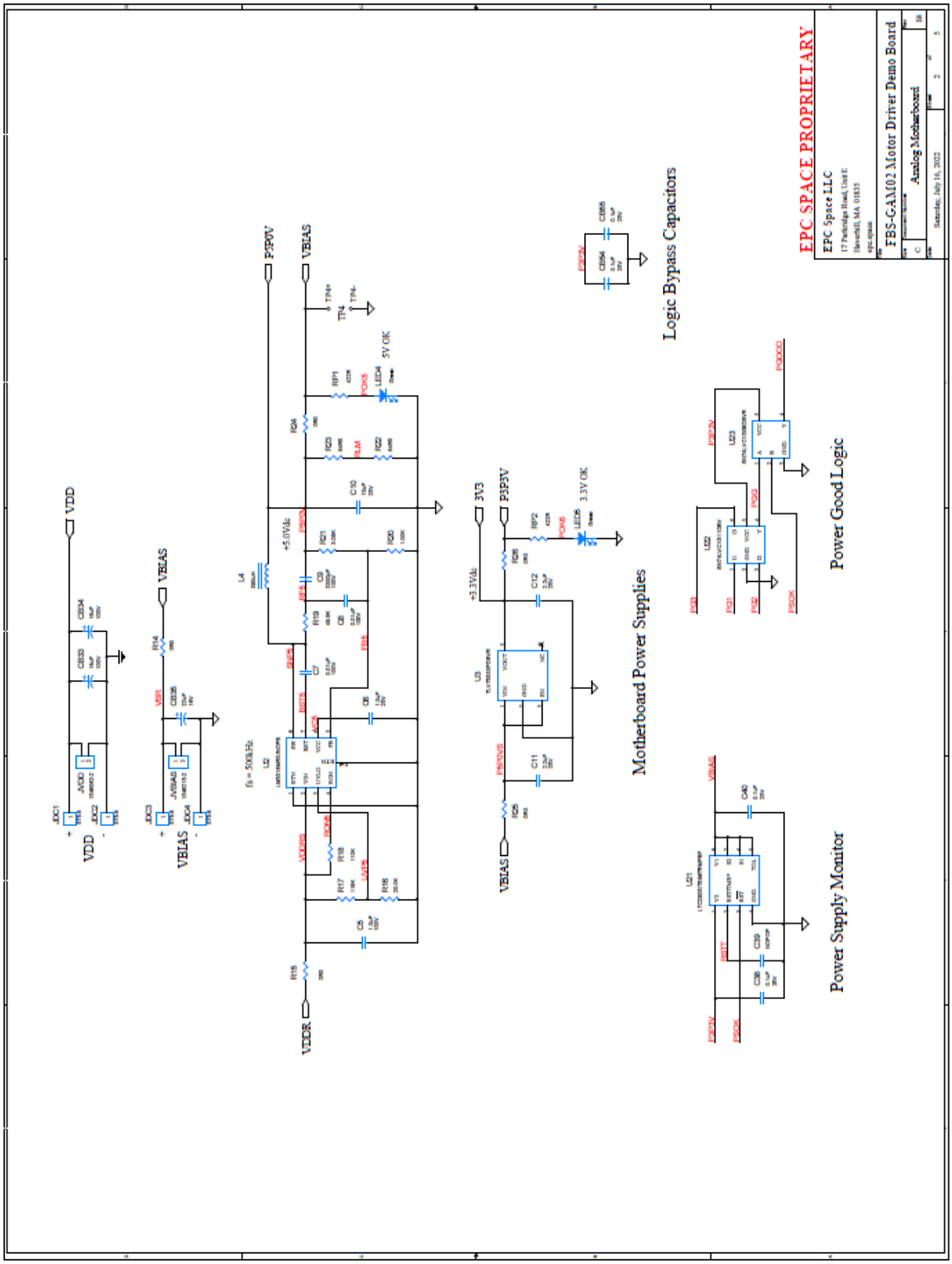


Figure 15 (cont.). *EPC7C006/FBS-GAM02 3-Phase Motor Control Board Schematic Diagram.*

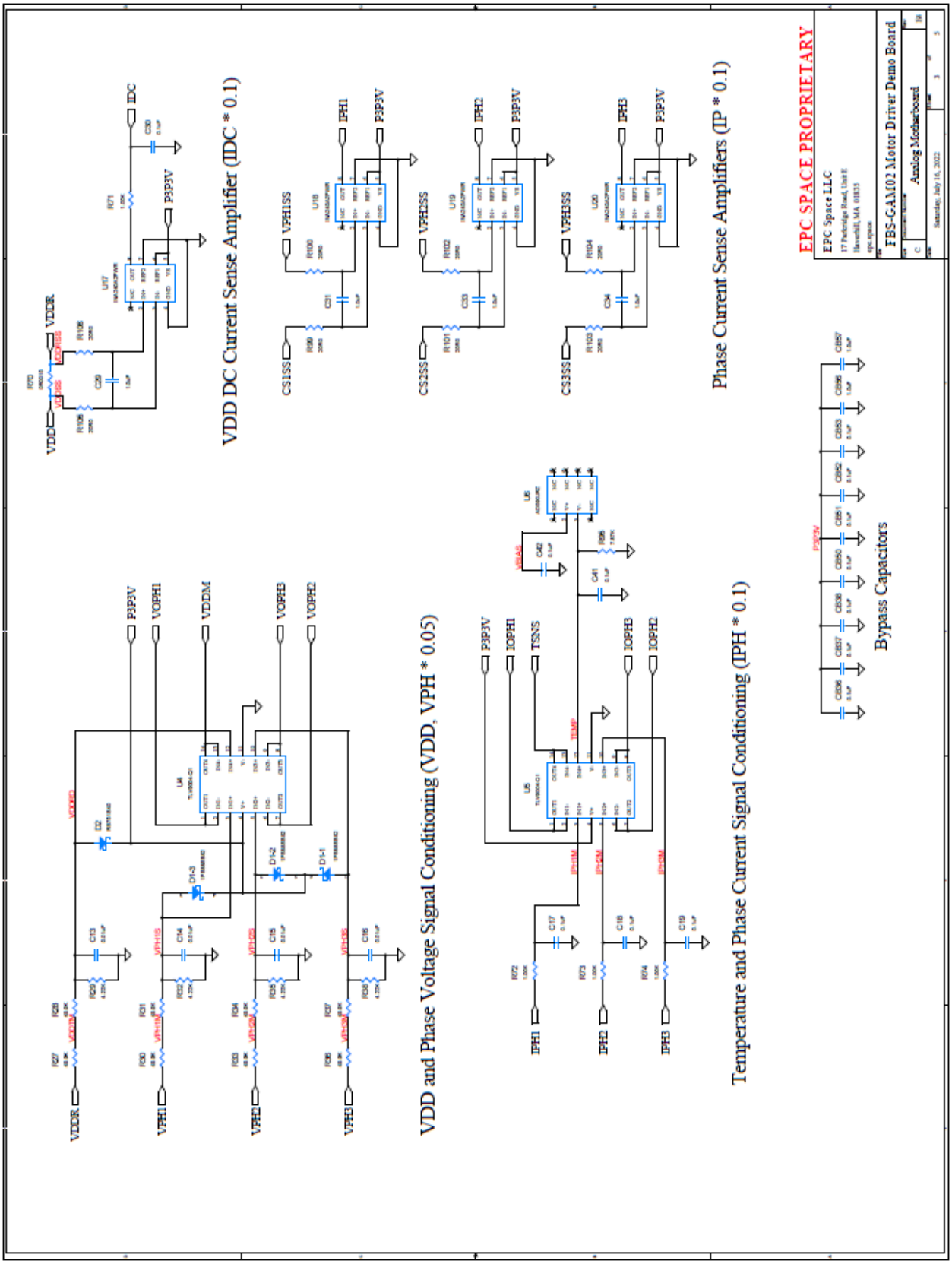


Figure 15 (cont.). *EPC7C006/FBS-GAM02 3-Phase Motor Control Board Schematic Diagram.*

