TPS65086x Evaluation Module

This user's guide describes the characteristics, operation, and use of the TPS65086x evaluation module (EVM). The TPS65086x EVM is a prototyping platform for evaluating the performance of the TPS65086x power management device. The EVM will require modification of the inductors, capacitors, ILIM resistors, and input sources in order to operate optimally for a given use case.

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1 Introduction

The TPS65086x is a highly integrated power management solution for multi-core processors, FPGAs and other System on Chips (SoCs).

Features of the TPS65086x include:

- Three Variable-Output Voltage Step-Down Controllers
  - Wide V_{IN} range from 5 V to 21 V
  - Scalable output current using external FETs with external current limit resistors at ILIMx pins
  - I^2C DVS Control (0.41 V to 1.67 V in 10-mV steps, 1 V to 3.575 V in 25-mV steps)
- Three variable-output voltage synchronous step-down converters
  - V_{IN} range from 3.0 V to 5.5 V
  - Up to 3 A of output current
  - I^2C DVS control from 0.425 V to 3.575 V in 25-mV steps
- Three LDO regulators with I^2C-adjustable-output voltage
  - LDOA1: from 1.35 V to 3.3 V for up to 200 mA of output current
  - LDOA2 and LDOA3: from 0.7 V to 1.5 V for up to 600 mA of output current
- VTT LDO for DDR3 and DDR4 memory termination
  - Fixed-output voltage of 0.5 × V_{BUCK6}
  - Can sink and source output current up to 500 mA
- Three load switches with slew-rate control
  - Up to 300 mA of output current with voltage drop less than 1.5% of nominal input voltage
  - R_{DSON} < 96 mΩ at input voltage of 1.8 V
- Built-in flexibility and configurability
  - Six input pins (CTL1–CTL6) configurable to Enable or Sleep Mode (CTL3 and CTL6) of any selected rails
  - Four output pins configurable to power good of any selected rails or controllable by I^2C
  - Open-drain interrupt output pin
- I^2C interface (Device Address 0x5E) supports standard mode (100 kHz), fast mode (400 kHz), and fast mode plus (1 MHz)
- 64-Pin, single-row, 0.4-mm pitch QFN package

NOTE: The TPS65086x EVM is designed to demonstrate some of the potential uses of the TPS65086x family. The EVM has more limitations than the TPS65086x device.

The limitations of the EVM follow:

- The FET for BUCK1 and BUCK6, the CSD87381P, has a maximum power dissipation of 4 W. The FET for BUCK2, the CSD87588N, has a maximum power dissipation of 6 W.
  - Care must be taken to ensure that this power dissipation limit is not exceeded
  - Higher input voltages reduce system efficiency so less output current can be provided
  - If the power dissipation limit is exceeded, the most common symptom is a short between the VIN and VOUT nodes
  - Replacing the FET and any non-ceramic capacitors should fix the issue

  .
- Inductor values are optimized for the given parameters with a 12-V input for controllers, 5-V input for converters:
  - BUCK1 - 470 nH - 1.05 V - 7 A (matches default)
  - BUCK2 - 220 nH - 1 V - 20 A (default voltage of 3.3 V is not optimized)
  - BUCK3 - 470 nH - 2.5 V - 3 A (matches default)

  - BUCK4 - 470 nH - 2.8 V - 3 A (matches default)
  - BUCK5 - 470 nH - 1.8 V - 3 A (matches default)
  - BUCK6 - 470 nH - 1.5 V - 10 A (matches default)
- BUCK2 has tantalum capacitors in order to demonstrate that the DCAP2 architecture can support these. An all ceramic solution would work as well here.
- BUCK1 - BUCK5 and LDOA2/A3 sleep state values are all assigned to CTL3. Sleep states are disabled for BUCK1 - BUCK3 by default, enabled for the remainder. They can be enabled or disabled by writing to the BUCKx_SLP_EN bits. Once enabled, if CTL3 is low, the BUCKx_SLP_VID group will determine the output voltage on these regulators. If CTL3 is high, the BUCKx_VID group will determine te output voltage on these regulators. BUCK6 is similarly assigned to CTL6 and the sleep state is enabled by default.

Finally, the sequence and rail assignments can be seen in Figure 1. Note that the CTL pins do not need to be switched in any particular order.

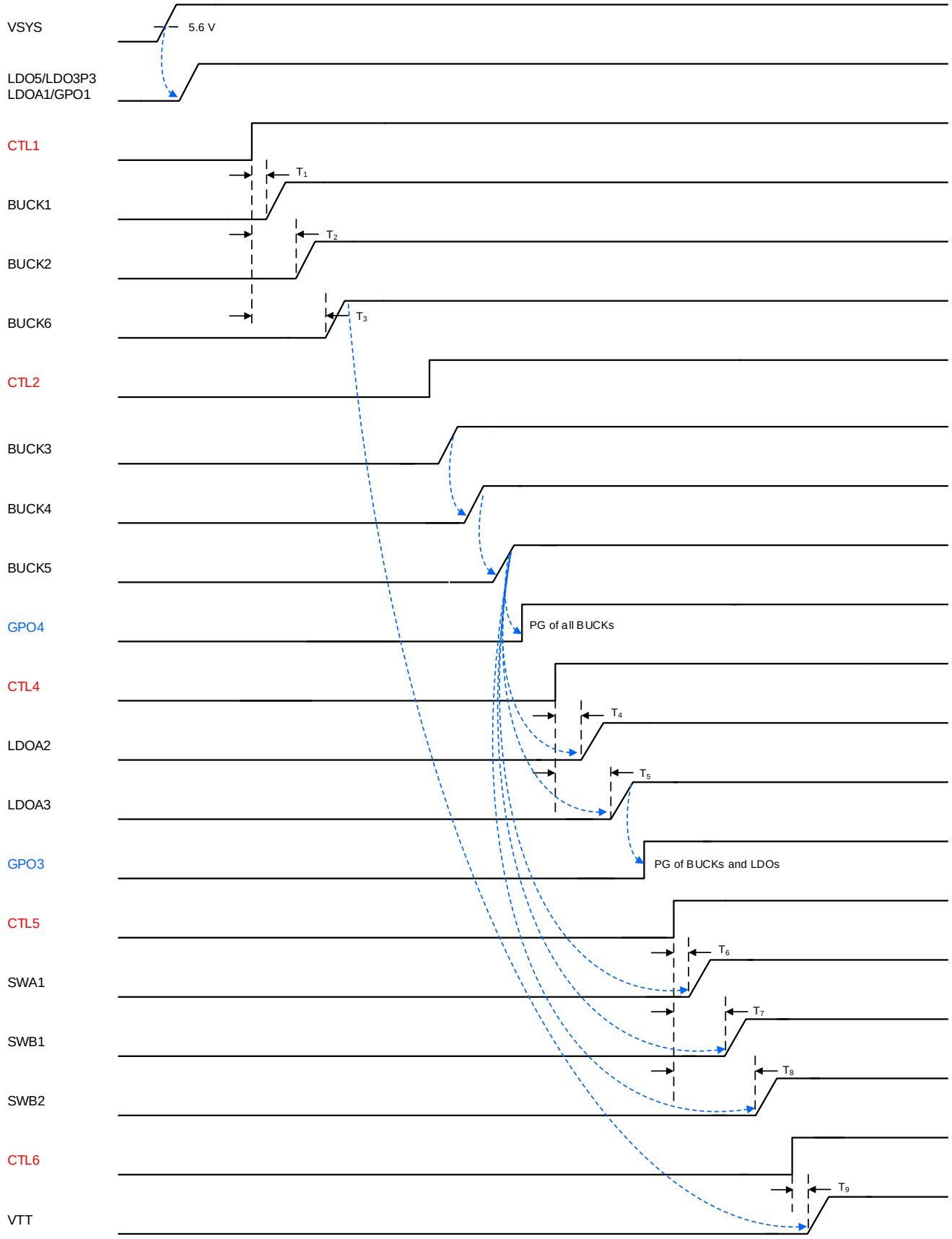

Figure 1. TPS650860 Power Up Sequencing

2 Requirements

2.1 Software

The EVM will power-up and operate without use of software. A GUI is supplied to provide a simple way to communicate to the device via I^2C. The GUI can be downloaded from:
http://www.ti.com/tool/IPG-UI

The EVM has a built-in USB2ANY module utilizing an MSP430. The GUI uses this to communicate with the device.

2.2 Host Computer

A computer with an available USB port is required to make use of the EVM software. The EVM software runs on the computer and communicates with the EVM via a USB-A to micro-B cable.

2.3 Power Supply

A DC power supply capable of delivering at least 5.6 V and 1 A is required to power on the EVM. If loading the EVM, a power supply with a 10 A limit or higher is recommended.

2.4 EVM Kit

The EVM kit contains the following items:

- TPS65086x HVL116A evaluation board
- USB A to micro-B cable

3 Terminal Block Descriptions

The EVM features 14 terminal blocks around the perimeter of the EVM. These are used for providing VSYS (J1) and loading the outputs. Each terminal block is labeled with the input or output on one side and GND on the other. Each terminal block also has a pair of test points for sense line probing.

4 Test Point Descriptions

Numerous test points are provided for sensing voltages on the EVM. The CTL1–6 test points also provide a way to override the on-board switches, when desired. Note that to override the switches, they must be in the 'OFF' position (not shorted to GND).

Table 1. Test Points(1)

Test Point	Description
CTL1	Controller Enable
CTL2	Converter Enable
CTL3	Sleep
CTL4	LDO Enable
CTL5	Load Switch Enable
CTL6	VTT Enable
GPO1	Push-Pull Output (Default '1')
GPO2	Open Drain Output (Default '0')
GPO3	Open Drain Global PGOOD
GPO4	Open Drain BUCK PGOOD
V5ANA	External 5-V supply input to internal load switch that connects this pin to LDO5P0 pin.
LDO5V	5-V internal LDO (LDO5P0) sense
LDO3P3	3.3-V internal LDO sense
VREF	Bandgap reference output
GND	Connected to GND planes
DIG_1P8V	1.8-V external LDO sense
USB_3P3V	3.3-V external LDO sense for USB2ANY onboard MSP430
BUCK3P3V	3.3-V external BUCK sense
BUCK5V	5-V external BUCK sense
EPGOOD	Power good indicator of external dual controller (requires pull-up to indicate properly)
Output Sense+ (Unlabeled)	Each rail has a sense+ line connected to the central output cap
Output Sense– (Unlabeled)	Each rail has a sense– line connected to the central output cap
Input Sense+ (TP1)	VSYS sense+ line connected to input cap of PMIC
Input Sense– (TP2)	VSYS sense– line connected to input cap of PMIC

(1) Test points are not designed to carry current. They are intended for measuring voltage.

5 Header Descriptions

There are 7 sets of headers which are used to provide greater access to several signals.

Table 2. Headers

Jumper	Description	Jumper Default Position
J21	Option to bypass the on-board 5-V external buck for the input to BUCK3, BUCK4, BUCK5, and V5ANA. 4 GND pins provided here as well.	VIN_BUCK345_ANA connected to BUCK5V with two jumpers to accommodate high current
J22	Option to bypass LDO5V for the input to DRV5V_2_A1 and DRV5V_1_6	VIN_DRV connected to LDO5V
J23	Option to bypass the on-board 3.3-V external buck for the input to SWA1. 2 GND pins provided here as well.	VIN_SWA1 connected to BUCK3P3V
J24	Option to bypass BUCKX_1P8V (1.8 V) for the input to LDOA2_A3	VIN_LDOA2_A3 connected to BUCKX_1P8V
J25	Option to bypass BUCKX_1P8V (1.8 V) for the input to SWB	VIN_SWB connected to BUCKX_1P8V
J33	SDA, SCL, and GND	Not intended for a jumper

6 Control, GPO, and External VRs

The EVM features a set of DIP switches for controlling CTL1–6 and 6 LEDs for GPO indicators. It also has built-in USB2ANY circuitry which utilizes an on-board MSP430 to enable the GUI to communicate with the device through a USB cable. Finally, it features an on-board TPS51285 device which provides 3.3- and 5-V rails from VSYS for use by BUCK3, BUCK4, BUCK5, V5ANA, and SWA1. Pads exist for the addition of Samtec HSEC8-110-01-S-DV-A vertical edge rate card sockets.

- For the CTL switches, S1, the “OFF” position is an open circuit and the CTL signal is pulled up to the corresponding rail. The “ON” position forces the CTL signal to GND.
- The LED order is D6, D1, D4, D5, D2, D3 with the resulting signal order from left to right being: USB, GPO1, GPO4, IRQB, GPO2, GPO3.

Table 3. Other Connectors

Designator	Description
S1	In order from left to write, the switches are for: CTL1 - CTL6. Note: the “ON” (up) position shorts the CTL signals to GND. As a result, to enable an active high signal, the switch should be set to the “OFF” (down) position.
D6	Indicator light for successful USB connection.
D1	GPO1
D2	GPO2
D3	GPO3
D4	GPO4
D5	Inverted IRQB status indicator (since IRQB is active low)

7 Setup

The general block diagram for the HVL116A EVM can be seen in Figure 2. Jumpers and shunt resistors can be used to reroute signals as needed.

