User's Guide
SLUU410–February 2010

bq24600/20/40 EVM (HPA421) Multi Cell Synchronous Switch-Mode Charger

Contents

List of Figures

List of Tables

PowerPAD is a trademark of Texas Instruments.

1 Introduction

1.1 EVM Features

- Evaluation Module for bq24600/bq24620/bq24640
- High Efficiency Synchronous Buck Charger
- User-programmable up to 26V Battery Voltage
- AC Adapter Operating Range 5V–28V
- LED Indication for Control and Status Signals.
- Test Points for Key Signals Available for Testing Purpose. Easy Probe Hook-up.
- Jumpers Available. Easy to Change Connections.

1.2 General Description

The bq24600 is a highly integrated Li-ion or Li-polymer switch-mode battery charge controller. The bq24620 is highly integrated switch-mode battery charge controller designed specifically to charge Lithium Phosphate battery chemistries. The bq24640 is highly integrated super capacitor switch-mode charge controller.

The devices offer a constant-frequency synchronous PWM controller with high accuracy charge current and voltage regulation, adapter current regulation, termination, charge preconditioning, and charge status monitoring, The bq24600/bq24620 charges the battery in three phases: preconditioning, constant current, and constant voltage. Charge is terminated when the current reaches a minimum user-selectable level. A programmable charge timer provides a safety backup for charge termination.

The bq24600/bq24620 automatically restarts the charge cycle if the battery voltage falls below an internal threshold, and enters a low-quiescent current sleep mode when the input voltage falls below the battery voltage.

For details, see bq24600 (SLUS891); BQ24620 (SLUS893) and bq24640 data sheet.

1.3 I/O Description

Table 1. I/O description

Jack	Description
J1 – ACPWR	AC adapter, positive output
J1 – GND	AC adapter, negative output
J2 – BATDRV_EXT	External BATDRV signal
J2 – ACDRV_EXT	External ACDRV signal
J2 – GND	Ground
J3 – VSYS	Connected to system
J3 – VBAT	Connected to battery pack
J3 – GND	Ground
J3 – TS	Temperature Qualification Voltage Input
J4 – GND	External power supply, negative output
J4 – ISET1	Charge Current Program Pin
J4 – VEXT	External power supply, positive output
J5 – $\overline{PG}$	Power Good (active low)
J5 – CHGEN	Charge-enable active-HIGH logic input.
J5 – VREF	IC reference voltage VREF
J5 – GND	Ground
JP1 – BATDRV_EXT	External BATDRV signal
JP1 – BATDRV	BATDRV net
JP1 – BATDRV_IN	Internal BATDRV signal
JP2 – ACDRV_EXT	External ACDRV signal

Table 1. I/O description (continued)

Jack	Description
JP2 – ACDRV	ACDRV net
JP2 – ACDRV_IN	Internal ACDRV signal
JP3 – VEXT	External power supply from J4
JP3 – PULLUP	Pull-up voltage source
JP3 – VREF	IC reference voltage VREF
JP4 – CHGEN	Charge-enable signal
JP4 – GND	Ground
JP5 – LEDPWR	LED Pull-up power line
JP5 – VPULLUP	Pull-up voltage source from JP3

1.4 Controls and Key Parameters Setting

Table 2. Controls and Key Parameters Setting

Jack	Description	Factory Setting
JP1	BATDRV setting Connect BATDRV to external signal BATDRV_EXT Connect BATDRV to internal signal BATDRV_IN	Connect BATDRV to BATDRV_IN
JP2	ACDRV setting Connect ACDRV to external signal ACDRV_EX Connect ACDRV to internal signal ACDRV_IN	Connect ACDRV to ACDRV_IN
JP3	VPULLUP setting 1-2 : Connect VPULLUP to VREF 2-3 : Connect VPULLUP to VEXT	Jumper On 1-2 (VPULLUP and VREF)
JP4	CHGEN is pulled high and the output is enabled when Jumper is on.	Jumper Off
JP5	The pull-up power source supplies the LEDs when on. LED has no power source when off.	Jumper On

Table 3. Recommended Operating Conditions

Symbol	Description	Min	Typ	Max	Unit	Notes
Supply voltage, V_{IN}	Input voltage from ac adapter input	5	24	28	V	
Battery voltage, V_{BAT}	Voltage applied at VBAT terminal of J5	2.1	21	26	V	
Supply current, I_{AC}	Maximum input current from ac adapter input	0		4.5	A	
Charge current, I_{chrg}	Battery charge current	2	3	8	A	
Operating junction temperature range, T_J		0		125	°C	

The bq246000/20/40 EVM board requires a regulated supply approximately 0.5 V minimum above the regulated voltage of the battery pack to a maximum input voltage of 28 VDC. R14 and R15 can be changed to regulate output.

$$V_{BAT} = 2.1\ V \times \left[1 + \frac{R14}{R15}\right] \text{ for bq24600/40;} \qquad V_{BAT} = 1.8\ V \times \left[1 + \frac{R14}{R15}\right] \text{ for bq24620}$$

Adjust the input voltage as required. Output set to operate at 21V (bq24600), 18V (bq24620) or 19.8V (bq24640) from the factory.

2 Test Summary

2.1 Definitions

This procedure details how to configure the HPA421 evaluation board. On the test procedure the following naming conventions are followed. See the HPA421 schematic for details.

VXXX :	External voltage supply name (VADP, VBT, VSBT)
LOADW:	External load name (LOADR, LOADI)
V(TPyyy):	Voltage at internal test point TPyyy. For example, V(TP12) means the voltage at TP12.
V(Jxx):	Voltage at jack terminal Jxx.
V(TP(XXX)):	Voltage at test point "XXX". For example, V(ACDET) means the voltage at the test point which is marked as "ACDET".
V(XXX, YYY):	Voltage across point XXX and YYY.
I(JXX(YYY)):	Current going out from the YYY terminal of jack XX.
Jxx(BBB):	Terminal or pin BBB of jack xx
Jxx ON :	Internal jumper Jxx terminals are shorted
Jxx OFF:	Internal jumper Jxx terminals are open
Jxx (-YY-) ON:	Internal jumper Jxx adjacent terminals marked as "YY" are shorted
Measure:→A,B	Check specified parameters A, B. If measured values are not within specified limits the unit under test has failed.
Observe → A,B	Observe if A, B occur. If they do not occur, the unit under test has failed.

