Application Guide for the EPC7C021 Evaluation Board

EPC Space (www.epc.space)

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ESD Precaution.

Proper ESD precautions should be employed when handling the EPC7C021 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 EPC7C021 EPC7011L7 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 EPC7011L7 IC's connected as a three-phase motor driver.

EPC7C021 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 EPC7011L7 IC and the EPC7011L7 data sheet for further details regarding the specifications and operation of the EPC7011 IC.

EPC7C021 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 EPC7C021 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:

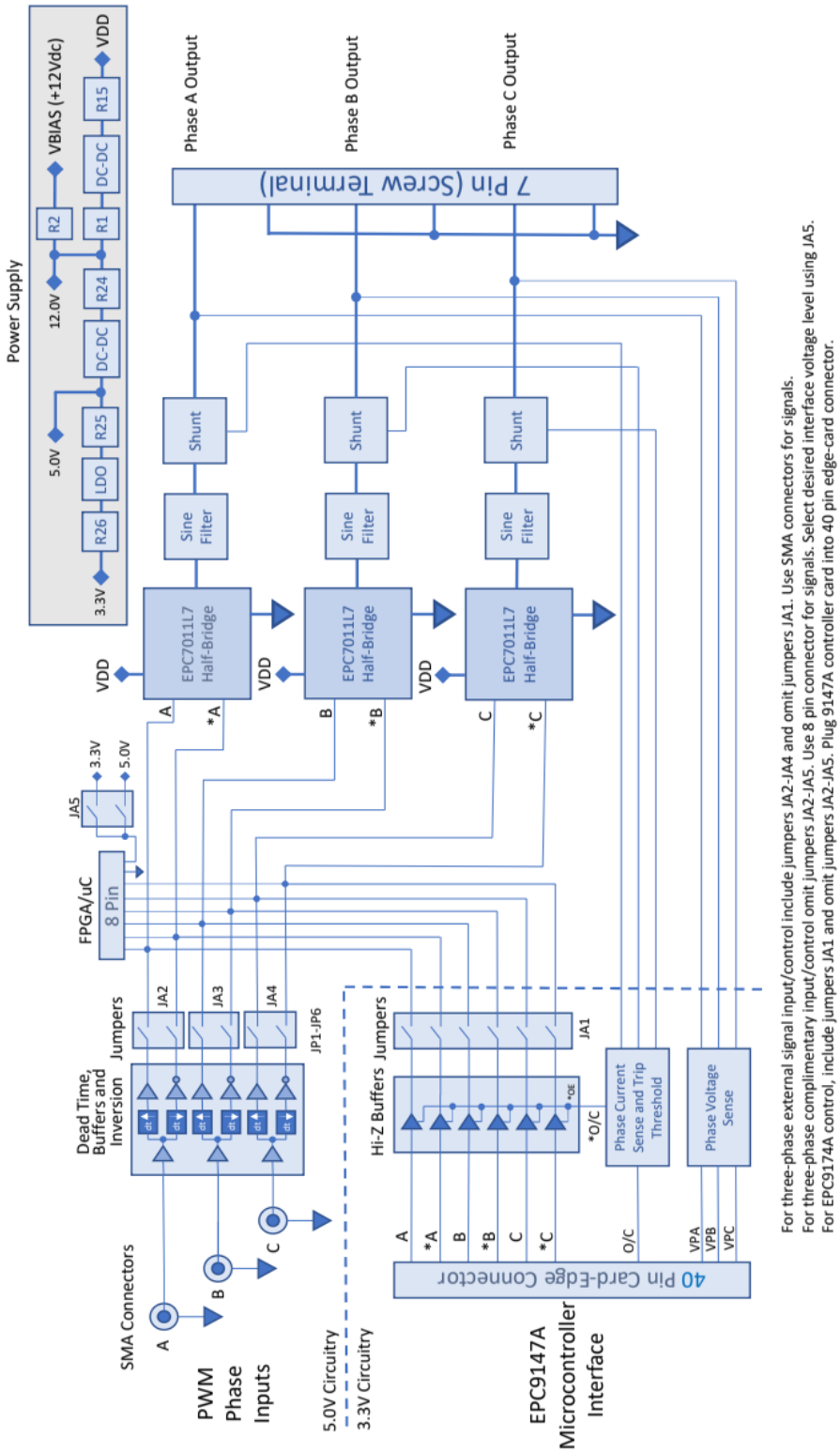


Figure 1. *EPC7C021 Eval. Board Functional Block Diagram.*

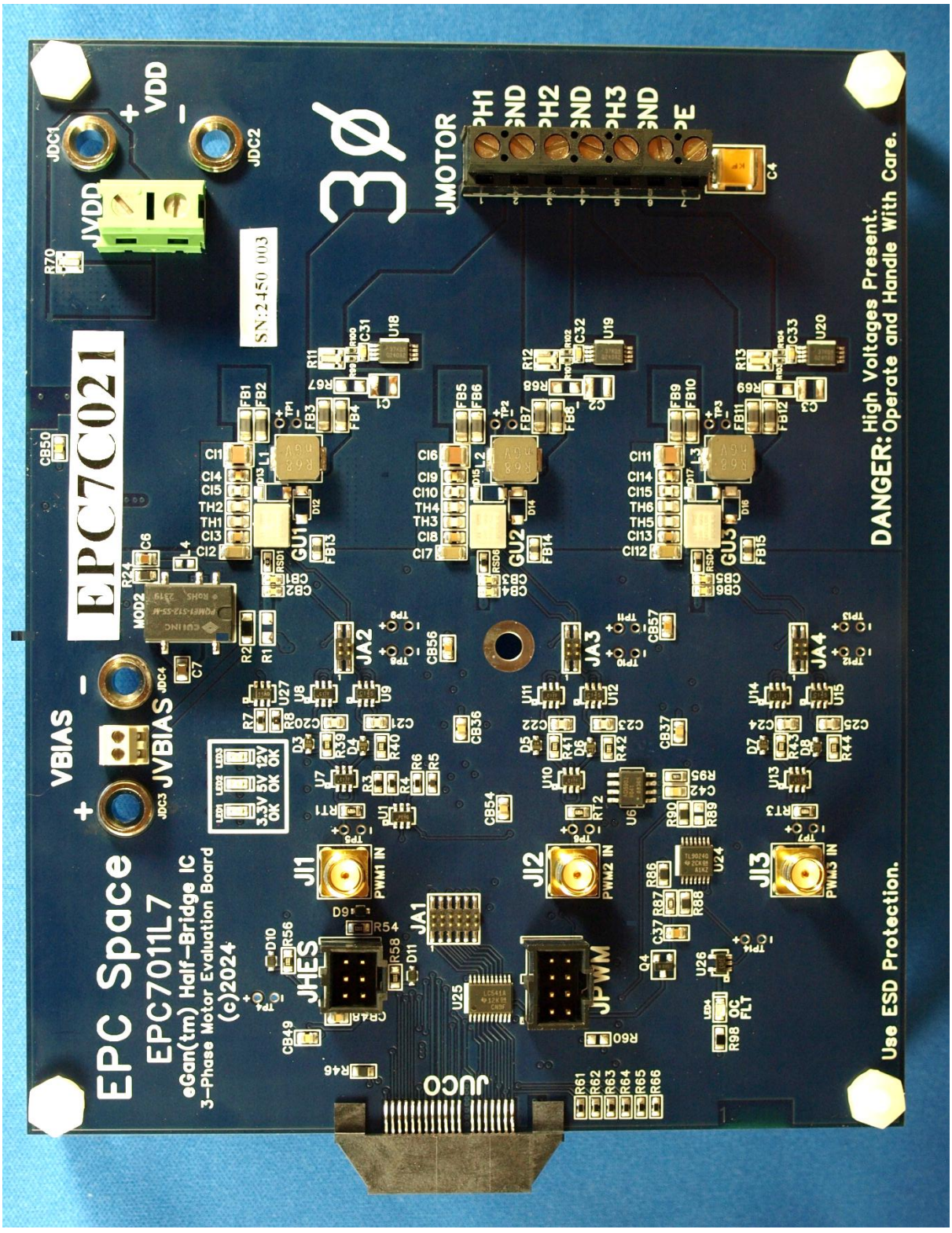


Figure 2a. *EPC7C021 Eval. Board (Top View).*

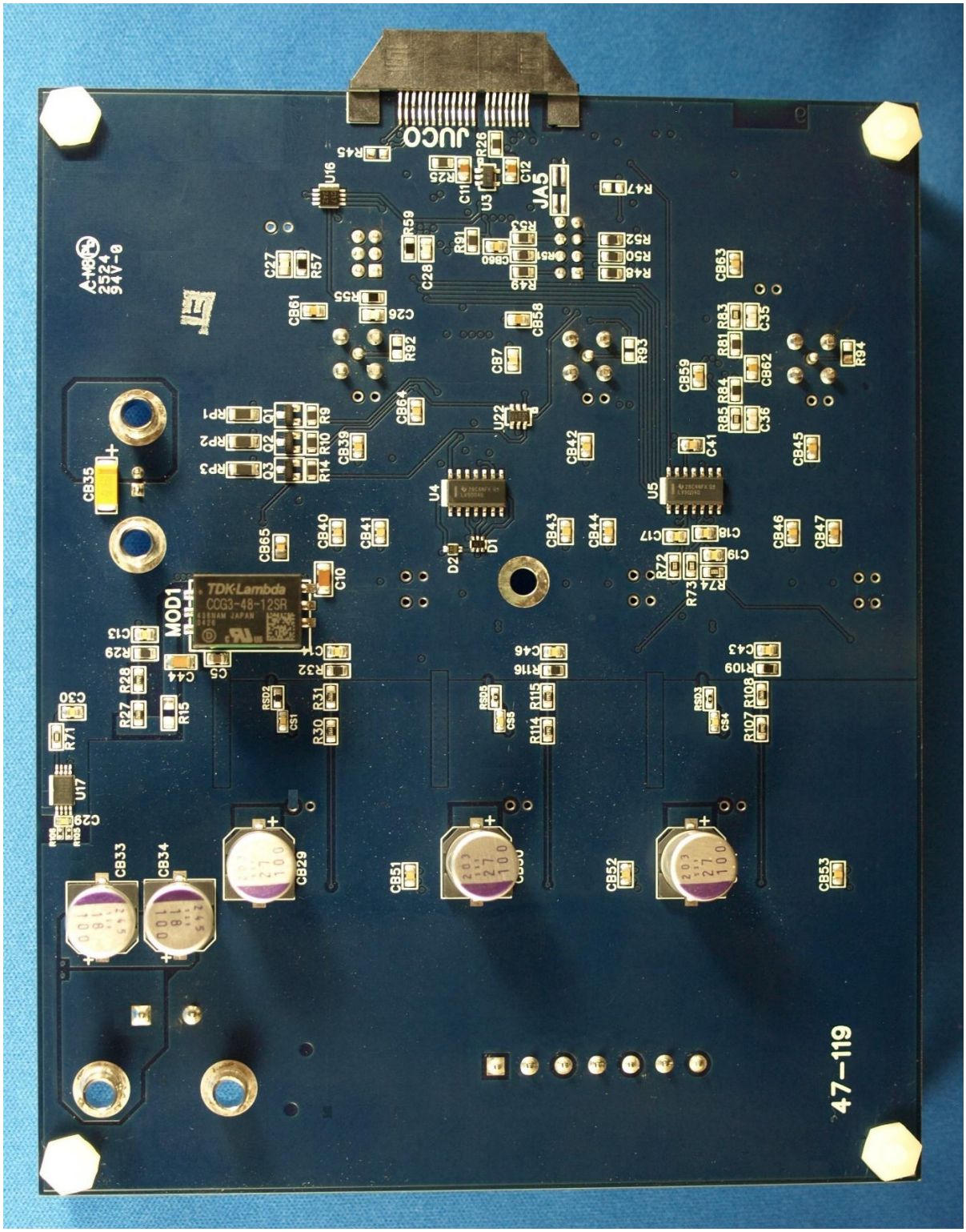


Figure 2b. *EPC7C021 Eval. Board (Bottom View).*

Powering the EPC7C021 Evaluation Board.

VDD and VBIAS Power Sequencing.

There is NO power sequencing requirement for the EPC7C021 board.

Configuring the 12.0V, 5.0V and 3.3Vdc Power Supplies.

The EPC7C021 board is configured to provide flexibility to end-user for providing the 12V (VBIAS) power to the board. Referring to Figure 1, the 12V 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. EPC7C021 Evaluation Board 12Vdc (VBIAS) Options.

12V (VBIAS) Power Provided By	Connectors Used	Resistors		
		R1	R2	R15
VDD	JDC1 & JDC2 or JVDD	Omitted	Present	Omitted
External 12V Power Supply	JDC3 & JDC4 or JVBIAS	Present	Omitted	Present

With 12Vdc power provided to the EPC7C021 board via the options shown in Table I, the 5.0Vdc and 3.3V DC power required by the board may be derived in one of the several ways as shown in Table II. This power architecture is designed to give the end-user flexibility to utilized either on-board or off-board power supplies.

TABLE II. EPC7C021 Evaluation Board 5.0V and 3.3Vdc Options.

