Evaluation Board User Guide

DC3195A-B

LTM4652

Quad Bidirectional ±128A Inverting µModule Regulator

General Description

The DC3195A-B evaluation board features the LTM®4652 µModule® (micromodule) regulator, which is configured as a quad polyphase single –5V output capable of bidirectional ±128A load current. The input voltage range is 4.5V to 13V. The maximum V_{IN} + $|V_{OUT}|$ should not exceed 18V for this inverting output evaluation board. Derating is necessary for certain V_{IN}, V_{OUT}, frequency, and thermal conditions.

The DC3195A-B evaluation board can be configured to source or sink the output load current. Figure 2 and Figure 3 show the hardware test setup diagrams for both conditions, respectively. The evaluation board is optimized using a default frequency of 780kHz under the $9V_{IN}$ and $–5V_{OUT}$ operating conditions. The LTM4652 current mode architecture is peak current mode control. The evaluation board operates in continuous current mode (CCM) by default, but it can be placed in pulse-skipping mode (PSM) to optimize efficiency at light loads.

The LTM4652 is available in a thermally enhanced 144-pin (16mm × 16mm × 4.92mm) BGA package. Temperature sensing options are included through the onboard circuit.

The LTM4652 features an exposed metal top which is electrically unconnected for heatsinking capability.

The inverting configuration feature of the LTM4652 has a different maximum current limit compared to the noninverting configuration feature. (Refer to DN1021 for more information). The LTM4652 data sheet gives a complete description of the device. The data sheet and this user guide must be read before using or making any hardware changes to the DC3195A-B evaluation board.

Features and Benefits

- ±128A Sourcing and Sinking Current
- Parallel for High-Power Applications

DC3195A-B Evaluation Board Files

FILE	DESCRIPTION
DC3195A-B	Evaluation board files.

Ordering Information appears at end of this user guide.

Evaluation Board Photo

Figure 1. DC3195A-B Evaluation Board (Part Marking is either Ink Mark or Laser Mark)

Performance Summary

Specifications are at T_A = 25°C.

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage range	V_{IN}		4.5	9	13	V
Output voltage	V_{OUT}	R_{FB} = 8.06kΩ		–5		V
Switching frequency	f_{SW}	f_{SET} connected to $INTV_{CC}$		780		kHz
Maximum output current	I_{OUT}	V_{IN} = 9V, V_{OUT} = –5V, f_{SW} = 780kHz		±128		A
Efficiency						
Sourcing current	η	V_{IN} = 12V, I_{OUT} = 128A, f_{SW} = 780kHz		89.8		%
Sinking current	η	V_{IN} = 12V, I_{OUT} = –128A, f_{SW} = 780kHz		90		%

Quick Start

Required Equipment

- Two power supplies
- Two electronic loads
- Two digital multimeters (DMMs)
- One high-current diode (sinking condition)

Quick Start Procedure

The DC3195A-B evaluation board is an easy way to evaluate the performance of the LTM4652 in a multiphase application.

Sourcing Current Condition Procedure

See *Figure 2* for the proper measurement equipment setup for the sourcing current condition and use the following procedure.

1. With power off, connect the input power supply to VIN (J1) and to GND (J3).
2. Connect the output load's positive lead to GND (J2) and to the negative lead to VOUT– (J4). *Optional:* if the electronic load has more leads available, they can be connected to J13 and J14 to improve output current flow in the evaluation board.
3. Connect the DMM between the input test points VIN (E3) and GND (E4) to measure input voltage. Connect another DMM between test points GND (E2) and VOUT– (E6) to measure the DC output voltage.
4. Before powering up the DC3195A-B evaluation board, check the default position of the jumpers. The jumpers must be in the following positions for a typical application.

JP2	RUN	ON
JP9	BIAS	OFF
JP10	MODE	Forced continuous mode (FCM)

5. Turn on the power supply at the input, measure and increase V_{IN} between 4.5V and 13V. The typical output voltage should be –5.096V ±1% (or between –5.054V to –5.15V).
6. Once the input and output voltages are properly established, adjust the input voltage to 9V and the load current within the operating range of 0A to 128A maximum. Observe the output voltage regulation, output ripple voltage, switching node waveforms, and other parameters.

