# *bq24610EVM-HV (HPA603)*

## >7 Cell Li-ion battery Charger

# User's Guide

# 1 Introduction

## 1.1 EVM Features

- **Evaluation Module For 8-cell Li-ion battery. To support other voltage battery, the output voltage set point can be changed by changing the feedback voltage divider.**
- **High Efficiency Synchronous Buck Charger**
- **User-programmable Battery Voltage**
- **Test Points for Key Signals Available for Testing Purpose. Easy Probe Hook-up.**
- **Jumpers Available. Easy to Change Connections.**

## 1.2 General Description

The bq24610 is highly integrated Li-ion or Li-polymer switch-mode battery charge controllers. It offers a constant-frequency synchronous PWM controller with high accuracy charge current and voltage regulation, termination, charge preconditioning, and charge status monitoring,

The bq24610 EVM charges the battery in three phases: preconditioning, constant current, and constant voltage. Charge is terminated when the current reches a minimum user-selectable level. A programmable charge timer provides a safety backup for charge termination. The bq24610 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 bq24610 (SLUS892) data sheets.

## 1.3 I/O Description

Table 1:

| Jack | Description |
|---|---|
| J1–Vin | input positive terminal |
| J1–PGND | Input ground terminal |
| J2– BAT | Output positive terminal |
| J2– PGND | Output ground |
| J2– TS | Temperature Qualification Voltage Input |
| J2–TS1 | Temperature Qualification Voltage Input 1 |
| JP1–CE | Charge enable pin |
| JP1–GND | Ground |

## 1.4 Controls and Key Parameters Setting

Table 2:

| Jack | Description | Factory Setting |
|---|---|---|
| JP1 | Charge enable setting<br>Installed : Disable charge<br>Non-installed: Allow charge | Jumper installed: disable charge |

## 1.5 Recommended Operating Conditions

Table 3:

| Symbol | Description | Minimum | Typical | Maximum | Unit | Notes |
|---|---|---|---|---|---|---|
| Supply voltage, $V_{IN}$ | Input voltage from ac adapter input | 33 | 48 | 60 | V | |
| Battery voltage, $V_{BAT}$ | Voltage applied at VBAT terminal | 0 | 33.6 | 50 | V | |
| Supply current, $I_{AC}$ | Maximum input current from ac adapter input | 0 | | 4.5 | A | |
| Charge current, $I_{chrg}$ | Battery charge current | 1 | 3 | 4 | A | |
| Operating junction temperature range, $T_J$ | | 0 | | 125 | °C | |

# 2 Test Summary

### 2.1 DEFINITIONS

This procedure details how to configure the HPA603 evaluation board. On the test procedure the following naming conventions are followed. Refer to the HPA603 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 60-V @ 5-A is required.
Power Supply #2 (PS#2): a power supply capable of supplying 5-V @ 1-A is required.

*2.2.2* *LOAD #1*

A 60V (or above), 5A (or above) electronic load that can operate at constant current mode

*2.2.3* *METERS*

Four Fluke 75 multimeters, (equivalent or better)
The current meters must be capable of measuring 5A+ current.

*2.2.4* Oscilloscope

Tektronix TDS3054 scope or equivalent, 10X voltage probe.

## 2.3 EQUIPMENT SETUP

A) Set the power supply #1 for 0V ± 100mVDC, with the current limit set to > 5 A and then turn off supply.
B) Connect the output of power supply #1 in series with a current meter (multi-meter) to J1 (VIN, GND).
C) Connect a voltage meter across J1 (VIN, GND).
D) Set the power supply #2 for 0V ± 100mVDC, 0.2 ± 0.1A current limit and then turn off supply.
E) Connect the output of the power supply #2 across J2 (TS, GND).
F) Connect Load #1 in series with a current meter to J2 (BAT, GND). Turn off Load #1.
G) Connect a voltage meter across J2 (BAT, GND).
H) Connect an oscilloscope's probe across J2 (BAT, GND).
I) If JP1 is not installed, install the jumper.
J) After the steps above, the test setup for HPA603 is shown in Figure 1.

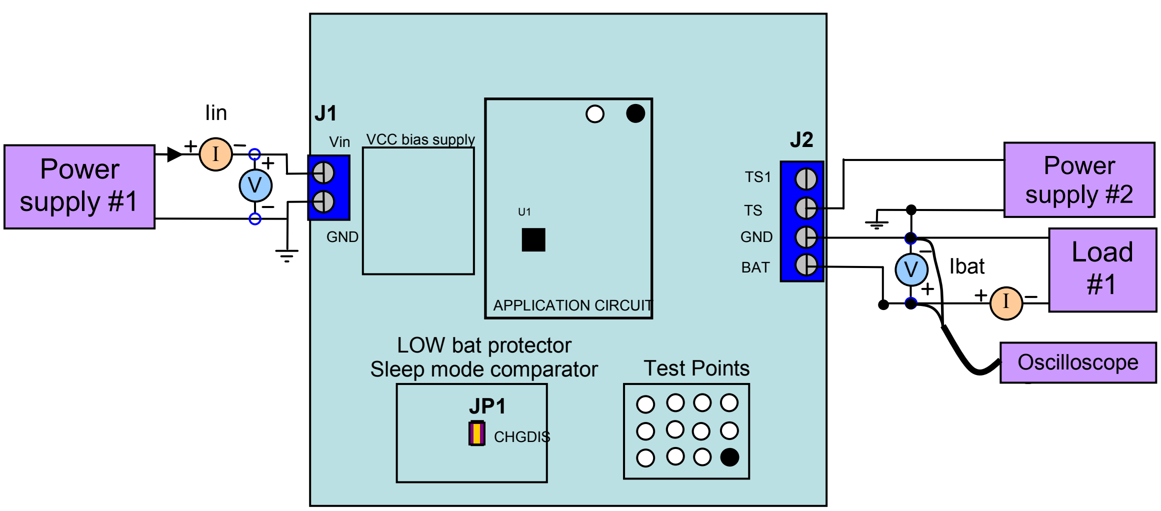


Figure 1: Original test setup for HPA603 (bq24610EVM-HV)