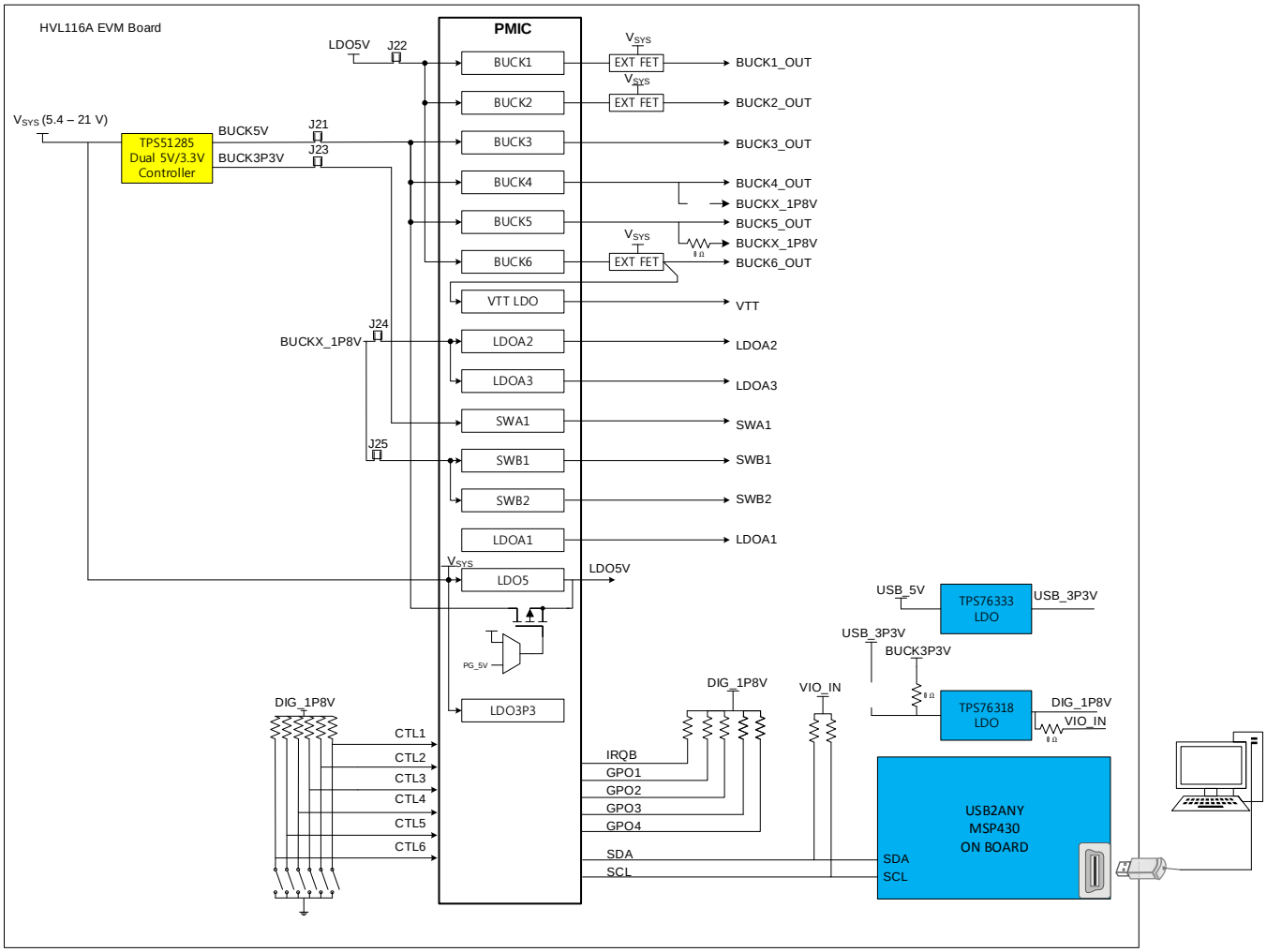

Figure 2. HVL116A Block Diagram

Figure 3 is an example setup for using the TPS65086x EVM:

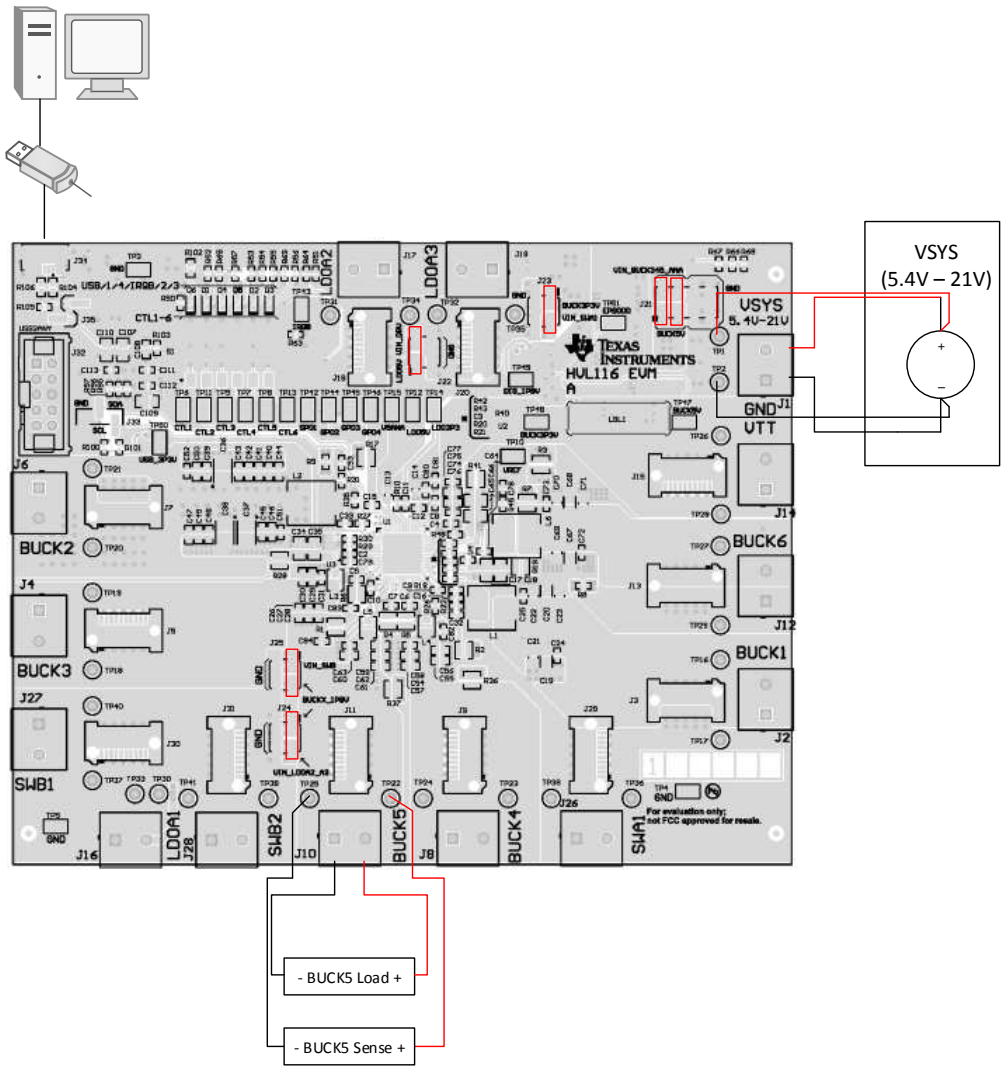

Figure 3. TPS65086x EVM Setup

For the default TPS650860 part, the GPO1 LED and LDOA1 should turn on as VSYS is applied, regardless of the state of the CTL pins. If all CTL pins are low, then no other output power rails will be enabled. As the CTL switches are set to the "OFF" position and the CTL pins are allowed to pullup to DIG_1P8V, the other rails are enabled based on the sequence in the datasheet.

8 Software

8.1 Software Installation Instruction

A GUI is supplied to provide a simple way to communicate to the device via I^2C. The GUI can be downloaded from:
http://www.ti.com/tool/IPG-UI

Information on the installation of the IPG-UI can be found in the *IPG-UI User's Guide* (SLVUAH9)

8.2 Using the TPS65086x GUI

Detailed information on the usage of the IPG-UI can also be found in the *IPG-UI User's Guide* (SLVUAH9). A brief overview is provided here for reference.

The proper device must first be selected from the "Select Devices" drop-down menu.

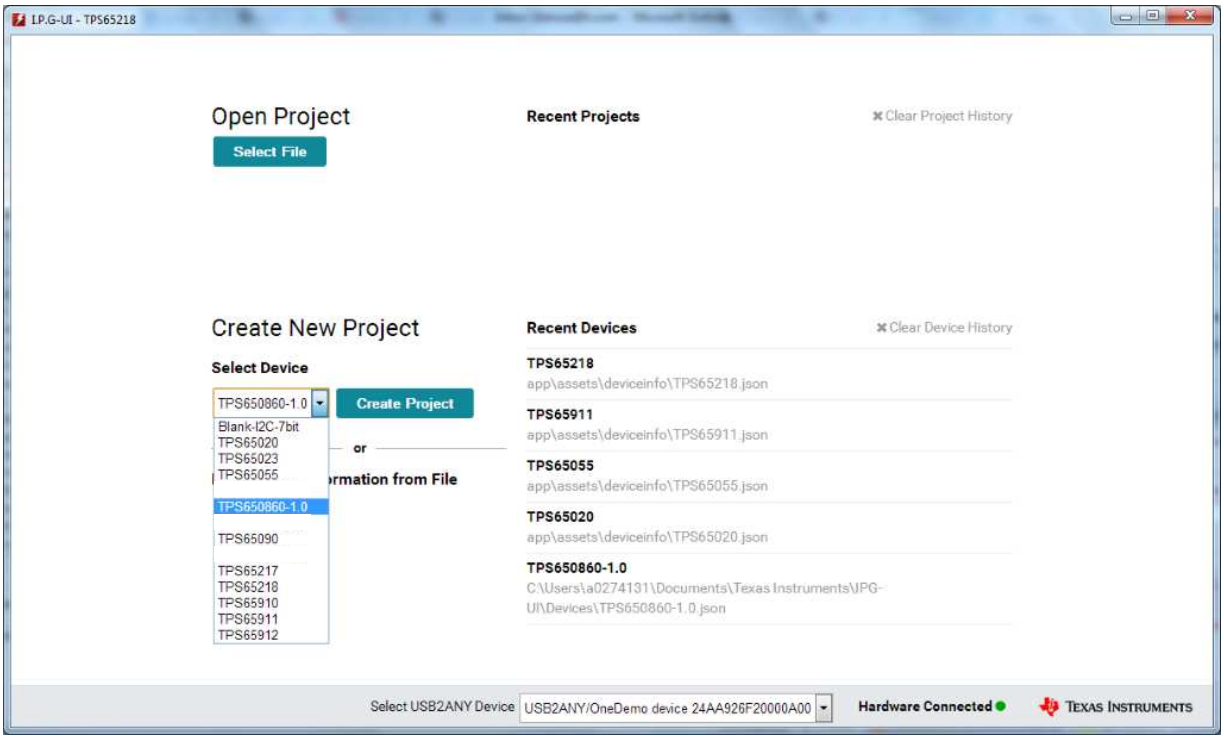

Figure 4. GUI Front Page

From there, the next screen is the device introduction page, which includes a brief overview as well as the functional block diagram for the device.

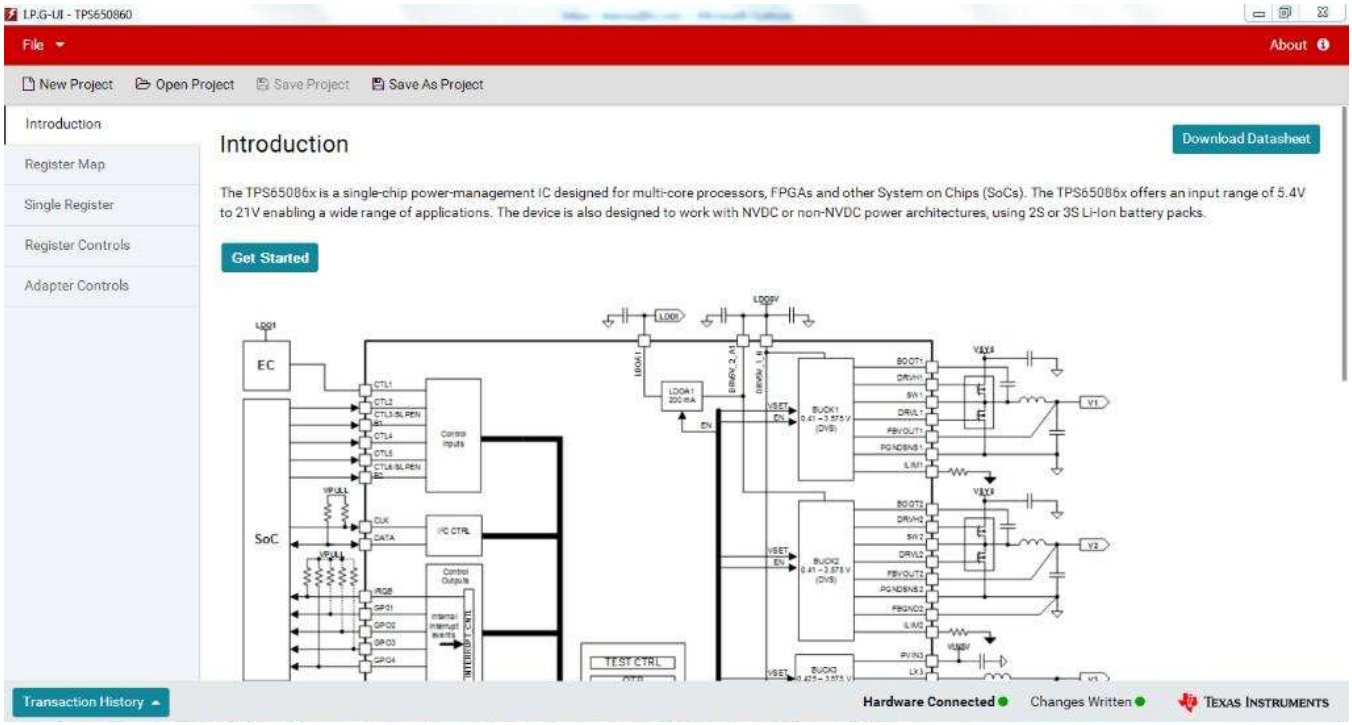

Figure 5. GUI Device Introduction

Finally, clicking on "Get Started" or on "Register Map" takes you to the I²C controls for the device sorted by register address.

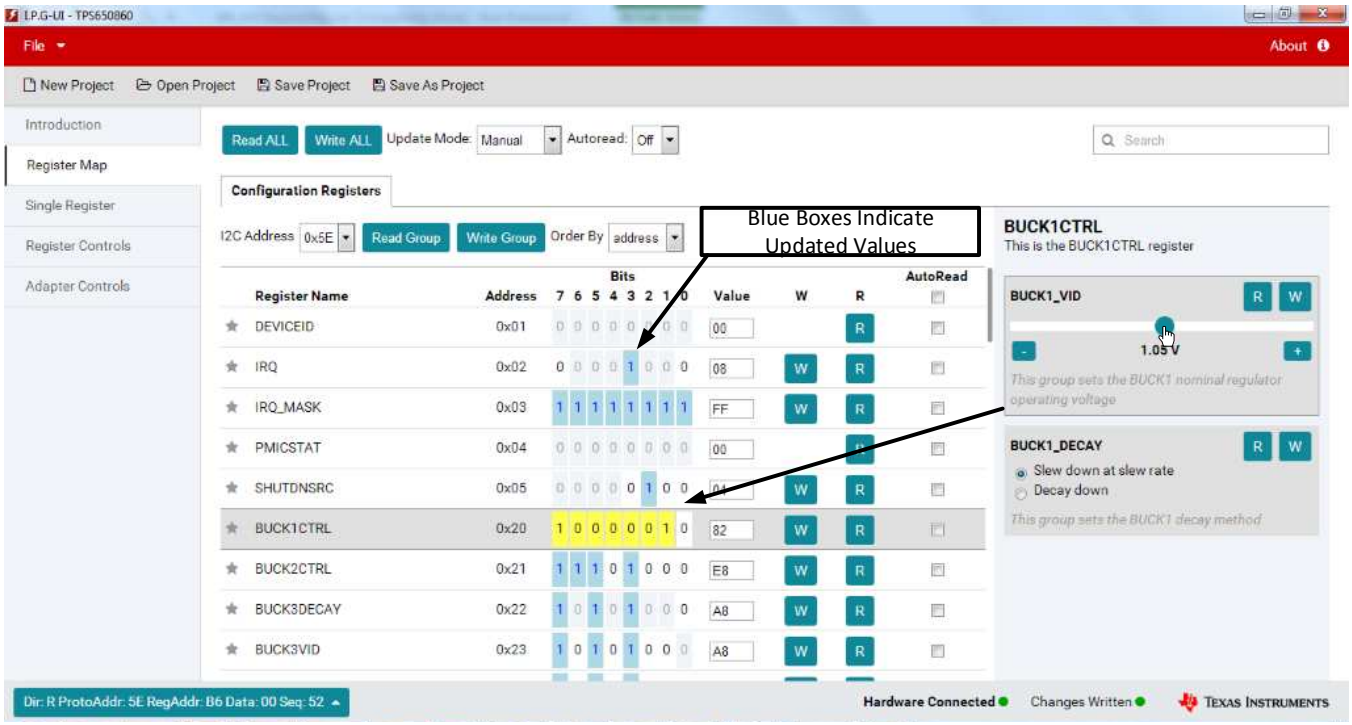

Figure 6. GUI Register Map

Alternatively, the part can be controlled using the "Register Controls" tab to sort by functionality rather than by I²C address location.