Power Option	Resistors		Note
	R25	R26	
5.0Vdc On-Board	N/A	N/A	Note 1
3.3Vdc On-Board	Present	Present	Note 2
3.3Vdc External	Omitted	Omitted	Note 3

Note 1: With pins 1 and 4 of JA5 shorted, the maximum current that may be drawn from JPWM, pin 8 is 20mAdc.

Note 2: With pins 2 and 3 of JA5 shorted, the maximum current that may be drawn from JPWM, pin 8 is 50mAdc.

Note 3: With pins 2 and 3 shorted, the maximum current that is drawn from an external power supply by JPWM, pin 8 is 30mA.

The maximum current drawn by the 5Vdc (VBIAS) on-board circuitry is 35mA, 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 100mA current drain required by the EPC9147A controller daughtercard when it is connected to the EPC7C021 board via connector JUCO.

VBIAS Power Supply Resistor and Jumper Locations.

The resistors in question in Table I are located on the top side (R1 and R2) and bottom side (R15) of the EPC7C021 board, in the upper right-hand corner, as shown in Figure 3.

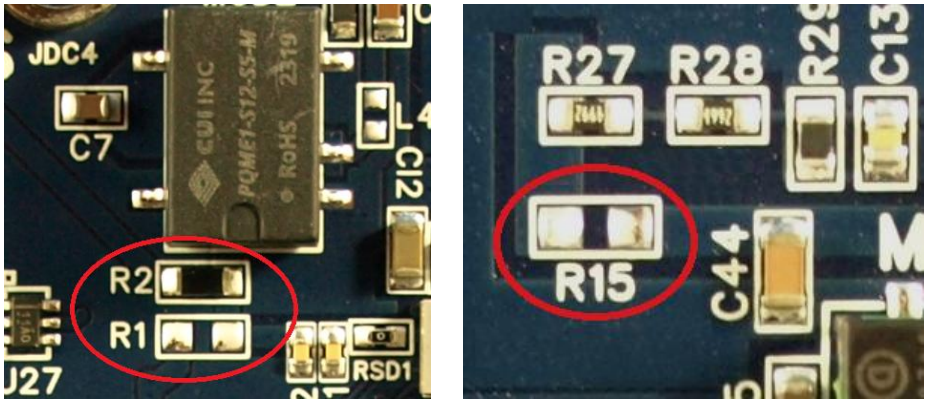


Figure 3. *Resistors R1, R2 (Top Side) and R15 (Bottom Side) Locations.*

The resistors in question in Table II are located on the bottom side of the EPC7C021 board, in the far right, middle of the board adjacent to JUCO, as shown in Figure 4.

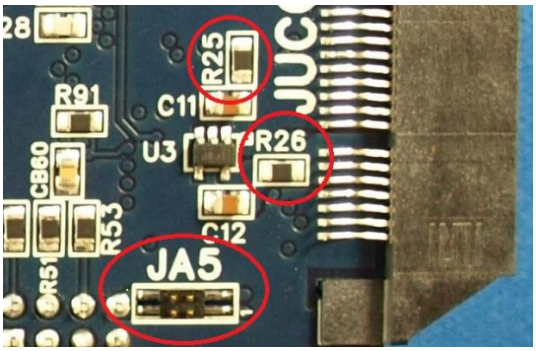


Figure 4. *Resistors R25, R26 and JA5 (Bottom Side) Locations.*

Indicator LEDs: LED1, LED2, LED3 and LED4

The EPC7C021 evaluation board is provided with visual indication that the 12.0Vdc, 5.0Vdc and 3.3Vdc power supplies on the board are functioning and withing 5% of their nominal values. LED1, LED2 and LED3, glow **GREEN** when the +3.3Vdc, +5Vdc and +12.0Vdc power supplies, respectively, are within their operating tolerances.

The locations of Indicators LED1 through LED3 are shown in Figure 5.

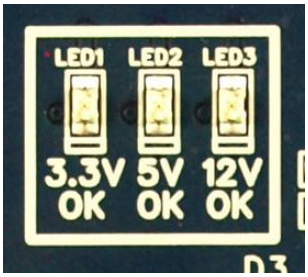


Figure 5. *Indicator LED1 through LED5 Locations.*

Indicator LED4 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 LED4 is shown in Figure 6.

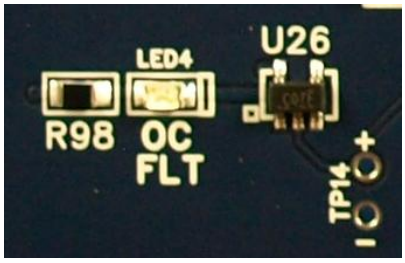


Figure 6. *Indicator LED6 Location.*

Description of Test Points.

The description of each test point on the EPC7C021 Evaluation Board is found in Table III.

TABLE III. EPC7C021 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	+5.0V 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 BIN PWM Signal Monitor.
TP9	0.100	Phase 1 TIN PWM Signal Monitor.
TP10	0.100	Phase 2 BIN PWM Signal Monitor.
TP11	0.100	Phase 2 TIN PWM Signal Monitor.
TP12	0.100	Phase 3 BIN PWM Signal Monitor.
TP13	0.100	Phase 3 TIN 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 EPC7C021 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.

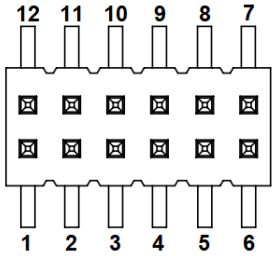


Figure 7. *JA1 Pinout.*

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 GU3 from JUCO.
2	11	High-side PWM drive signal to GU3 from JUCO.
3	10	Low-side PWM drive signal to GU2 from JUCO.
4	9	High-side PWM drive signal to GU2 from JUCO.
5	8	Low-side PWM drive signal to GU1 from JUCO.
6	7	High-side PWM drive signal to GU1 from JUCO.

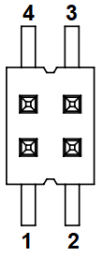


Figure 8. *JA2-JA5 Pinouts.*

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 GU1 from JI1.
2	3	Low-side PWM drive signal to GU1 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 GU2 from JI2.
2	3	Low-side PWM drive signal to GU2 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 GU3 from JI3.
2	3	Low-side PWM drive signal to GU3 from JI3.

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

JA5 Pin # Shorted to	JA5 Pin #	Description/Functionality
1	4	+5.0V 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 can be present on JA5 pin1 to pin 4 or pin2 to pin 3, but NEVER in both positions.

Description of Connectors.

There are thirteen (13) connectors provided on the EPC7C021 Eval. Board. There are three (3) connectors to provide 12.0V 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. EPC7C021 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 EPC7C021 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.

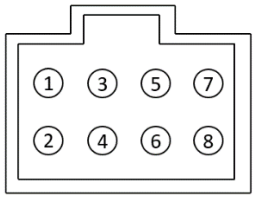


Figure 10. *JPWM Pinout.*

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	VEXT	3.3Vdc/5.0V to external circuitry

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 2MHz.

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 25ns nominal dead times to drive the low- and high-side logic inputs for each EPC7011L7 IC 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 2MHz.

JHES Connector Details.

Connector JHES is provided such that the end-user of the EPC7C021 Eval. Board can provide optional three-phase Hall-effect position logic signals from the motor being driven to the EPC7C021 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.

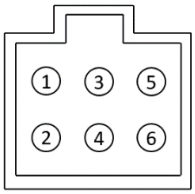


Figure 11. *JHES Pinout.*

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 EPC7C021 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.

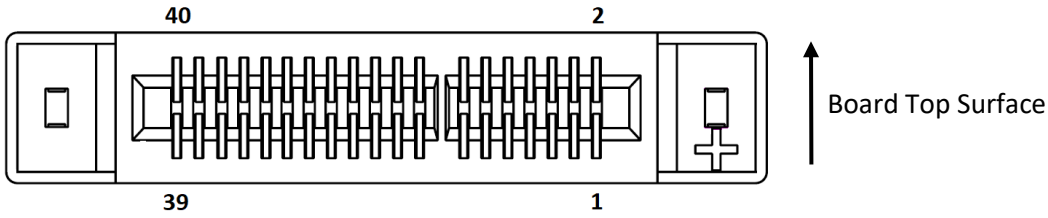


Figure 12. *JUCO Pinout.*

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, the three bias power supply status signal (PGOOD) 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.

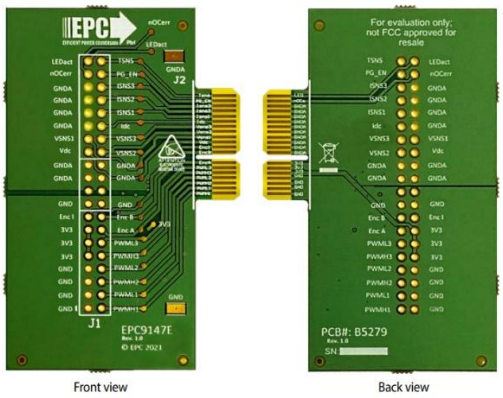


Figure 13. *EPC9147E Interface Board.*

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 +12.0V > 10.8Vdc, +5.0V > 4.5Vdc and +3.3V > 3.0Vdc are all true. PGOOD = logic low (“0”) otherwise.
40	TEMP	O	A	TEMP is the output of an Analog Devices AD590 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 EPC7C021 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 EPC7C021 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.

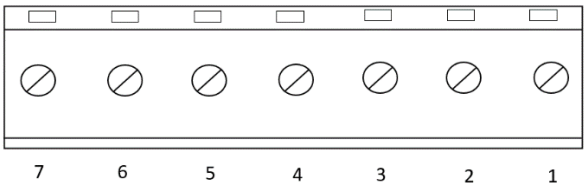


Figure 14. JMOTOR Pinout.

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 EPC7C021 evaluation board is provided with three different ways of providing PWM drive signals to the EPC7011L7 phase driver IC's:

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 IC as well as a phase inversion for the low-side driver. These processed signals are then applied to the EPC7011L7 IC's 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 EPC7C021 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 EPC7011L7 phase drive IC's with some on-card buffering and conditioning from the connector JUCO. The low- and high-side drive signals for each EPC7011L7 IC, including dead times and operating frequencies, are provided by the EPC9147A control 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 EPC7C021 Evaluation Board is shipped with a fixed, approximate 200ns dead time between the BIN and TIN and TIN and BIN logic inputs of each of the three EPC7011L7 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 10ns, minimum, by replacing the 22pF capacitors in reference designations C20 through C25 with 10pF values (10pF, COG, 5%, EIA 0805).

IMPORTANT NOTE: The dead time should **NEVER** be reduced below 20ns. 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 EPC7011L7 IC's are either 20ns (default as shipped) or the desired value set by the end-user.

Operation at Lower PWM Switching Frequencies.

Three capacitors, CS1, CS2 and CS3, are bootstrap elements for the high-side drivers in the EPC7011L7 IC for each of the three phases. These capacitors are shipped with 10uF values, allowing the EPC7C021 board to operate at switching frequencies down to 200kHz. If lower switching frequencies are required (down to 50kHz), then a 10uF capacitor (0805 size and rated for 50Vdc) should be used for CS1, CS2 and CS3.

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 6A peak current is sourced by VDD or a phase output, the voltage at IDDM, VIPH1, VIPH2 or VIPH3 is 1.65 – (6 * 0.075) = 1.20V. Similarly, when 6A peak current is sunk by VDD or a phase current, the voltage at IDDM, VIPH1-VIPH3 is 1.65 + (6 * 0.075) = 2.10V.

Optional Phase Output Filters.

The EPC7C021 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 an EIA 1206 case size and each capacitor is an EIA 0805 case size.

Board Temperature Sensor Output (TEMP).

The EPC7C021 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°C, 1.72V for T_{board} = -55°C and 3.32V for T_{board} = 150°C. The sensed temperature accuracy is +/-1°C.

Thermal "Helpers" TH1-TH6.

The EPC7C021 board is provided with thermal augmentation for each EPC7011L7 IC in the form of an EIA size 0805 "Thermal Wick" AlN chip. These components help to enlarge the thermal footprint of the EPC7011U7 IC's by "wicking" heat from the body of the device and conducting it to copper etch at another electrical potential. It is recommended that for operation at or near the full rated current of the EPC7011L7 IC that these elements be utilized. If operating currents are below 4A, then these helpers may be removed and replaced by additional high-frequency VDD bypass capacitors. Figure 15 shows the position of TH1 and TH2 for GU1, for Phase 1. TH3, TH4 and GU2, and TH5, TH6 and GU3 all have similar physical relationships/proximities on the EPC7C021 board.

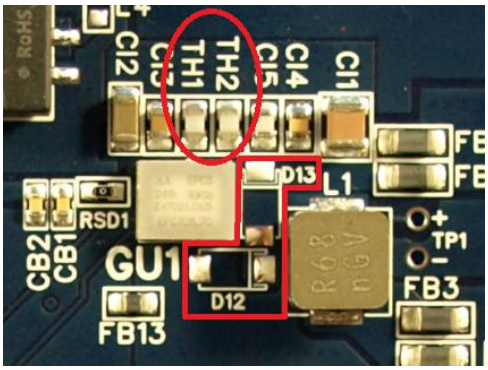


Figure 15. *GU1 With Thermal Helpers TH1 and TH2.*

Optional Schottky Catch Diodes (D12-D17).