Assembly drawings have location for jumpers, test points and individual components.

2.2 Equipment

2.2.1 Power Supplies

Power Supply #1 (PS#1): a power supply capable of supplying 30-V at 5-A is required.
Power Supply #2 (PS#2): a power supply capable of supplying 5-V at 1-A is required.
Power Supply #3 (PS#3): a power supply capable of supplying 30-V at 1-A is required.

2.2.2 LOAD #1

A 30V (or above), 5A (or above) electronic load that can operate at constant current mode

2.2.3 LOAD #2

A Kepco bipolar operational power supply/amplifier, 0 ± 30V (or above), 0 ± 6A (or above).

2.2.4 METERS

Seven Fluke 75 multimeters, (equivalent or better)
Or: Four equivalent voltage meters and three equivalent current meters.
The current meters must be capable of measuring 5A+ current.

2.3 Equipment Setup

(A) Set the power supply #1 for 0V ± 100mVDC, 5 ± 0.1A current limit and then turn off supply.
(B) Connect the output of power supply #1 in series with a current meter (multimeter) to J1 (VIN, GND).
(C) Connect a voltage meter across J1 (VIN, GND).
(D) Set the power supply #2 for 0V ± 100mVDC, 1 ± 0.1A current limit and then turn off supply.
(E) Connect the output of the power supply #2 to J3 (TS, GND).
(F) Connect Load #1 in series with a current meter to J3 (SYS, GND). Turn off Load #1.
(G) Connect Load #2 in series with a current meter to J3 (BAT, GND).Turn off Load #2.
(H) Connect a voltage meter across J3 (BAT, GND).
(I) Connect an oscilloscope's probe across J3 (BAT, GND).
(J) Connect a voltage meter across J3 (SYS, GND).
(K) JP1: Connect to BATDRV_IN, JP2: Connect to ACDRV_IN, JP3 (VPULLUP and VREF): ON, JP4: OFF, JP5: ON.

After the steps above, the test setup for HPA421 is shown in Figure 1.

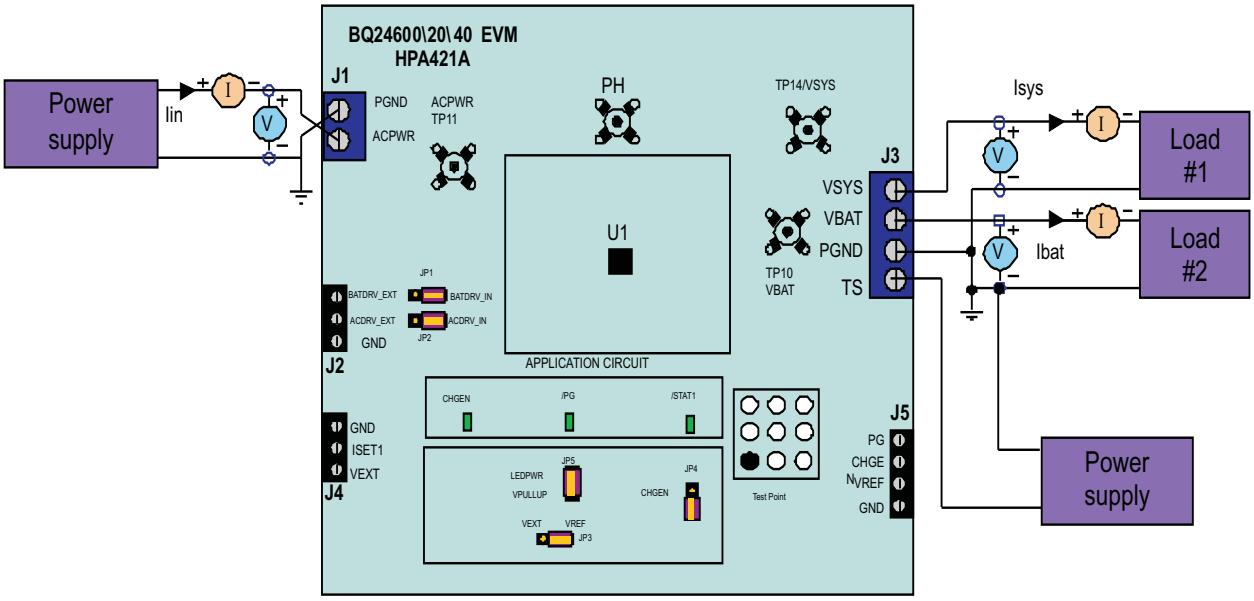

Figure 1. Original Test Setup for HPA421 (bq24600/20/40 EVM)

2.4 Procedure

2.4.1 AC ADAPTER DETECTION THRESHOLD

1. Make sure EQUIPMENT SETUP steps are followed. Turn on PS#2.
2. Turn on PS#1
   Measure → V(J3(SYS)) = 0 ± 500mV
   Measure → V(TP(VREF)) = 0V ± 1000mV
   Measure → V(TP(REGN)) = 0V ± 500mV
3. Increase the output voltage on PS#1 until D6 ($\overline{PG}$) on but do not exceed 5V. Set the power supply #2 to 1.8V ± 100mVDC
   Measure → V(J1(VIN)) = 4.2V ± 0.5V
   Measure → V(J3(SYS)) = 4.2V ± 0.5V
   Measure → V(TP(VREF)) = 3.3V ± 200mV
   Measure → V(TP(REGN)) = 0V ± 500mV
   Observe → D7 (STAT) blink; D6 ($\overline{PG}$) on