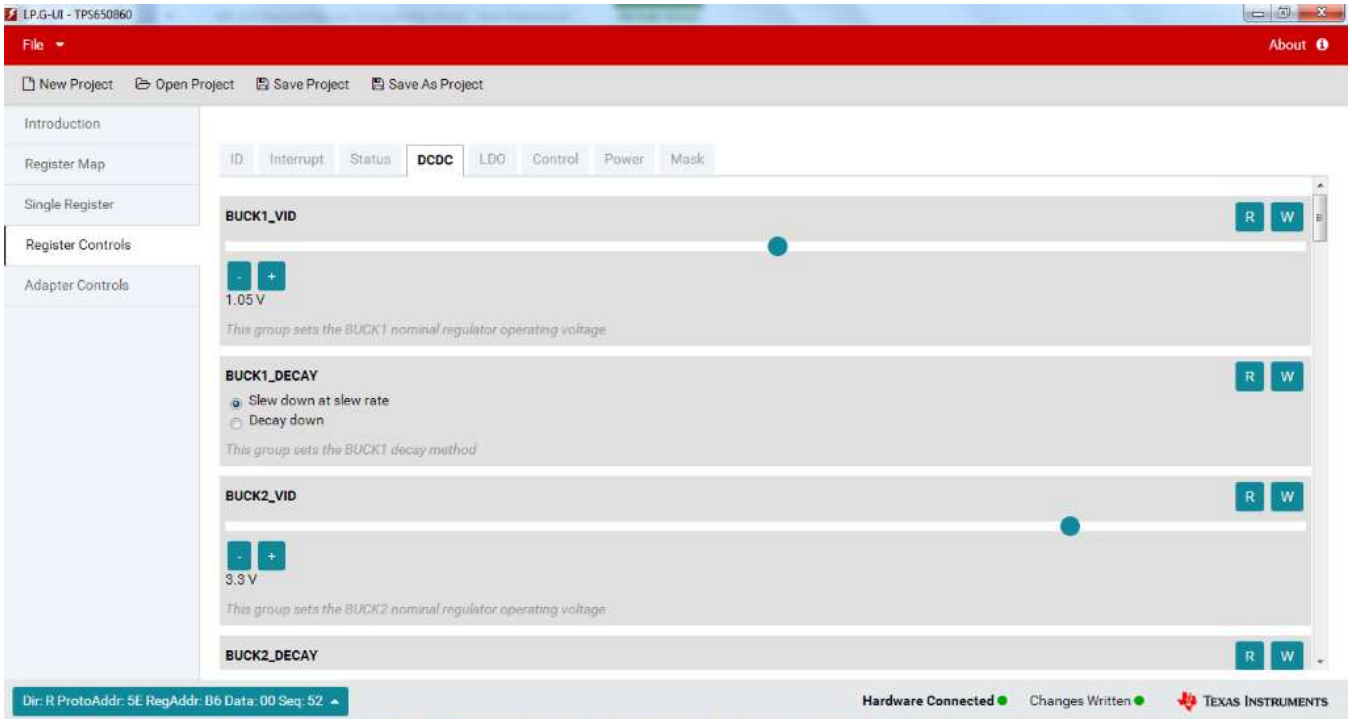

Figure 7. GUI Register Controls

With this information, it is possible to begin evaluating the TPS65086x device.

9 Sample Test Procedure

For reference, a sample procedure for measuring BUCK1 efficiency is described. A similar approach can be utilized for the other rails.

First, the relevant inputs need to be identified. For BUCK1, there are four device level inputs which each have a 0-Ω resistor which can be removed to isolate them:

1. Input to VSYS pin (R10): Powers up the TPS650860 and is used for internal LDOs to power the digital.
2. Input to V5ANA pin (R17): Powers the converters as well as a power path input to the LDO5P0 output pin.
3. Input to the DRV5V_1_6 and DRV5V_2_A1 pins (R8 and R9): Powers the controller drivers and LDOA1.
4. Input to the FET (R19 for BUCK1): Powers the output stage.

In order to measure accurate system level efficiency, all of the above resistors should be removed and external wires (using a 4-wire approach with voltage sense on the input capacitor) added to the board.

For quicker measurements where the accuracy is not as essential, there is a shorter alternative. First, the VSYS pin power draw (1 mA typical) is small and may be neglected if focusing on high load conditions. V5ANA can be powered from the VIN_BUCK345_ANA header and the DRV5V_x_x can be powered from the VIN_DRV header. Finally, the 2-mΩ sense resistor on the FET inputs can be used to sense the input current and a wire can be added to the input capacitor to measure the input voltage. Load should be applied through the screw terminals and output voltage should be sensed using the test points next to the screw terminals. Efficiency should be determined based on the measured output power and input power, not on the assumed values due to IR drops in the wires.

To enable only a single rail, all CTL pins should be low (S1 switches to "ON" - short to GND) and the BUCKx_EN bit located in the I2C_RAIL_ENx register (address 0xA0 and 0xA1) should be set to '1'. For BUCK1 - BUCK3, the voltage can be changed using the BUCKx_VID groups. For BUCK4 - BUCK 6, the voltage can be changed using the BUCKx_SLP_VID groups unless the BUCKx_SLP_EN is disabled first, in which case the BUCKx_VID groups are used as well.

10 Schematics, PCB Layouts, and Bill of Materials

10.1 Schematic

Figure 8 through Figure 13 illustrate the HVL116A schematics.