The EPC7C021 board is provided with unpopulated shapes for optional Schottky clamp diodes for each of the EPC7011L7 IC's. The PCB footprint shape implemented is for an EIA-standard SOD-123FL package, which provides the designer with multiple choices for the diode used, if desired. Figure 15 shows the relationship of D12 and D13 directly adjacent to GU1. The remaining diodes D14-D17 share a similar physical relationship to GU2 and GU3.

Optional EPC9147A Motor Control Daughtercard.

The EPC Space EPC7C021 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 is contained at that link.

IMPORTANT NOTE: The standard EPC9147A board is shipped with 25ns, which safely operate the EPC7011L7 IC's on the EPC7C021 board and will not damage or destroy the board.

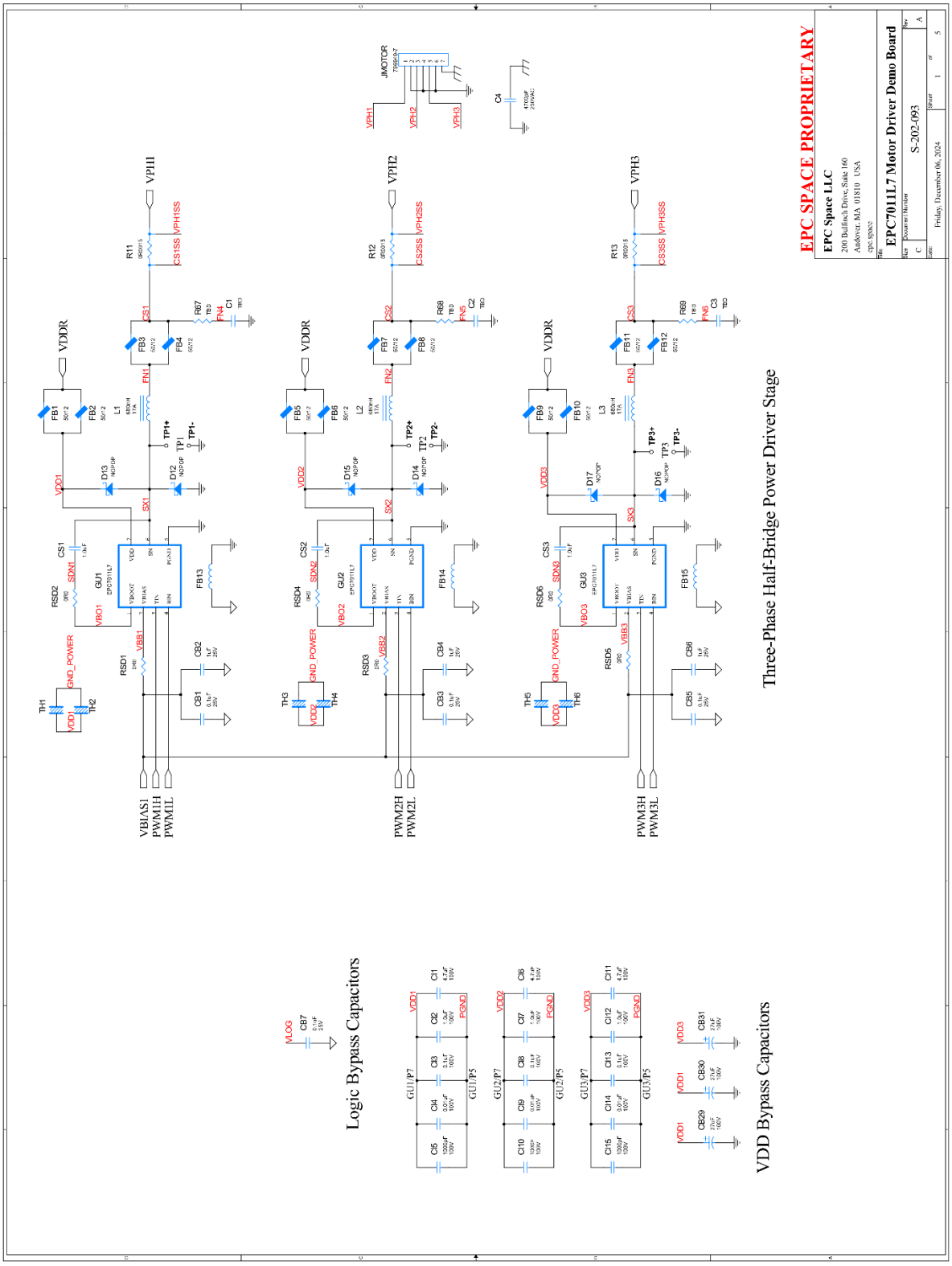


Figure 16. *EPC7C021/EPC7011L7 3-Phase Motor Control Board Schematic Diagram.*

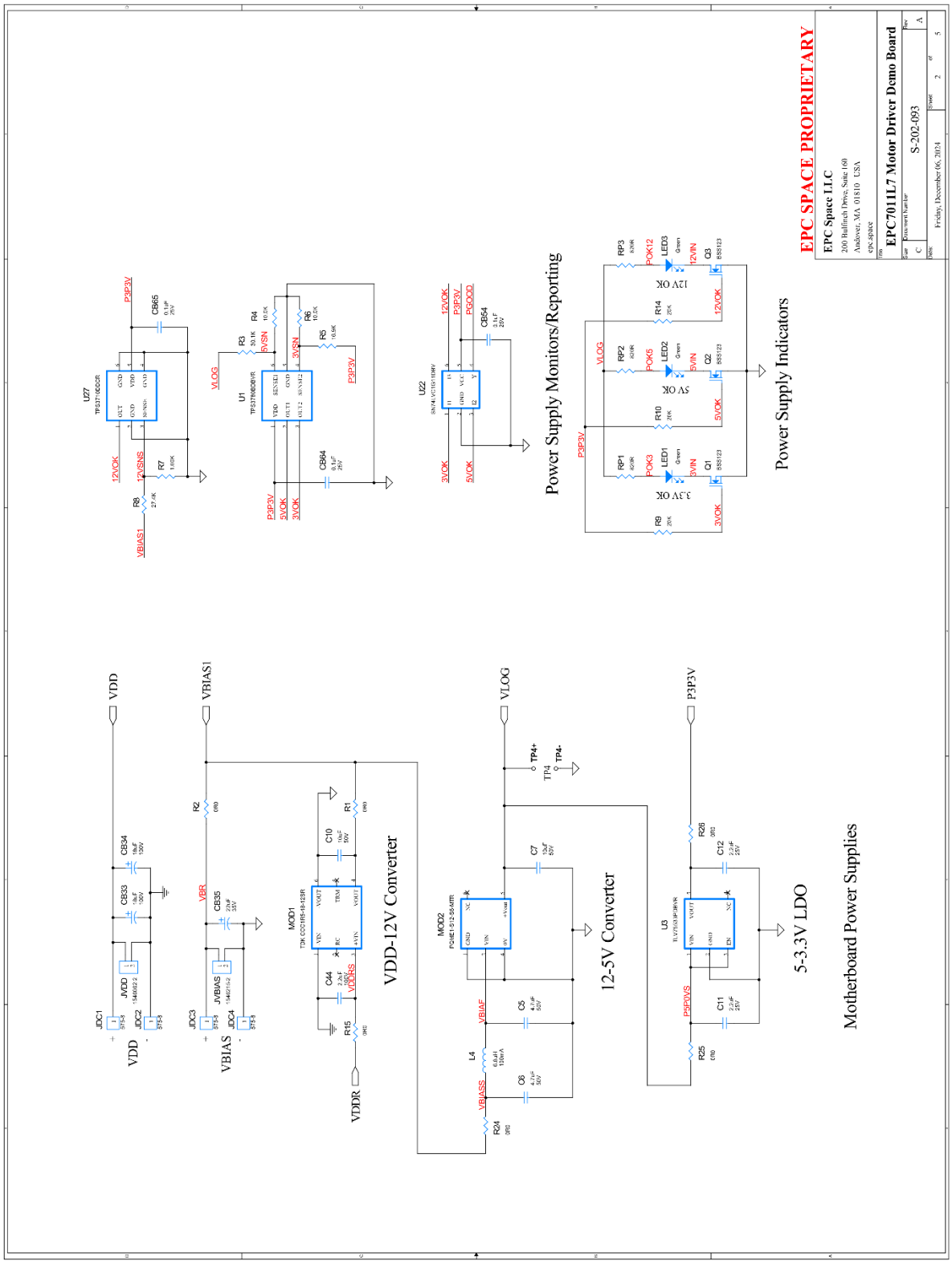


Figure 16 (cont.). *EPC7C021/EPC7011L7 3-Phase Motor Control Board Schematic Diagram.*

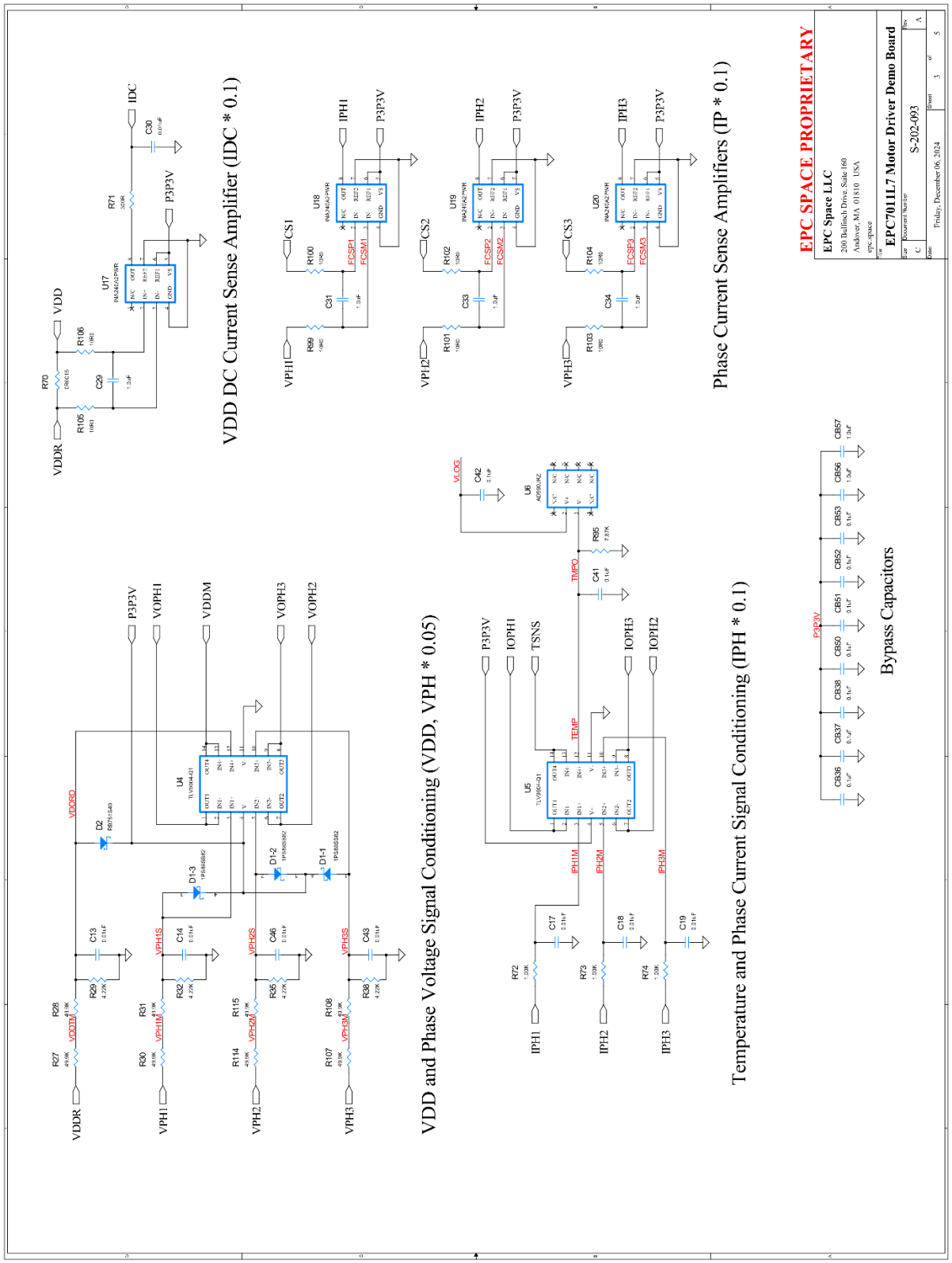


Figure 16 (cont.). *EPC7C021/EPC7011L7 3-Phase Motor Control Board Schematic Diagram.*