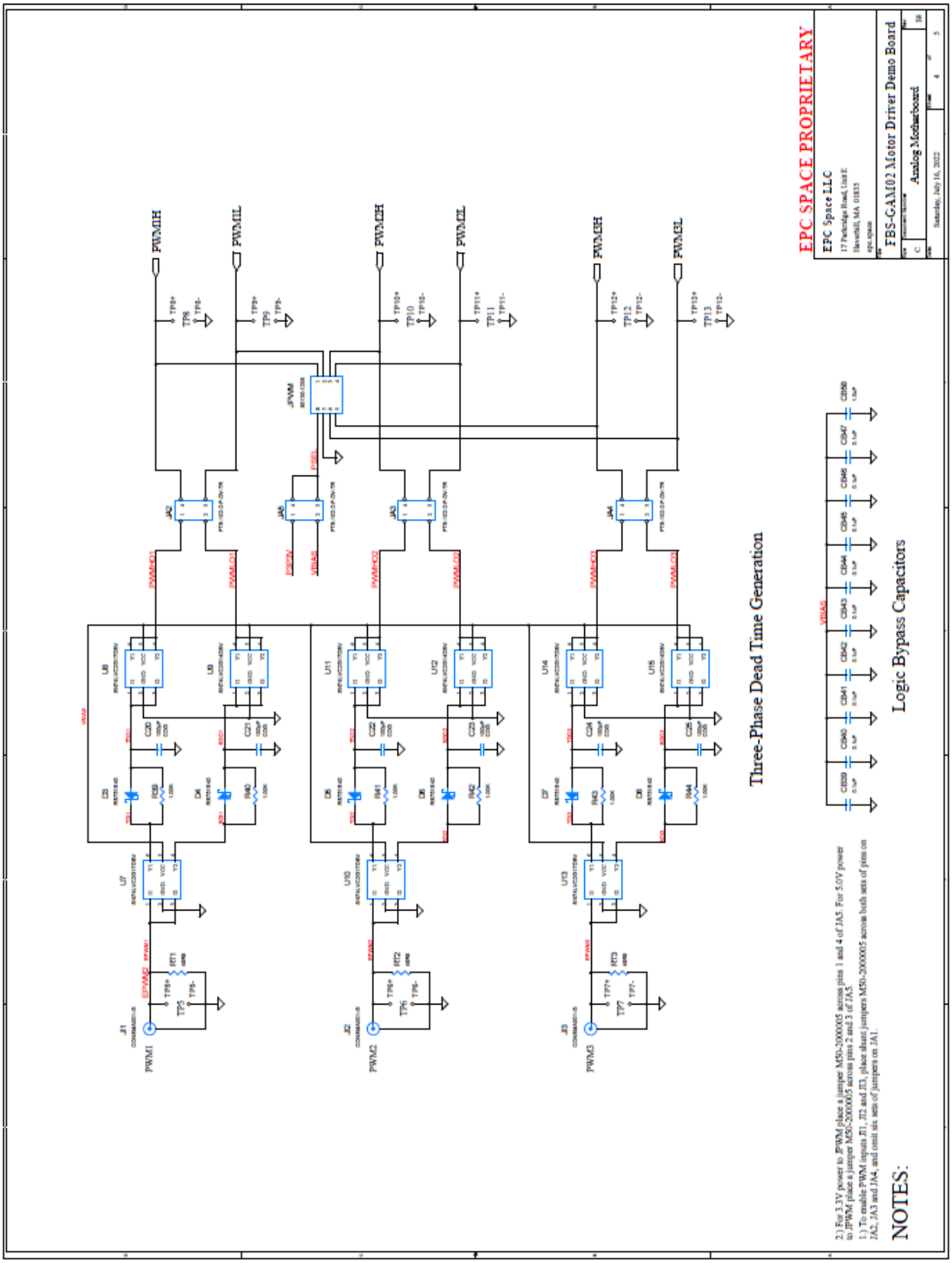


Figure 15 (cont.). *EPC7C006/FBS-GAM02 3-Phase Motor Control Board Schematic Diagram.*

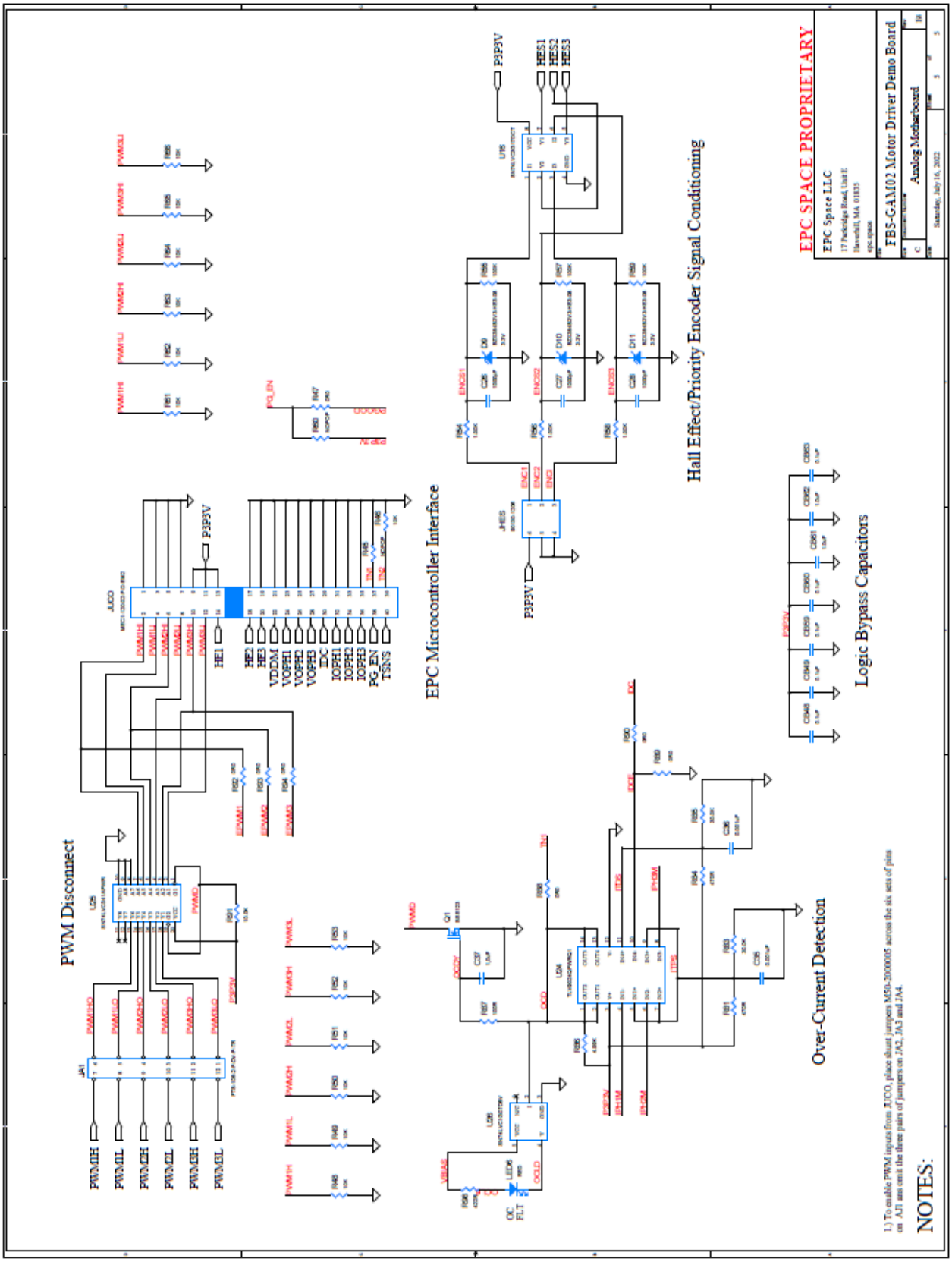


Figure 15 (cont.). *EPC7C006/FBS-GAM02 3-Phase Motor Control Board Schematic Diagram.*

EPC7C005 / FBS-GAM02-P-R50 POL Evaluation Board BOM

The BOMs for the FBS-GAM02-P-C50 POL Evaluation Board is shown in Table XIV. All active and passive components used are qualified to AEC-QXXX standards where possible.

Table XIV. EPC7C005/FBS-GAM02-P-C50 POL Evaluation Board Bill of Materials.

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N
1	4	JDC1,JDC2,JDC3,JDC4	Solderable Banana Staking Jack	Keystone	575-8
2	33	C17,C18,C19,C38,C40,C41,C42,CB1, CB3,CB5,CB7,CB36,CB37,CB38,CB39,CB40, CB41,CB42,CB43,CB44,CB45,CB46,CB47, CB48,CB49,CB50,CB51,CB52,CB53,CB54,CB55, CB59,CB60,CB63	0.1uF/25V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C104K3RACAUTO
3	9	CB9,CB10,CB11,CB16, CB17,CB18,CB23,CB24,CB25	0.1uF/100V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C104K1RECAUTO
4	4	C5,CB12,CB19,CB26	1.0uF/100V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08051C105K4T2A
5	9	C6,CB2,CB4,CB6,CB56,CB57,CB58,CB61,CB62	1.0uF/25V/X7R/10%/0805 Ceramic Capacitor	Kemet	C0805C105K3RACAUTO
6	4	C29,C31,C33,C34	1.0uF/25V/X7R/10%/AEC-Q200/0603 Ceramic Capacitor	TDK	CGA3E1X7R1E105K080AC
7	5	C7,C8,CB8,CB15,CB22	0.01uF/100V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08051C103K4T2A
8	6	CB13,CB14,CB20,CB21,CB27,CB28	2.2uF/100V/X7R/10%/1206 Ceramic Capacitor	AVX	12061C225K4T2A
9	3	CB29,CB30,CB31	27uF/100V/20%/30mΩ/F12 Size/Aluminum Organic Electrolytic Capacitor	Panasonic	100SXV27M
10	2	CB33,CB34	18uF/100V/20%/30mΩ/F12 Size/Aluminum Organic Electrolytic Capacitor	Panasonic	100SXV18M
11	2	C11,C12	2.2uF/25V/X7R/10%/0805 Ceramic Capacitor	TDK	CGA4J3X7R1E225K125AB
12	1	CB35	22uF/16V/Tantalum/10%/C Case SMT Capacitor	Kemet	T494C226M016AT
13	1	C4	4700pF/250VAC/X7R/10%/Safety Certified Ceramic Capacitor	Vishay	VJ2220Y472KXUSTX1
14	1	C9	3300pF/100V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C332K1RECAUTO
15	1	C10	10uF/25V/X7R/10%/AEC-Q200/1206 Ceramic Capacitor	Kemet	C1206C106K3RACAUTO
16	9	C13,C14,C15,C16, C29,C30,C31,C33,C34	0.01uF/50V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C103K5RACAUTO
17	6	C20,C21,C22,C23,C24,C25	100pF/25V/COG/5%/AEC-Q200/0805 Ceramic Capacitor	AVX	08053A101J4T2A
18	3	C26,C27,C28	1000pF/50V/COG/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08055A102K4T2A
19	**NOPOP**	C1,C2,C3	**Customer will populate.**	N/A	N/A
20	**NOPOP**	CS1,CS2,CS3	**Customer will populate.**	N/A	N/A
21	**NOPOP**	C39	**Customer will populate.**	N/A	N/A