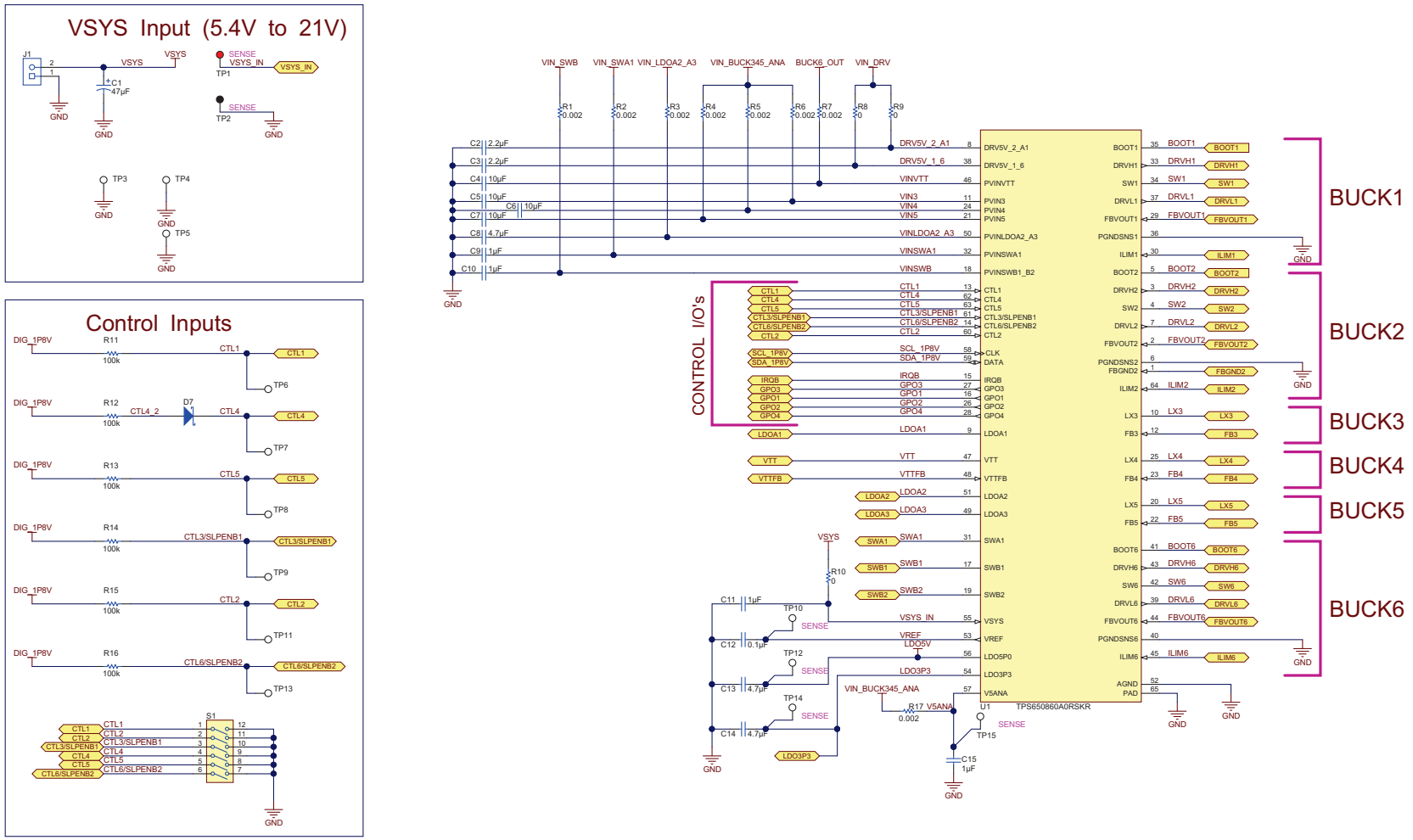

Figure 8. HVL116A Schematic Page 1

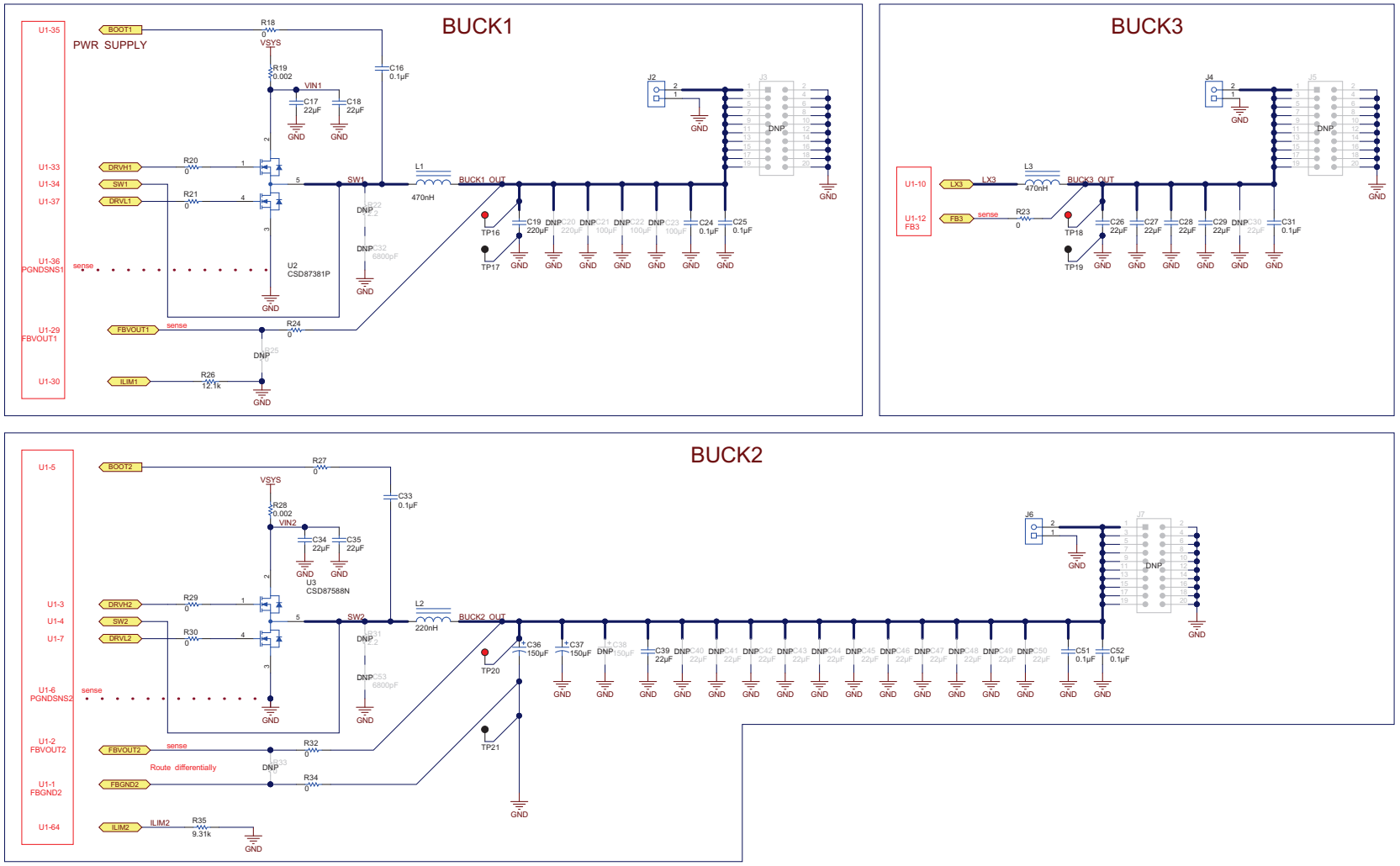

Figure 9. HVL116A Schematic Page 2

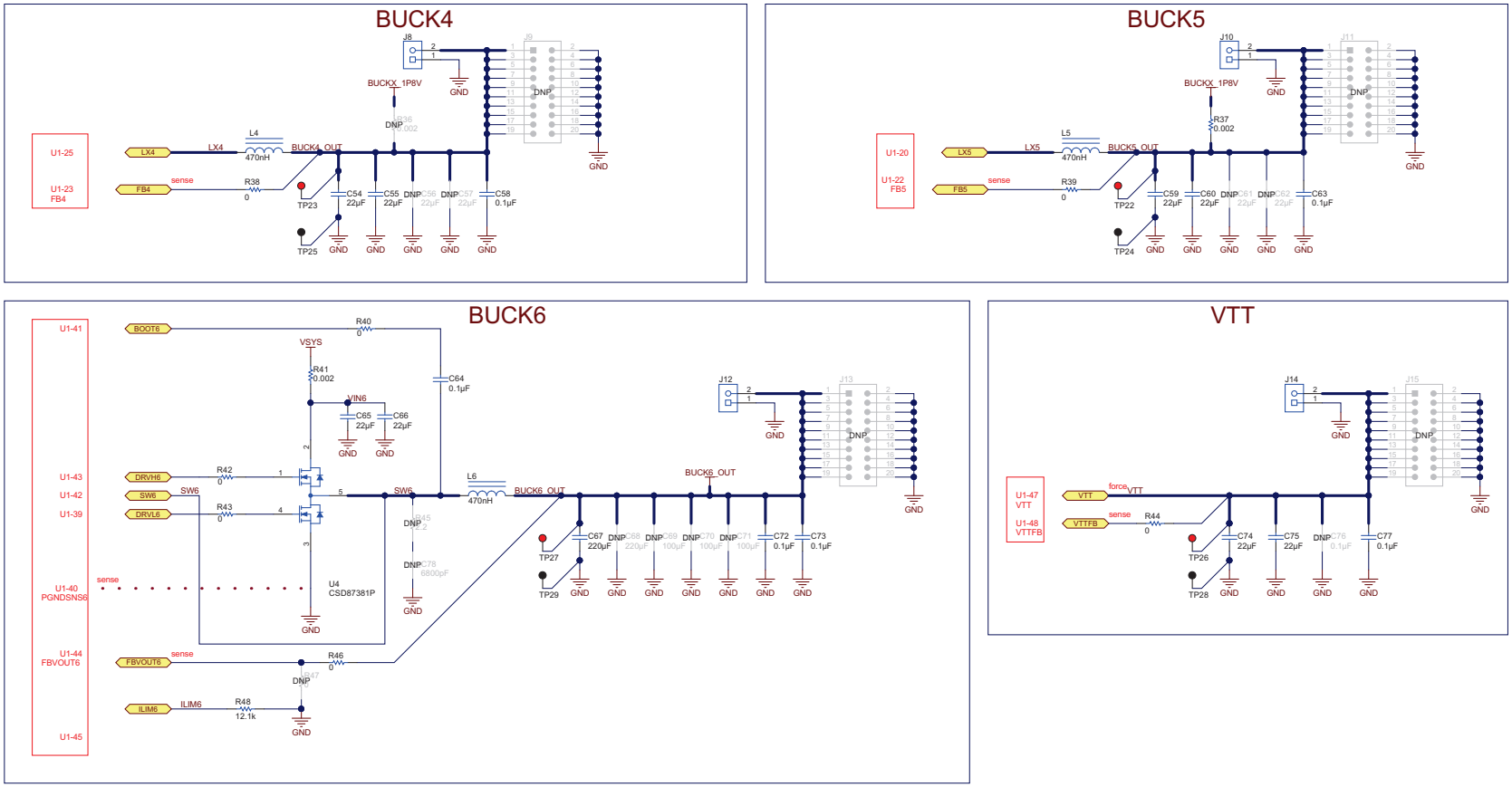

Figure 10. HVL116A Schematic Page 3

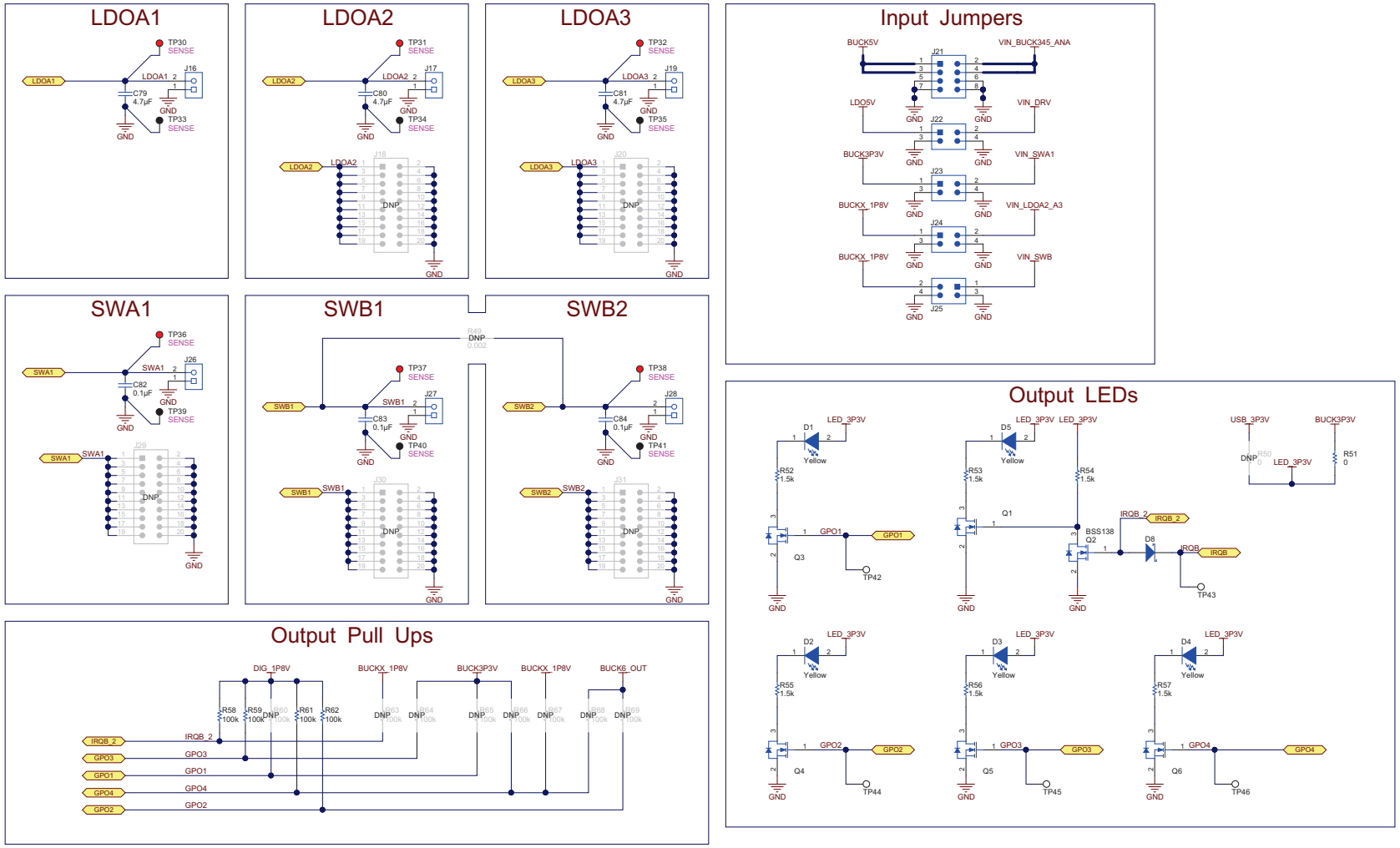

Figure 11. HVL116A Schematic Page 4

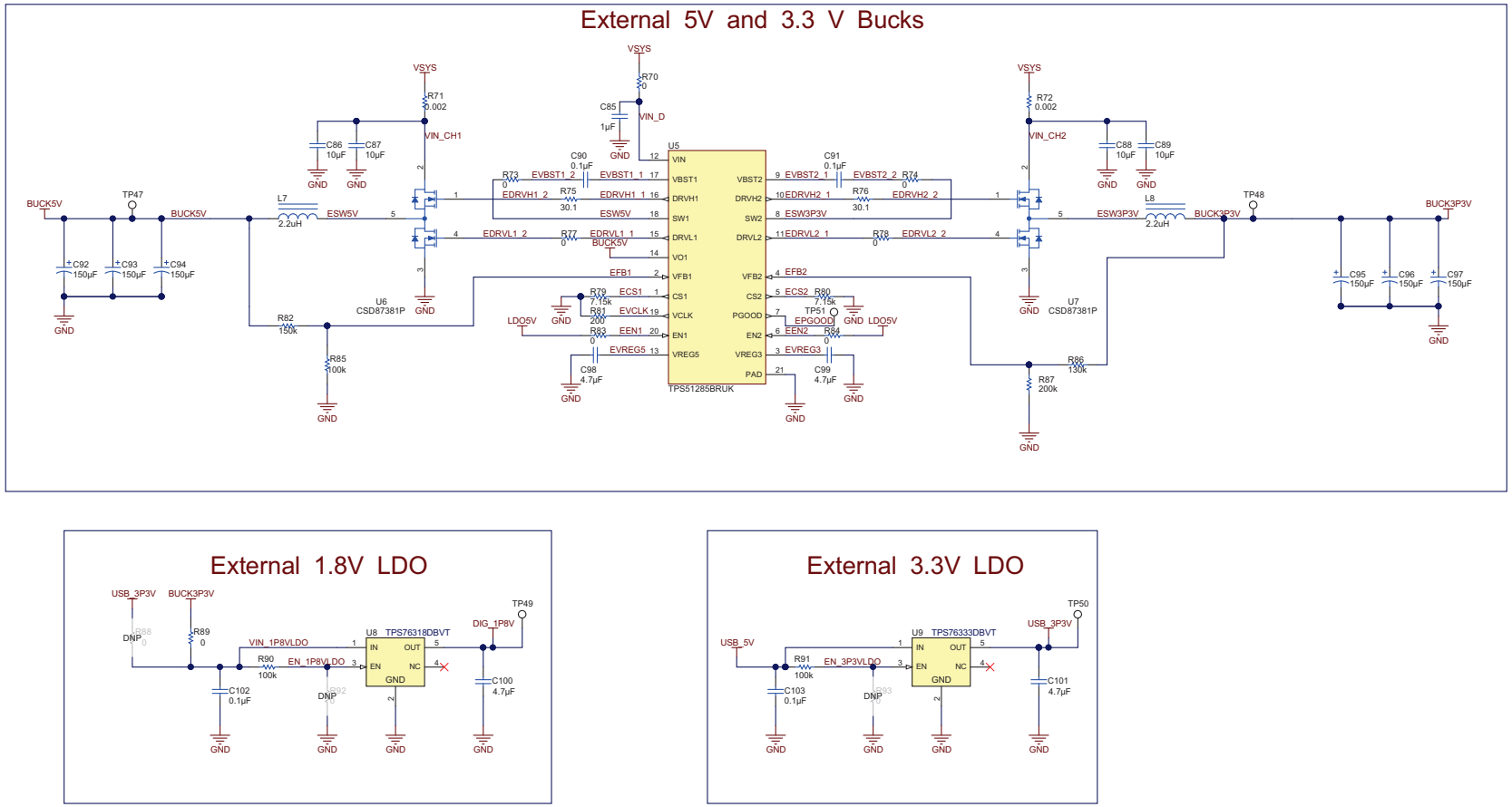

Figure 12. HVL116A Schematic Page 5

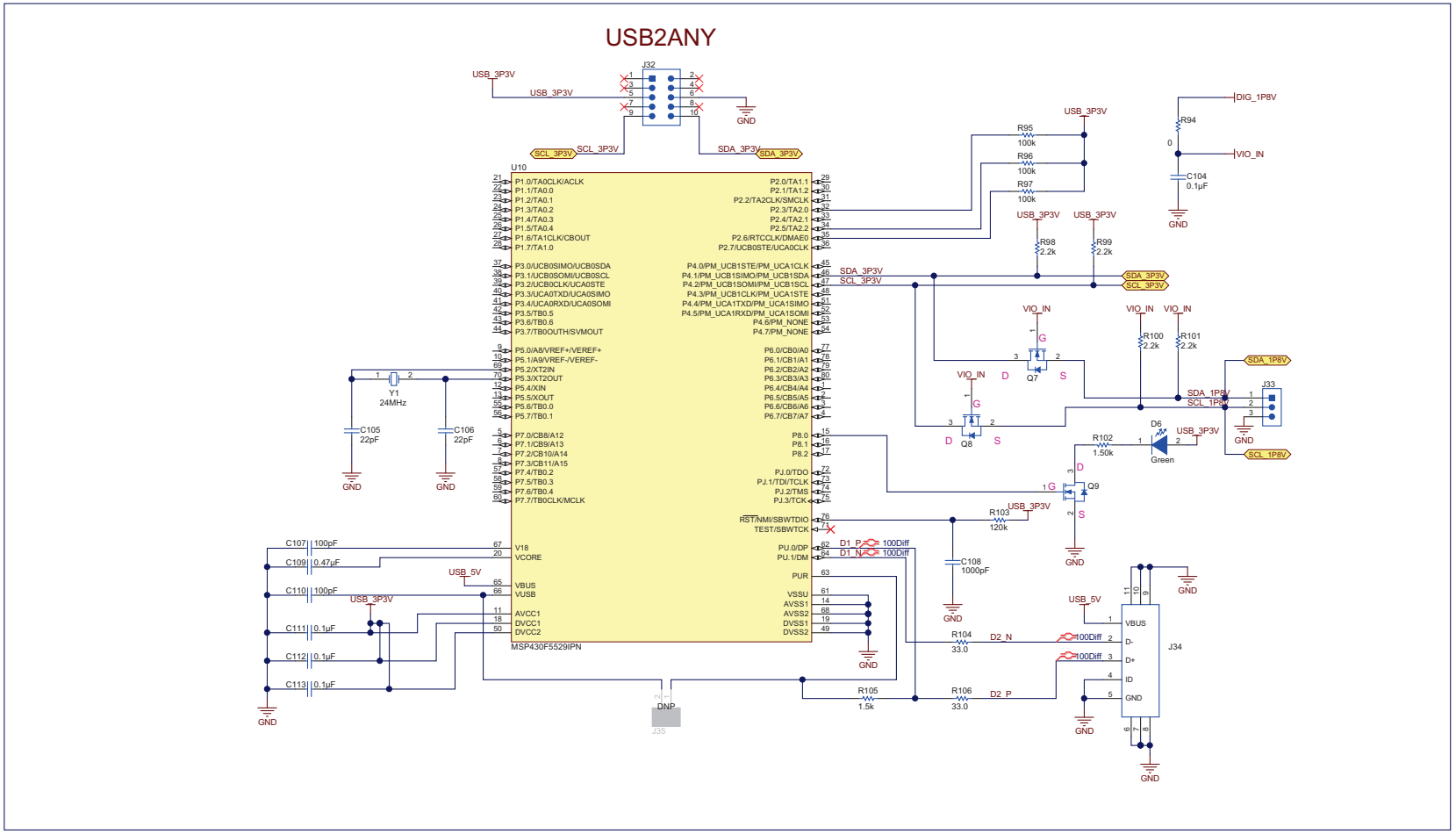

Figure 13. HVL116A Schematic Page 6

10.2 PCB Layouts

Figure 14 through Figure 25 illustrate the HVL116A PCB layouts.