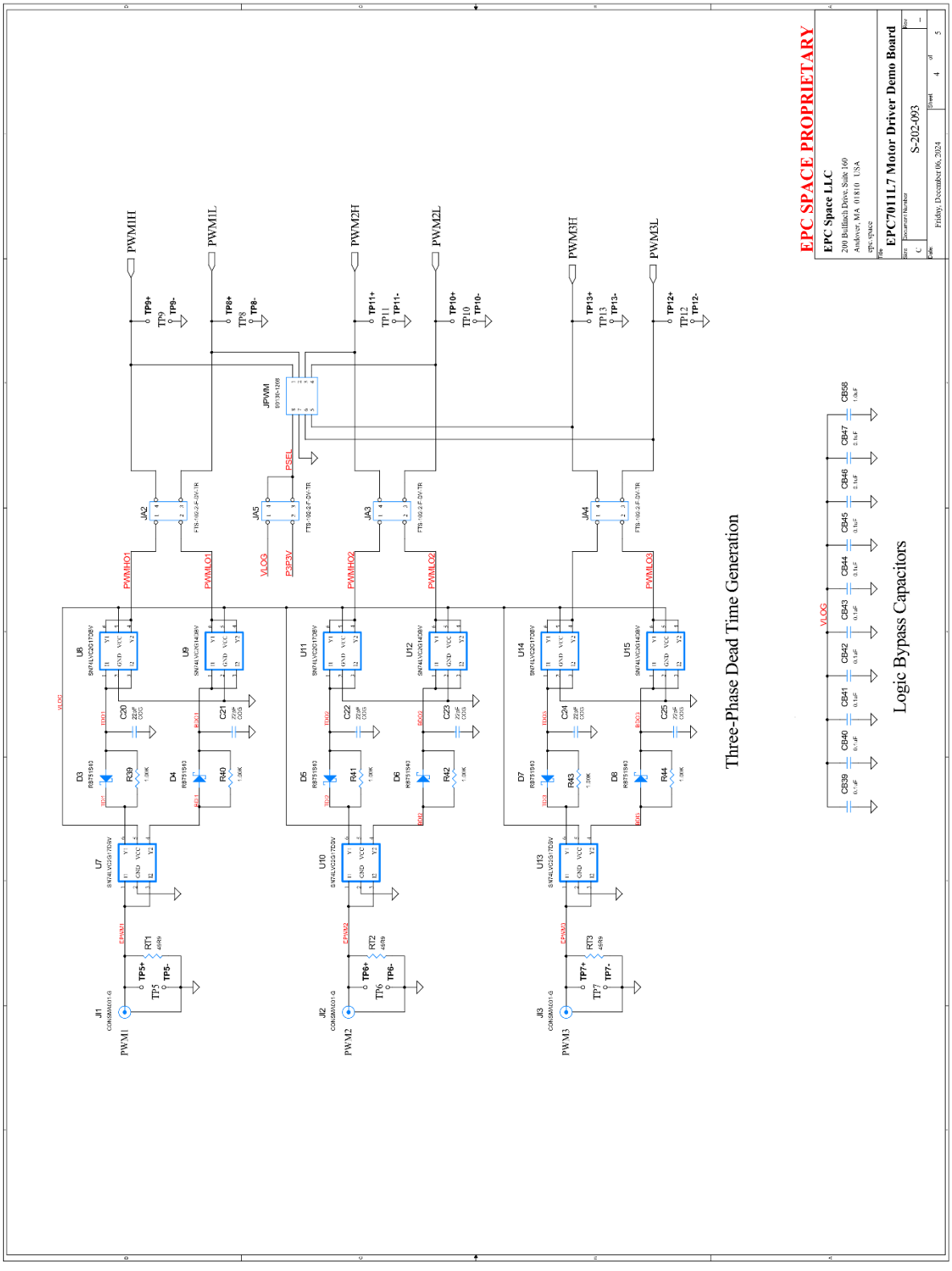


Figure 16 (cont.). *EPC7C021/EPC7011L7 3-Phase Motor Control Board Schematic Diagram.*

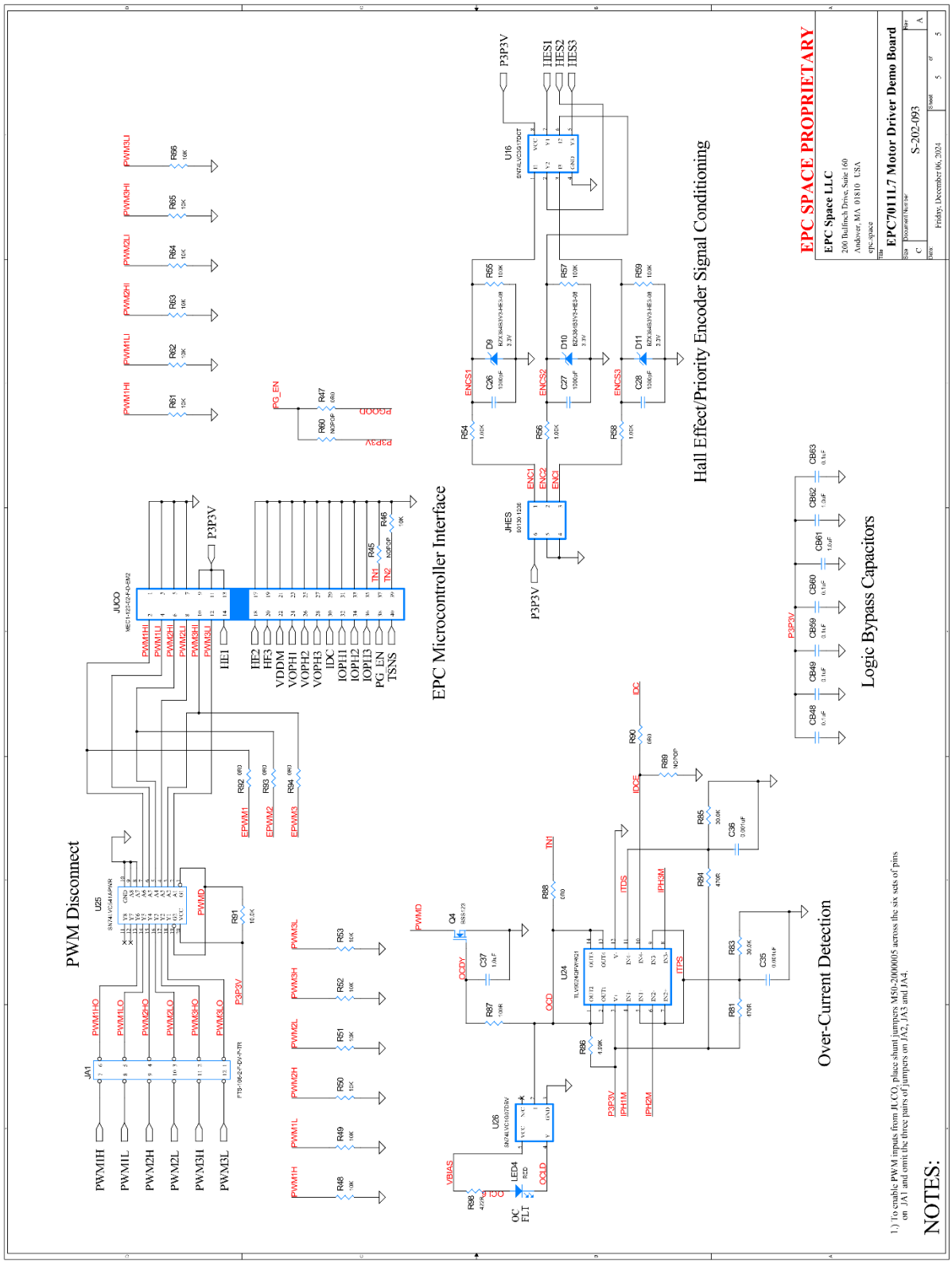


Figure 16 (cont.). *EPC7C021/EPC7011L7 3-Phase Motor Control Board Schematic Diagram.*

Table XIV (cont.). EPC7C021/EPC7011L7 3-Phase Motor Driver Evaluation Board Bill of Materials.

EPC7C021 / EPC7011L7 3-Phase Motor Driver Evaluation Board BOM

The BOMs for the EPC7011L73-Phase Motor Driver Evaluation Board is shown in Table XIV. All active and passive components used are qualified to AEC-QXXX standards where possible.

Table XIV. EPC7C021/EPC7011L7 3-Phase Motor Driver Evaluation Board Bill of Materials.

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N	Size/Package
1	4	JDC1,JDC2,JDC3,JDC4	Solderable Banana Staking Jack	Keystone	575-8	0.208" Dia. Hole
2	26	C41,C42,CB7,CB36,CB37, CB39,CB40,CB41,CB42,CB43,CB44,CB45, CB46,CB47,CB48,CB49,CB50,CB51,CB52, CB53,CB54,CB59,CB60,CB63,CB64,CB65	0.1uF/25V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C104K3RACAUTO	C0805
3	3	CB1,CB3,CB5	0.1uF/50V/X7R/10%/AEC-Q200/0603 Ceramic Capacitor	AVX	06035C103K4T2A	C0603
4	3	CI3,CI8,CI13	0.1uF/100V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C104K1RECAUTO	C0805
5	3	CI2,CI7,CI12	1.0uF/100V/X7R/10%/AEC-Q200/1206 Ceramic Capacitor	AVX	12061C105K4T2A	C1206
6	6	C37,CB56,CB57,CB58,CB61,CB62	1.0uF/25V/X7R/10%/0805 Ceramic Capacitor	Kemet	C0805C105K3RACAUTO	C0805
7	10	C29,C31,C32,C33,CB2,CB4,CB6,CS1,CS4,CS5	1.0uF/50V/X7R/10%/AEC-Q200/0603 Ceramic Capacitor	Kyocera/AVX	KAM15AR71H104KT	C0603
8	3	CI4,CI9,CI14	0.01uF/100V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08051C103K4T2A	C0805
9	8	C13,C14,C17,C18,C19,C30,C43,C46	0.01uF/25V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08053C103K4T2A	C0805
10	2	C7,C10	10uF/50V/X5R/10%/0805 Ceramic Capacitor	TDK	GRM21BR61H106KE43K	C0805
11	3	CI1,CI6,CI11	4.7uF/100V/X7R/10%/1210 Ceramic Capacitor	AVX	12101C475K4T2A	C1210
12	3	CI5,CI10,CI15	1000pF/100V/COG/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08051A102K4T2A	C0805
13	3	CB29,CB30,CB31	27uF/100V/20%/30mΩ/F12 Size/Aluminum Organic Electrolytic Capacitor	Panasonic	100SXV27M	Panasonic F12
14	2	CB33,CB34	18uF/100V/20%/30mΩ/F12 Size/Aluminum Organic Electrolytic Capacitor	Panasonic	100SXV18M	Panasonic F12
15	2	C5,C6	4.7uF/25V/X7R/10%/0805 Ceramic Capacitor	Kemet	C0805C475K3RACAUTO	C0805
16	1	C44	2.2uF/100V/X7R/10%/1206 Ceramic Capacitor	;	12061C225K4T2A	C1206
17	2	C11,C12	2.2uF/25V/X7R/10%/0805 Ceramic Capacitor	TDK	CGA4J3X7R1E225K125AB	C0805
18	1	CB35	22uF/16V/Tantalum/10%/C Case SMT Capacitor	Kemet	T494C226M016AT	TANT_C
19	1	C4	4700pF/250VAC/X7R/10%/Safety Certified Ceramic Capacitor	Vishay	VJ2220Y472KXUSTX1	C2220
20	2	C35,C36	0.001uF/50V/X7R/10%/AEC-Q200/0805 Ceramic Capacitor	Kemet	C0805C102K5RACAUTO	C0805
21	6	C20,C21,C22,C23,C24,C25	22pF/25V/COG/5%/AEC-Q200/0805 Ceramic Capacitor	AVX	08051A220J4T2A	C0805

Table XIV (cont.). EPC7C021/EPC7011L7 3-Phase Motor Driver Evaluation Board Bill of Materials.

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N	Size/Package
22	3	C26,C27,C28	1000pF/50V/COG/10%/AEC-Q200/0805 Ceramic Capacitor	AVX	08055A102K4T2A	C0805
23	**NOPOP**	C1,C2,C3	**Customer will populate.**	N/A	N/A	C1210
24	**UNUSED**	C8,C9,C15,C16,C34,C38,C39,C40,C45, CB8-CB28,CB32,CB38,CB55	**Unused Capacitor Reference Designations.**	N/A	N/A	N/A
25	1	D1	15V/30mA/Low Cj/3-Element/Schottky Diode Array/SOT-363	Nexperia	1PS88SB82,165	SOT-363
26	7	D2,D3,D4,D5,D6,D7,D8	0.12A/40V/SOD-323 Schottky Diode	Nexperia	RB751V40,115	SOD-323-2
27	3	D9,D10,D11	3.3V/200mW/2%/Zener Diode/SOD-323-2	Vishay	BZX384B3V3-HE3-08	SOD-323-2
28	**NOPOP**	D12,D13,D14,D15,D16,D17				
29	3	LED1,LED2,LED3	568nm Green Water Clear/0805 Package LED	Bivar	SM0805GCL	D0805
30	1	LED4	660nm Red Water Clear/0805 Package LED	Bivar	SM0805RC	D0805
31	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	R1206
32	3	FB13,FB14,FB15	6A/0.0010 Ohm/30 Ohm@100MHz/Ferrite Beads/0805	TDK	MPZ2012S300ATD25	R0805
33	3	GU1,GU2,GU3	50V/6A Half-Bridge Power Stage IC/L7 Package	EPC Space	EPC7011L7	EPCS L7 Package
34	1	JA1	6 Dual Pin Array Connector/Header/1.27mm Spacing	Samtec	FTS106-02-F-DV-P-TR	FTS106-02-F-DV-P-TR
35	4	JA2,JA3,JA4,JA5	2 Dual Pin Array Connector/Header/1.27mm Spacing	Samtec	FTS102-02-F-DV-TR	FTS102-02-F-DV-TR
36	1	JHES	6 Pin, Two Row, Straight Shrouded Connector/Through-Hole/C-Grid III	Molex	90130-1206	0.1" Centers
37	3	JI1,JI2,JI3	SMA/Vertical/50 Ohms/Brass-Gold/Through Hole	TE/Linx	CONSMA001-G	CONSMA001-G
38	1	JMOTOR	5.08mm Terminal Block/Side Entry/Vertical/7 Position/Black	TE/Buchanan	796949-7	796949-7
39	1	JPWM	8 Pin, Two Row, Straight Shrouded Connector/Through-Hole/C-Grid III	Molex	90130-1208	0.1" Centers
40	1	JUCO	1.00mm/Standard Card Edge Connectors/Mini Edge Card Socket/Vertical	Samtec	MEC1-120-02-F-D-EM2	MEC1-120-02-F-D-EM2
41	1	JVBIAS	2.54mm Terminal Block/Side Entry/Vertical/2 Position/Gray	TE/Buchanan	1546215-2	1546215-2
42	1	JVDD	7.50mm Terminal Block/Side Entry/Vertical/2 Position/Black	TE/Buchanan	1546062-2	1546062-2

Table XIV (cont.). EPC7C021/EPC7011L7-P-C50 POL Evaluation Board Bill of Materials.