## 2.4 PROCEDURE

*2.4.1 Vcc Bias Supply Power Up*

2.4.1.1 Turn on PS#1. Set the power supply #1 to 48V ± 1VDC

*Measure* → V(TP(VREF)) = 3.3V ± 0.1V
*Measure* → V(TP(REGN)) = 0V ± 0.5V
*Measure* → V(TP(Vcc)) = 8.5V ± 0.5V

*2.4.2 CHARGE VOLTAGE REGULATION*

2.4.2.1 Turn on PS#2. Set the power supply #1 to 1.8V ± 100mVDC

2.4.2.2 Take JP1 off (Enable the charging).

*Oscilloscope Measure* → Peak V(J2(BAT)) = 33.6V ± 1V
*Measure* → V(TP(REGN)) = 6V ± 500mV

*2.4.3 CHARGE CURRENT REGULATION*

2.4.3.1 Set the output voltage to 15V. Turn on Load#1.

Measure → Ibat = 500mA ± 200mA

2.4.3.2 Set the output voltage to 28V.Turn on Load#1.

Measure → Ibat = 4.15A ± 300mA

*2.4.4 CHARGE CUT-OFF BY THERMISTOR*

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2.4.4.1 Slowly increase the output voltage of PS2 until Ibat = 0 ±10Ma

*Measure* → V(J4(TS)) = 2.44V ± 200mV
Measure → Ibat = 0mA ± 100mA

2.4.4.2 Slowly decrease the output voltage of PS2 to 1.8V ± 100mV

Measure → Ibat = 4150mA ± 300mA

# 3 PCB Layout Guideline

The switching node rise and fall times should be minimized for minimum switching loss. Proper layout of the components to minimize high frequency current path loop is important to prevent electrical and magnetic field radiation and high frequency resonant problems. Here is a PCB layout priority list for proper layout. Layout PCB according to this specific order is essential.

1). Place input ceramic capacitor as close as possible to switching MOSFET's supply and ground connections and use shortest copper trace connection.

2). The gate drive IC, UCC27201, should be placed close to the switching MOSFET's gate terminals and keep the gate drive signal traces short for a clean MOSFET drive. The IC can be placed on the other side of the PCB of switching MOSFETs.

3). Place inductor input terminal to switching MOSFET's output terminal as close as possible. Minimize the copper area of this trace to lower electrical and magnetic field radiation but make the trace wide enough to carry the charging current. Do not use multiple layers in parallel for this connection. Minimize parasitic capacitance from this area to any other trace or plane.

4). The charging current sensing resistor should be placed right next to the inductor output. Route the sense lead nets close to each other (minimize loop area) and do not route the sense leads through a high-current path.

5). Place output capacitor next to the sensing resistor output and ground.

6). Output capacitor ground connections need to be tied to the same copper that connects to the input capacitor ground before connecting to system ground.

8). Route analog ground separately from power ground. Connect analog ground and connect power ground separately. Connect analog ground and power ground together using power pad as the single ground connection point. Or using a 0Ω resistor to tie analog ground to power ground (power pad should tie to analog ground in this case if possible).

9). Decoupling capacitors should be placed next to the IC pins and make trace connection as short as possible.

10). It is critical that the exposed power pad on the backside of the IC package be soldered to the PCB ground. Ensure that there are sufficient thermal vias directly under the IC, connecting to the ground plane on the other layers.