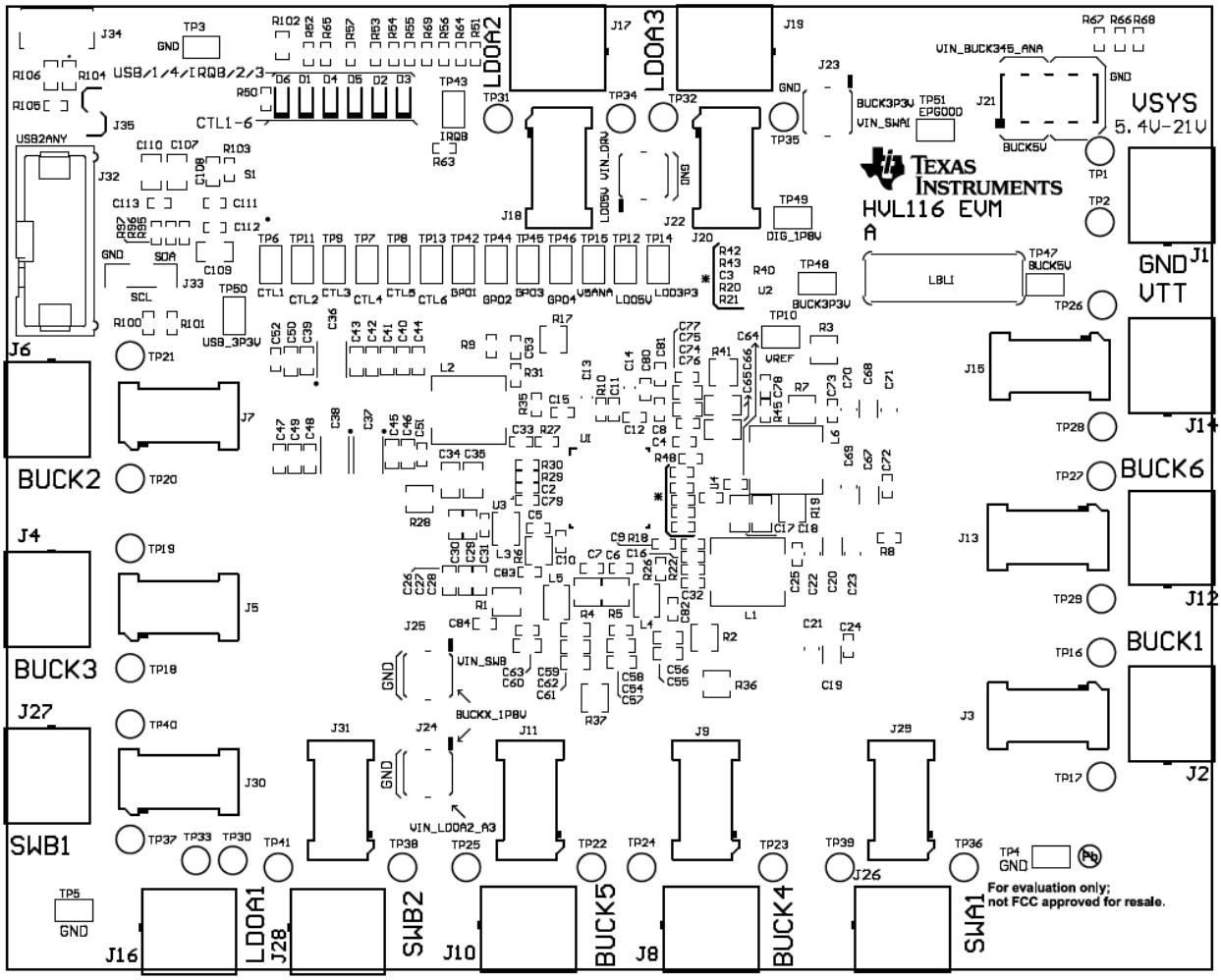

Figure 14. Top Overlay

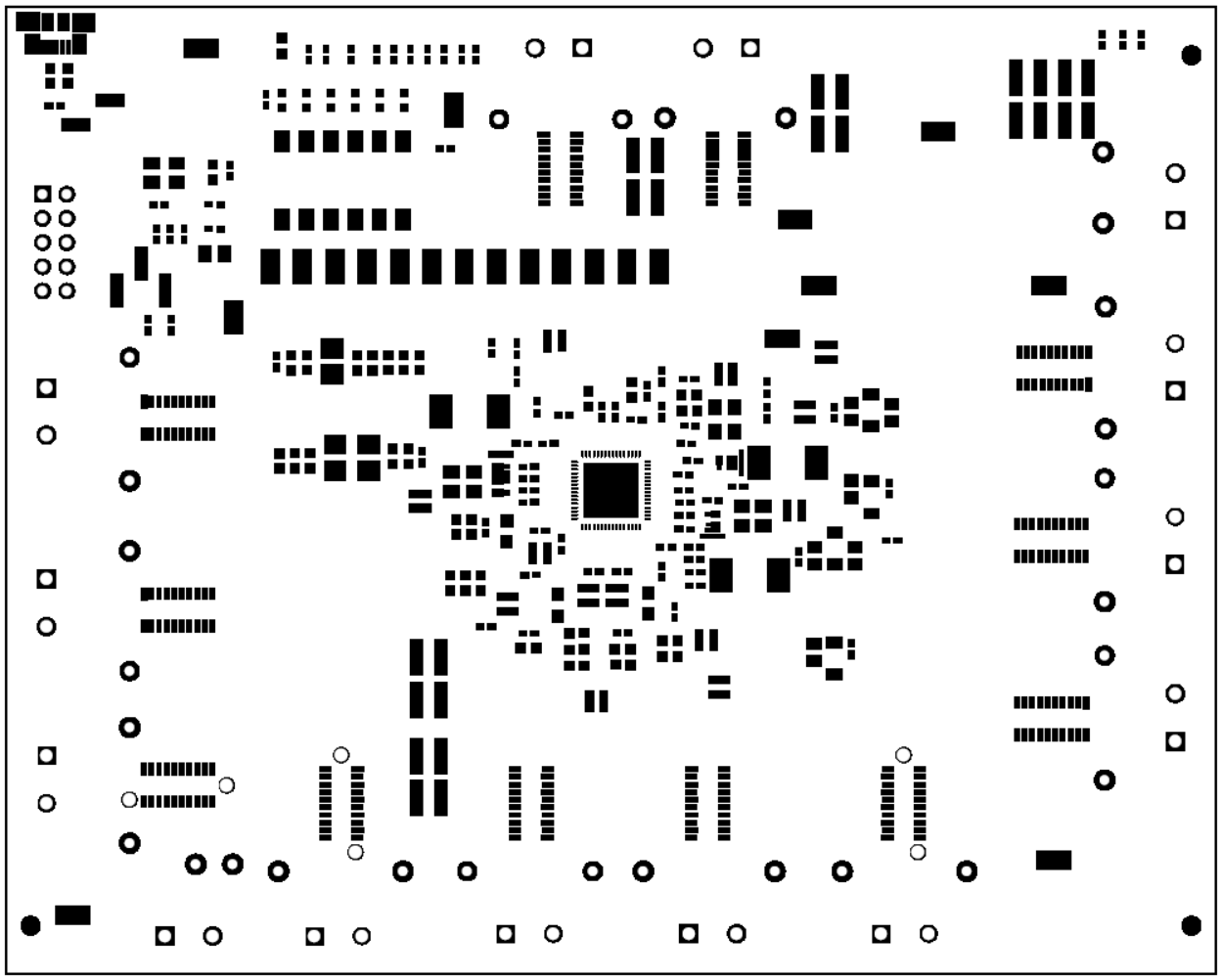

Figure 15. Top Solder Mask

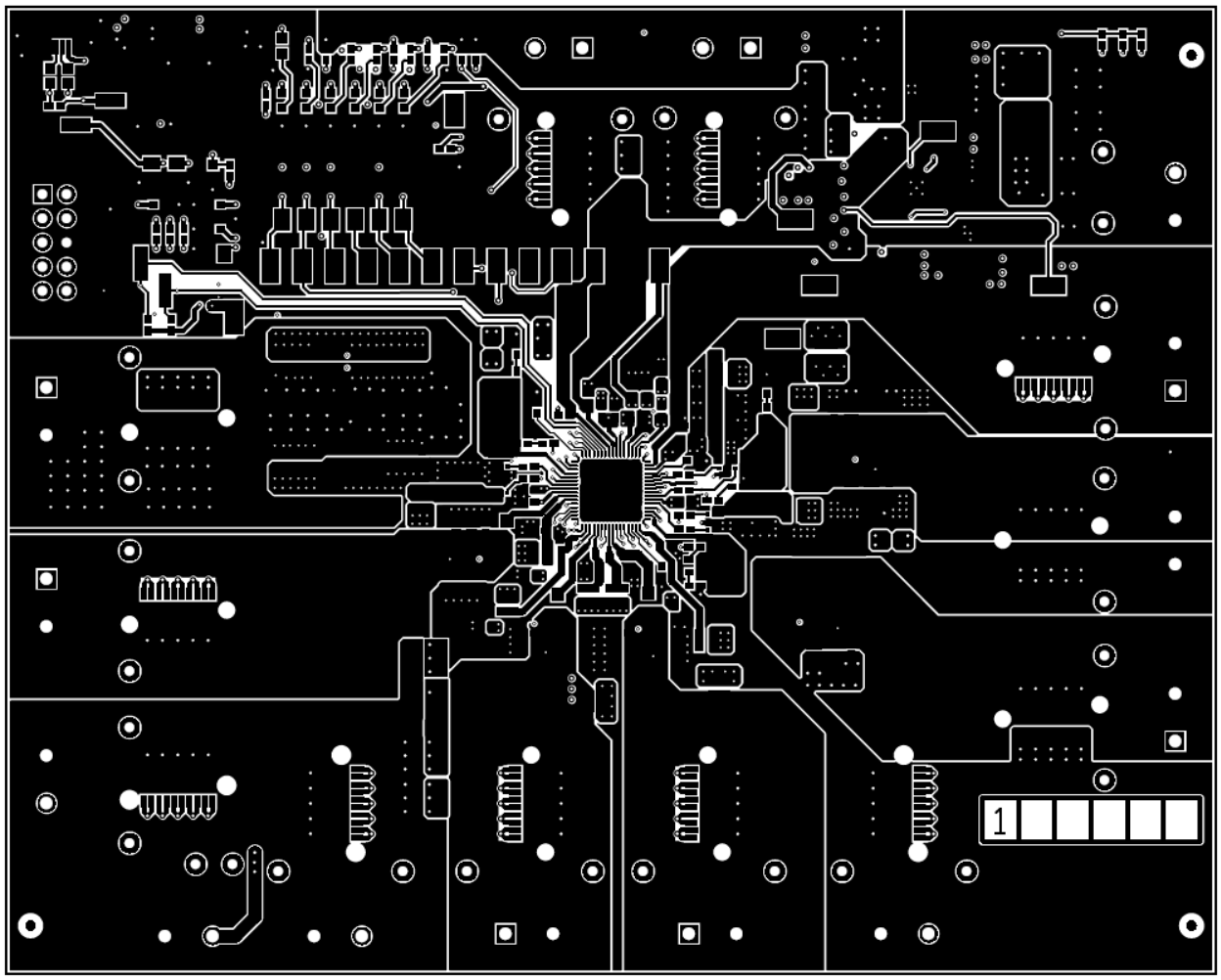

Figure 16. Top Layer

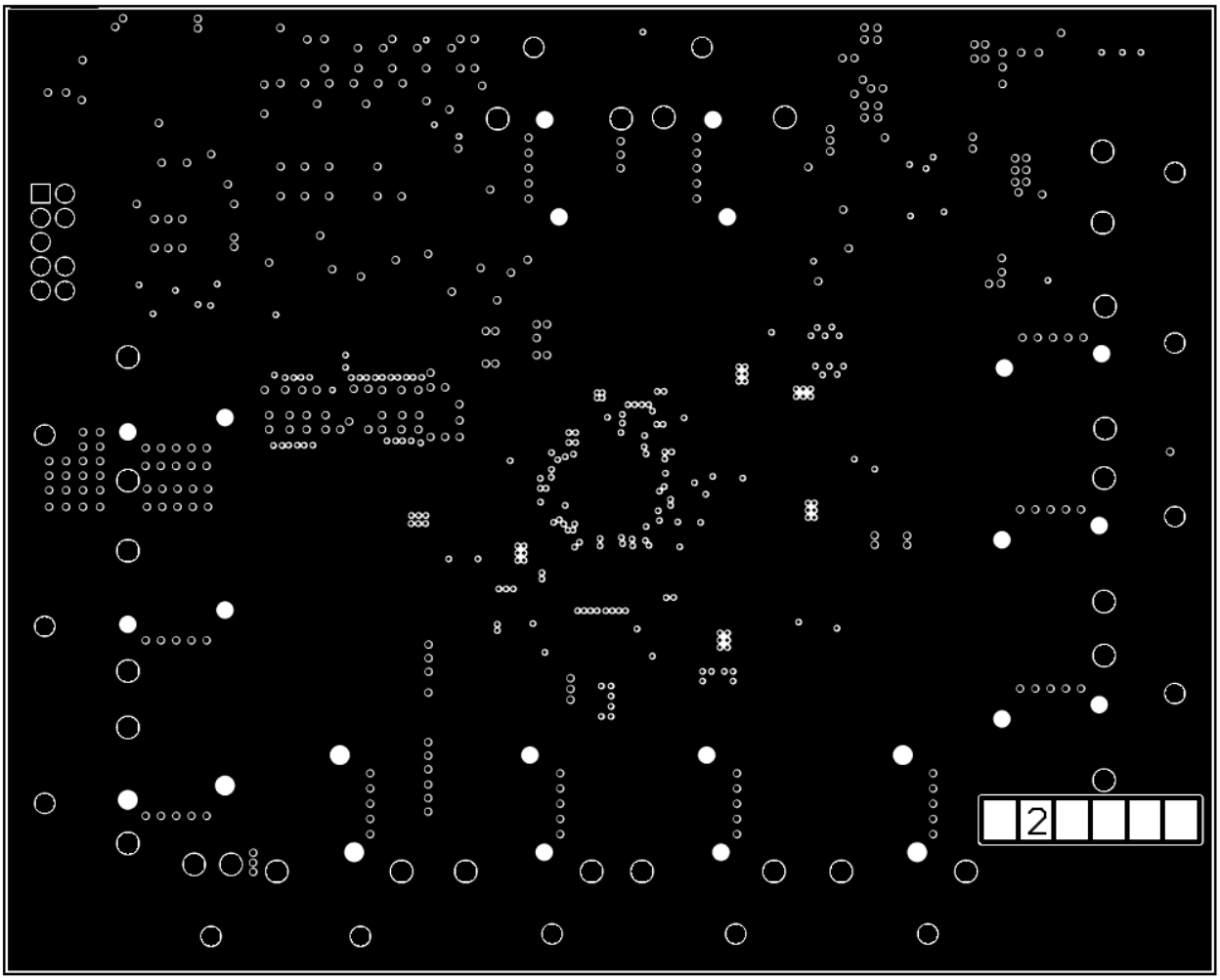

Figure 17. GND Layer

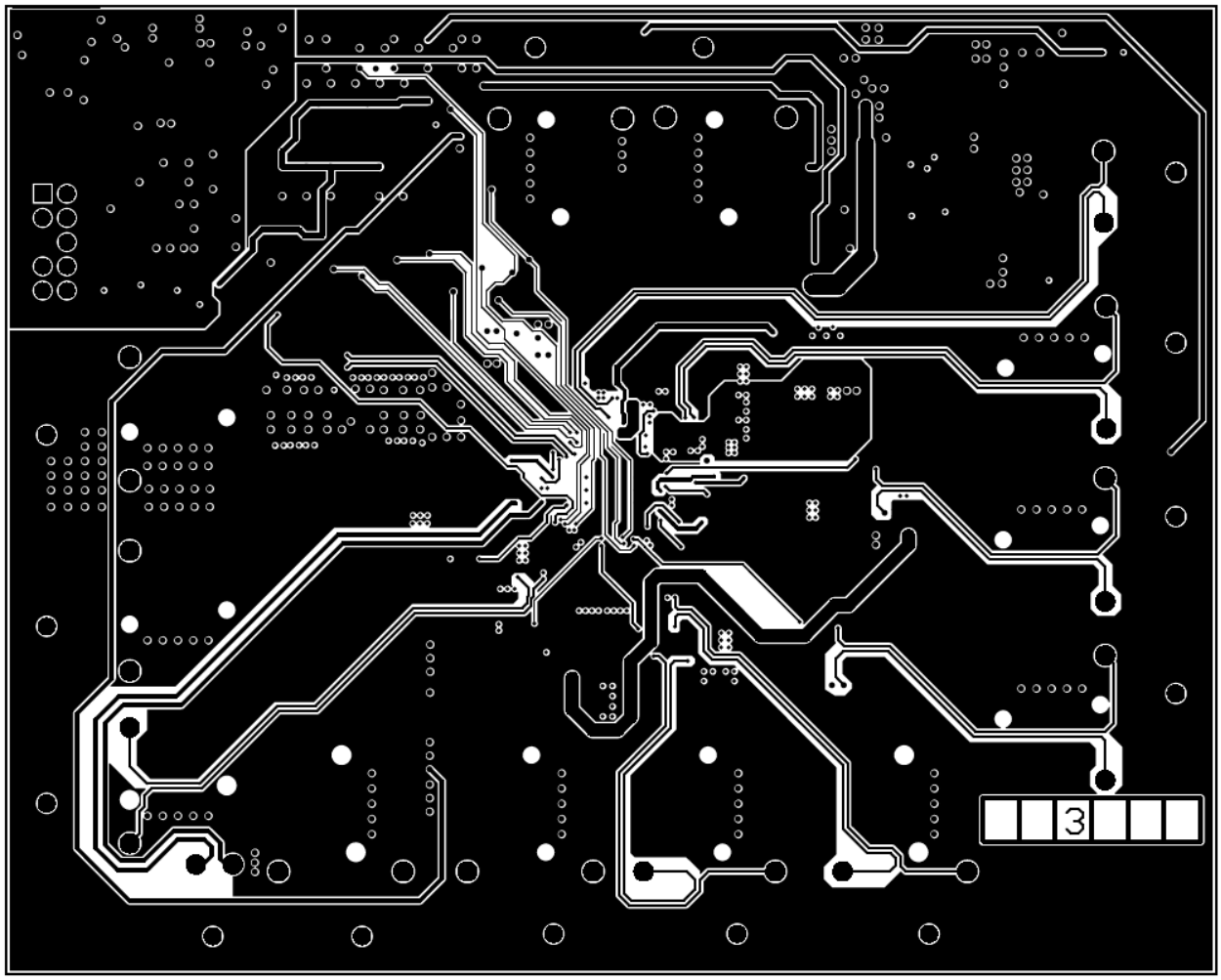

