SiC413 Reference Board User's Manual
4 A, 26 V Integrated Synchronous Buck Regulator

THE CHIP

PRODUCT SUMMARY	
Input Voltage Range	4.75 V to 26 V
Output Voltage Range	0.6 V to 13.2 V
Operating Frequency	500 kHz
Continuous Output Current	4 A
Peak Efficiency	93 %
Highside/Lowside R_{DS_ON}	35 mΩ/19 mΩ
Package	SO-8

DESCRIPTION

The SiC413 is an integrated, dc-to-dc power conversion solution with built-in PWM-optimized high- and low-side n-channel MOSFETs and advanced PWM controller. The SiC413 provides a quick and easy to use POL voltage regulation solution for a wide range of applications. Vishay Siliconix proprietary packaging technology is used to optimize the power stage and minimize power losses associated with parasitic impedances and switching delays. The co-packaged Gen III TrenchFET power MOSFETs deliver higher efficiency than lateral DMOS monolithic solutions.

FEATURES

- 4.75 V to 26 V input voltage range
- Integrated PWM controller and Gen III trench MOSFETs
- Built-in bootstrap diode
- 500 kHz fixed switching frequency
- Internal soft start
- Break-before-make operation
- Integrated current sense
- Cycle by cycle overcurrent protection
- Output over voltage protection
- Thermal shutdown
- Quick and easy single chip converter
- SO-8 package

APPLICATIONS

- LCD TV, set-top box and DVD player
- Desktop PC and server
- Add-in graphic board
- Memory, FPGA and µP device power supplies
- Point of load dc-to-dc conversion
- Telecom and networking equipment

REFERENCE BOARD PHOTOS

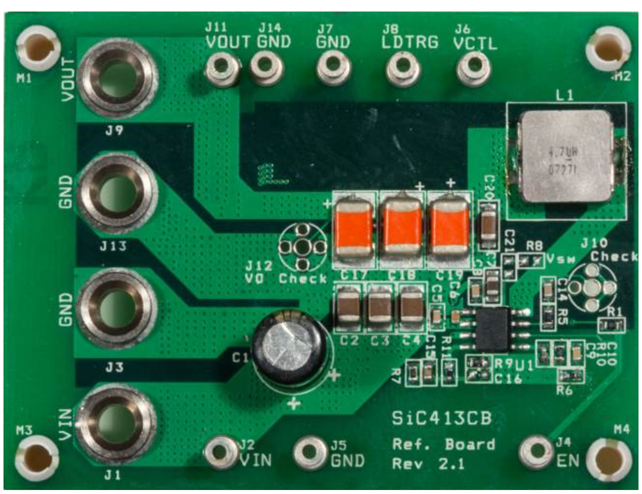


Figure 1. Top of the PCB

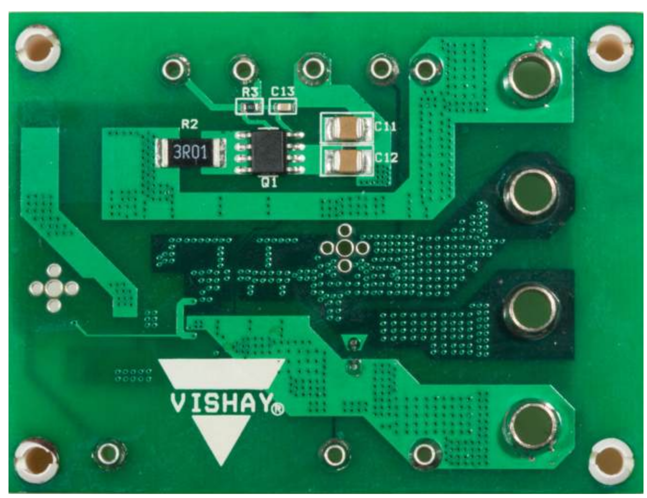


Figure 2. Bottom of the PCB

THE REFERENCE BOARD

This reference board allows the end user to evaluate the SiC413 chip for its features and all functionalities. It can also be a reference design for a user's application.

SPECIFICATION

Input voltage (V): 4.75 to 24
Output voltage (V): 0.6 to 12.0
Output current (A): 0 to 4

Notes:
- This board is, by default, preset to 3.3 V output with 12 V input
- This board can be set to any output voltage between 0.6 V and 12 V, and any input voltage between 4.75 V and 24 V. For a specific input/output voltage combination, the values of inductor and compensation network may need to be modified and the output capacitors may need an increase or decrease.