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N	Size/Package
43	3	L1,L2,L3	17A/680nH/20%/Power Inductor/4.2 milliohms/6mm x 6mm	Kemet	MPXV1D0650LR68	MPXV1D0650LR68
44	1	L4	0.12A/6.8uH/20%/ Inductor/740 milliohms/0603	Murata	LQM18DN6R8M70L	R0603
45	1	MOD1	DC-DC Converter Module/48V-12V/0.25A/3W/SMD	TDK	CCG3-48-12SR	CCG3-48-12SR
46	1	MOD2	DC-DC Converter Module/12V-5V/0.15A/0.75W/SMD	CUI, Inc.	PQME1-S12-S5-MTR	PQME1-S12-S5-M
47	4	Q1,Q2,Q3,Q4	60V/0.3A N-Channel GP MOSFET/SOT23-3	Nexperia	BSS123N H6327	SOT23-3
48	**UNUSED**	R16,R17,R18,R19,R20,R21,R22,R23,R33,R34,R35, R36,R37,R38,R75,R76,R77,R78,R79,R80,R82,R96, R97,R107,R108,R109,R110,R111,R112,R113	**Unused Resistor Reference Designations.**	N/A	N/A	N/A
49	**NOPOP**	R1,R15	0 Ohm Jumper Resistor/1206	Vishay	RCS12060000Z0EA	R1206
50	**NOPOP**	R67,R68,R69	**Customer will populate.**	N/A	N/A	R1206
51	**NOPOP**	R46,R60,R89,R92,R93,R94	0 Ohm Jumper Resistor/0805	Vishay	RCS08050000Z0EA	R0805
52	1	R2	0 Ohm Jumper Resistor/1206	Vishay	RCS12060000Z0EA	R1206
53	1	R3	30.1K/1%/0603/Thick Film Chip Resistor	Vishay	CRCW060330K1FKEA	R0603
54	8	R4,R6,R61,R62,R63,R64,R65,R66	10.0K/1%/0603/Thick Film Chip Resistor	Vishay	CRCW060310K0FKEA	R0603
55	1	R5	16.9K/1%/0603 Thick Film Chip Resistor	Vishay	CRCW060316K9FKEA	R0603
56	1	R7	1.00K/1%/0603 Thick Film Chip Resistor	Vishay	CRCW06031K00FKEA	R0603
57	1	R8	27.4K/1%/0603 Thick Film Chip Resistor	Panasonic	ERJ-UP3F2742V	R0603
58	3	R9,R10,R14	10K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW080510K0FKEA	R0805
59	4	R11,R12,R13,R70	0R0015/1%/0612/4 Terminal/Thick Film Chip Resistor	Bourns	CST0612-FC-R0015E	R0612
60	6	R24,R25,R26,R47,R88,R90	0 Ohm Jumper Resistor/0805	Vishay	RCS08050000Z0EA	R0805
61	8	R27,R28,R30,R31,R107,R108,R114,R115	49.9K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080549K9FKEA	R0805
62	4	R29,R32,R109,R116	4.22K/1%/0805/Thick Film Chip Resistor	Vishay	CRCW08054K22FKEA	R0805
63	12	R39,R40,R41,R42,R43,R44,R54,R56,R58,R72,R73,R74	1.00K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW08051K00FKEA	R0603

Table XIV (cont.). EPC7C021/EPC7011L7-P-C50 POL Evaluation Board Bill of Materials.

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N	Size/Package
64	8	R46,R48,R49,R50,R51,R52,R53,R91	10.0K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080510K0FKEA	R0805
65	3	R55,R57,R59	100K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW0805100KFKEA	R0805
66	1	R71	300R/1%/0805 Thick Film Chip Resistor	Panasonic	ERJ-6ENF3000V	R0805
67	2	R81,R84	470R/1%/0805 Thick Film Chip Resistor	Vishay	CRCW0805470RFKEB	R0805
68	2	R83,R85	30.0K%/0805 Thick Film Chip Resistor	Vishay	CRCW080530K0FKEA	R0805
69	1	R86	4.99K%/0805 Thick Film Chip Resistor	Vishay	RCS08054K99FKEA	R0805
70	1	R87	100R/1%/0805 Thick Film Chip Resistor	Panasonic	ERJ-6ENF1000V	R0805
71	1	R95	7.87K/1%/0805 Thick Film Chip Resistor	Panasonic	ERJ-6ENF7871V	R0805
72	1	R98	422R/1%/0805/Thick Film Chip Resistor	Vishay	CRCW0805422RFKEA	R0805
73	8	R99,R100,R101,R102,R103,R104,R105,R106	10R0/1%/0402 Thick Film Chip Resistor	Panasonic	ERJ-2RKF10R0X	R0402
74	3	RP1,RP2,RP3	820R/1%/1206/Thick Film Chip Resistor	Vishay	CRCW1206820RFKEA HP	R1206
75	3	RSD1,RSD3,RSD5	0 Ohm Jumper Resistor/0603	Vishay	RCS06030000Z0EA	R0603
76	3	RSD2,RSD4,RSD6	20R0/1%/0603/Thick Film Chip Resistor	Vishay	CRCW060320R0FKEA	R0603
77	3	RT1,RT2,RT3	49R9/1%/0805/Thick Film Chip Resistor	Vishay	CRCW080549R9FKEA	R0805
78	6	SJMP1,SJMP2,SJMP3,SJMP4,SJMP5,SJMP6	Shunt Jumper/1.27mm Spacing	Harwin	M50-2000005	N/A
79	1	SJMP7	Shunt Jumper/1.27mm Spacing	Harwin	M50-2000005	N/A
80	6	TH1,TH2,TH3,TH4,TH5,TH6	AlN Thermal "Helper" Chip/0.025" Thick/Wraparound Term/0805	IMS Vishay	BGR-0805WA THJP0805ABT1	R0805
81	**UNUSED**	U2,U21,U23	**Unused IC Reference Designations.**	N/A	N/A	N/A
82	1	U1	Dual/Open-Drain Voltage DetectorAdjustable/Supervisor/SOT-23-6	TI	TPS3780BDBVR	SOT-23-6
83	1	U3	LDO/500mA/3.3V/1.5-5.5V/SOT-23-5	TI	TLV75533PDBVR	SOT-23-5
84	2	U4,U5	Quad Op-Amp/1.8-5.5V/1MHz BW/RRIO/SOIC-14	TI	TLV9004-Q1	SOIC-14

Table XIV (cont.). EPC7C021/EPC7011L7-P-C50 POL Evaluation Board Bill of Materials.

Master BOM

Item	Quantity	Ref. Des.	Description/Value	Mfgr.	Mfgr. P/N	Size/Package
85	1	U6	2-Terminal Temperature Transducer IC/SOIC-8	Analog Devices	AD590JRZ	SOIC-8
86	6	U7,U8,U10,U11,U13,U14	Dual Schmitt Trigger Buffer/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC2G17DBV	SOT-23-6
87	3	U9,U12,U15	Dual Schmitt Trigger Inverter/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC2G14DBV	SOT-23-6
88	1	U16	Triple Schmitt Trigger Buffer/Little Logic/1.65-5.5V/LVC/SM-8	TI	SN74LVC3G17DCTR	SM-8
89	4	U17,U18,U19,U20	IC Current Sense Amplifier/100kHz BW/2.7-5.5V/80 Sense/Av=50/TSSOP-8	TI	INA240A2QPWRQ1	TSSOP-8
90	1	U22	Single Triple Input AND Gate/Little Logic/1.65-5.5V/LVC/SOT-23-6	TI	SN74LVC1G11DBVR	SOT-23-6
91	1	U24	Qual High-Speed Comparator/Open Drain/1.65-5.5V/TSSOP-14	TI	TLV9024QPWRQ1	TSSOP-14
92	1	U25	Octal Three-State Buffer/1.65-3.6V/LVC/TSSOP-20	TI	SN74LVC541APWR	TSSOP-20
93	1	U26	Single Schmitt-Trigger Buffer Gate/Open Drain/Little Logic/1.65-5.5V/LVC/SOT-23-5	TI	SN74LVC1G07DBV	SOT-23-5
94	1	U27	Single/Open-Drain Voltage DetectorAdjustable/Supervisor/TSOT-23-6	TI	TPS3710DDCR	TSOT-23-6
95	5	Misc. Hardware	Spacer/Hex/PVC/6-32/0.75" Length	Essentra	144-HS-6-6	N/A
96	5	Misc. Hardware	Screw/6-32/Nylon/Round head/Slotted/0.5" Length	Essentra	010632R050	N/A
97	1	PCB	6.45" x 5.22" x 0.063" 6 Layer FR-4 PCB, Double-Sided	TBD	47-119	N/A

Printed Circuit Board and Layout Details.

The printed circuit board (PCB) for the EPC7C021 EPC7011L7 3-Phase Motor Driver Evaluation Board is constructed with six layers. The PCB is 6.45” 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 control daughtercard.

The individual Gerber layers for the PCB are shown in Figures 17 to 27, following:

Figure 17. *EPC7C021/EPC7011L7 3-Phase Motor Driver Evaluation Board Top Silkscreen.*

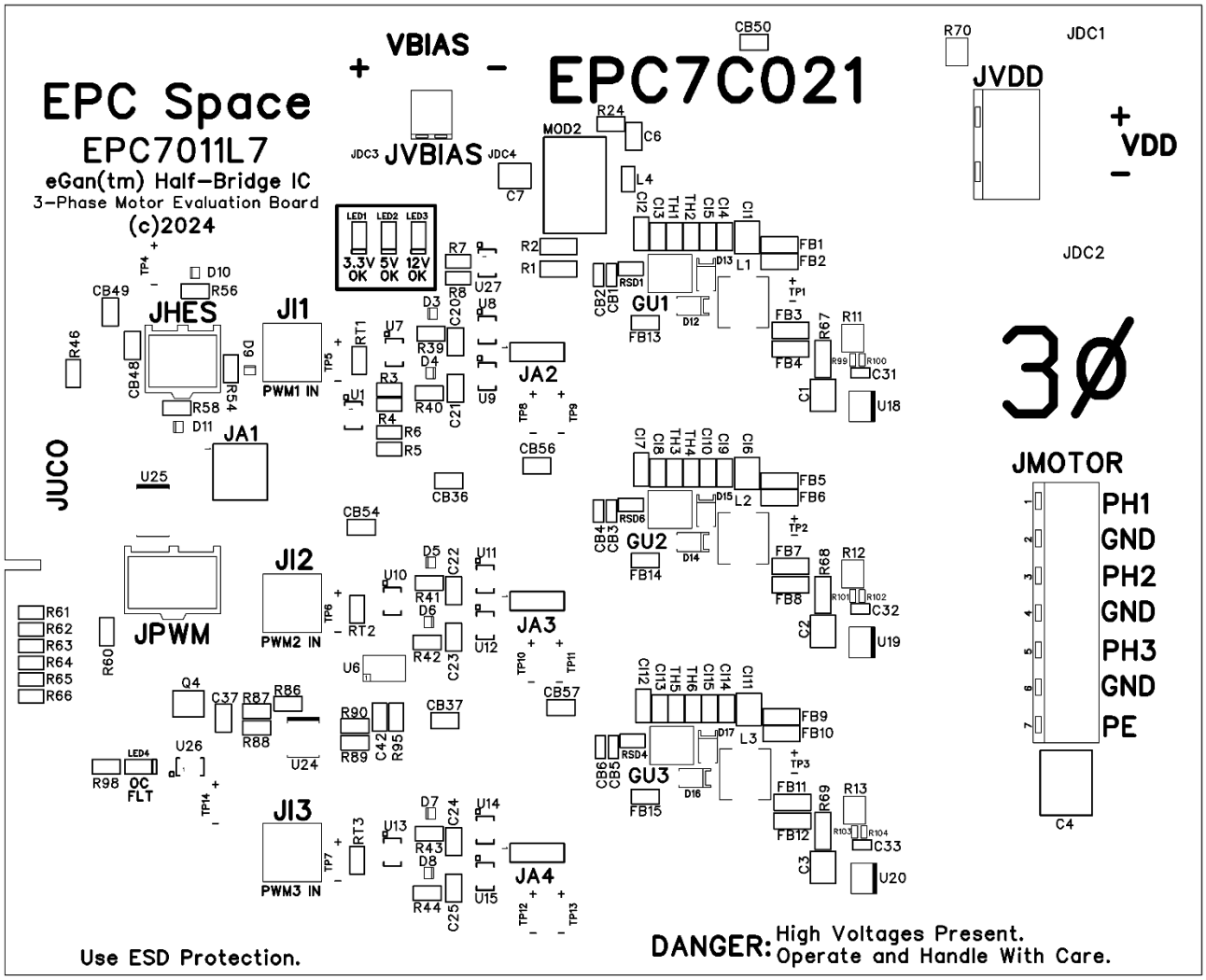


Figure 18. *EPC7C021/EPC7011L7 3-Phase Motor Driver Evaluation Board Top Solder Mask.*