Figure 18. Signal Layer 1

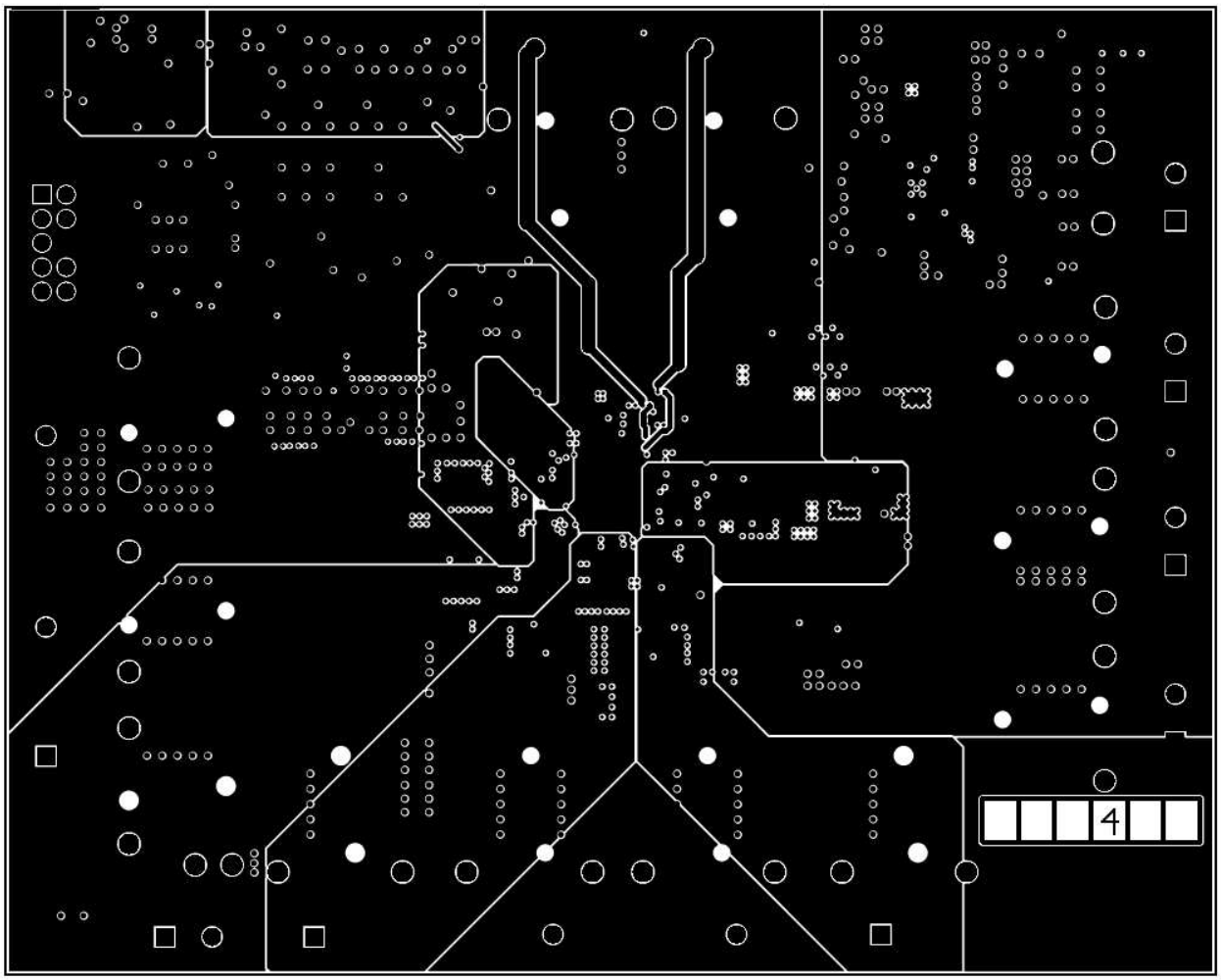

Figure 19. Signal Layer 2

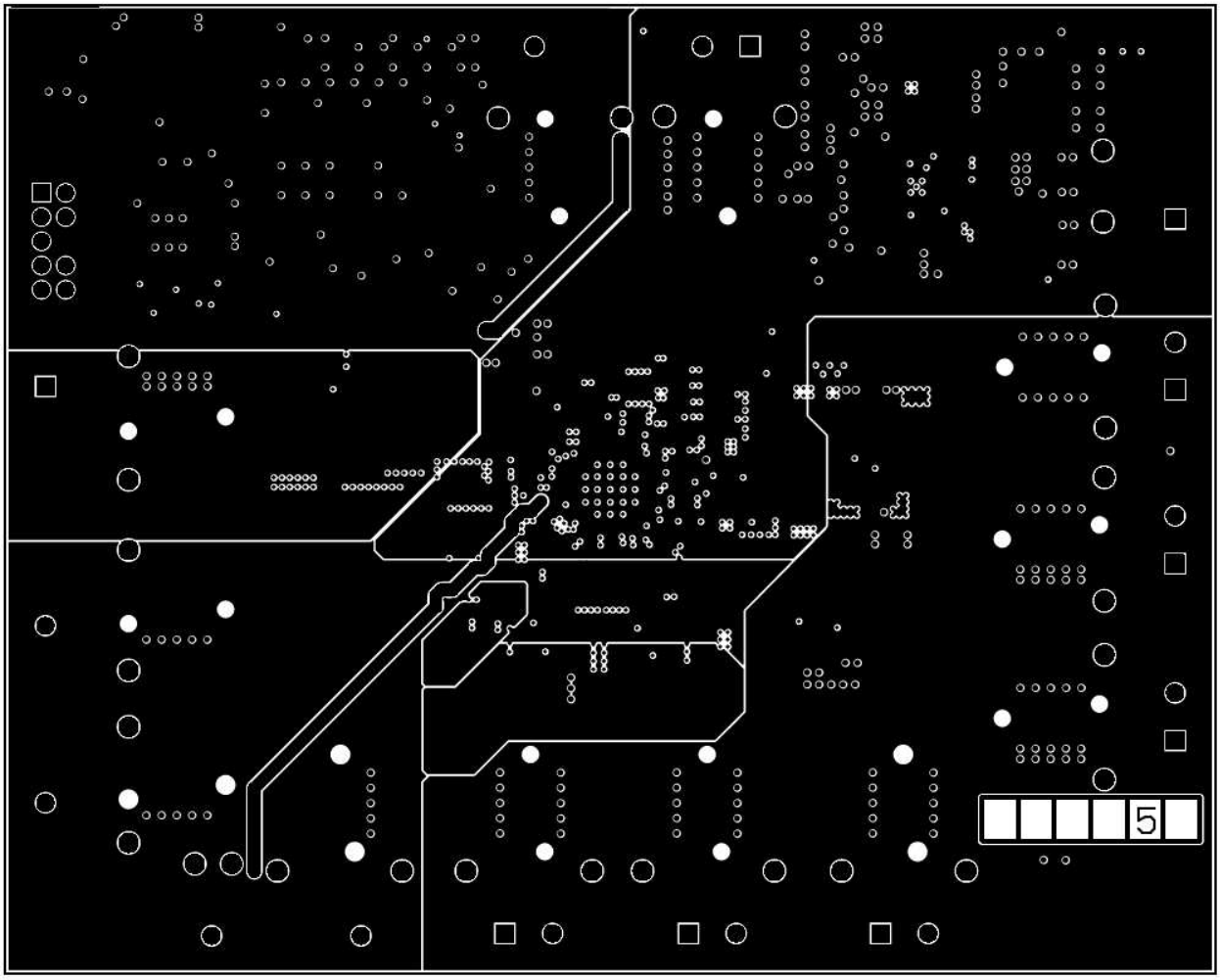

Figure 20. Power Layer

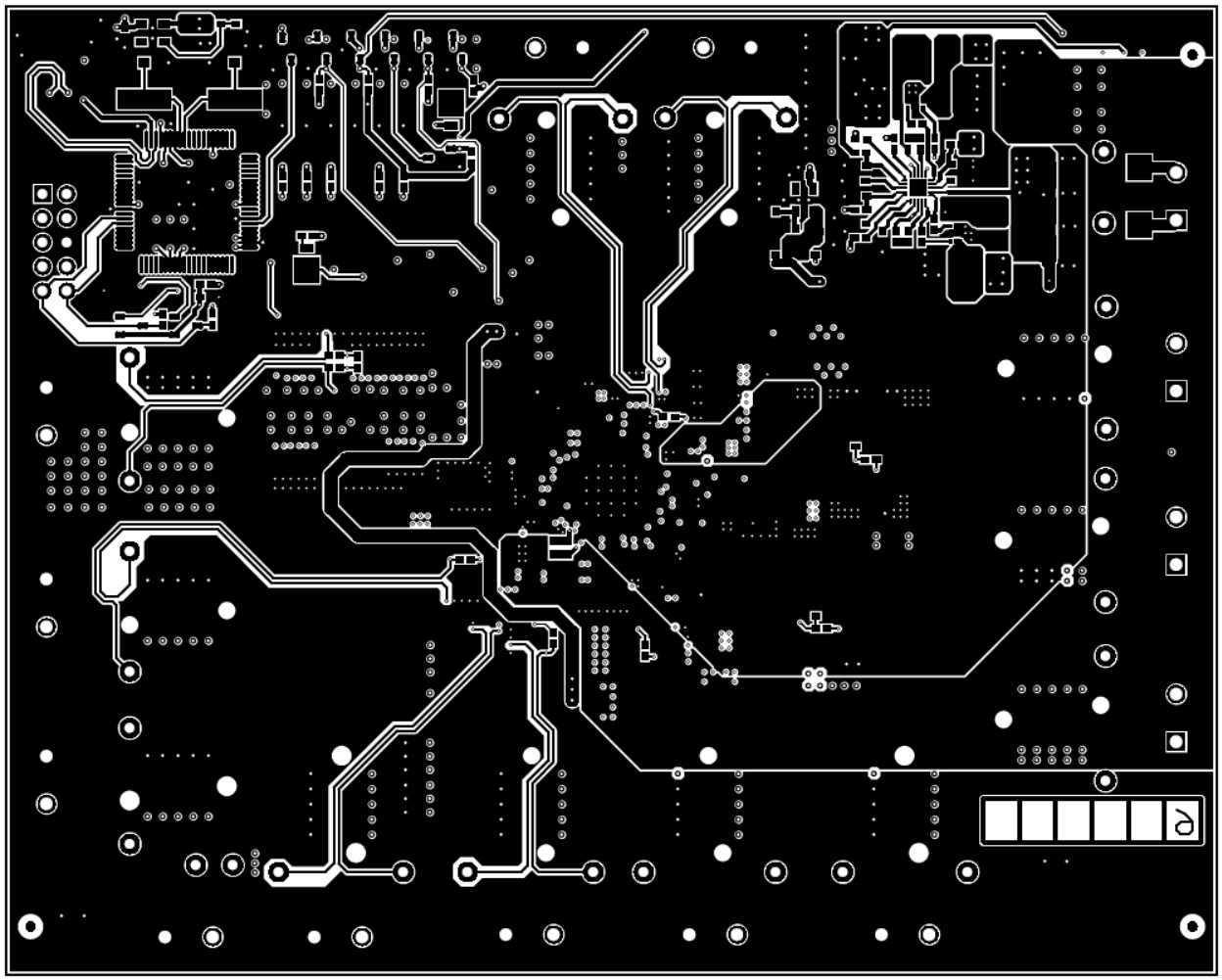

Figure 21. Bottom Layer

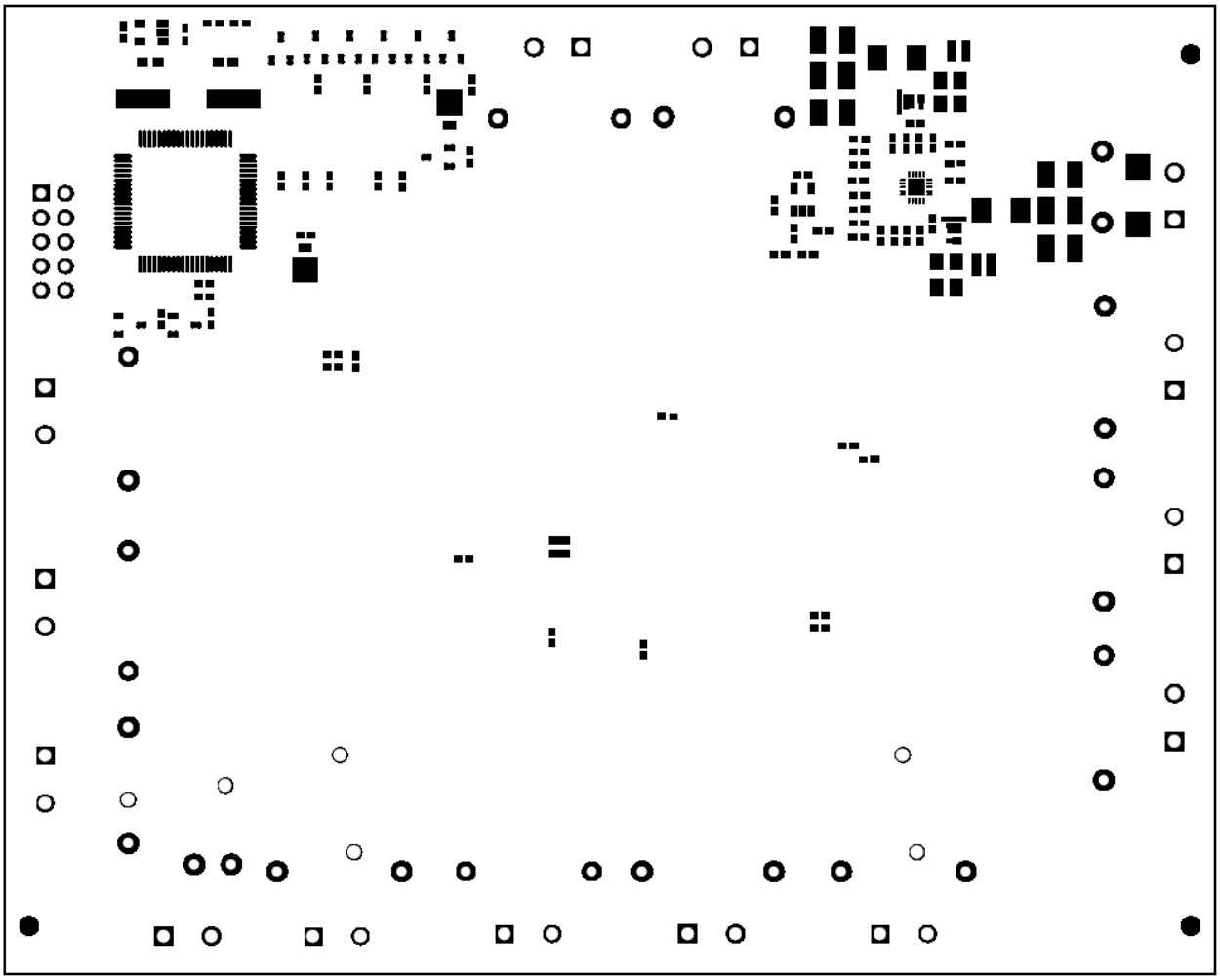

Figure 22. Bottom Solder Mask