# 4 Bill of Materials, Board Layout and Schematics

## 4.1 Bill of Materials

| COUNT | RefDes | Value | Description | Size | Part Number | MFR |
|---|---|---|---|---|---|---|
| 1 | C1 | 0.22uF | Capacitor, Ceramic, 100V, X7R, 20% | 1206 | STD | STD |
| 3 | C10, C16, C28 | 0.1uF | Capacitor, Ceramic, 16V, X7R, 10%, | 0603 | STD | STD |
| 4 | C11, C17, C20, C24 | 0.1uF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | STD | STD |
| 2 | C12, C36 | 4.7uF | Capacitor, Ceramic, 16V, X7R, 20% | 1206 | STD | STD |
| 2 | C14, C19 | 22pF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | STD | STD |
| 1 | C2 | 33uF | Capacitor, Radial, Aluminum, 100V, 20% | 0.492 inch | UPW2A330MPD | Nichicon |
| 0 | C21, C22 | Open | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | STD | STD |
| 1 | C25 | 3.3nF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | TDK |
| 1 | C26 | 10uF | Capacitor, Radial, Aluminum, 100V, 20% | 0.492 inch | RFS-100V100MH4#5 | Elna America |
| 2 | C27, C29 | 100pF | Capacitor, Ceramic, 16V, X7R, 5%, | 0603 | STD | STD |
| 2 | C3, C37 | 2.2uF | Capacitor, Ceramic, 100V, X7R, 10% | 1812 | STD | STD |
| 1 | C30 | 1.0uF | Capacitor, Ceramic, 16V, X7R, 10% | 0603 | STD | STD |
| 1 | C31 | 15pF | Capacitor, Ceramic, 50V, X5R, 10% | 0402 | Std | Std |
| 1 | C32 | 2.2uF | Capacitor, Ceramic, 100V, X7R, 10% | 1210 | Std | Std |
| 1 | C33 | 0.1uF | Capacitor, Ceramic, 6.3V, X5R, 20% | 0402 | Std | Std |
| 1 | C34 | 3300pF | Capacitor, Ceramic, 6.3V, X5R, 20% | 0402 | Std | Std |
| 1 | C35 | 0.1uF | Capacitor, Ceramic, 10V, X5R, 20% | 0402 | Std | Std |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | C38 | Open | Capacitor, Ceramic, 100V, X7R, 20% | 0805 | STD | STD |
| 1 | C4 | 0.22uF | Capacitor, Ceramic, 100V, X7R, 10% | 1206 | STD | STD |
| 2 | C5, C6 | 2.2uF | Capacitor, Ceramic, 50V, X5R, 20% | 1812 | STD | STD |
| 3 | C7, C13, C18 | 0.1uF | Capacitor, Ceramic, 16V, X7R, 10% | 0603 | STD | STD |
| 1 | C8 | 0.1uF | Capacitor, Ceramic, 100V, X7R, 10% | 1206 | STD | STD |
| 3 | C9, C15, C23 | 1.0uF | Capacitor, Ceramic, 16V, X7R, 20% | 0805 | STD | STD |
| 1 | D1 | BZX84B15-V | Diode, Zener, 15-V, 300-mW | SOT-23 | BZX84B15-V | Diodes |
| 1 | D2 | MMSD701T1G | Schottky Barrier Diodes, 70-V, 200-mA, 225mW, | SOD-123 | MMSD701T1G | On Semi |
| 0 | D3, D4 | Open | Diode, Signal, 300-mA, 75-V, 350-mW | SOD-123 | 1N4148W-7-F | Diodes |
| 1 | D5, D8 | 1N4148W-7-F | Diode, Signal, 300-mA, 75-V, 350-mW | SOD-123 | 1N4148W-7-F | Diodes |
| 0 | D6 | Open | Diode, Schottky Barrier Rectifier, 2A, 100V | SMB | B2100-13 | Diodes |
| 1 | D7 | DDZ5V6BS | Diode, Zener, 5.6V, 900mA, 200mW | SOD-323 | DDZ5V6BS | Diodes |
| 1 | D9 | BAT54 | Diode, Schottky, 200-mA, 30-V | SOT-23 | BAT54 | Vishay |
| 1 | J1 | ED1609-ND | Terminal Block, 2 pin, 15A, 5.1mm | 0.40 x 0.35 inch | ED1609 | OST |
| 1 | J2 | ED2227 | Terminal Block, 4 pin, 15A, 5.1mm | 0.80 x 0.35 inch | ED2227 | OST |
| 1 | JP1 | PEC02SAAN | Header, Male 2-pin, 100mil spacing, | 0.100 inch x 2 | PEC02SAAN | Sullins |
| 1 | L1 | 22uH | Inductor, Low Profile High Current, 6A, 20% | 0.51 x 0.52 inch | 7443551221 | Wurth |
| 1 | L2 | 100uH | Inductor, SMT, 2.48A, 89milliohm | 0.402 x 0.394 inch | MSS1038-104ML | Coilcraft |
| 2 | Q1, Q2 | SI7852DP | MOSFET, NChan, 80V, 10.9A, 22 millohm | PWRPAK S0-8 | Si7852DP | Vishay-Siliconix |
| 0 | Q3, Q5 | Open | MOSFET, NChan, 80V, 10.9A, 22 millohm | PWRPAK S0-8 | Si7852DP | Vishay-Siliconix |
| 1 | Q4 | SI7469DP | MOSFET, PChan, 80V, 28A, 29millohm | PWRPAK S0-8 | SI7469DP | Vishay |
| 0 | Q6 | SI7469DP | MOSFET, PChan, 80V, 28A, 29millohm | PWRPAK S0-8 | SI7469DP | Vishay |
| 1 | R1 | 200k | Resistor, Metal Film, 1/4 watt, 5% | 1206 | Std | Std |
| 1 | R10 | 100k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 2 | R11, R12 | 15.0k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 4 | R13, R14, R25, R26 | 0 | Resistor, Chip, 1/16W, 5% | 0603 | Std | Std |
| 1 | R22 | 2.00k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 3 | R17, R19, R36 | 10.0k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 1 | R18 | 0.02 | Resistor, Chip, 1/2W, 1% | 2010 | WSL2010R0100FEA | Dale |
| 1 | R2 | 51.1 | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R20 | 100k | Resistor, Chip, 1/10W, 1% | 0805 | Std | Std |
| 1 | R21 | 4.02k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R23 | 464k | Resistor, Chip, 1/10W, 1% | 0805 | Std | Std |
| 1 | R24 | 30.9k | Resistor, Chip, 1/10W, 1% | 0805 | Std | Std |
| 2 | R28, R29 | 1.00M | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R3 | 40.2 | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 2 | R30, R33 | 866k | Resistor, Chip, 1/10W, 1% | 0805 | Std | Std |
| 2 | R16, R31 | 10.0k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R35 | 750k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R37 | 100k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 1 | R38 | 10k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R39 | 5.49k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 1 | R4 | 9.31k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 1 | R40 | 154k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 1 | R41 | 88.7K | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 1 | R42 | 113k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 0 | R43, R44 | Open | Resistor, Chip, 1/2W, 1% | 2010 | STD | STD |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | R45 | 3.3 | Resistor, Chip, 1/10W, 1% | 0805 | Std | Std |
| 2 | R46, R47 | 200 | Resistor, Chip, 1/2W, 1% | 2010 | Std | Std |
| 1 | R5 | 432k | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 2 | R6, R27 | 1.00k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R7 | 10 | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 3 | R15, R32, R34 | 23.2k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R8 | 100 | Resistor, Chip, 1/16W, 1% | 0402 | Std | Std |
| 0 | R9 | OPEN | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 0 | SH1, SH2 | | Short jumper | | | |
| 0 | TP1, TP18, TP19 | STD | Test Point, 0.020 Hole | | STD | STD |
| 1 | TP10 | STAT2 | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP11 | REGN | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP12 | VREF | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP3, TP13 | GND | Test Point, Black, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5001 | Keystone |
| 1 | TP14 | VCC | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP15 | CHGEN | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP17 | BTST | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 3 | TP2， TP4,TP5 | 5002 | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP16 | TS | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP6 | TTC | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP7 | ISET2 | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP8 | ISET1 | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | TP9 | STAT1 | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | U1 | bq24610RGE | IC, | QFN-24 | bq24610RGE | TI |
| 1 | U2 | INA169 | IC, 2.7V to 60V High-Side Current Shunt Monitor | SOT23-5 | INA169 | TI |
| 1 | U3 | UCC27201QDD | IC, High Freq. Half Bridge Driver, 120V 3A Peak | EPSO-8 | UCC27201QDD | TI |
| 1 | U4 | LM2903PW | IC, Dual Differential Comparators, 2-36 Vin | TSSOP-8 (PW) | LM2903PW | TI |
| 1 | U5 | LM358AD | IC, Dual Operational Amplifiers | SO-8 | LM358AD | TI |
| 1 | U6 | TPS54060DGQ | IC, DC-DC Converter, 60V, 0.5A | MSOP-10 | TPS54060DGQ | TI |
| 1 | -- | HPA603 | PCB, 4 In x 4 In x 0.62 In | | HPA603 | Any |