Table XIV (cont.). EPC7C005/FBS-GAM02-P-C50 POL Evaluation Board Bill of

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N
22	1	D1	15V/30mA/Low Cj/3-Element/Schottky Diode Array/SOT-363	Nexperia	1PS88SB82,165
23	7	D2,D3,D4,D5,D6,D7,D8	0.12A/40V/SOD-323 Schottky Diode	Nexperia	RB751V40,115
24	3	D9,D10,D11	3.3V/200mW/2%/Zener Diode/SOD-323-2	Vishay	BZX384B3V3-HE3-08
25	5	LED1,LED2,LED3,LED4,LED5	568nm Green Water Clear/0805 Package LED	Bivar	SM0805GCL
26	1	LED6	660nm Red Water Clear/0805 Package LED	Bivar	SM0805RC
27	12	FB1,FB2,FB3,FB4,FB5,FB6, FB7,FB8,FB9,FB10,FB11,FB12	12A/0.0016 Ohm/50 Ohm@100MHz/Ferrite Beads/1206	Murata	BLM31SN500SH1L
28	1	JA1	6 Dual Pin Array Connector/Header/1.27mm Spacing	Samtec	FTS106-02-F-DV-P-TR
29	4	JA2,JA3,JA4,JA5	2 Dual Pin Array Connector/Header/1.27mm Spacing	Samtec	FTS102-02-F-DV-TR
30	1	JHES	6 Pin Straight Shrouded Connector/Through-Hole/C-Grid III	Molex	90136-1206
31	3	JI1,JI2,JI3	SMA/Vertical/50 Ohms/Brass-Gold/Through Hole	Molex	73391-0060
32	1	JMOTOR	5.08mm Terminal Block/Side Entry/Vertical/7 Position/Black	TE/Buchanan	796949-7
33	1	JPWM	8 Pin Straight Shrouded Connector/Through-Hole/C-Grid III	Molex	90136-1208
34	1	JUCO	1.00mm/Standard Card Edge Connectors/Mini Edge Card Socket/Vertical	Samtec	MEC1-120-02-F-D-EM2
35	1	JVBIAS	2.54mm Terminal Block/Side Entry/Vertical/2 Position/Gray	TE/Buchanan	1546215-2
36	1	JVDD	7.50mm Terminal Block/Side Entry/Vertical/2 Position/Black	TE/Buchanan	1546062-2
37	3	L1,L2,L3	17A/330nH/20%/Power Inductor/4.2 milliohms/6mm x 6mm	Kemet	MPXV1D0624LR33
38	1	L4	390uH/10%/500mA/Power Inductor/12.7mm x 12.7mm	Bourns	SRR1205-391KL
39	3	MOD1,MOD2,MOD3	FBS GAM02-P-C50	EPC Space	FBS GAM02-P-C50
40	**NOPOP**	MOD1,MOD2,MOD3	EPC GAM02A-P-C50	EPC Space	EPC GAM02A-P-C50
41	1	Q1	60V/0.3A N-Channel GP MOSFET/SOT23-3	Nexperia	2N7002P,215
42	**NOPOP**	R45	TBD		
43	**NOPOP**	R67,R68,R69	**Customer will populate.**	N/A	N/A
44	**NOPOP**	R60,R89,R92,R93,R94	0 Ohm Jumper Resistor/0805	Vishay	RCS08050000Z0EA
45	**NOPOP**	R60,R89	0 Ohm Jumper Resistor/0805	Vishay	RCS08050000Z0EA
46	9	R1,R2,R3,R10,R25,R26,R47,R88,R90	0 Ohm Jumper Resistor/0805	Vishay	RCS08050000Z0EA
47	1	R14	0 Ohm Jumper Resistor/1206	Vishay	RCS12060000Z0EA

Table XIV (cont.). EPC7C005/FBS-GAM02-P-C50 POL Evaluation Board Bill of

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N
48	**NOPOP**	R15,R24	0 Ohm Jumper Resistor/1206	Vishay	RCS12060000Z0EA
49	5	R7,R8,R9,RP1,RP2	422R/1%/1206/Thick Film Chip Resistor	Vishay	CRCW1206422RFKEA
50	3	R4A,R5A,R6A	4.70K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW08054K70FKEA
51	**NOPOP**	R4B,R5B,R6B	4.70K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW08054K70FKEA
52	4	R11,R12,R13,R70	0R0015/1%/0612/4 Terminal/Thick Film Chip Resistor	Bourns	CST0612-FC-R0015E
53	1	R16	20.0K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080520K0FKEA
54	1	R17	118K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW0805118KFKEA
55	1	R18	110K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW0805110KFKEA
56	10	R19,R27,R28,R30,R31,R33,R34,R36,R37	49.9K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080549K9FKEA
57	13	R20,R39,R40,R41,R42,R43,R44, R54,R56,R58,R72,R73,R74	1.00K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW08051K00FKEA
58	1	R21	3.09K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW08053K09FKEA
59	3	RT1,RT2,RT3	49R9/1%/0805/Thick Film Chip Resistor	Vishay	CRCW080549R9FKEA
60	2	R22,R23	84R5/1%/0805/Thick Film Chip Resistor	KOA Speer	RK73H2ATTD84R5F
61	4	R29,R32,R35,R38	4.22K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW08054K22FKEA
62	8	R46,R48,R49,R50,R51,R52,R53,R91	10.0K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080510K0FKEA
63	6	R61,R62,R63,R64,R65,R66	10.0K/1%/0603 Thick Film Chip Resistor	Vishay	CRCW060310K0FKEA
64	3	R55,R57,R59	100K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW0805100KFKEA
65	1	R71	300R/1%/0805 Thick Film Chip Resistor	Panasonic	ERJ-6ENF3000V
66	8	R99,R100,R101,R102,R103,R104,R105,R106	20R0/1%/0402 Thick Film Chip Resistor	Panasonic	ERJ-2RKF20R0X
67	2	R81,R84	470R/1%/0805 Thick Film Chip Resistor	Vishay	CRCW0805470RFKEB
68	2	R83,R85	30.0K%/0805 Thick Film Chip Resistor	Vishay	CRCW080530K0FKEA
69	1	R86	4.99K%/0805 Thick Film Chip Resistor	Vishay	RCS08054K99FKEA
70	1	R87	100R/1%/0805 Thick Film Chip Resistor	Panasonic	ERJ-6ENF1000V
71	1	R95	7.87K/1%/0805 Thick Film Chip Resistor	Panasonic	ERJ-6ENF7871V
72	6	SJMP1,SJMP2,SJMP3,SJMP4,SJMP5,SJMP6	Shunt Jumper/1.27mm Spacing	Harwin	M50-2000005
73	1	SJMP7	SJMP7	Harwin	M50-2000005