2.4.2 CHARGER REGULATION VOLTAGE

1. Increase the voltage of PS#1 until V(J1(VIN)) = 24V ± 0.1V.
   Measure → V(J3(BAT, GND)) = 0V ± 1V
2. Put JP4 on.
   Measure → Peak V(J3(BAT)) = 21V ± 1V (bq24600)
   Peak V(J3(BAT)) = 18V ± 1V (bq24620)
   Peak V(J3(BAT)) = 19.8V ± 1V (bq24640)
   Measure → V(TP(REGN)) = 6V ± 500mV
   Observe → D5(CHGEN) on; D7($\overline{\text{STAT}}$) blink; D6 ($\overline{\text{PG}}$) on. (bq24600/20)
   D5(CHGEN) on; D7($\overline{\text{STAT}}$) on; D6 ($\overline{\text{PG}}$) on. (bq24640)

2.4.3 CHARGE CURRENT

1. Take JP4 off (Disable the charging).
2. Connect the Load #2 in series with a current meter (multimeter) to J3 (BAT, GND). Make sure a voltage meter is connected across J3 (BAT, GND). Turn on the Load #2. Use the constant voltage mode. Set the output voltage to 12V (HPA421 -001) or 2V (HPA421,-002,-003).
3. Connect the output of the Load #1 in series with a current meter (multimeter) to J3 (SYS, GND). Make sure a voltage meter is connected across J3 (SYS, GND). Turn on the power of the Load #1. Set the load current to 1A ±50mA but disable the output. Make sure Ibat = 0A ± 10mA and Isys = 0A ± 10mA.
4. Put JP4 on (Enable the charging).
   Observe → D5 (CHG EN) on
5. *Measure* → Ibat = 300mA ± 200mA (bq24600)
   Ibat = 125mA ± 60mA (bq24620)
   Ibat = 3A ± 300mA (bq24640)
   Observe → D7 (**$\overline{\text{STAT}}$**) on.
6. Set the Load #2 output voltage to 16.5V.
   Ibat = 3000mA ± 300mA
   D7 (**$\overline{\text{STAT}}$**) on.
7. Set the Load #2 output voltage to 22V (bq600/40) or 19V (bq620).
   Measure → Ibat = 0mA ± 300mA
   Observe → D5(CHGEN) on; D6 ($\overline{\text{PG}}$) on. (bq24600/20)
   D5(CHGEN) on; D7($\overline{\text{STAT}}$) blink, D6 ($\overline{\text{PG}}$) on. (bq24640)
8. Set the Load #2 output voltage back to 16.5V.
   Measure → Ibat = 3000mA ± 300mA
   Observe → D5(CHGEN) on; D7($\overline{\text{STAT}}$) on, D6 ($\overline{\text{PG}}$) on.

2.4.4 CHARGER CUT-OFF BY THERMISTOR

1. Slowly increase the output voltage of PS2 until Ibat = 0 ±10mA.
   Measure → V(J3(TS)) = 2.44V ±300mV
   Observe → D7 ($\overline{\text{STAT}}$) blink.
2. Slowly decrease the output voltage of PS2 to 1.4V±0.1V.
   Measure → V(J3(TS)) = 1.4V ±100mV
   Measure → Ibat = 3000mA ± 300mA (bq24600/640)
   Ibat = 375mA ± 150mA (bq24620)
   Observe → D7($\overline{\text{STAT}}$) on.
3. Slowly decrease the output voltage of PS2
   Continue to decrease the output voltage of PS2 slowly until Ibat = 0 ±10mA
   Measure → V(J4(TS)) = 1.14V ±200mV
   Observe → D7($\overline{\text{STAT}}$) blink.
4. Slowly increase the output voltage of PS2 to 1.8V ± 300mV.
   Measure → Ibat = 3000V ± 200mV
   Observe → D7($\overline{\text{STAT}}$) on.

2.4.5 POWER PATH SELECTION

1. Take JP4 off (Disable the charging)
   Observe → D5(CHGEN) off; D7 ($\overline{\text{STAT}}$) blink.
2. Set JP3 Jumper On 2-3 (VPULLUP and VEXT). Connect the output of the power supply #3 to J2(VEXT, GND). Set the power supply #3 for 3.3V ± 200mVDC, 1 ± 0.1A current limit.
3. Set Load #2 at 16.5V ± 500mV.
   Measure → V(J3(SYS)) = 24V ±1mV (adapter connected to system)
   Measure → ACDRV = 9V ± 2V; BATDRV = 24V ± 1V
   Observe → D6($\overline{\text{PG}}$) on.
4. Turn off PS#1
5. *Measure* → V(J3(SYS)) = 16.5V ± 0.5mV (battery connected to system)
   Measure → ACDRV = 16V ± 1V; BATDRV = 1.5V ± 1V
6. *Observe* → D6($\overline{\text{PG}}$) off.
7. Turn off power supply #2 and #3. Set JP3 on 1-2 (VPULLUP and VREF).

3 PCB Layout Guideline

1. It is critical that the exposed PowerPAD™ on the backside of the bq24600/20/40 package be soldered to the PCB ground. Make sure there are sufficient thermal vias right underneath the IC, connecting to the ground plane on the other layers.
2. The control stage and the power stage should be routed separately. At each layer, the signal ground and the power ground are connected only at the power pad.
3. Charge current sense resistor must be connected to SRP, SRN with a Kelvin contact. The area of this loop must be minimized. The decoupling capacitors for these pins should be placed as close to the IC as possible.
4. Decoupling capacitors for DCIN, VREF, VCC, REGN should make the interconnections to the IC as short as possible.
5. Decoupling capacitors for BAT must be placed close to the corresponding IC pins and make the interconnections to the IC as short as possible.
6. Decoupling capacitor(s) for the charger input must be placed very close to Q4 drain and Q5 source.