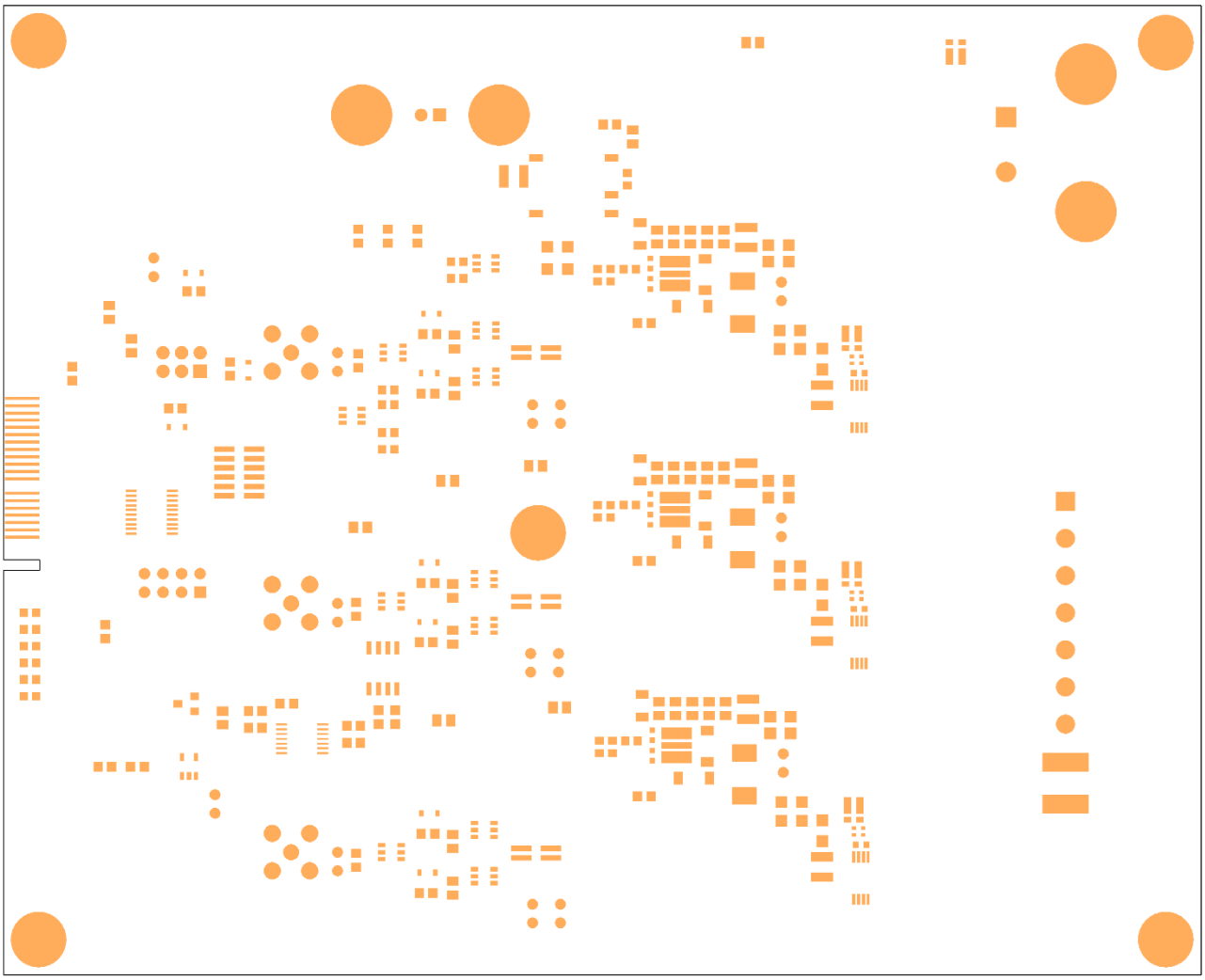


Figure 19. *EPC7C021/EPC7011L7 3-Phase Motor Driver Evaluation Board Top Copper Etch (2 oz).*

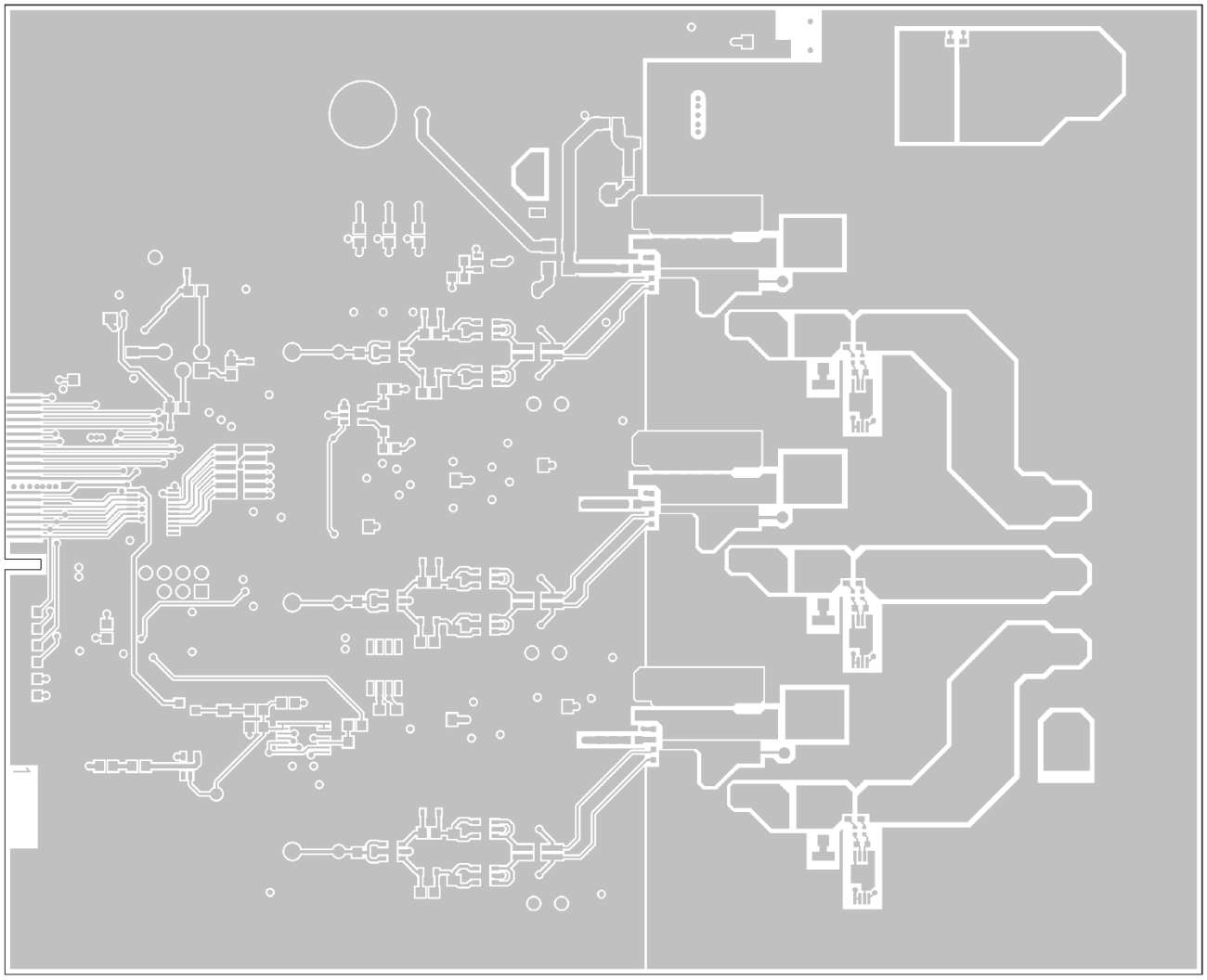


Figure 20. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Inner Layer 1 Copper Etch (1 oz).*

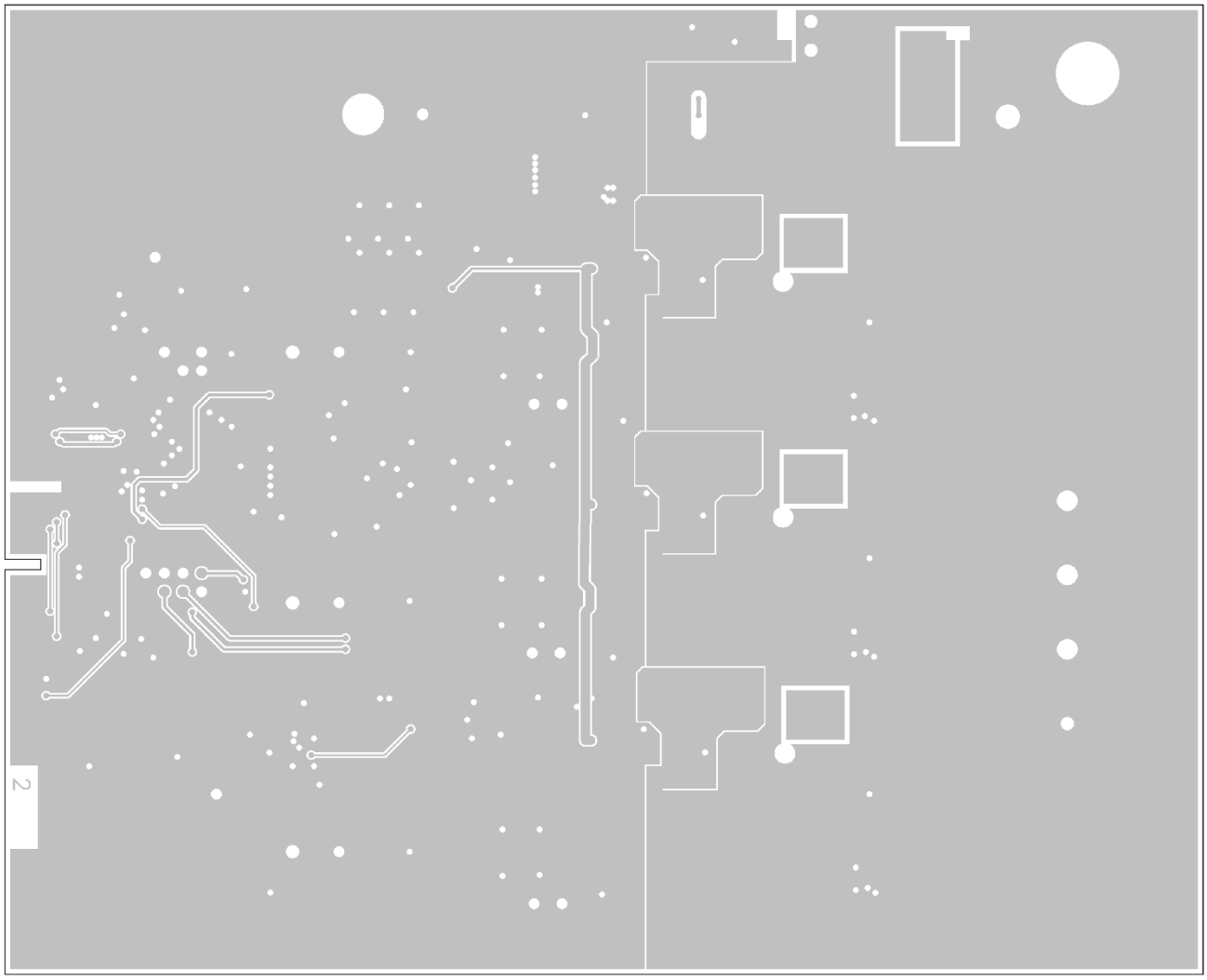


Figure 21. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Inner Layer 2 Copper Etch (1 oz).*