Table XIV (cont.). EPC7C005/FBS-GAM02-P-C50 POL Evaluation Board Bill of

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N
74	1	U1	Triple Open-Drain Inverter/Little Logic/1.65-5.5V/LVC/SM-8	TI	SN74LVC3G06DCTR
75	1	U2	100V/300mA/Synchronous Buck Converter/SO-PowerPad-8	TI	LM5018MRX/NOPB
76	1	U3	3.3V/200mA/LDO Linear Regulator/SOT-23-5	Analog Devices	ADM7160AUJZ-3.3-R7
77	2	U4,U5	Quad Op-Amp/1.8-5.5V/1MHz BW/RRIO/SOIC-14	TI	TLV9004-Q1
78	1	U6	IC Temperature Sensor IC/SOIC-8	Analog Devices	AD590JRZ
79	6	U7,U8,U10,U11,U13,U14	Dual Schmitt Trigger Buffer/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC2G17DBV
80	3	U9,U12,U15	Dual Schmitt Trigger Inverter/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC2G14DBV
81	1	U16	Triple Schmitt Trigger Buffer/Little Logic/1.65-5.5V/LVC/SM-8	TI	SN74LVC3G17DCTR
82	4	U17,U18,U19,U20	IC Current Sense Amplifier/100kHz BW/2.7-5.5V/80 Sense/Av=50/TSSOP-8	TI	INA240A2QPWRQ1
83	1	U21	Dual Power Supply/Monitor/SOT-23-8	Analog Devices	LTC2905ITS8#TRMPBF
84	1	U22	Single Triple Input AND Gate/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC1G11DBVR
85	1	U23	Multifunction Gate/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC1G0832DBVR
86	1	U24	Qual High-Speed Comparator/Open Drain/1.65-5.5V/TSSOP-14	TI	TLV9024QPWRQ1 TCC374CPWR
87	1	U25	Octal Three-State Buffer/1.65-3.6V/LVC/TSSOP-20	TI	SN74LVC541APWR
88	1	U26	Single Open Drain Buffer Gate/Little Logic/1.65-5.5V/LVC/SOT-23-5	TI	SN74LVC1G07DBVTG4
89	6	Misc. Hardware	Spacer/Hex/PVC/6-32/0.75" Length	Essentra	144-HS-6-6
90	6	Misc. Hardware	Screw/6-32/Nylon/Round head/Slotted/0.5" Length	Essentra	010632R050
91	1	PCB	6.80" x 5.22" x 0.063" 6 Layer FR-4 PCB, Double-Sided	TBD	47-056

Printed Circuit Board and Layout Details.

The printed circuit board (PCB) for the EPC7C006 FBS-GAM02 3-Phase Motor Driver Evaluation Board is constructed with six layers. The PCB is 6.80" x 5.22" and is 0.063" thick. The outer layers are 2 oz/in2 and the inner layers are 1 oz/in2 copper etch. All electronic components are SMT-packages and the connectors are a combination of SMT and through-hole. The PCB shape of connector JUCO overhangs the board to facilitate ease of external connection to the EPC9147A daughtercard.

The individual Gerber layers for the PCB are shown in Figures 16 to 26, following:

Figure 16. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Evaluation Board Top Silkscreen.*

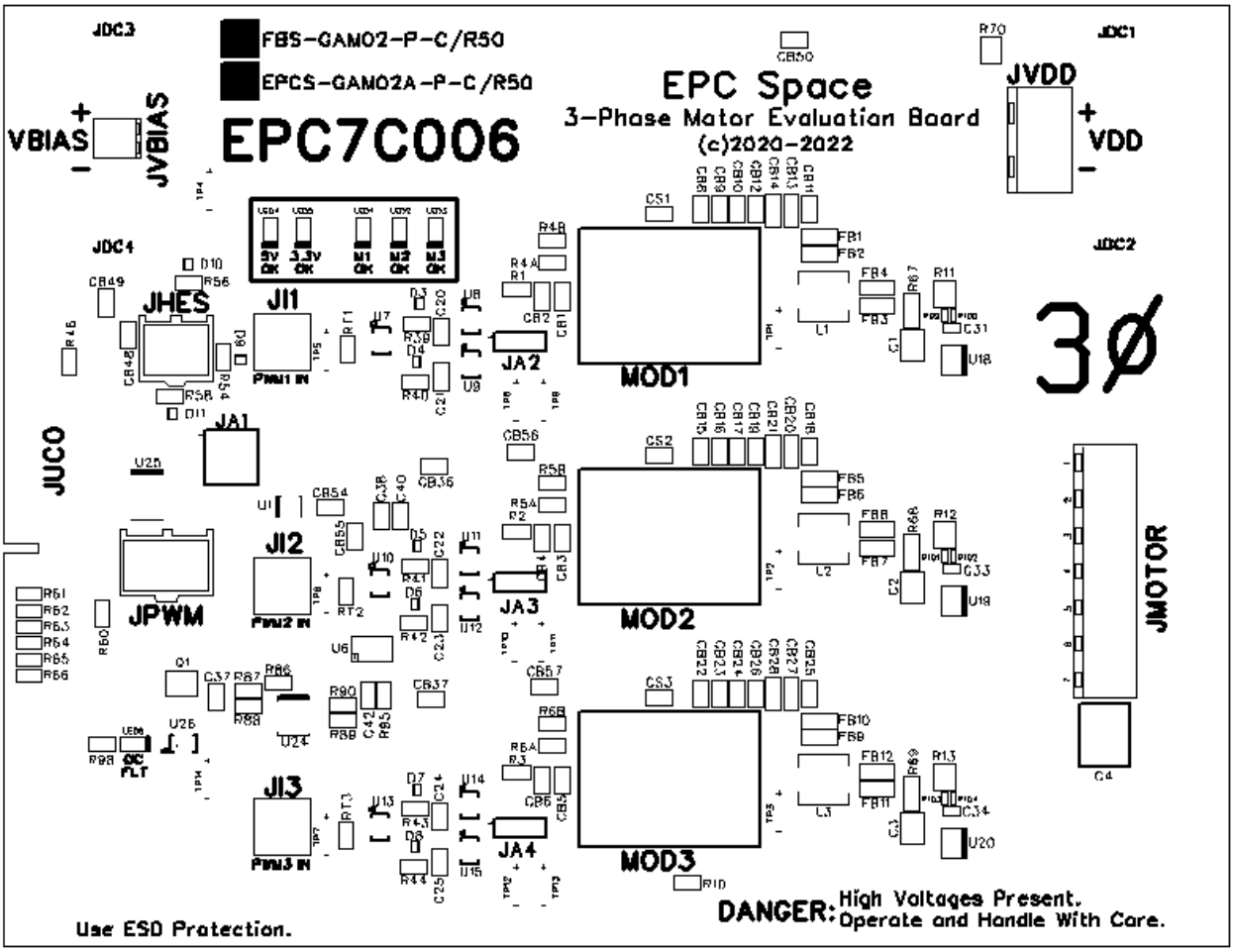


Figure 17. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Evaluation Board Top Solder Mask.*

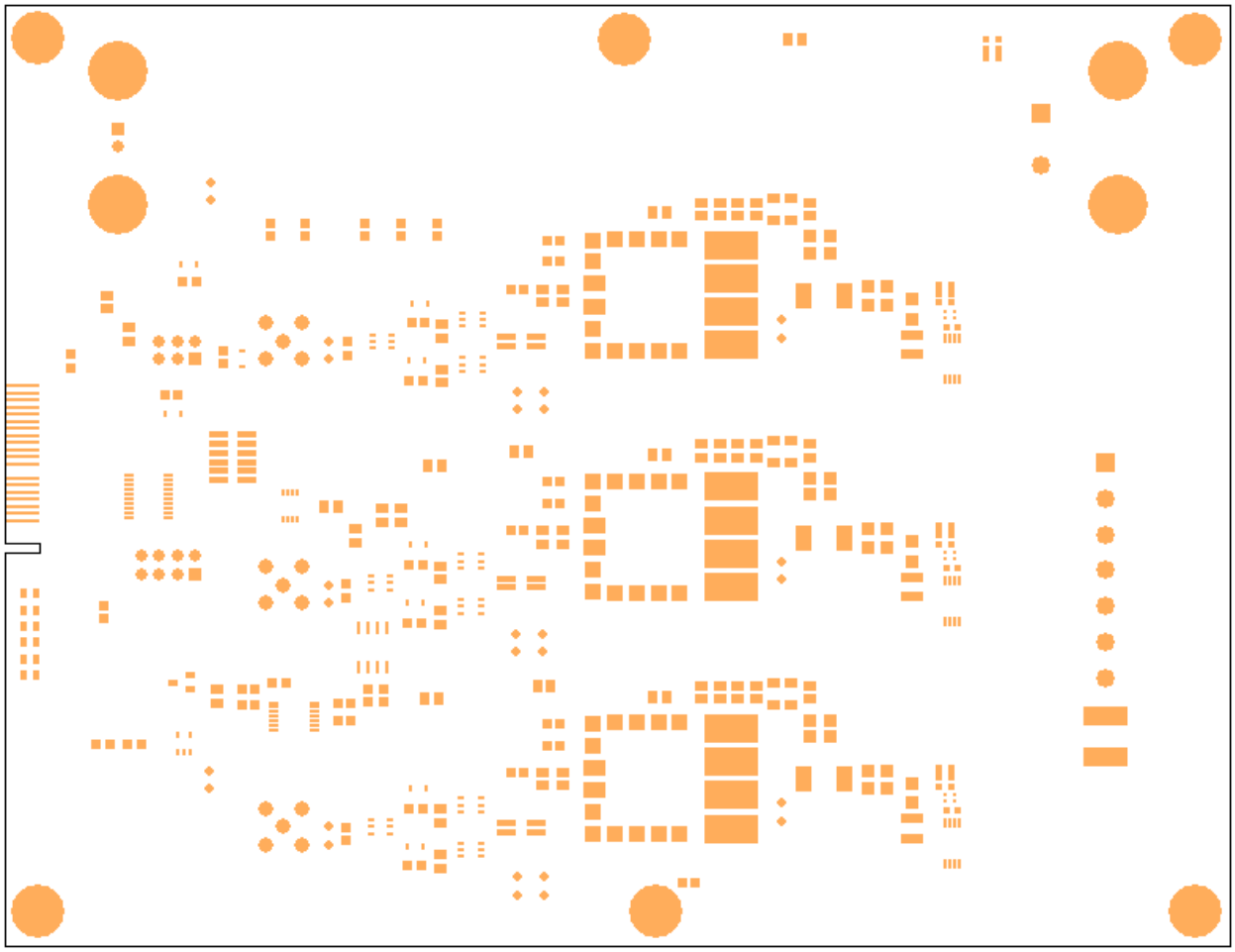


Figure 18. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Evaluation Board Top Copper Etch (2 oz).*