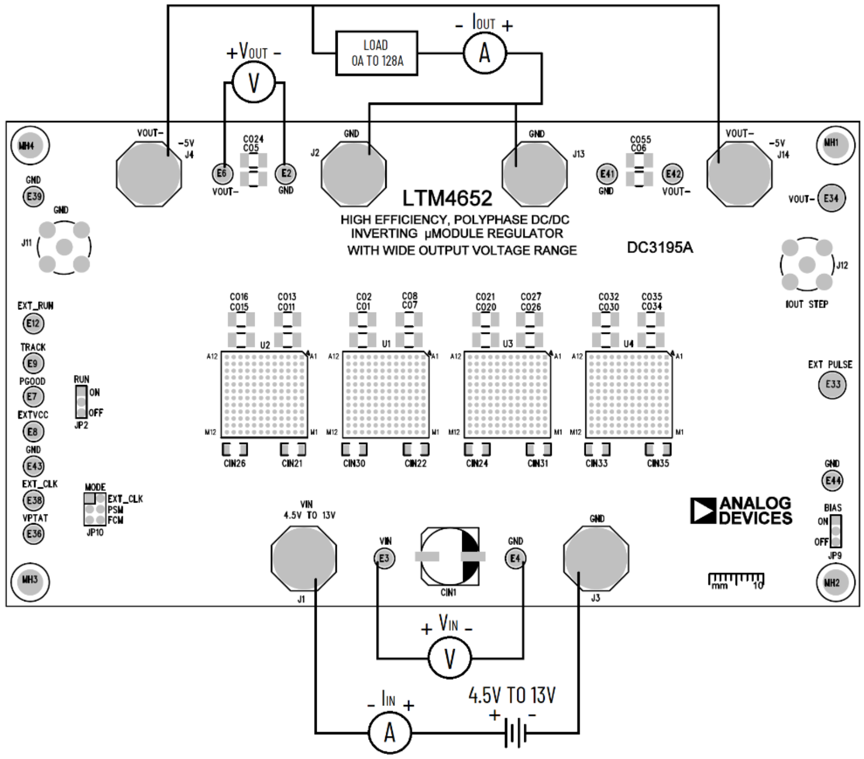


Figure 2. DC3195A-B Evaluation Board Sourcing Current Test Setup

Sinking Current Condition Procedure

See *Figure 3* for the proper measurement equipment setup for the sinking current condition and use the following procedure. This procedure shows how to use an electric load to test the sinking current capability.

1. With power off, connect an ammeter to VIN (J1), then connect the input power supply and free-wheeling load in parallel between the ammeter and GND (J3).
2. On the output, starting from VOUT– (J4), connect the bias supply, the output load, and the load reverse protection diode to GND (J2). The diode should have a current rating greater than the maximum desired output load value and a voltage rating greater than $VF\_DIODE + |V_{OUT}|$. Refer to SMC Diode Solutions 50HQ035, which can provide up to 60A current as an example.
3. Connect a DMM between the input test points: VIN (E3) and GND (E4) to monitor the input voltage. Connect a DMM between GND (E2) and VOUT– (E6), to monitor DC output voltage.
4. Before powering up the DC3195A-B evaluation board, check the default position of the jumpers and switches. The jumpers must be in the following positions for a typical application.

JP2	RUN	ON
JP9	BIAS	OFF
JP10	MODE	FCM

5. Turn on the output bias power supply, measure, and increase the voltage to 10V. Turn on the input power supply voltage and raise the V_{IN} between 4.5V and 13V. The typical output voltage should be –5.096V ±1% (or between –5.054V to –5.15V).
6. Once the input and output voltages are properly established, adjust the input voltage to 9V.

7. When sinking current in this configuration, an electronic load is used as the free-wheeling load, and it must be turned on first. Turn on the free-wheeling load and increase above $I_{OUT} \times |V_{OUT}|/V_{IN}$. Current will be flowing from the V_{IN} power supply and into the free-wheeling load.
8. The output sinking current can now be applied within the reverse protection diodes' operable range up to the quad output maximum of 128A. If more current than the reverse protection diode can supply is needed, a second load branch with bias voltage and protection diode can be added. Monitor diode temperature stress and consider applying cooling to the inductors if needed. Observe the output voltage regulation, output ripple voltage, switching node waveforms, and other parameters.

   Note: When removing the loads and powering the circuit off, this procedure must be followed in reverse step order. Decrease the sinking current to 0A, and turn off the output load, decrease the free-wheeling load to 0A, and turn off the free-wheeling load, the run pin may be pulled low here. Then, turn off the V_{IN} supply, and lastly, turn off the output V_{BIAS} power supply.