4 Board Layout

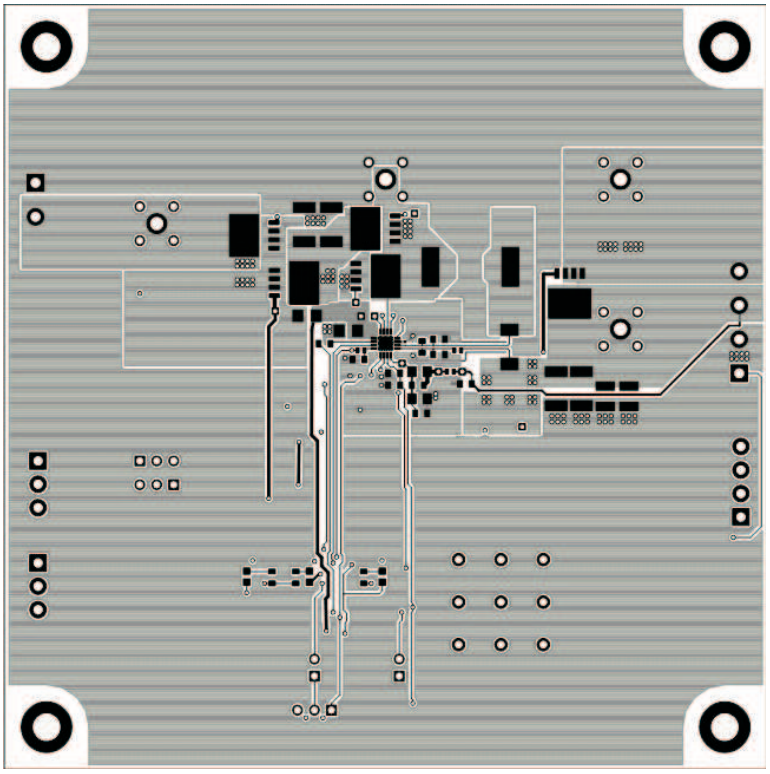

Figure 2. Top Layer

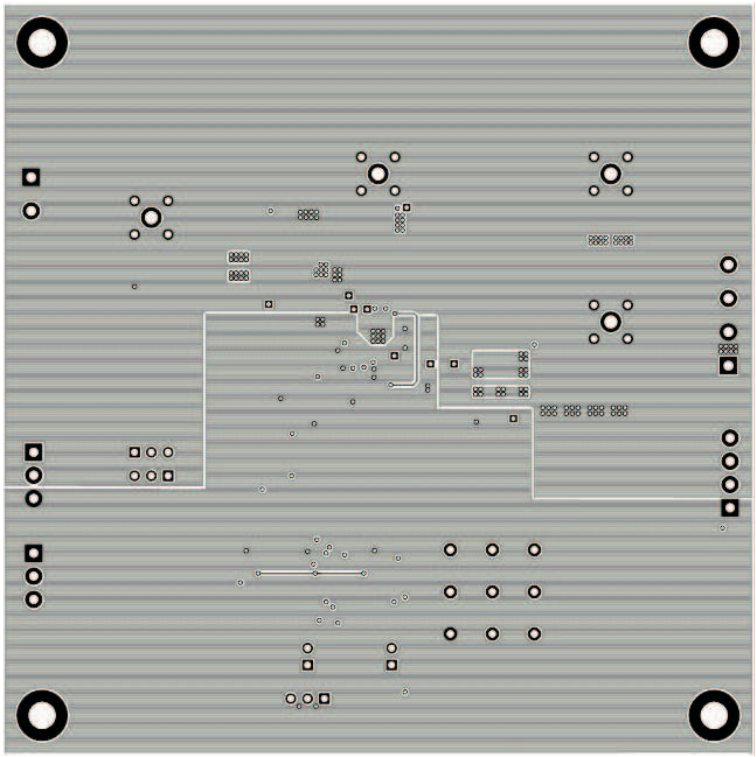

Figure 3. 2nd Layer

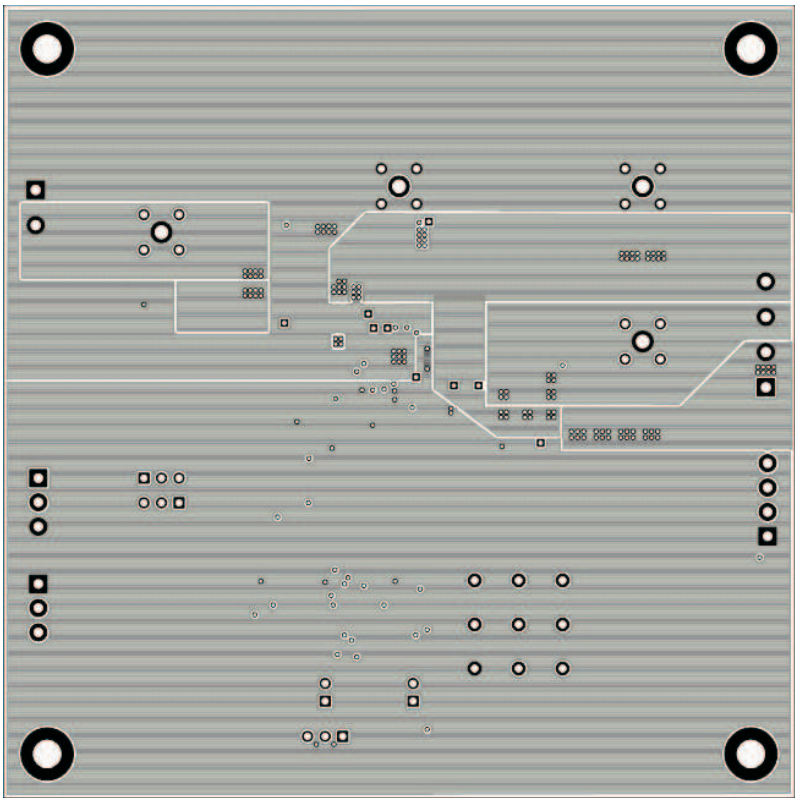

Figure 4. 3rd Layer

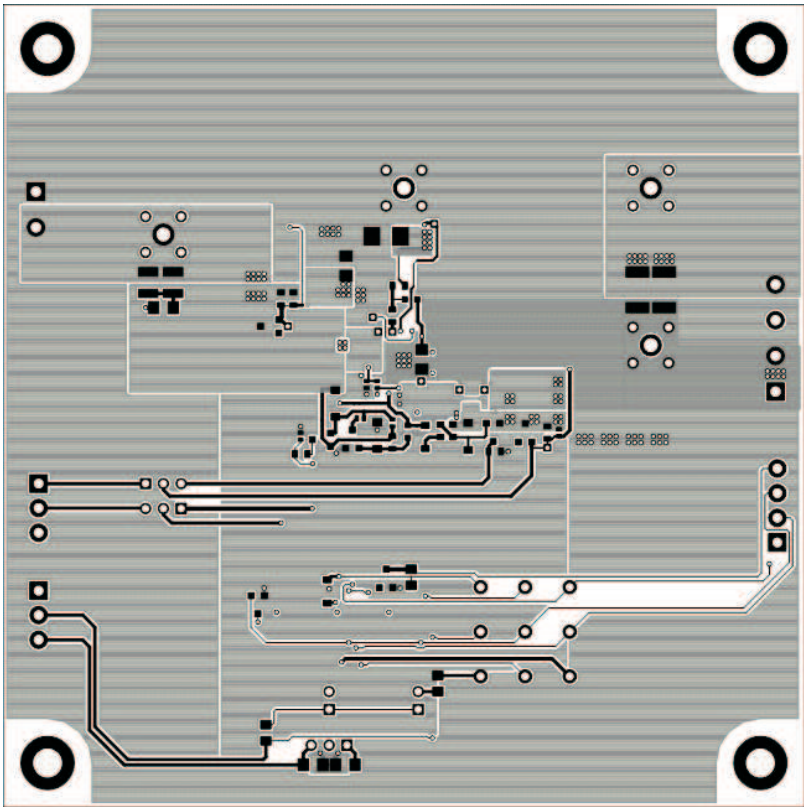

Figure 5. Bottom Layer

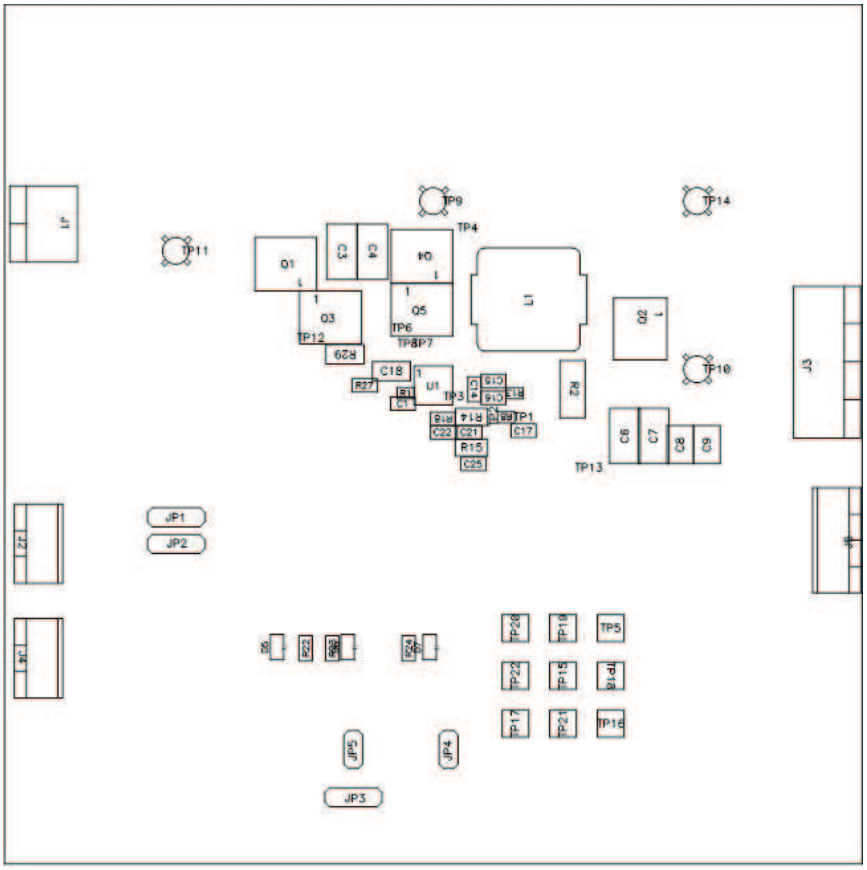

Figure 6. Top Assembly

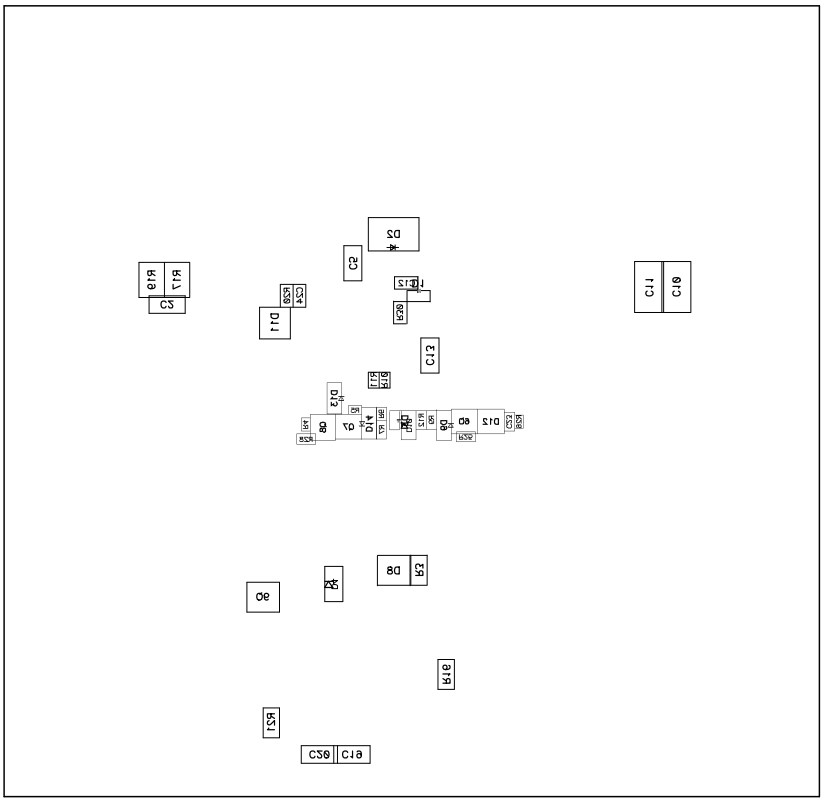

Figure 7. Bottom Assembly

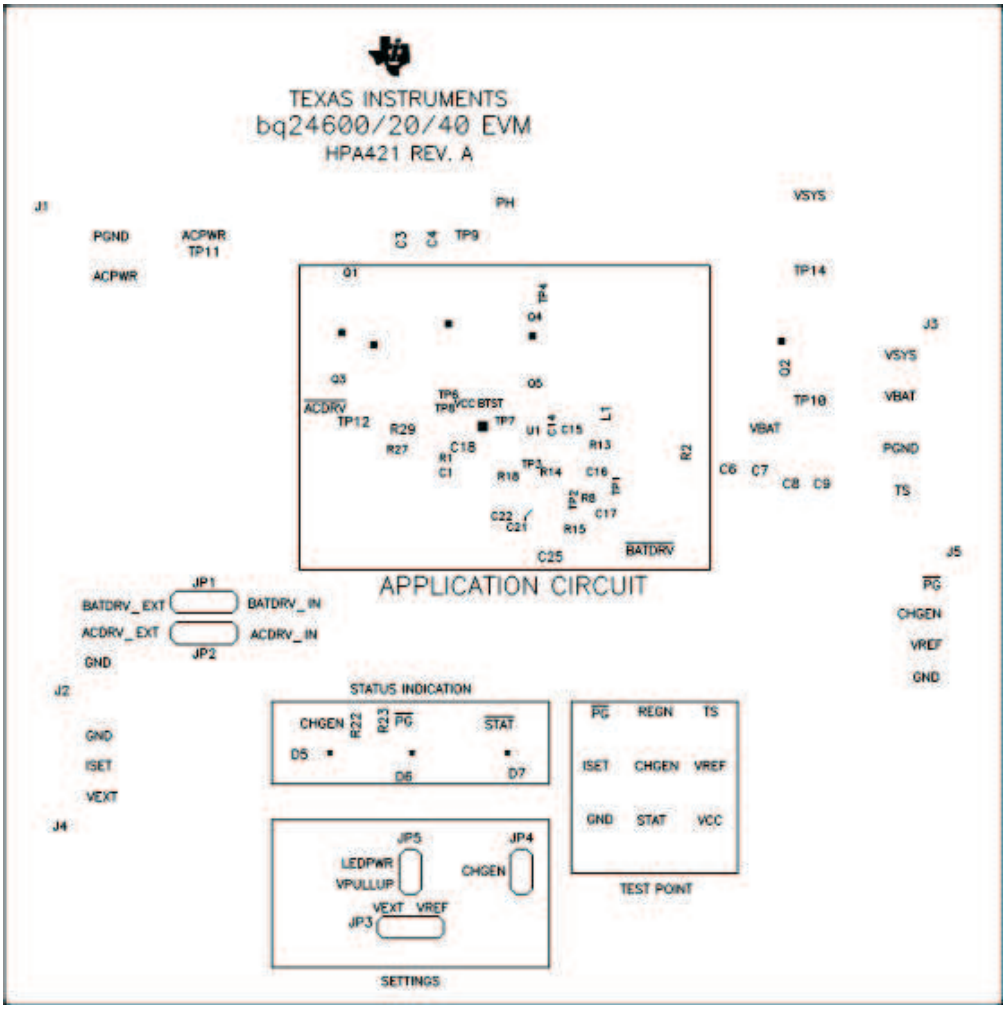

Figure 8. Top Silkscreen

5 Schematics

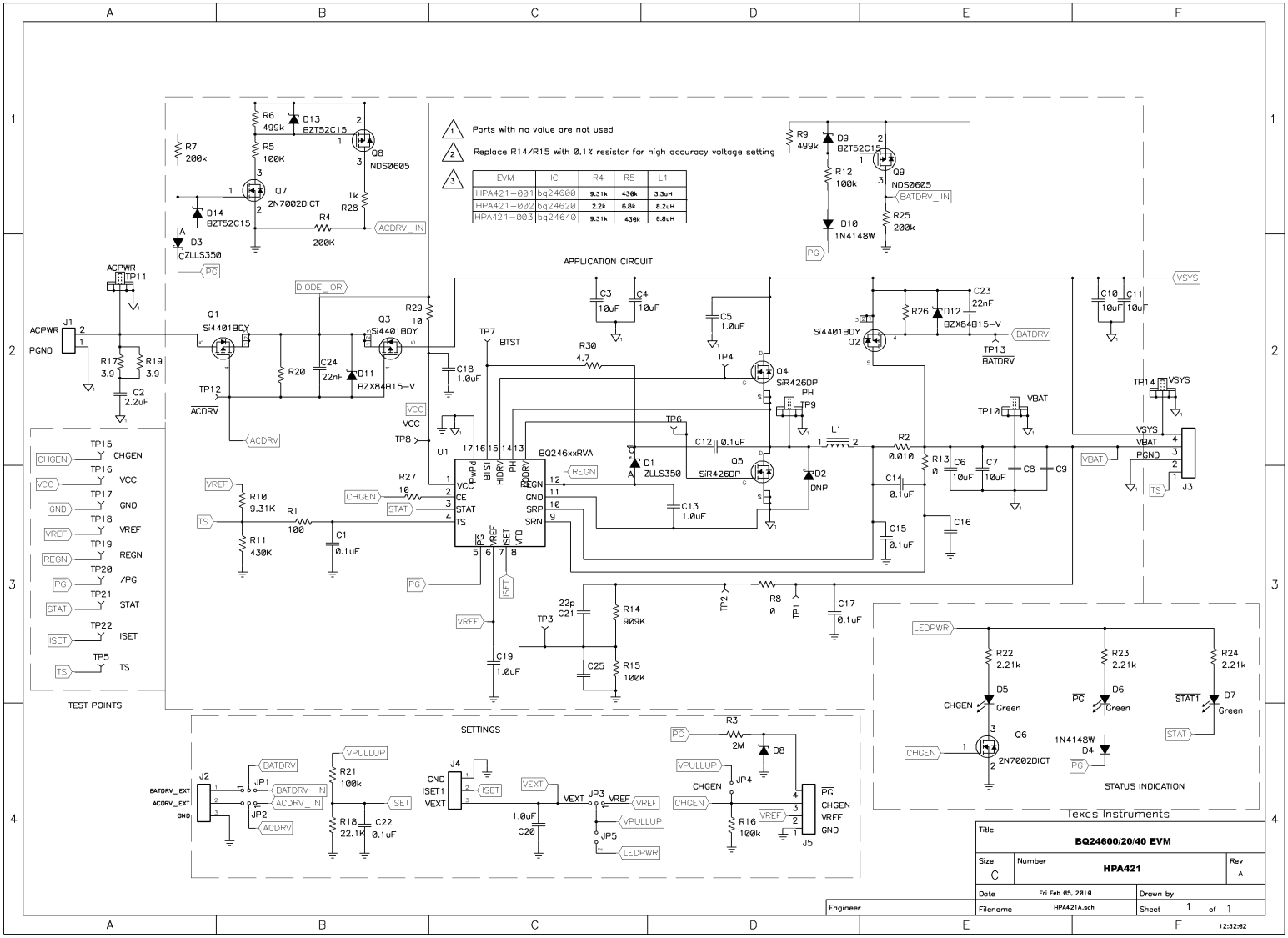

Figure 9. bq246xx EVM Schematic (Sheet 1 of 1)

6 Bill of Materials

Table 4. Bill of Materials

bq24600 -001	bq24620 -002	bq24640 -003	RefDes	Value	Description	Size	Part Number	MFR