## 4.2 Board Layout

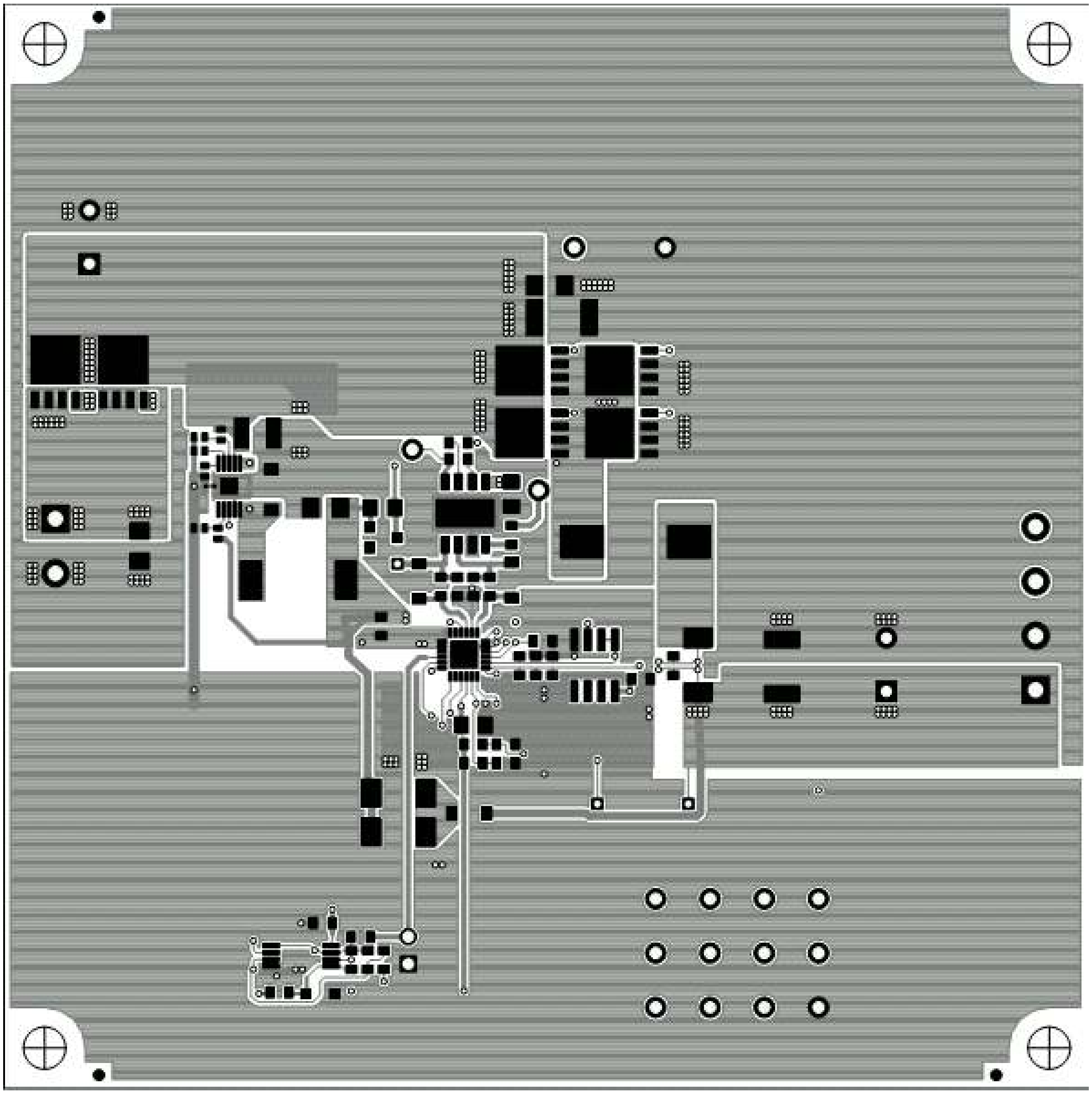

Figure 2. Top Layer

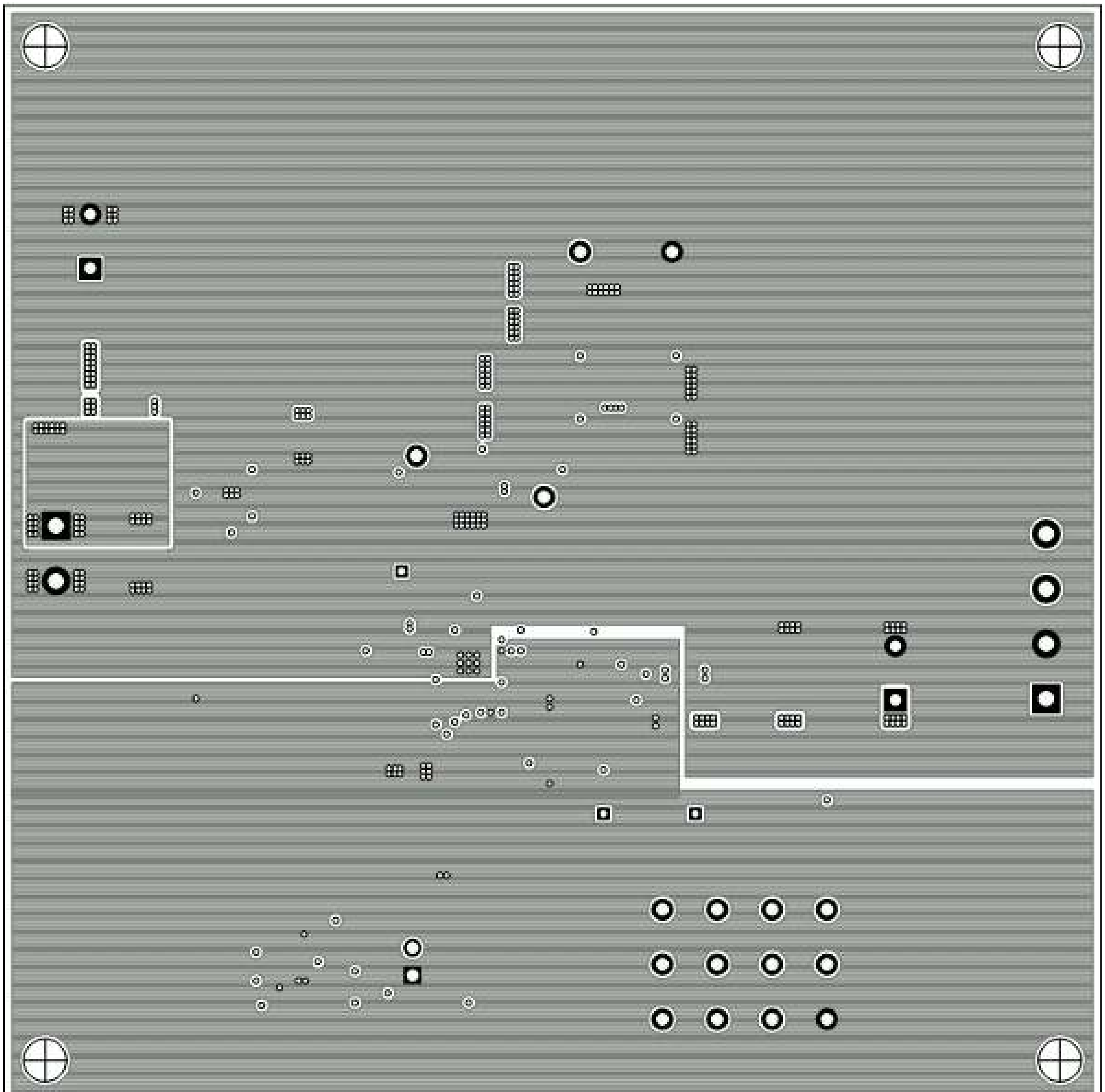

Figure 3. 2nd Layer