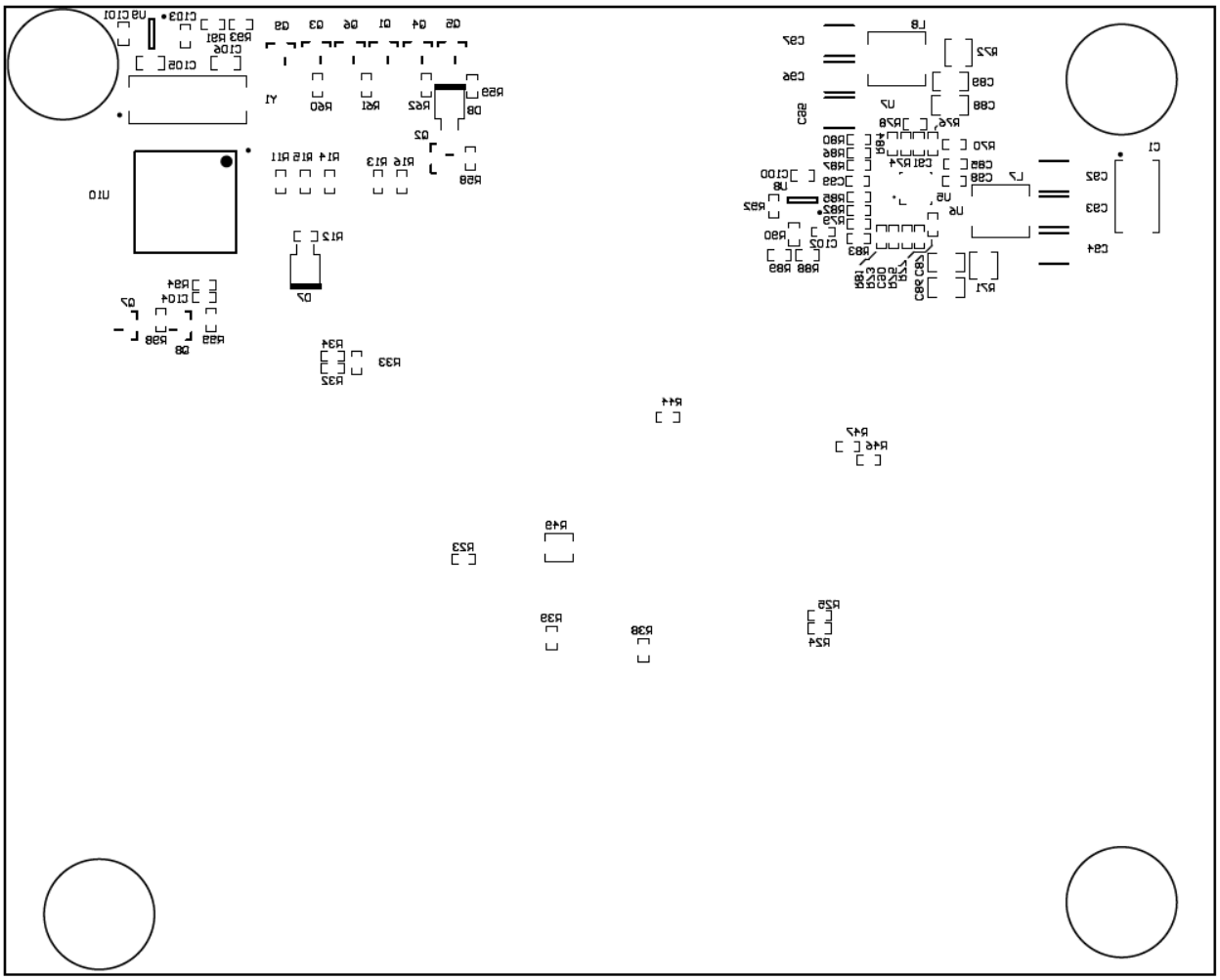

Figure 23. Bottom Silk Overlay

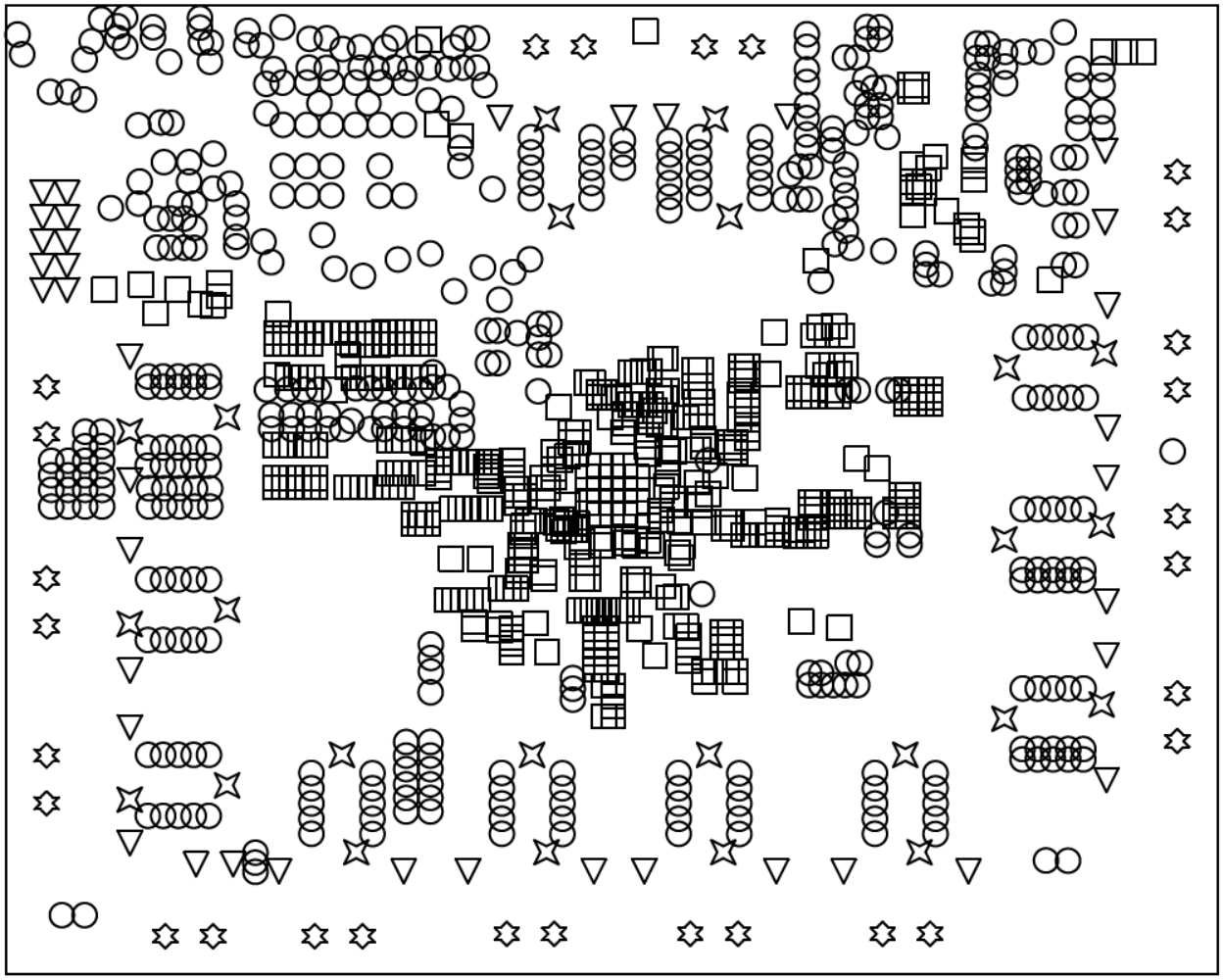

Figure 24. Drill Drawing

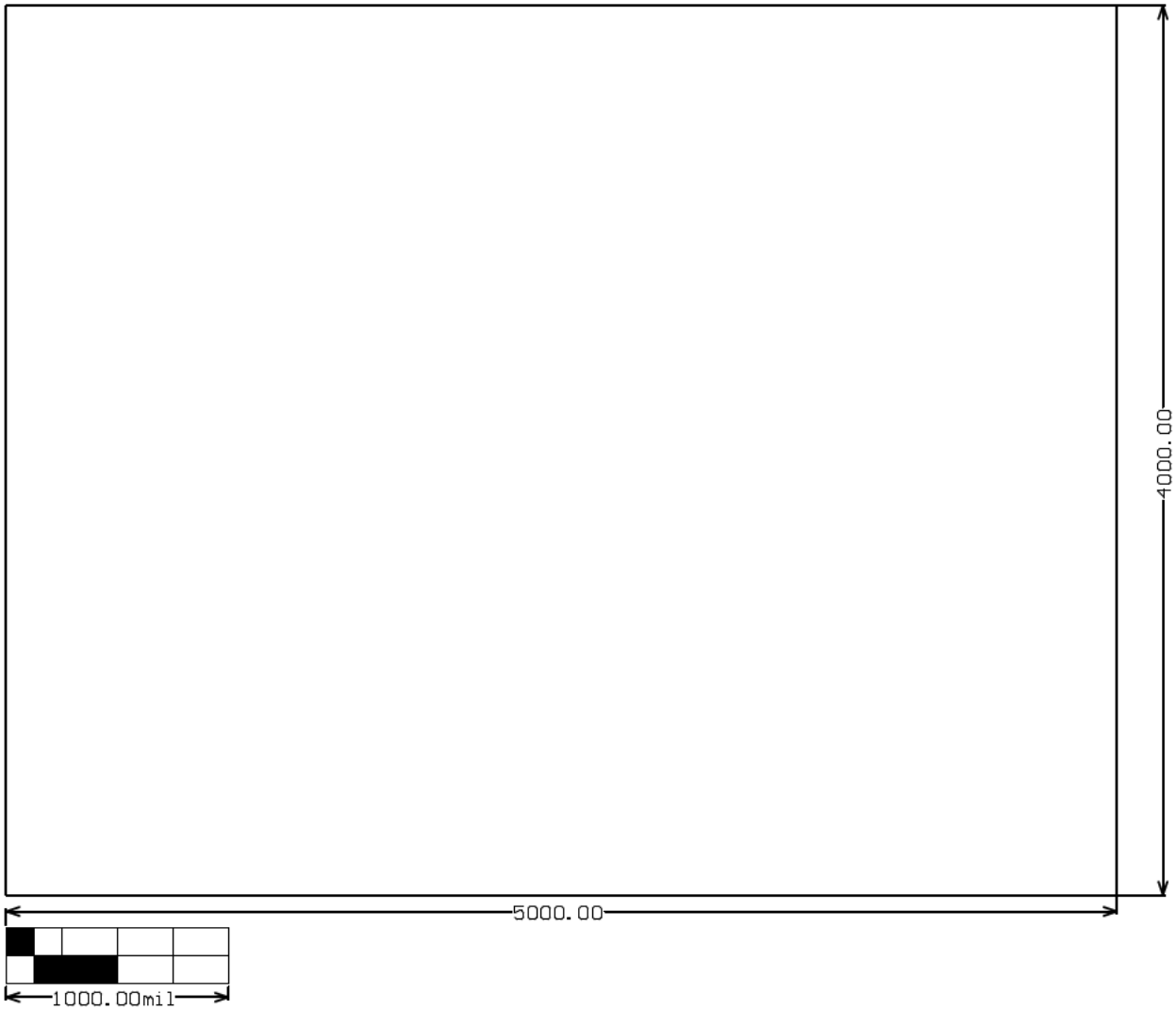

Figure 25. Board Dimensions

10.3 Bill of Materials

Table 4 lists the HVL116A bill of materials.