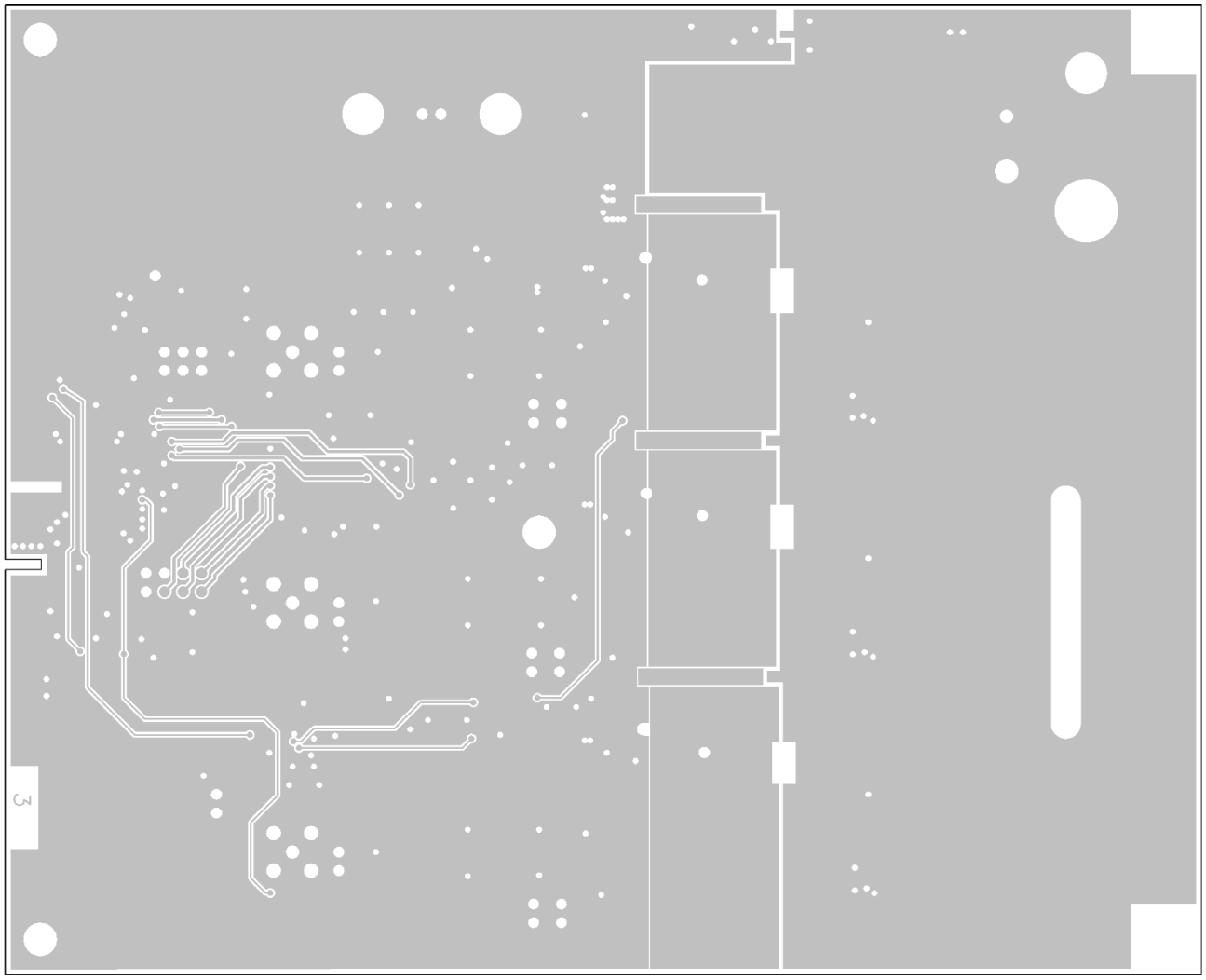


Figure 22. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Inner Layer 3 Copper Etch (1 oz).*

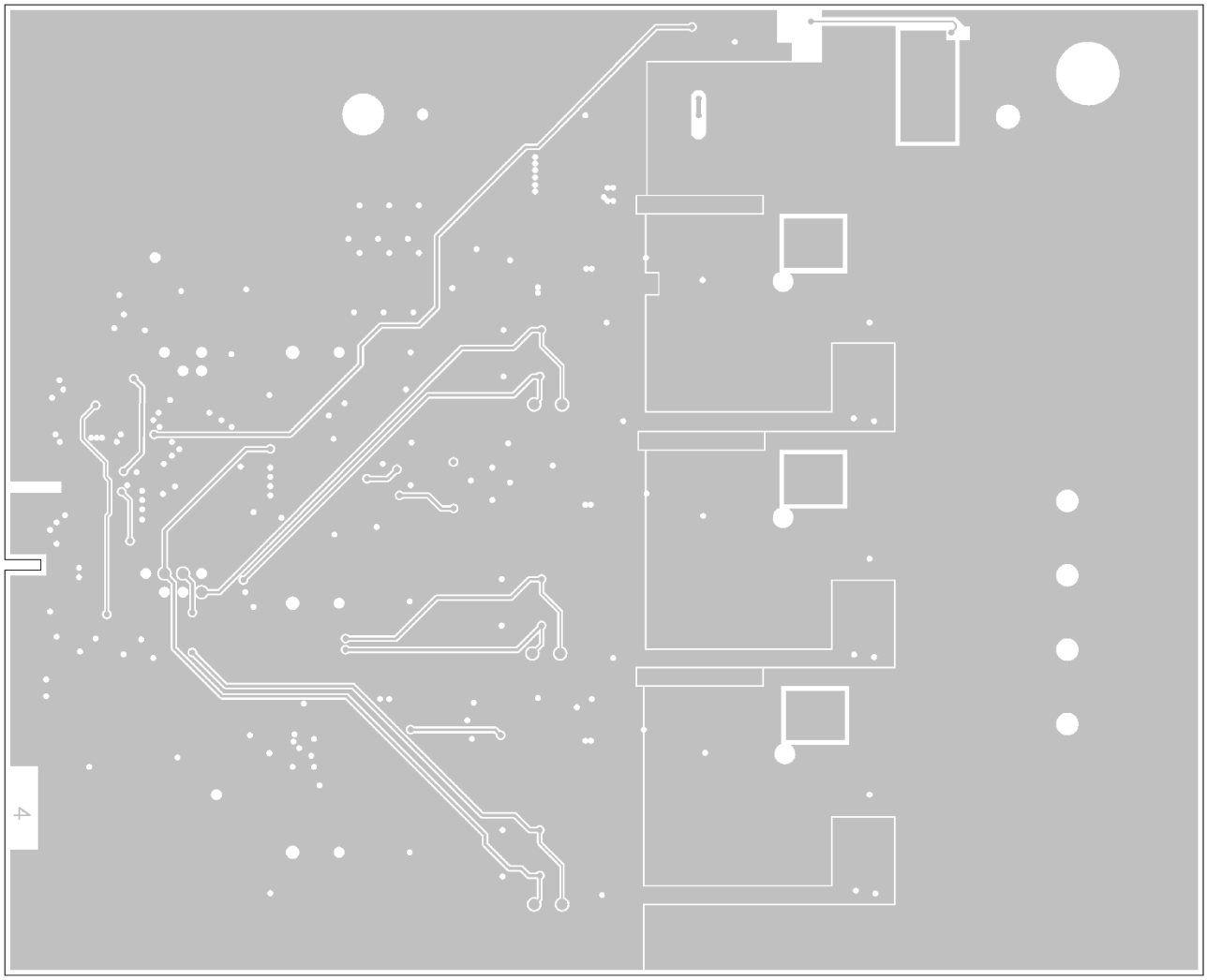


Figure 23. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Inner Layer 4 Copper Etch (1 oz).*

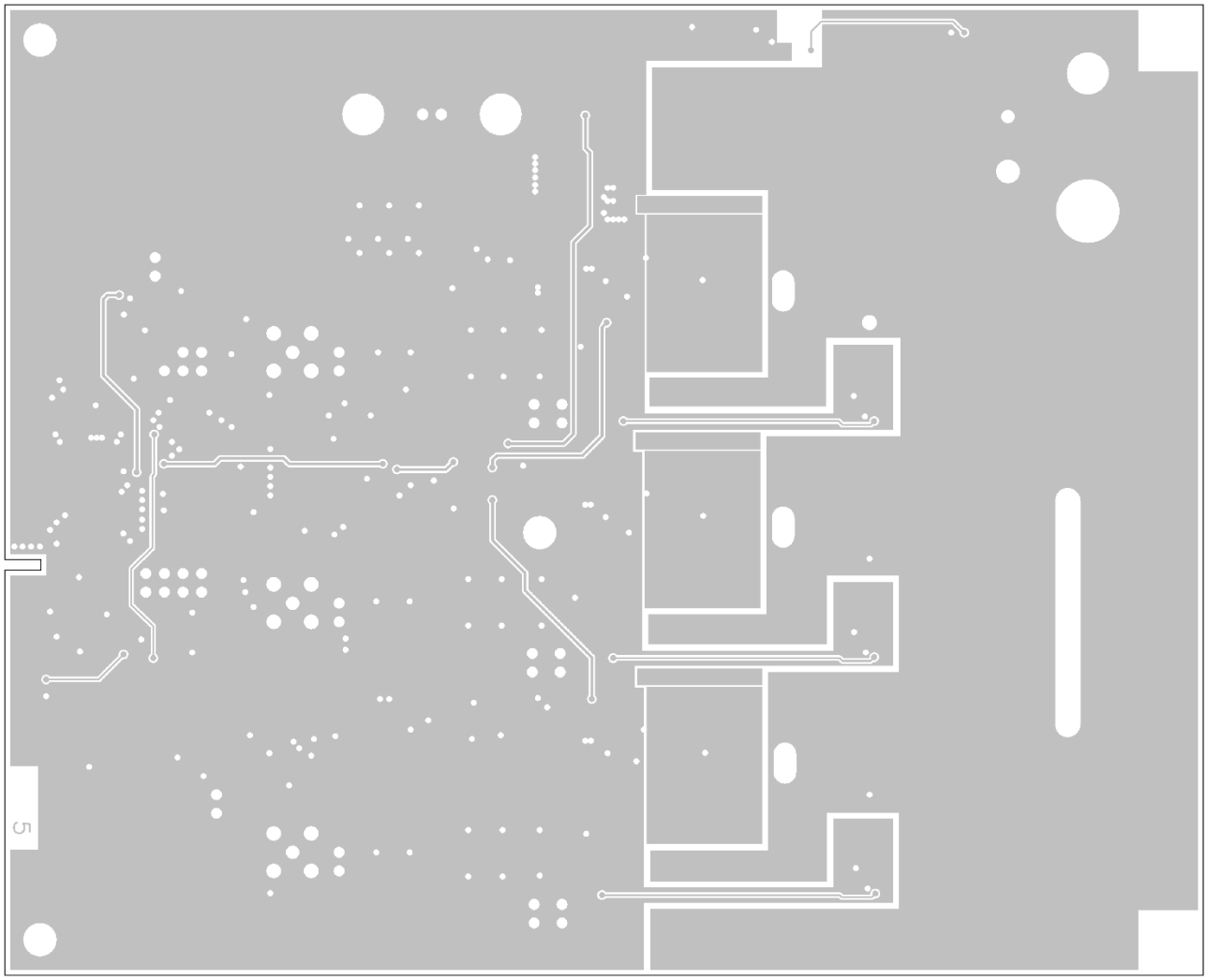


Figure 24. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Bottom Copper Etch (2 oz).*

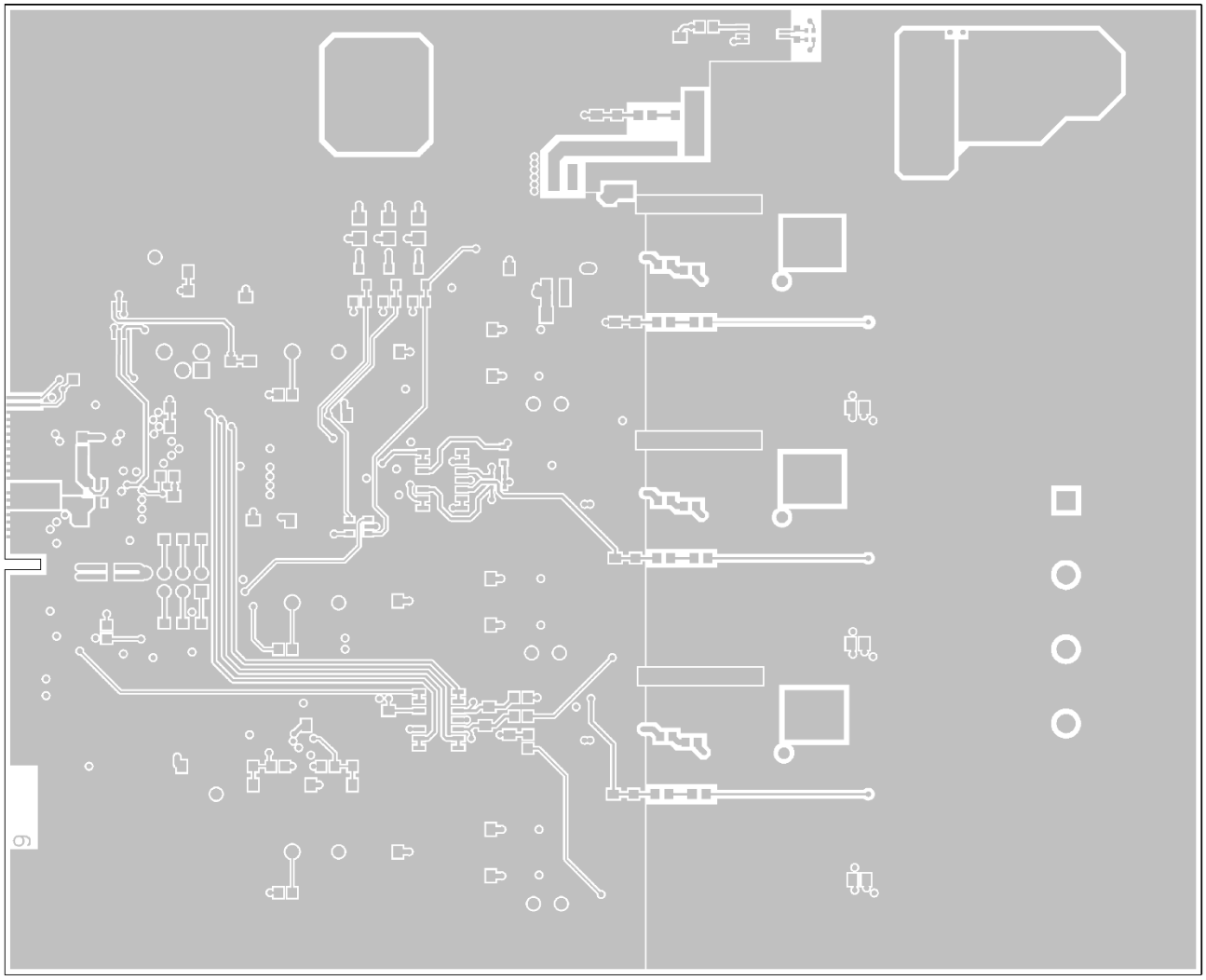


Figure 25. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Bottom Silkscreen.*