INPUT CAPACITORS

The input capacitors are chosen as a combination of electrolytic and ceramics so that the capacitance, the rms current, the ESR, the input voltage ripple and the cost can be all fairly satisfied. For a combination of high voltage input and low voltage output (low duty cycle), the electrolytic capacitors (C1) may not be required.

INDUCTORS

If off-the-shelf inductors are to be used, then their DCR and saturation current parameters are the key besides their inductance values. The DCR causes an I^2R loss, which will decrease the system efficiency and generate heat on the board. The saturation current has to be higher than the maximum output current plus ripple current. In over current condition the inductor current may be drastically high. All these need to be put into consideration when selecting the inductor.
On this board Vishay IHLP4040DZ series inductors are used to meet cost requirement and get better efficiency.

OUTPUT CAPACITORS

Voltage, ESR, rms current capability and capacitance are essential elements to consider when choosing output capacitors. The ESR and capacitance affect the output voltage ripple, transient response and system stability. The rms current capability determines the capacitor power dissipation and life time. To meet all the 4 element requirements, combination of ceramics and tantalum can be used.

CONNECTION AND SIGNAL/TEST POINTS

Power sockets

V_{IN} (J1), GND (J3): Input voltage source with V_{IN} to be positive. Connect to a 4.75 V to 24 V source that powers SiC413.
V_{OUT} (J9), GND (J13): Output voltage with V_{OUT} to be positive. Connect to a load that draws less than 4 A current.

Signal and test leads

V_{IN} (J2), GND (J5): Intput voltage sense pins with V_{IN} to be positive. Connect to a volt meter or an oscilloscope probe if display or waveform is needed.
V_{OUT} (J11), GND (J14): Output voltage sense pins with V_{OUT} to be positive. Connect to a volt meter or an oscilloscope probe if display or waveform is needed.
V_{CTRL} (J6), LDTRG (J8), GND (J7): Load step control signal input. Connect V_{CTRL} and GND to a power source, V_{EXT}, which supplies enough voltage to generate the load step needed. Connect LDTRG and GND to a pulse generater that creates the MOSFET on/off signal for the load step.
EN: SiC413 enable signal input. To enable the system leave this point open, otherwise connect it to any GND.

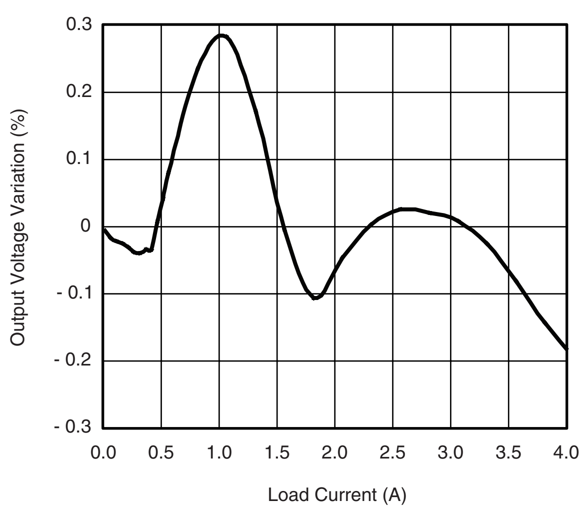


Figure 3. 12 V - 3.3 V Load Regulation

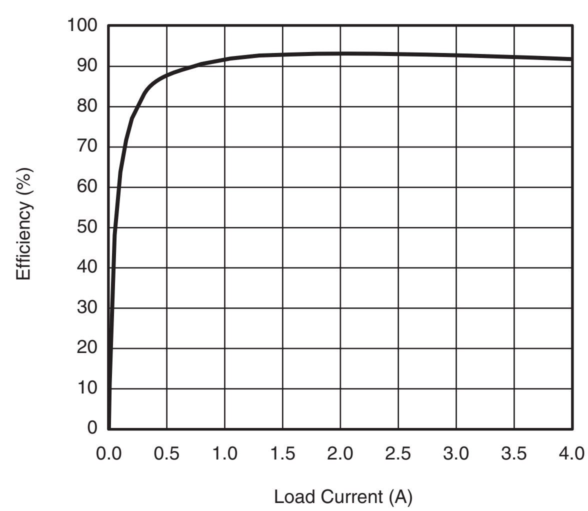


Figure 4. 12 V - 3.3 V Efficiency

SET UP LOAD STEP

The hardware to test transient response is included in the board, which allows users to see how the transient response performs. The setup steps are:

1. Decide what load step is wanted, then based on the output voltage calculate the external voltage V_{EXT} that will be connected between V_{CTRL} and GND. For example, a load step of 2 A between 0.5 A (I_1) and 2.5 A (I_2) is required and the output voltage is 3.3 V. $V_{EXT} = V_O - (I_2 - I_1) * 3.01\ \Omega = V_O - (2.5\text{ A} - 0.5\text{ A}) * 3.01\ \Omega = -2.72$ V. Preset a DC source voltage to V_{EXT} = 2.72 V (current capability around 1 A) and connect it to the board with positive side to GND and negative side to V_{CTRL} (if V_{EXT} is a positive value, then connect the DC source positive to V_{CTRL} and negative to GND).

2. Preset a waveform from a function generator using the following parameters and set its output to OFF (refer to the specific function generator manual for its setup):
   Shape: square
   Freqency: 50 Hz or whatever is required
   Duty cycle: 1 % to 2 % or whatever is required
   Amplitude: -12 V low level and + 10 V high level
   Rising time and **falling time:** 1 µs or whatever is required.

3. Connect the function generator output positive to LDTRG and negative to GND.

4. Preset the current of an electronic load to I_1 and turn it on.

5. Set up an oscilloscope using the following parameters.
   Channel 1 for probing output voltage: AC coupled, 20 mV/div to 50 mV/div, 100 mV offset, or whatever is required .
   Channel 2 for probling the current on the 3.01 Ω resistor (R2) (needs to be an isolated probe): DC coupled, 3 V/div (corresponds to 1 A/div) for I_O < 2.5 A or 5 V/div (corresponds to 1.661 A/div) for I_O > 2.5 A.
   Time base: 100 µs/div
   Bandwidth: 20 MHz

6. Connect oscilloscope channel 1 probe positive to V_{OUT} (J11) and negative to GND (J14), and channel 2 probe positive to V_{OUT} (J11) and negative to Q1 DRAIN.

7. Turn on the system power. Output voltage should be shown on the electronic load with current of I_1.

8. Turn on the power source for V_{EXT}.

9. Set the function generator output to be ON. The transient response waveforms should be seen on the oscilloscope.

10. If needed, re-adjust the trigger waveform's rising and falling time on the function generator so that the current slew rate is satisfied (the current slew rate can be seen on oscilloscope channel 2 waveform by setting the time base to 1 µs or 500 ns).

11. To change load step, decrease or increase the value of V_{EXT}.

12. To cease transient response test, simply set the function generator output to off, turn off the power source for V_{EXT}, and then shut down the system power.

CHANGE OUTPUT VOLTAGE

If, at any time, different output voltage is needed, then simply change the value of R9 based on the following formula:

$$R9 = R7/(V_O/V_{REF} - 1) = 10K/(V_O/0.6 - 1)$$

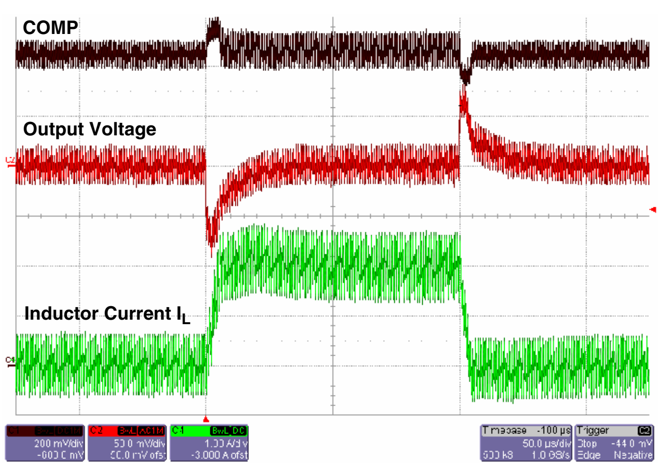


Figure 5. An Example of Load Step Waveforms

PCB LAYOUT

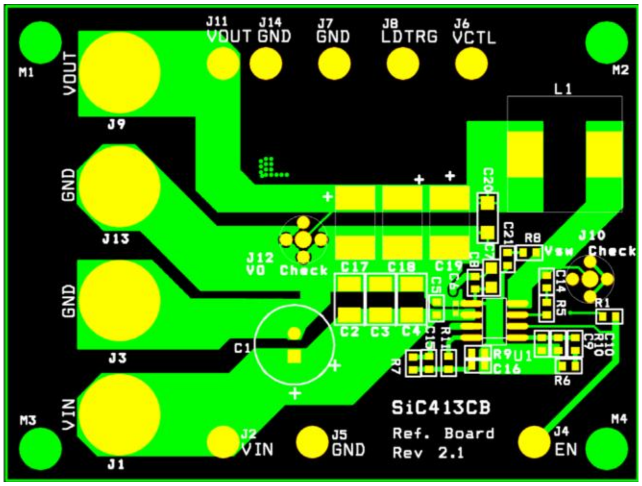


Figure 6. Top

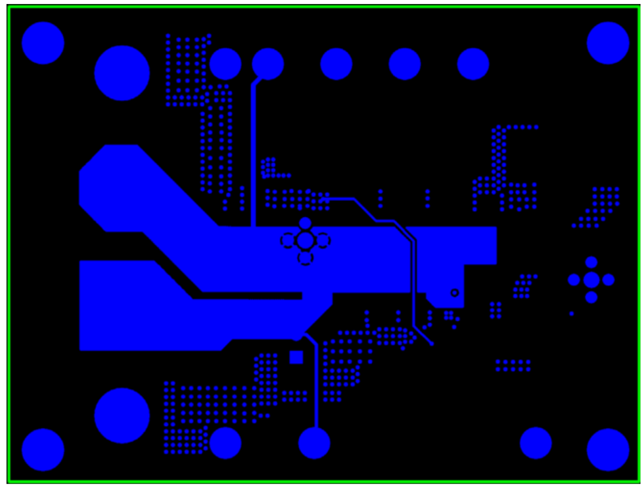


Figure 8. Inner Layer 2

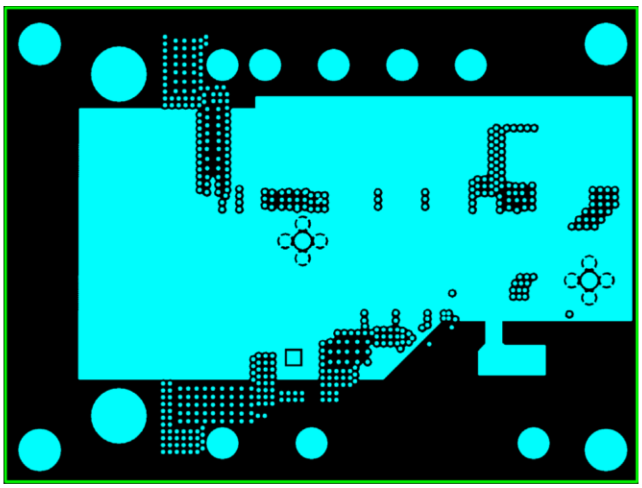


Figure 7. Inner Layer 1

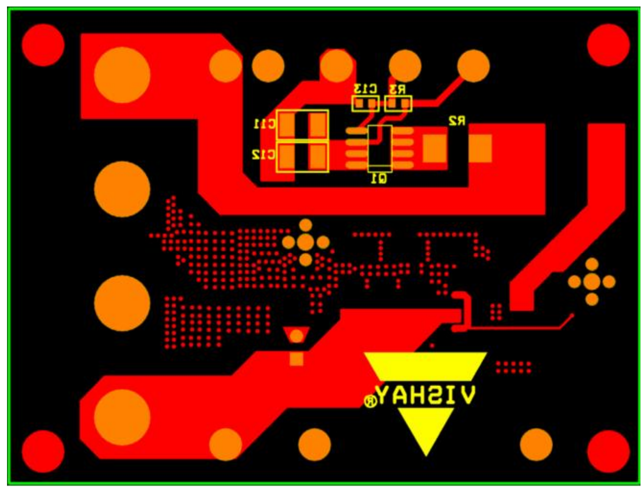
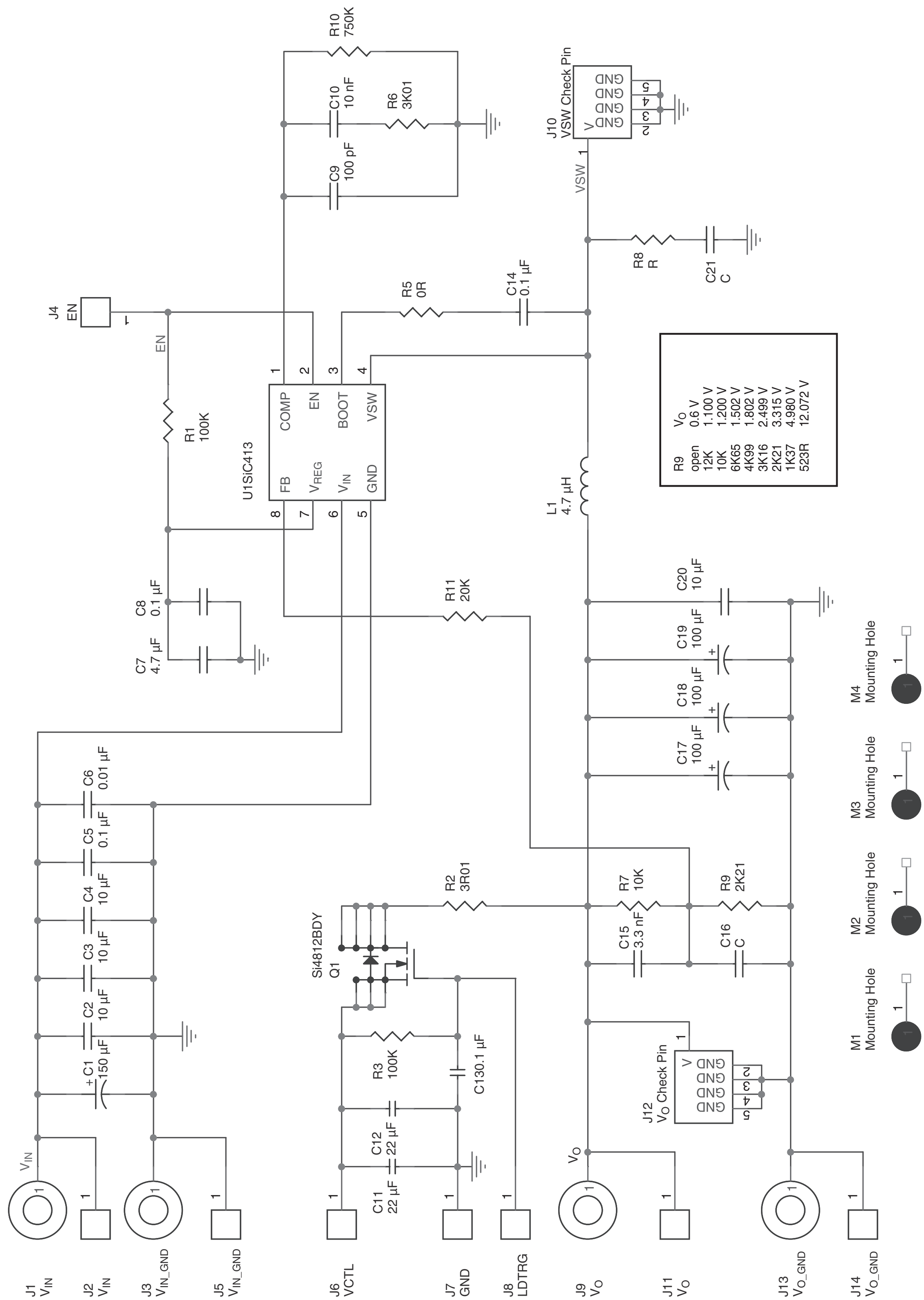


Figure 9. Bottom Layer

SCHEMATIC


U1SiC413
COMP
EN
BOOT
VSW
FB
VREG
VIN
GND
R10 750K
C10 10 nF
R6 3K01
C9 100 pF
J10 VSW Check Pin
R5 0R
C14 0.1 µF
R8 R
C21 C
J4 EN
R1 100K
L1 4.7 µH
R9 VO
open 0.6 V
12K 1.100 V
10K 1.200 V
6K65 1.502 V
4K99 1.802 V
3K16 2.499 V
2K21 3.315 V
1K37 4.980 V
523R 12.072 V
C8 0.1 µF
C7 4.7 µF
R11 20K
C20 10 µF
C19 100 µF
C18 100 µF
C17 100 µF
C6 0.01 µF
C5 0.1 µF
C4 10 µF
C3 10 µF
C2 10 µF
C1 150 µF
Q1 Si4812BDY
R2 3R01
R7 10K
R9 2K21
C15 3.3 nF
C16 C
R3 100K
C130.1 µF
C12 22 µF
C11 22 µF
J12 VO Check Pin
M1 Mounting Hole
M2 Mounting Hole
M3 Mounting Hole
M4 Mounting Hole
J1 VIN
J2 VIN
J3 VIN_GND
J5 VIN_GND
J6 VCTL
J7 GND
J8 LDTRG
J9 VO
J11 VO
J13 VO_GND
J14 VO_GND