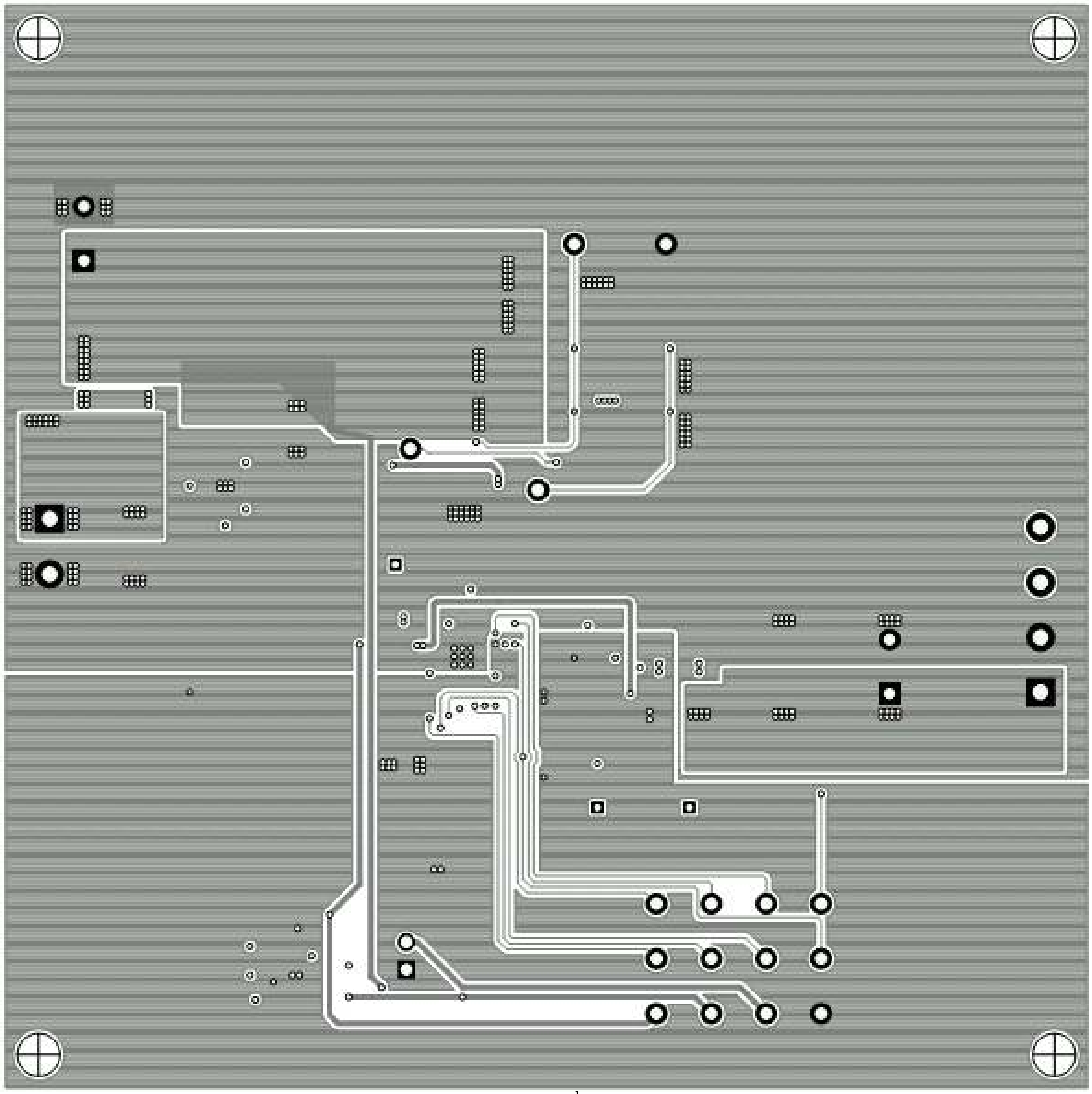

Figure 4 3rd Layer

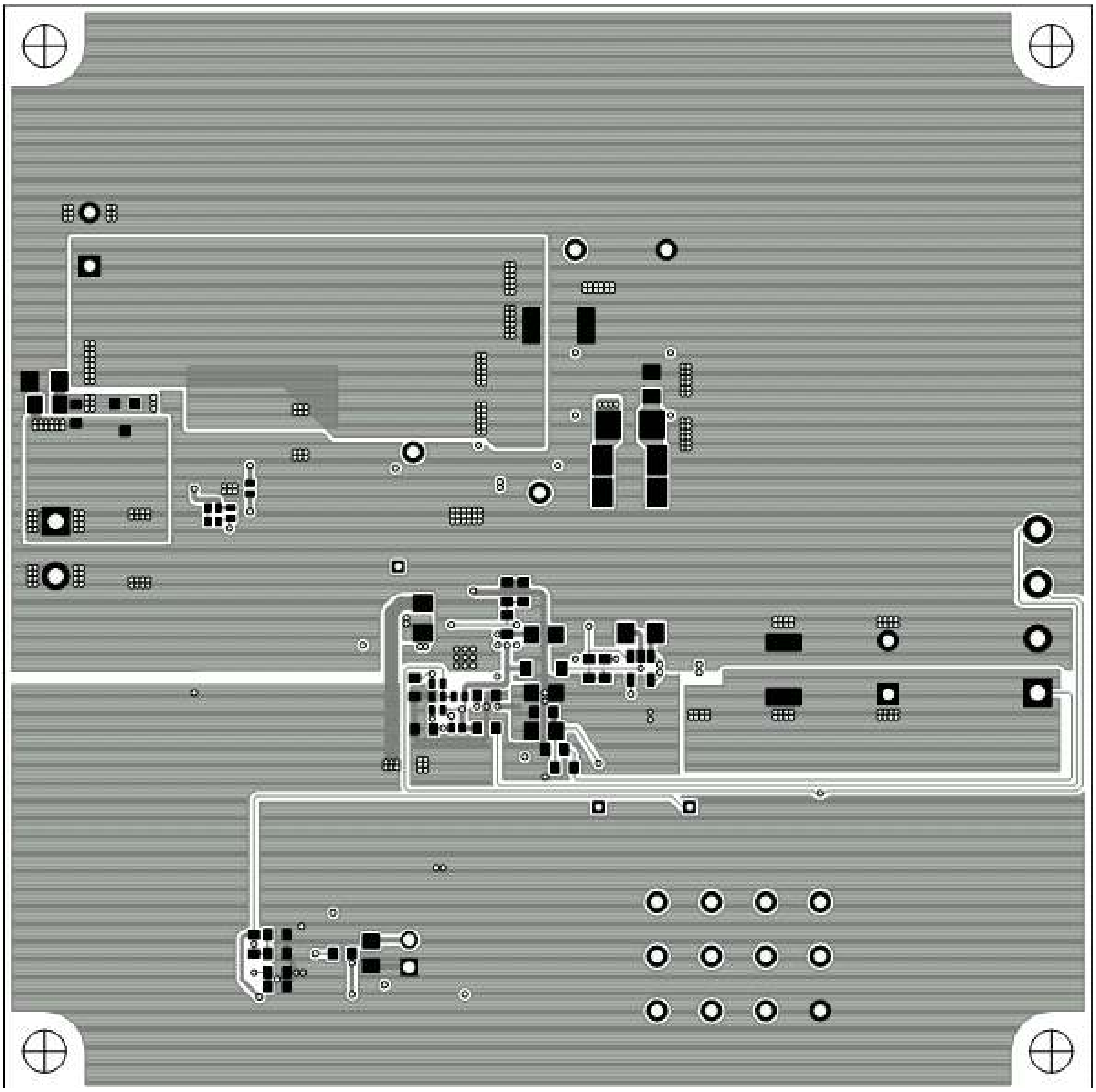

Figure 5. Bottom Layer