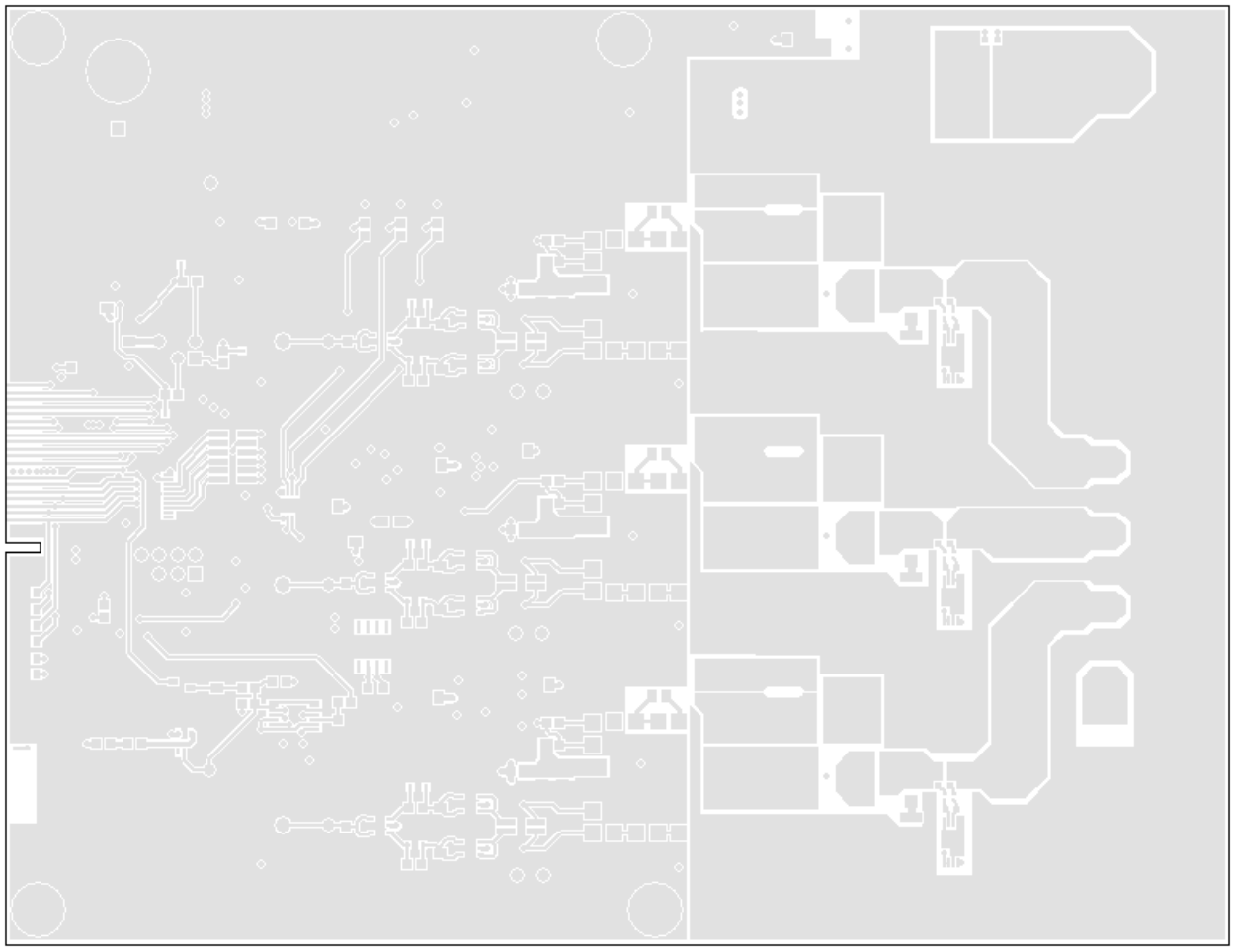


Figure 19. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Inner Layer 1 Copper Etch (1 oz).*

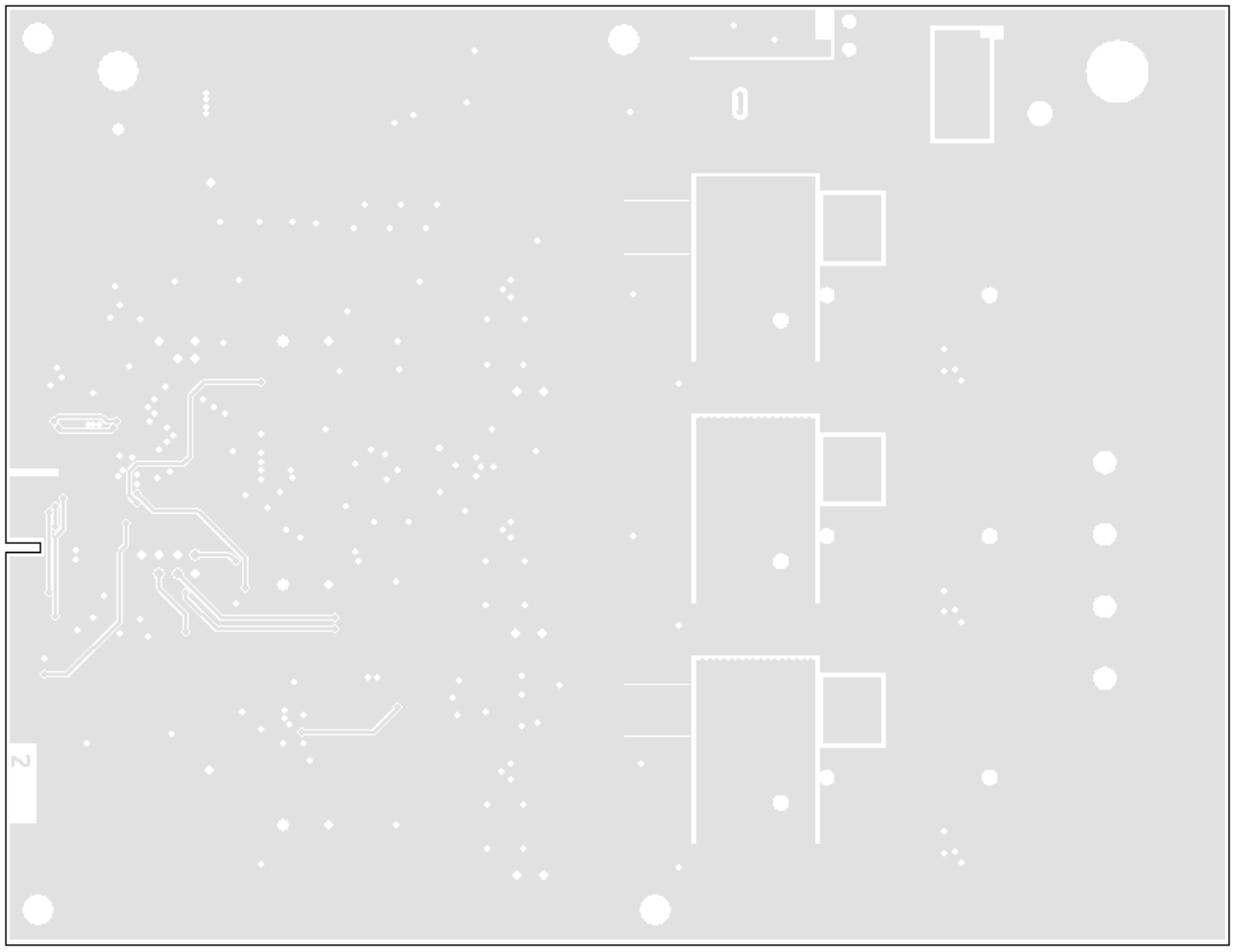


Figure 20. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Inner Layer 2 Copper Etch (1 oz).*