1	0	0	U1	BQ24600RVA	IC, 28V Synchronous Switchmode Charge Management	QFN16[RVA]	BQ24600RVA	TI
0	1	0	U1	BQ24620RVA	IC, 28V Synchronous Switchmode Charge Management	QFN16[RVA]	BQ24620RVA	TI
0	0	1	U1	BQ24640RVA	IC, 28V Synchronous Switchmode Charge Management	QFN16[RVA]	BQ24640RVA	TI
6	6	6	C1,C12,C14,C15 ,C17,C22	0.1uF	Capacitor, Ceramic, 50V, X7R, 10%	603	C1608X7R1H104K	TDK
2	2	2	C23, C24	22nF	Capacitor, Ceramic, 50V, X7R, 10%	603	Std	TDK
1	1	1	C21	22p	Capacitor, Ceramic, 50V, X7R, 10%	603	Std	TDK
0	0	0	C16	DNP	Capacitor, Ceramic, 50V, X7R, 10%	603	Std	TDK
0	0	0	C25	DNP	Capacitor, Ceramic, 50V, X7R, 10%	603	Std	TDK
5	5	5	C5,C13,C18,C19 ,C20	1.0uF	Capacitor, Ceramic, 50V, X7R, 10%	1206	C3216X7R1H105K	TDK