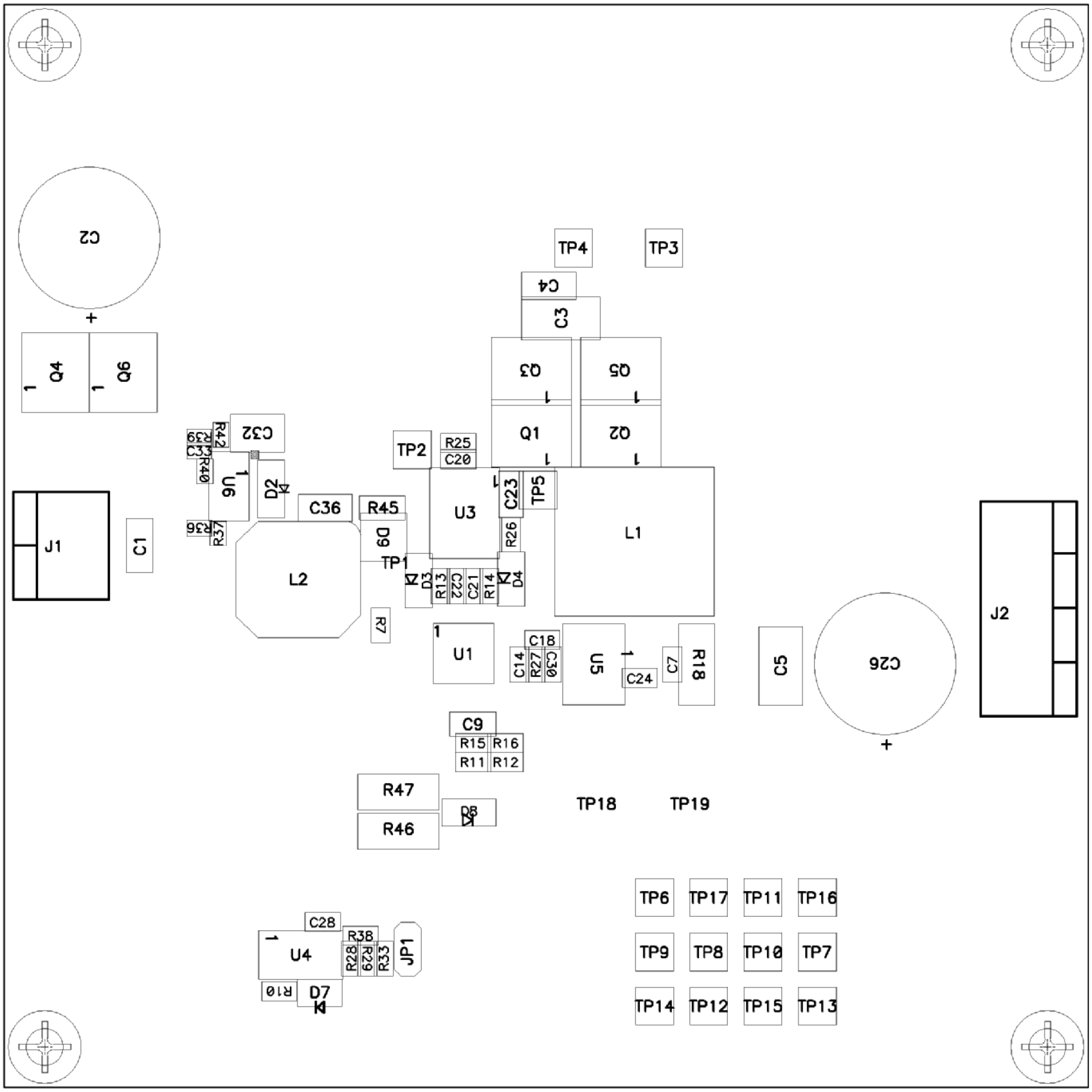


Figure 6. Top Assembly

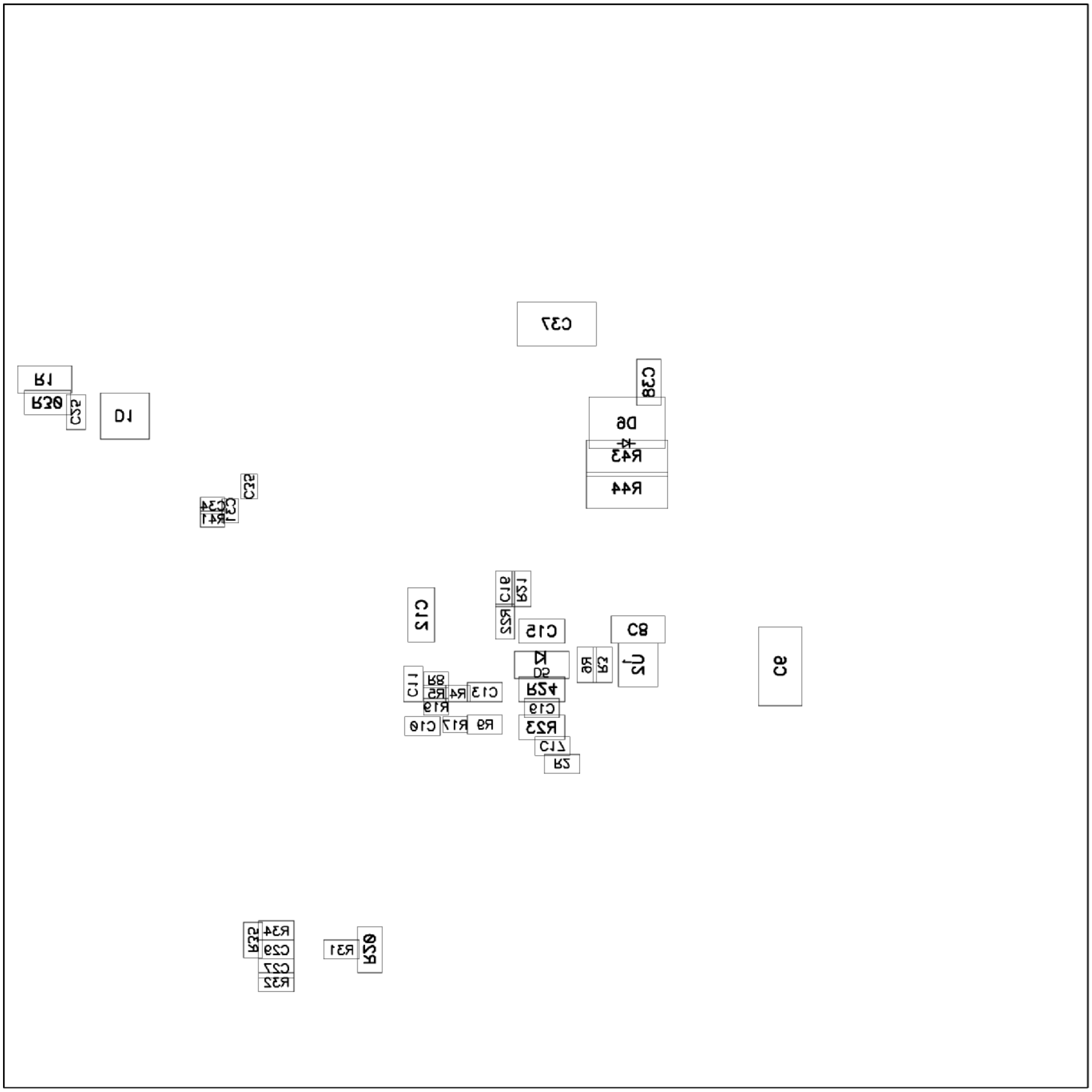

Figure 7. Bottom Assembly