Table 4. HVL116A Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		HVL116 EVM	Any
C1	1	47uF	CAP, TA, 47 µF, 35 V, +/- 10%, 0.3 ohm, SMD	7343-43	T495X476K035ATE300	Kemet
C2, C3	2	2.2uF	CAP, CERM, 2.2 µF, 6.3 V, +/- 10%, X5R, 0402	0402	CL05A225KQ5NNNC	Samsung
C4, C5, C6, C7	4	10uF	CAP, CERM, 10 µF, 10 V, +/- 20%, X5R, 0402	0402	CL05A106MP5NUNC	Samsung Electro-Mechanics
C8, C79, C80, C81, C98, C99, C100, C101	8	4.7uF	CAP, CERM, 4.7 µF, 6.3 V, +/- 20%, X5R, 0402	0402	GRM155R60J475ME47D	Murata
C9, C10, C15	3	1uF	CAP, CERM, 1 µF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A105KE15D	Murata
C11, C85	2	1uF	CAP, CERM, 1 µF, 35 V, +/- 10%, X5R, 0402	0402	GRM155R6YA105KE11D	Murata
C12, C16, C24, C25, C31, C33, C51, C52, C58, C63, C64, C72, C73, C77, C82, C83, C84, C90, C91, C102, C103, C104, C111, C112, C113	25	0.1uF	CAP, CERM, 0.1 µF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A104KA01D	Murata
C13, C14	2	4.7uF	CAP, CERM, 4.7 µF, 10 V, +/- 20%, X5R, 0603_095	0603_095	GRM188R61A475ME15	Murata
C17, C18, C34, C35, C65, C66	6	22uF	CAP, CERM, 22 µF, 25 V, +/- 20%, X5R, 0805	0805	GRM21BR61E226ME44	Murata
C19, C67	2	220uF	CAP, CERM, 220 µF, 4 V, +/- 20%, X5R, 1206_190	1206_190	GRM31CR60G227ME11L	Murata
C26, C27, C28, C29, C39, C74, C75	7	22uF	CAP, CERM, 22 µF, 6.3 V, +/- 20%, X5R, 0603	0603	GRM188R60J226MEA0J	Murata
C36, C37	2	150uF	CAP, TA, 150 µF, 6.3 V, +/- 20%, 0.025 ohm, SMD	3528-21	T520B157M006ATE025	Kemet
C54, C55, C59, C60	4	22uF	CAP, CERM, 22 µF, 6.3 V, +/- 20%, X5R, 0603	0603	C1608X5R0J226M080AC	TDK
C86, C87, C88, C89	4	10uF	CAP, CERM, 10 µF, 35 V, +/- 10%, X5R, 0805	0805	GRM21BR6YA106KE43L	Murata
C92, C93, C94, C95, C96, C97	6	150uF	CAP, Tantalum Polymer, 150 µF, 6.3 V, +/- 20%, 0.07 ohm, 3528-15 SMD	3528-15	6TPG150M	Panasonic
C105, C106	2	22pF	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	06035A220JAT2A	AVX
C107, C110	2	100pF	CAP, CERM, 100 pF, 50 V, +/- 10%, C0G/NP0, 0805	0805	C0805C101K5GACTU	Kemet
C108	1	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C102K5RACTU	Kemet
C109	1	0.47uF	CAP, CERM, 0.47 µF, 16 V, +/- 5%, X7R, 0805	0805	0805YC474JAT2A	AVX
D1, D2, D3, D4, D5	5	Yellow	LED, Yellow, SMD	LED_0603	150060YS75000	Wurth Elektronik
D6	1	Green	LED, Green, SMD	LED_0603	150060VS75000	Wurth Elektronik
D7, D8	2	10V	Diode, Schottky, 10 V, 1 A, POWERMITE	POWERMITE	MBRM110LT1G	ON Semiconductor
FID1, FID2, FID3, FID4, FID5, FID6	6		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
H5	1		USB A MALE TO MICRO B MALE 6'	-	3025013-06	Qualtek
J1, J2, J4, J6, J8, J10, J12, J14, J16, J17, J19, J26, J27, J28	14		Terminal Block, 2x1, 5mm, Green, TH	Terminal Block, 2x1, 5mm, TH	1935776	Phoenix Contact
J21	1		Header, 100mil, 4x2, Gold, SMT	Header, 100mil, 4x2, SMT	0015910080	Molex
J22, J23, J24, J25	4		Header, 100mil, 2x2, Tin, SMT	2x2 100mil Tin Header	15-91-2040	Molex
J32	1		Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	5x2 Shrouded header	N2510-6002-RB	3M
J33	1		Header, 100mil, 3x1, Gold, SMT	Samtec_TSM-103-01-X-SV	TSM-103-01-L-SV	Samtec

Table 4. HVL116A Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
J34	1		Connector, Receptacle, Micro-USB Type B, R/A, Bottom Mount SMT	7.5x2.45x5mm	0473460001	Molex
L1, L6	2	470nH	Inductor, Drum Core, Powdered Iron, 470 nH, 11 A, 0.0073 ohm, SMD	7.05 x 1.6 x 6.6mm	PIMB061H-R47MS	Cyntec
L2	1	220nH	Inductor, Ferrite, 220 nH, 21 A, 0.0032 ohm, SMD	7x2.2x6.6mm	PIMB062D-R22MS	Cyntec
L3, L4, L5	3	470nH	Inductor, Drum Core, Powdered Iron, 470 nH, 4.5 A, 0.025 ohm, SMD	Inductor, 3.2x1.2x2.5mm	PIFE32251B-R47MS	Cyntec
L7, L8	2	2.2uH	Inductor, Drum Core, Powdered Iron, 2.2 µH, 5 A, 0.03 ohm, SMD	Inductor, 5.2x1.6x5.2mm	PIMB051H-2R2MS	Cyntec
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650"H x 0.200"W	THT-14-423-10	Brady
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9	9	50V	MOSFET, N-CH, 50 V, 0.22 A, SOT-23	SOT-23	BSS138	Fairchild Semiconductor
R1, R2, R3, R4, R5, R6, R7, R17, R19, R28, R37, R41, R71, R72	14	0.002	RES, 0.002, 2%, 1 W, 0508	0508	KRL2012E-M-R002-G-T5	Susumu Co Ltd
R8, R9, R10, R18, R20, R21, R23, R24, R27, R29, R30, R32, R34, R38, R39, R40, R42, R43, R44, R46, R51, R70, R73, R74, R77, R78, R83, R84, R89, R94	30	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R11, R12, R13, R14, R15, R16, R90, R91, R95, R96, R97	11	100k	RES, 100 k, 5%, 0.063 W, 0402	0402	CRCW0402100KJNED	Vishay-Dale
R26, R48	2	12.1k	RES, 12.1 k, 1%, 0.063 W, 0402	0402	CRCW040212K1FKED	Vishay-Dale
R35	1	13.3k	RES, 13.3 k, 1%, 0.063 W, 0402	0402	CRCW040213K3FKED	Vishay-Dale
R52, R53, R54, R55, R56, R57, R105	7	1.5k	RES, 1.5 k, 5%, 0.063 W, 0402	0402	CRCW04021K50JNED	Vishay-Dale
R58, R59, R61, R62, R85	5	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale
R75, R76	2	30.1	RES, 30.1, 1%, 0.063 W, 0402	0402	CRCW040230R1FKED	Vishay-Dale
R79, R80	2	7.15k	RES, 7.15 k, 1%, 0.063 W, 0402	0402	CRCW04027K15FKED	Vishay-Dale
R81	1	200	RES, 200, 5%, 0.063 W, 0402	0402	CRCW0402200RJNED	Vishay-Dale
R82	1	150k	RES, 150 k, 1%, 0.063 W, 0402	0402	CRCW0402150KFKED	Vishay-Dale
R86	1	130k	RES, 130 k, 1%, 0.063 W, 0402	0402	CRCW0402130KFKED	Vishay-Dale
R87	1	200k	RES, 200 k, 1%, 0.063 W, 0402	0402	CRCW0402200KFKED	Vishay-Dale
R98, R99, R100, R101	4	2.2k	RES, 2.2 k, 5%, 0.063 W, 0402	0402	CRCW04022K20JNED	Vishay-Dale
R102	1	1.50k	RES, 1.50 k, 1%, 0.1 W, 0603	0603	CRCW06031K50FKEA	Vishay-Dale
R103	1	120k	RES, 120 k, 1%, 0.063 W, 0402	0402	CRCW0402120KFKED	Vishay-Dale
R104, R106	2	33.0	RES, 33.0, 1%, 0.1 W, 0603	0603	CRCW060333R0FKEA	Vishay-Dale
S1	1		Switch, SPST 6Pos, SMT	10.4x3.9x9.3mm	SDA06H1SBD	C&K Components
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6	6		Shunt, 100mil, Gold plated, Black	Shunt 2 pos. 100 mil	881545-2	TE Connectivity
TP1, TP16, TP18, TP20, TP22, TP23, TP26, TP27, TP30, TP31, TP32, TP36, TP37, TP38	14	Red	Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone
TP2, TP17, TP19, TP21, TP24, TP25, TP28, TP29, TP33, TP34, TP35, TP39, TP40, TP41	14	Black	Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone

Table 4. HVL116A Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP42, TP43, TP44, TP45, TP46, TP47, TP48, TP49, TP50, TP51	23	SMT	Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone
U1	1		Configurable Multi-Rail PMU for Multi-Core Processor, RSK0064C	RSK0064C	TPS650860A0RSKR	Texas Instruments
U2, U4, U6, U7	4		Synchronous Buck NexFET Power Block II, MPC0005A	MPC0005A	CSD87381P	Texas Instruments
U3	1		Synchronous Buck NexFET Power Block II, MPA0005A	MPA0005A	CSD87588N	Texas Instruments
U5	1		Ultra-Low Quiescent (ULQ(TM)) Dual Synchronous Step-Down Controller with 5V and 3.3V LDOs, RUK0020B	RUK0020B	TPS51285BRUK	Texas Instruments
U8	1		Single Output LDO, 150 mA, Fixed 1.8 V Output, 2.7 to 10 V Input, with Low IQ, 5-pin SOT-23 (DBV), -40 to 125 degC, Green (RoHS & no Sb/Br)	DBV0005A	TPS76318DBVT	Texas Instruments
U9	1		Single Output LDO, 150 mA, Fixed 3.3 V Output, 2.7 to 10 V Input, with Low IQ, 5-pin SOT-23 (DBV), -40 to 125 degC, Green (RoHS & no Sb/Br)	DBV0005A	TPS76333DBVT	Texas Instruments
U10	1		Mixed Signal MicroController, PN0080A	PN0080A	MSP430F5529IPN	Texas Instruments
Y1	1		Crystal, 24.000MHz, 20pF, SMD	Crystal, 11.4x4.3x3.8mm	ECS-240-20-5PX-TR	ECS Inc.
C20, C68	0	220uF	CAP, CERM, 220 µF, 4 V, +/- 20%, X5R, 1206_190	1206_190	GRM31CR60G227ME11L	Murata
C21, C22, C23, C69, C70, C71	0	100uF	CAP, CERM, 100 µF, 6.3 V, +/- 20%, X5R, 0805	0805	GRM21BR60J107M	Murata
C30, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50	0	22uF	CAP, CERM, 22 µF, 6.3 V, +/- 20%, X5R, 0603	0603	GRM188R60J226MEA0J	Murata
C32, C53, C78	0	6800pF	CAP, CERM, 6800 pF, 25 V, +/- 10%, X7R, 0402	0402	GRM155R71E682KA01D	Murata
C38	0	330uF	CAP, Tantalum Polymer, 330 µF, 2 V, +/- 20%, 0.015 ohm, 3528-21 SMD	3528-21	2TPE330MAFB	Panasonic
C56, C57, C61, C62	0	22uF	CAP, CERM, 22 µF, 6.3 V, +/- 20%, X5R, 0603	0603	C1608X5R0J226M080AC	TDK
C76	0	0.1uF	CAP, CERM, 0.1 µF, 10 V, +/- 10%, X5R, 0402	0402	GRM155R61A104KA01D	Murata
J3, J5, J7, J9, J11, J13, J15, J18, J20, J29, J30, J31	0		Card Edge Socket, 0.8mm, 10x2, SMT	Card Edge Socket, 0.8mm, 10x2, SMT	HSEC8-110-01-S-DV-A	Samtec
J35	0		Header, 2.54 mm, 2x1, Gold, R/A, SMT	Header, 2.54 mm, 2x1, R/A, SMT	87898-0204	Molex
R22, R31, R45	0	2.2	RES, 2.2, 5%, 0.063 W, 0402	0402	CRCW04022R20JNED	Vishay-Dale
R25, R33, R47, R50, R88, R92, R93	0	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R36, R49	0	0.002	RES, 0.002, 2%, 1 W, 0508	0508	KRL2012E-M-R002-G-T5	Susumu Co Ltd
R60, R63, R64, R65, R66, R67, R68, R69	0	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

3 *Regulatory Notices:*

   3.1 *United States*

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

      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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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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:*

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