1	1	1	C2	2.2uF	Capacitor, Ceramic, 50V, X7R, 10%	1206	C3216X7R1H225K	TDK
0	0	0	C8,C9	DNP	Capacitor, Ceramic, 50V, X5R, 20%	1210	Std	Vishay
6	6	6	C3,C4,C6,C7,C1 0,C11	10uF	Capacitor, Ceramic, 50V, X5S, 20%	1812	UMK432C106MM-T	Taiyo Yuden
2	2	2	D4,D10	1N4148W	Diode, Signal, 300-mA, 75-V, 350-mW	SOD-123	1N4148W	Diodes
3	3	3	D9,D13,D14	BZT52C15	Diode, Zener, Planar Power, 15V	SOD-123	BZT52C15	Diodes
2	2	2	D11,D12	BZX84B15-V	Diode, Zener, 15-V, 300-mW	SOT-23	BZX84B15-V	Diodes
0	0	0	D8	DNP	Diode, Zener, xx-V, 300-mW	SOT-23	BZX84Bxx-x	Diodes
0	0	0	D2	DNP	Diode, Schottky, 1A, 30V	SMB	MBRS130TR	IR
2	2	2	D5,D7	Green	Diode, LED, Green, 2.1V, 20mA, 6mcd	603	LTST-C190GKT	Lite On
1	1	1	D6	Red	Diode, LED, Red, 1.8V, 20mA, 20mcd	603	LTST-C190CKT	Lite On
2	2	2	D1,D3	ZLLS350	Diode, Schottky, 1.16A, 40-V	SOD-523	ZLLS350	Zetex
0	1	0	L1	8.2uH	Inductor, IHLP5050EZERxxxM01	0.51 x 0.52 inch	IHLP5050EZERxxxM01	Vishay
1	0	0	L1	3.3uH	Inductor, IHLP5050EZERxxxM01	0.51 x 0.52 inch	IHLP5050EZERxxxM01	Vishay
0	0	1	L1	6.8uH	Inductor, IHLP5050EZERxxxM01	0.51 x 0.52 inch	IHLP5050EZERxxxM01	Vishay
2	2	2	JP4,JP5	PEC02SAAN	Header, Male 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN	Sullins
3	3	3	JP1–JP3	PEC03SAAN	Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN	Sullins
5	5	5	SJ1–SJ5	929950-00	Shorting jumpers, 2-pin, 100mil spacing,		929950-00	3M/ESD
2	2	2	R8,R13	0	Resistor, Chip, 1/16W, 5%	402	Std	Std