## 4.3 Schematics

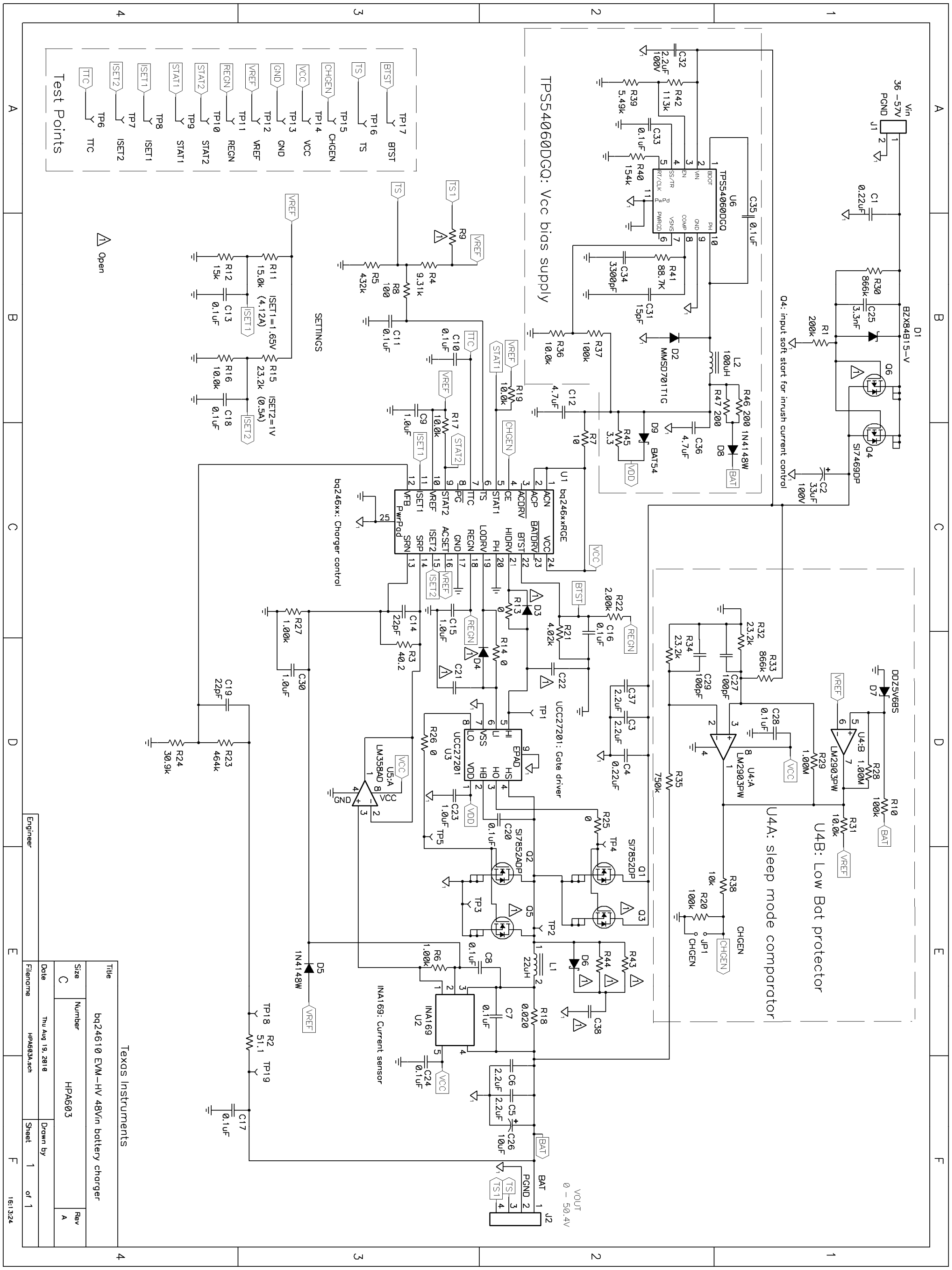


Figure 8. Schematic

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Persons handling the product must have electronics training and observe good laboratory practice standards.

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