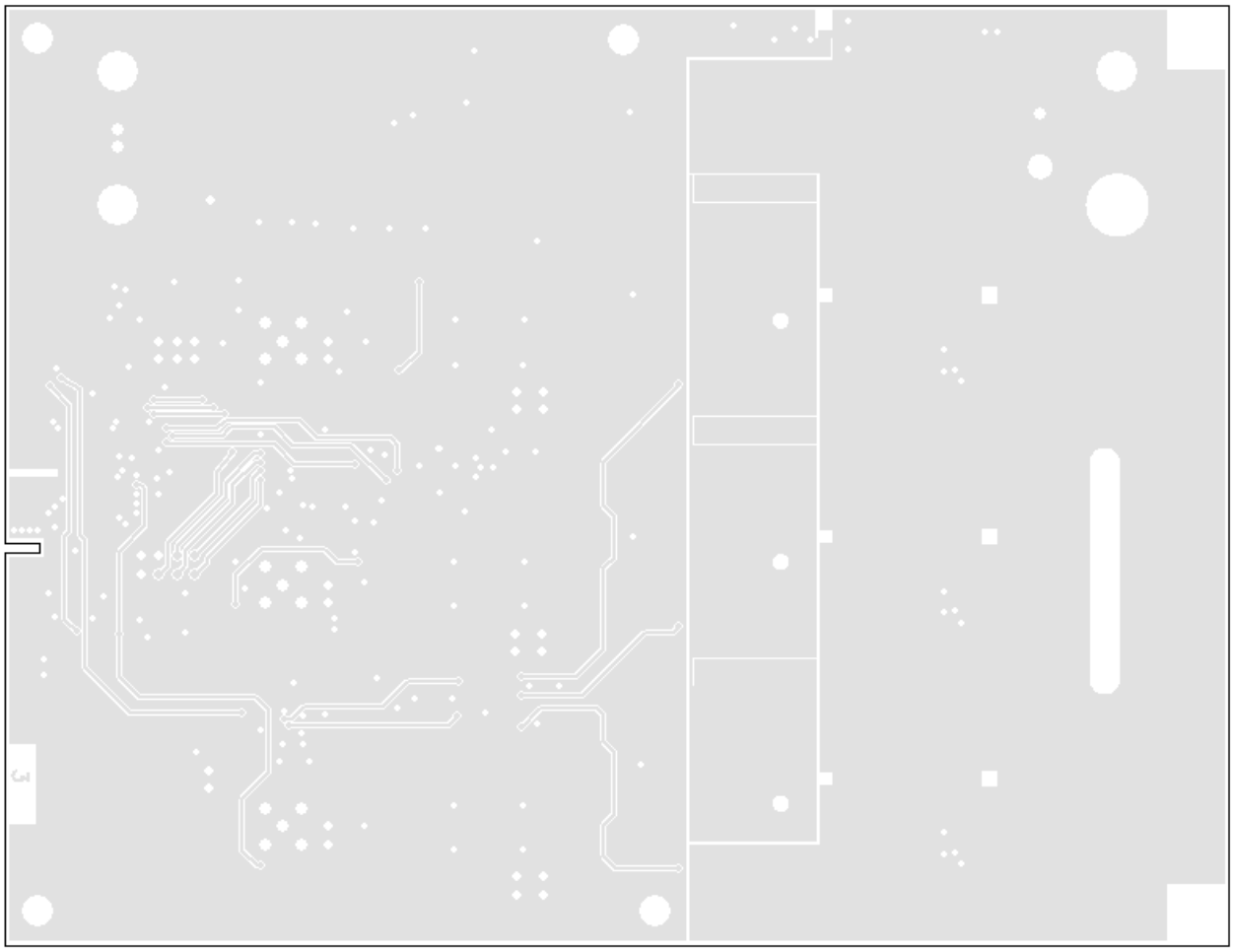


Figure 21. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Inner Layer 3 Copper Etch (1 oz).*

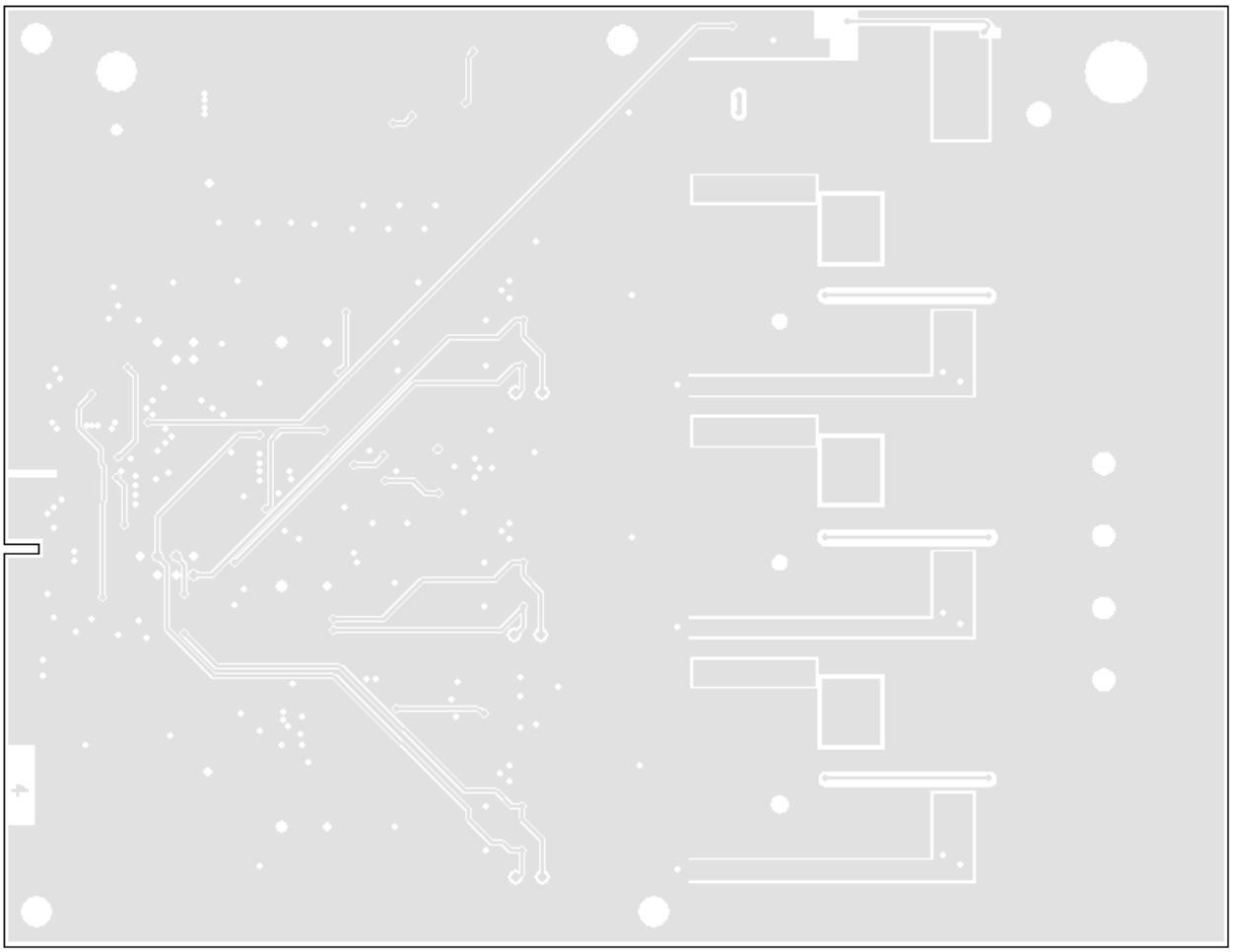


Figure 22. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Inner Layer 4 Copper Etch (1 oz).*