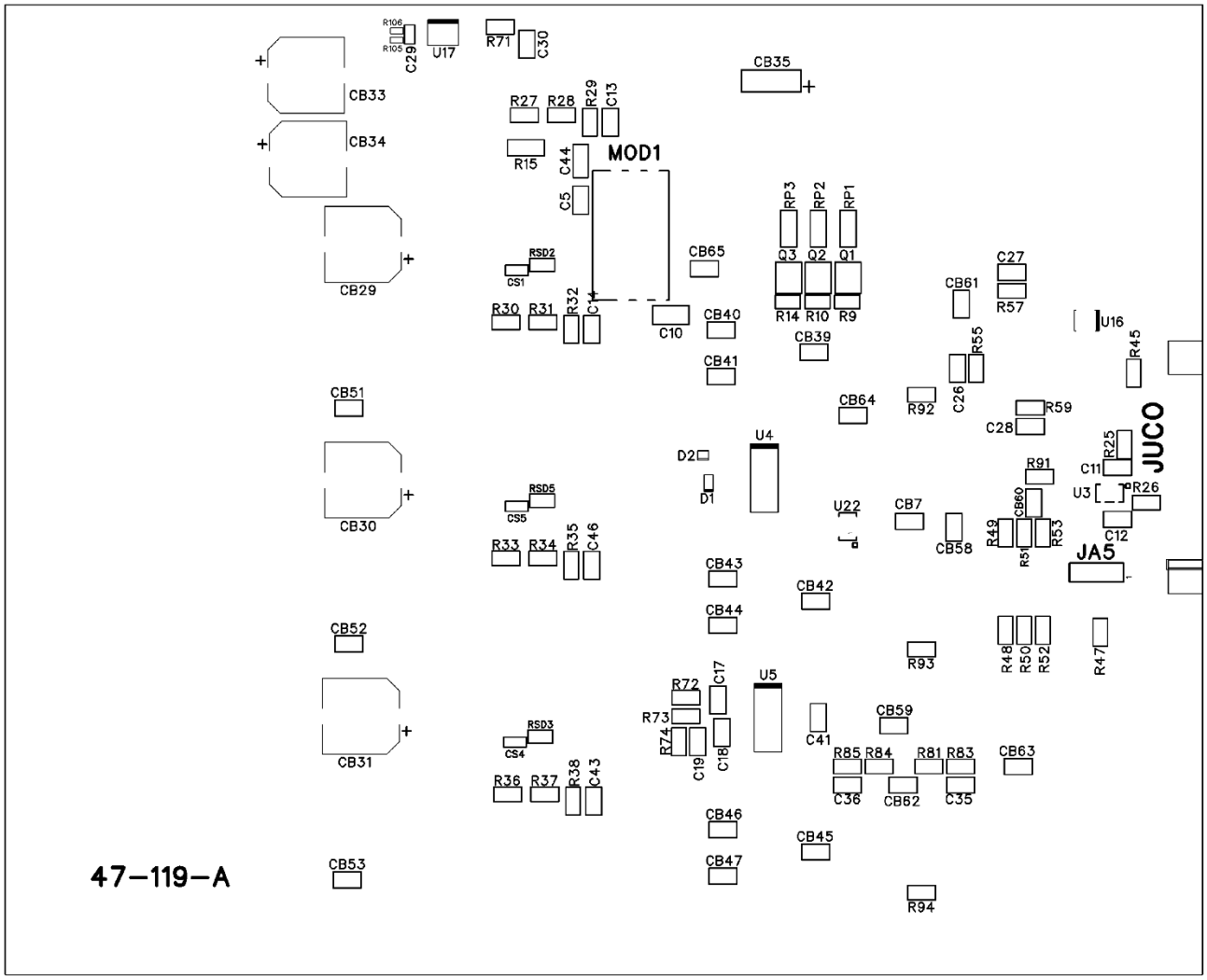


Figure 26. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Bottom Solder Mask.*

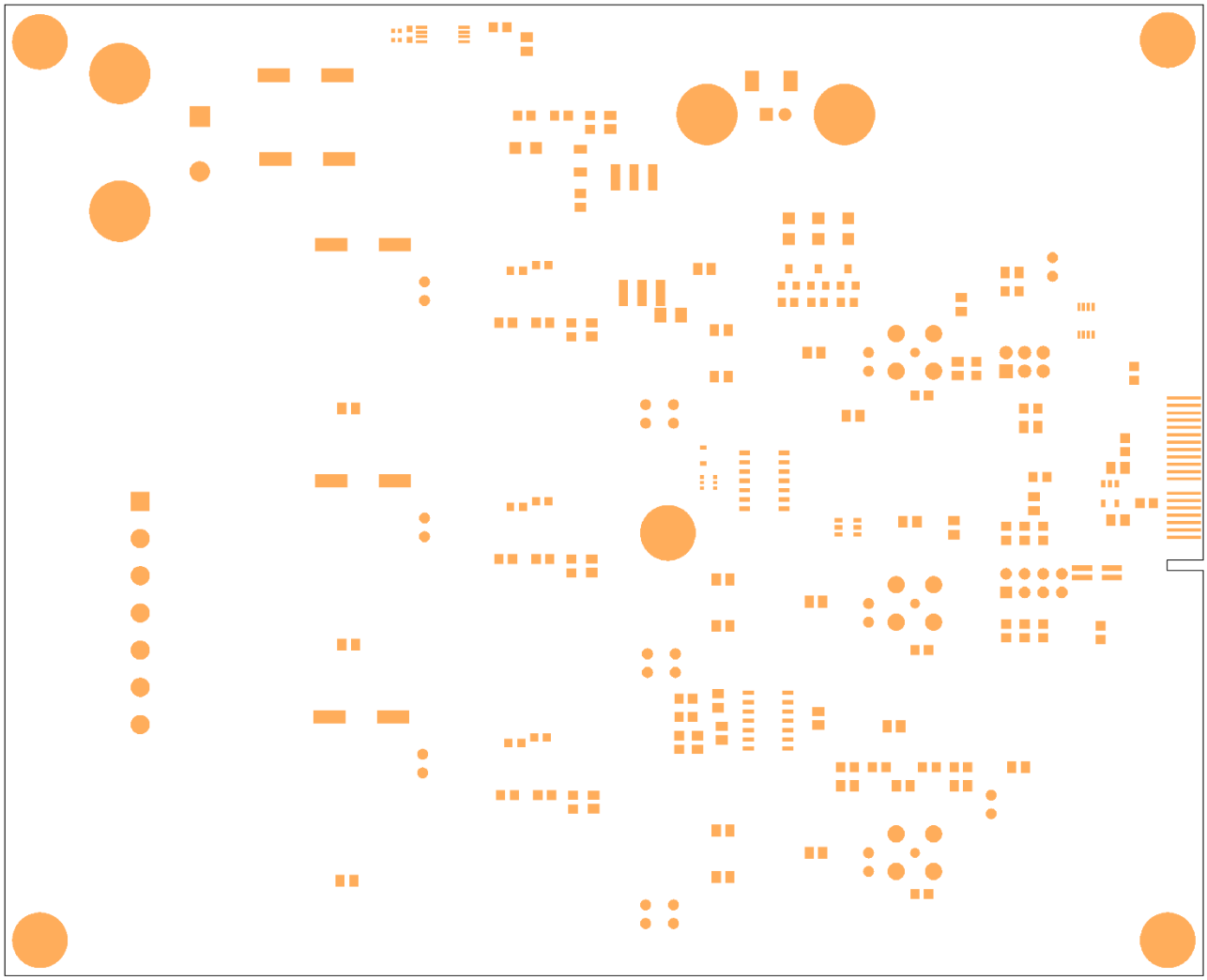
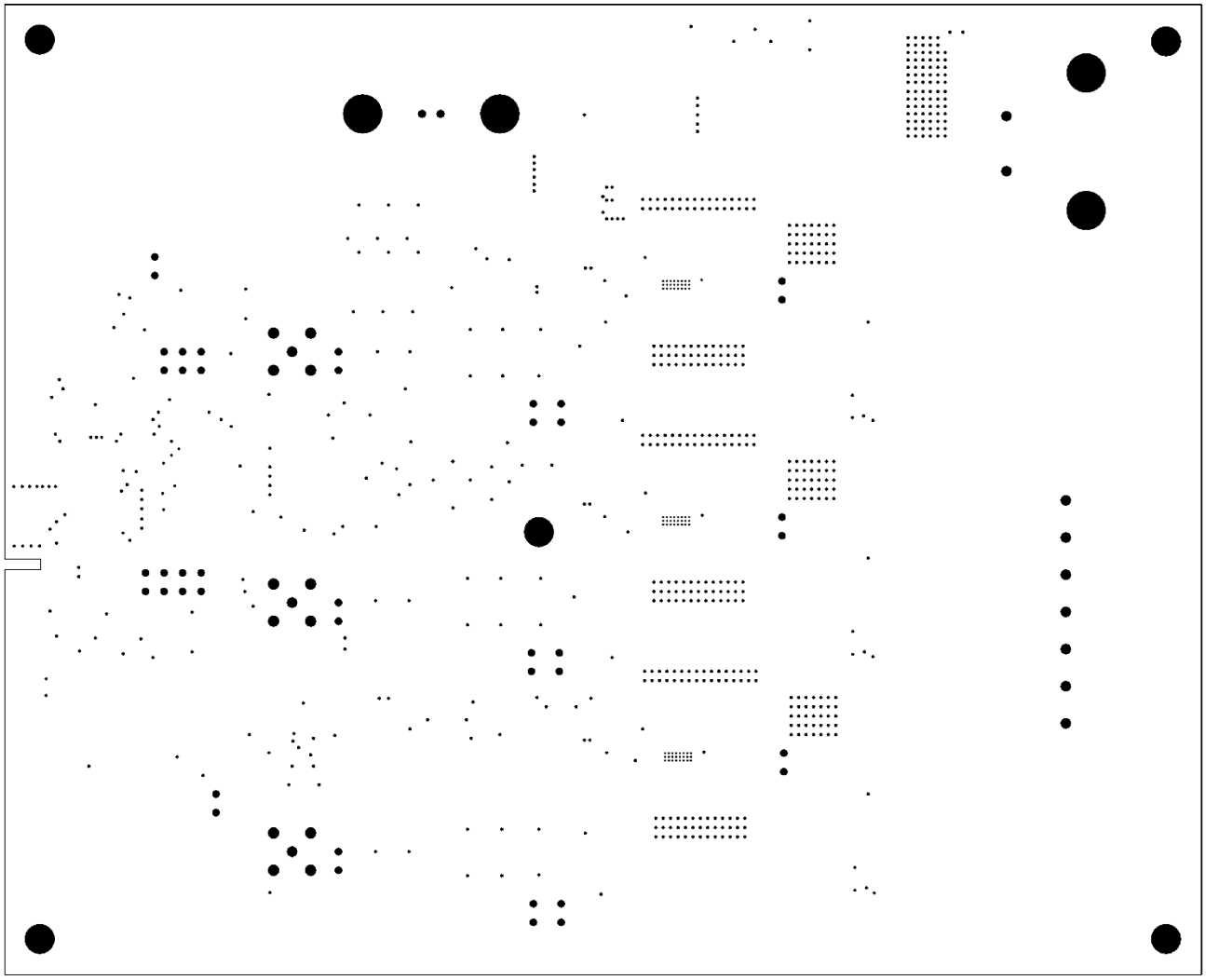


Figure 27. *EPC7C021/EPC7011L7 3-Phase Motor Driver Eval. Board Drill Pattern.*



NOTES:

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Revisions:

Revision	Date	Status
1	6/2/2025	Release