Table 4. Bill of Materials (continued)

bq24600 -001	bq24620 -002	bq24640 -003	RefDes	Value	Description	Size	Part Number	MFR
1	0	1	R10	9.31K	Resistor, Chip, 1/16W, 1%	402	Std	Std
0	1	0	R10	2.2K	Resistor, Chip, 1/16W, 1%	402	Std	Std
1	0	1	R11	430K	Resistor, Chip, 1/16W, 1%	402	Std	Std
0	1	0	R11	6.8K	Resistor, Chip, 1/16W, 1%	402	Std	Std
1	1	1	R1	100	Resistor, Chip, 1/16W, 1%	402	Std	Std
1	1	1	R5	100K	Resistor, Chip, 1/16W, 1%	402	Std	Std
1	1	1	R4	200K	Resistor, Chip, 1/16W, 1%	402	Std	Std
1	1	1	R6	499k	Resistor, Chip, 1/16W, 1%	402	Std	Std
0	0	0	R26	DNP	Resistor, Chip, 1/16W, 1%	402	Std	Std
1	1	1	R28	1k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	1	1	R30	4.7	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	1	1	R27	10	Resistor, Chip, 1/16W, 1%	603	Std	Std
3	3	3	R22–R24	2.21k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	1	1	R18	22.1K	Resistor, Chip, 1/16W, 1%	603	Std	Vishay
1	1	1	R12	100k	Resistor, Chip, 1/16W, 1%	603	Std	Std
2	2	2	R7,R25	200k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	1	1	R9	499k	Resistor, Chip, 1/16W, 1%	603	Std	Std
0	0	0	R20	DNP	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	1	1	R3	2M	Resistor, Chip, 1/10W, 1%	805	Std	Std
3	3	3	R15,R16,R21	100K	Resistor, Chip, 1/10W, 1%	805	Std	Std
1	1	0	R14	909K	Resistor, Chip, 1/10W, 1%	805	Std	Std
0	0	1	R14	845K	Resistor, Chip, 1/10W, 1%	805	Std	Std
1	1	1	R29	10	Resistor, Metal Film, 1/4 watt, 5%	1206	Std	Std
2	2	2	R17,R19	3.9	Resistor, 1/2W, 5%	1210	Std	Std
1	1	1	R2	0.01	Resistor, Chip, 1/2W, 1%	2010	WSL2010R0100FEA	Vishay, Dale
2	2	2	J2,J4	ED555/3DS	Terminal Block, 3-pin, 6-A, 3.5mm	0.41 x 0.25 inch	ED555/3DS	OST
1	1	1	J5	ED1516	Terminal Block, 4 pin, 6A, 3.5mm	0.55 x 0.25 inch	ED1516	OST
1	1	1	J1	ED1609-ND	Terminal Block, 2 pin, 15A, 5.1mm	0.40 x 0.35 inch	ED1609	OST
1	1	1	J3	ED2227	Terminal Block, 4 pin, 15A, 5.1mm	0.80 x 0.35 inch	ED2227	OST
1	1	1	TP17	GND	Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	5001	Keystone
0	0	0	TP1–TP4, TP6–TP8, TP12, TP13		Test Point, 0.020 Hole			

Table 4. Bill of Materials (continued)

bq24600 -001	bq24620 -002	bq24640 -003	RefDes	Value	Description	Size	Part Number	MFR
8	8	8	TP5, TP15, TP16, TP18–TP22	CHGEN,ISET,REGN ,STAT,TS,VCC,VRE F,~PG	Test Point, White, Thru Hole Color Keyed	0.100 x 0.100 inch	5002	Keystone
4	4	4	TP9–TP11,TP14	131-4244-00	Adaptor, 3.5-mm probe clip (or 131-5031-00)	0.200 inch	131-4244-00	Tektronix
1	1	1	Q7	2N7002DICT	MOSFET, N-ch, 60-V, 115-mA, 1.2-Ω	SOT23	2N7002DICT	Vishay-Liteon
1	1	1	Q6	2N7002DICT	MOSFET, N-ch, 60V, 115mA, 1.2Ω	SOT23	2N7002DICT	Vishay-Liteon
2	2	2	Q8, Q9	NDS0605	MOSFET,P-ch, -60 V, 180-mA, 5 Ω	SOT-23	NDS0605	Vishay
3	3	3	Q1–Q3	Si4401BDY	MOSFET, PChan, –40V, –8.7A, 21mΩ	PWRPAK S0-8	Si4401BDY	Vishay
1	1	1	Q4, Q5	SiR426DP	MOSFET, NChan, 40V, 30A, 12.5 mΩ	PWRPAK S0-8	SiR426DP	Vishay
4	4	4			6-32 NYL nuts	NY HN 632	H620-ND	Building Fasteners
4	4	4	ST1–ST4	4816	STANDOFF M/F HEX 6-32 NYL 0.500"	sf_thvt_325_rnd	4816	Keystone
1	1	1	PCB	HPA421	4x4.25 inch 4 layer 2oz. PCB	4x4.25 inch	PCB	

Evaluation Board/Kit Important Notice

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive.**

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.**

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please contact the TI application engineer or visit www.ti.com/esh.

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 18 V to 22 V and the output voltage range of 0 V to 18 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 125°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

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7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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