BILL OF MATERIAL							
Item	**Qty**	**Reference**	**Value**	**Voltage**	**PCB Footprint**	**Part Number**	**Manufacturer**
1	1	C1	150 µF	35 V	D8X11.5-D0.6X3.5	EEU-FM1V151	Panasonic
2	3	C2, C3, C4	10 µF	25 V	SM/C_1210	TMK325B7106MN-T	Taiyo Yuden
3	4	C5, C8, C13, C14	0.1 µF	50 V	SM/C_0603	VJ0603Y104KXACW1BC	Vishay
4	1	C6	0.01 µF	50 V	SM/C_0402	VJ0402Y103KXACW1BC	Vishay
5	1	C7	4.7 µF	10 V	SM/C_0805	LMK212B7475KG-T	Murata/Taiyo Yuden
6	1	C9	100 pF	50 V	SM/C_0603	VJ0603Y101KXACW1BC	Vishay
7	1	C10	10 nF	50 V	SM/C_0603	VJ0603Y103KXACW1BC	Vishay
8	2	C11, C12	22 µF	16 V	SM/C_1210	GRM32ER71C226ME18L	TAIYO YUDEN
9	1	C15	3.3 nF	50 V	SM/C_0603	VJ0603Y332KXACW1BC	Vishay
10	2	C16, C21	Not populated	50 V	SM/C_0603		Vishay
11	3	C17, C18, C19	100 µF	20 V	595D-D	595D107X9020D2T	Vishay
12	1	C20	10 µF	16 V	SM/C_1206	C3216X7R1C106M	TDK
13	1	J1	V_{IN}		SOLDER-BANANA	575-6	Keystone
14	1	J2	V_{IN}		Probe Hook	1540-2	Keystone
15	1	J3	V_{IN_GND}		SOLDER-BANANA	575-6	Keystone
16	1	J4	EN		Probe Hook	1540-2	Keystone
17	1	J5	V_{IN_GND}		Probe Hook	1540-2	Keystone
18	1	J6	VCTL		Probe Hook	1540-2	Keystone
19	1	J7	GND		Probe Hook	1540-2	Keystone
20	1	J8	LDTRG		Probe Hook	1540-2	Keystone
21	1	J9	V_O		SOLDER-BANANA	575-6	Keystone
22	1	J10	VSW check pin		LECROY PROBE PIN	PK007-015	LeCroy
23	1	J11	V_O		Probe Hook	1540-2	Keystone
24	1	J12	Vo check pin		LECROY PROBE PIN	PK007-015	LeCroy
25	1	J13	V_{O_GND}		SOLDER-BANANA	575-6	Keystone
26	1	J14	V_{O_GND}		Probe Hook	1540-2	Keystone
27	1	L1	4.7 µH		IHLP4040	IHLP4040DZER4R7M01	Vishay
28	4	M1, M2, M3, M4	Mounting hole		STACKING SPACER	8834	Keystone
29	1	Q1	Si4812BDY	30 V	SO-8	Si4812BDY	Vishay
30	2	R1,R3	100K	50 V	SM/C_0603	CRCW0603100KFKEA	Vishay
31	1	R2	3R01	200 V	C_2512	CRCW25123R01FKTA	Vishay
32	1	R5	0R	50 V	SM/C_0603	CRCW06030000FKEA	Vishay
33	1	R6	3K01	50 V	SM/C_0603	CRCW06033K01FKEA	Vishay
34	1	R7	10K	50 V	SM/C_0603	CRCW060310K0FKEA	Vishay
35	1	R8	R	50 V	SM/C_0603		Vishay
36	1	R9	2K21	50 V	SM/C_0603	CRCW06032K21FKEA	Vishay
37	1	R10	750K	50 V	SM/C_0603	CRCW0603750KFKEA	Vishay
38	1	R11	20K	50 V	SM/C_0603	CRCW060320K0FKEA	Vishay
39	1	U1	SiC413		SO-8	SiC413	Vishay

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