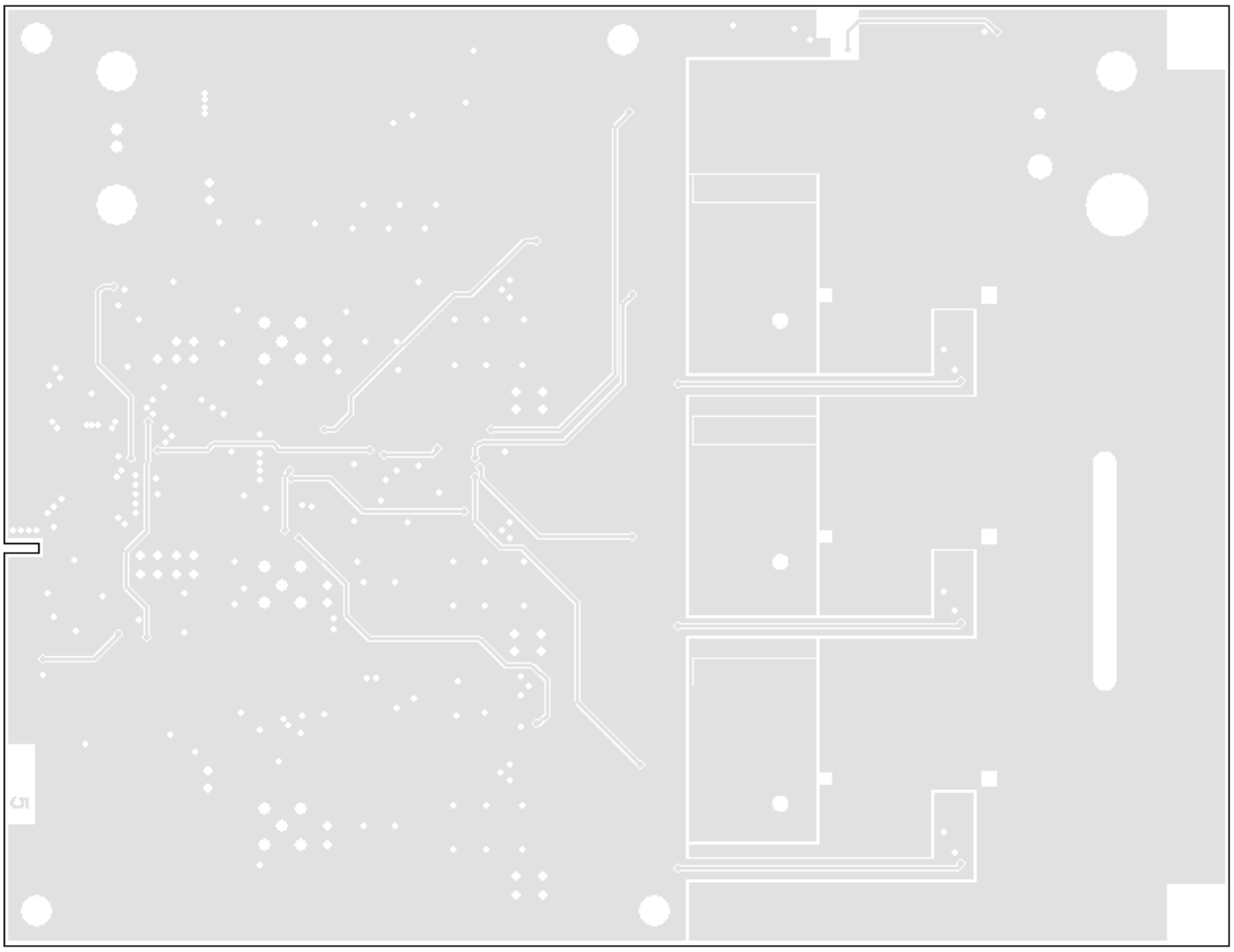


Figure 23. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Bottom Copper Etch (2 oz).*

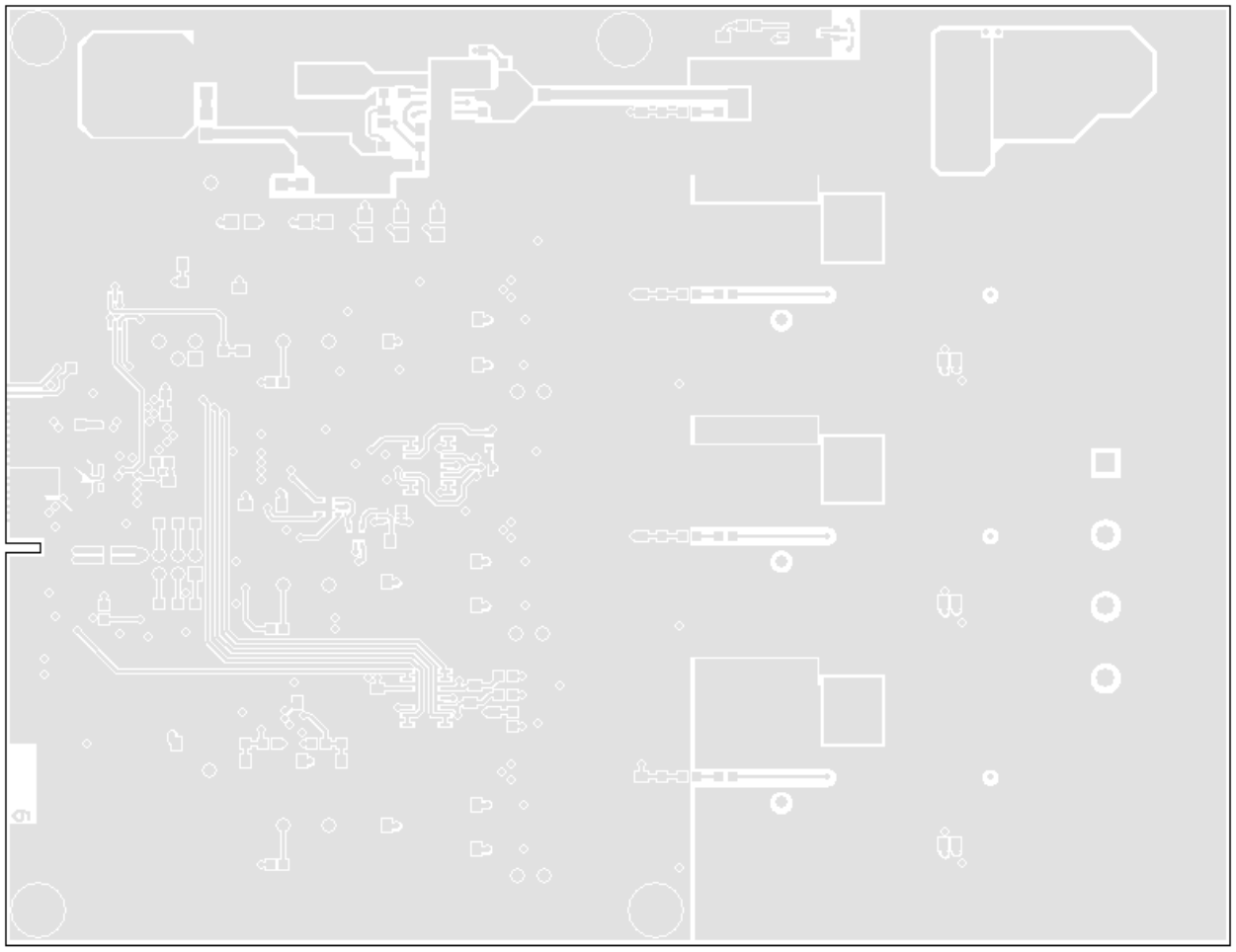


Figure 24. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Bottom Silkscreen.*

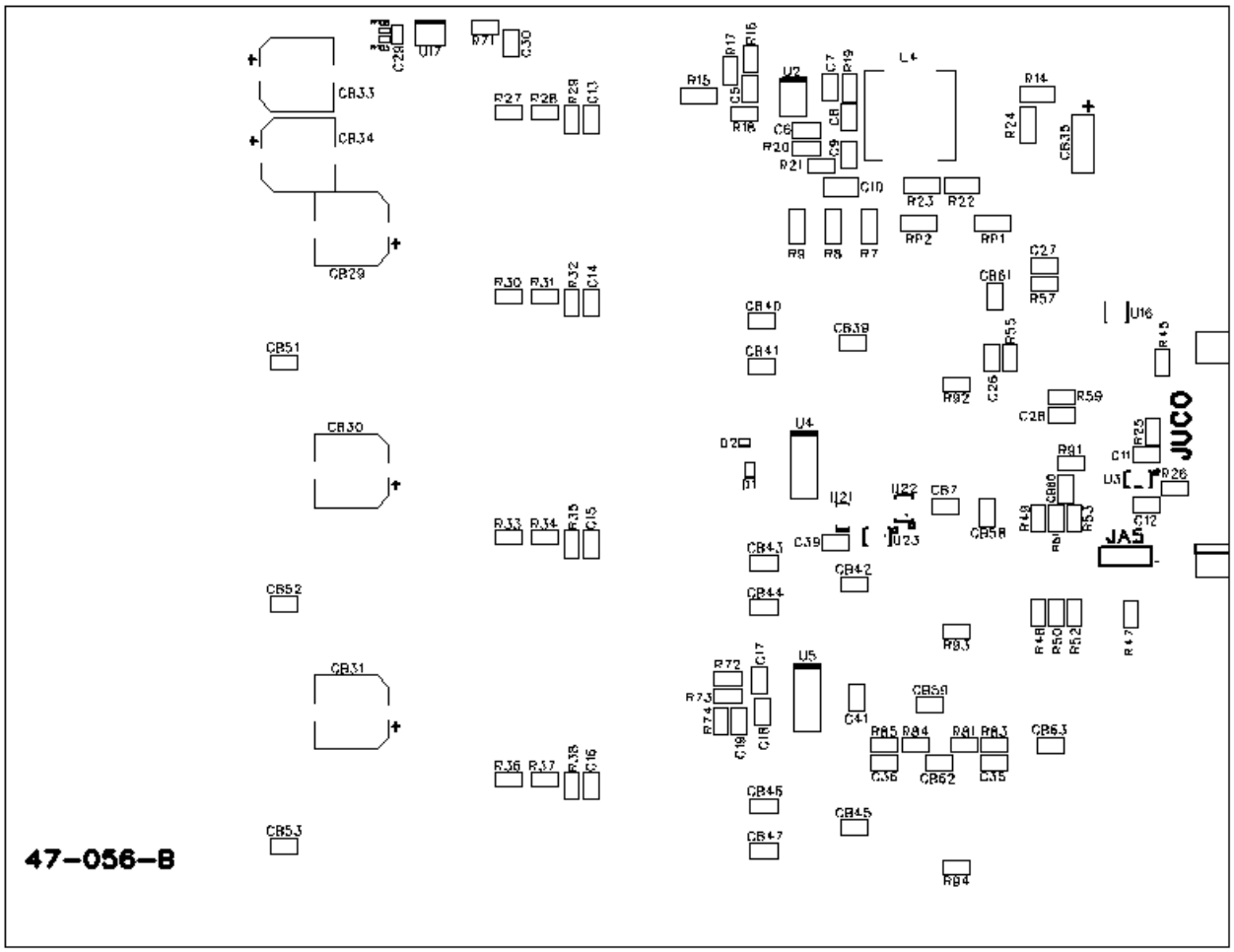


Figure 25. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Bottom Solder Mask.*

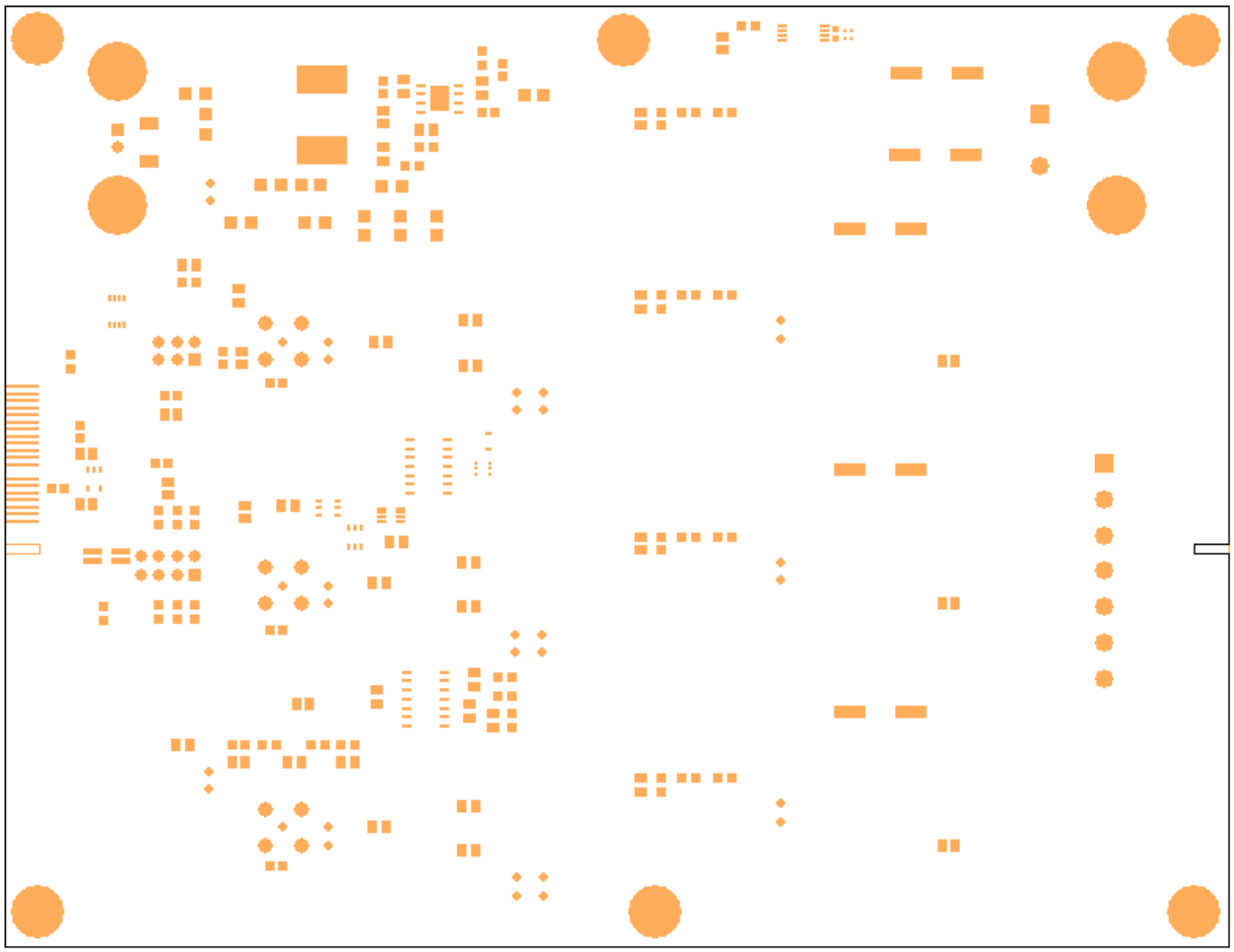
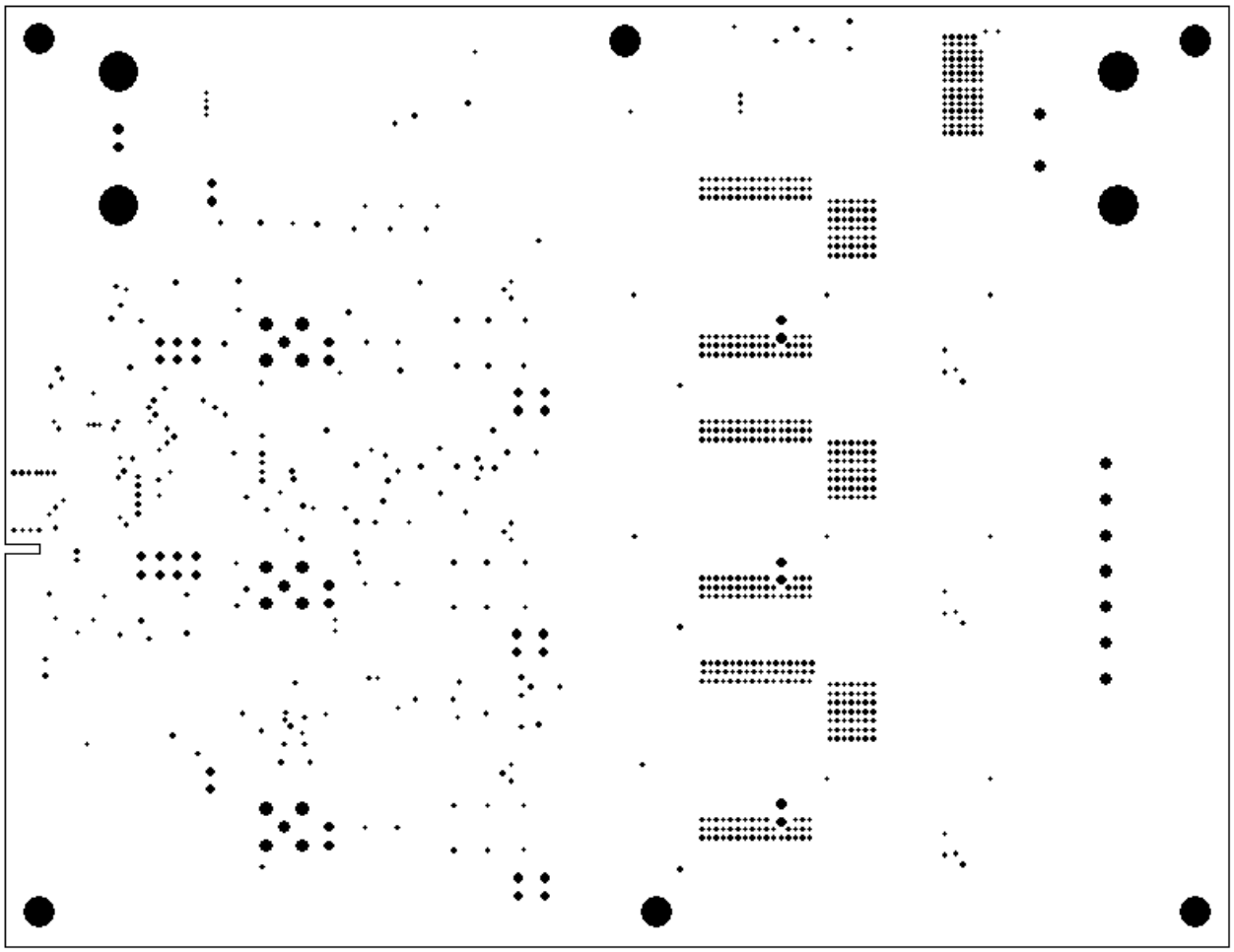


Figure 26. *EPC7C006/FBS-GAM02 3-Phase Motor Driver Eval. Board Drill Pattern.*



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Revisions:

Revision	Date	Status
PR	8/9/2021	Pre-Release
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A		Revision A

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