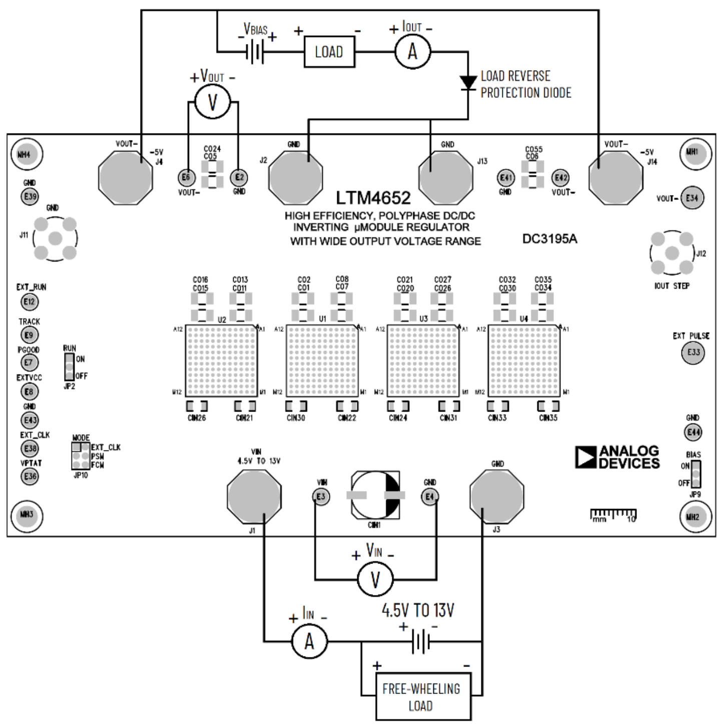


Figure 3. DC3195A-B Evaluation Board Sinking Current Test Setup

The DC3195A-B evaluation board provides a convenient onboard BNC terminal to measure the output ripple voltage accurately. Connect a short BNC cable from VOUT– (J5) to the input channel of an oscilloscope (scope probe ratio 1:1, ac-coupling) to observe the output ripple voltage. To properly measure the input and output voltage ripples, do not use the long ground lead on the oscilloscope probe. See [Figure 4](#) for the proper probing technique of input and output voltage ripples. Short, stiff leads need to be soldered to the (+) and (–) terminals of an input or output capacitor. The probe's ground ring needs to touch the (–) lead, and the probe tip needs to touch the (+) lead.

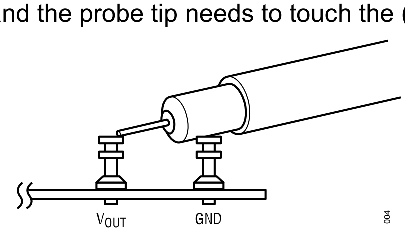


Figure 4. Scope Probe Placement for Measuring Input or Output Ripple Voltage

DC3195A-B Evaluation Board Features Procedure

- **Onboard Load Step Circuit.** The DC3195A-B evaluation board provides onboard load transient circuits to quickly check ΔV_{OUT} peak-to-peak deviation during rising or falling dynamic load transients for each channel. The simple load step circuit consists of a 40V N-channel power MOSFET in series with two paralleled 10mΩ, 0.5W, 1% current sense resistors. The MOSFET is configured as a voltage control current source (VCCS) device; therefore, the output current step and its magnitude are created and controlled by adjusting the amplitude of the applied input voltage step at the gate of the MOSFET. Use a function generator to provide a pulse between EXT PULSE (E33) and GND; this voltage pulse should be set at a pulse width of less than 2ms and a maximum duty cycle of less than 1% to avoid excessive thermal stress on the MOSFETs. The output current step is measured directly across the current sense resistors and monitored by connecting the BNC cable from IOUT STEP (J12) to the input of the oscilloscope (scope probe ratio 1:0.005, DC-coupling). The equivalent voltage-to-current scale is 5mV/1A. The load step current slew rate dI/dt can be changed by adjusting the rise time and fall time of the input voltage pulse.

  NOTE: When measuring VOUT− and load step current on J11 and J12 BNC connectors, do not connect other oscilloscope probes with reference to GND. Any additional oscilloscope probes must be referenced to VOUT− to avoid damage to measurement equipment.

- **Level Shift Circuits (RUN, SYNC, and PGOOD).** Level shift circuits are included in the DC3195A-B evaluation board to allow users to reference GND instead of V_{OUT-} when applying an external RUN voltage, an external CLKIN signal, or when measuring PGOOD. To use an external RUN signal, stuff R129 with a 0Ω resistor. A voltage greater than 2.0V must be applied between EXT_RUN (E12) and GND to enable the device. An external clock can be applied between EXT_CLK (E38) and GND over a frequency range of 250kHz to 780kHz. The clock input high threshold is 2V, and the clock input low threshold is 0.2V. To measure PGOOD with the level shifter at the turret (E7), the 5VBIAS voltage should be enabled by moving jumper JP9 to the ON position, R132 is removed, and a 0Ω resistor is placed at R127.

- **Temperature Sensing.** The LTM4652 IC's temperature is measured with an onboard circuit utilizing the Analog Devices LTC®2997 remote/internal temperature sensor. The $5V_{BIAS}$ circuit must be enabled by placing jumper JP9 in the ON position. The DC3195A-B evaluation board measures the temperature of U1 by default, but resistor connections can be adjusted to measure any µModule IC's internal temperature. The LTC2997 converts the voltage from a diode-configured PNP transistor located inside the LTM4652 through its $TEMP^+$ and $TEMP^-$ pins into the proportional to absolute temperature voltage (V_{PTAT}). This V_{PTAT} voltage correlates to the LTM4652 IC's temperature using the formula: *TEMP (K) =* $V_{PTAT}/4mV$.

Typical Performance Characteristics

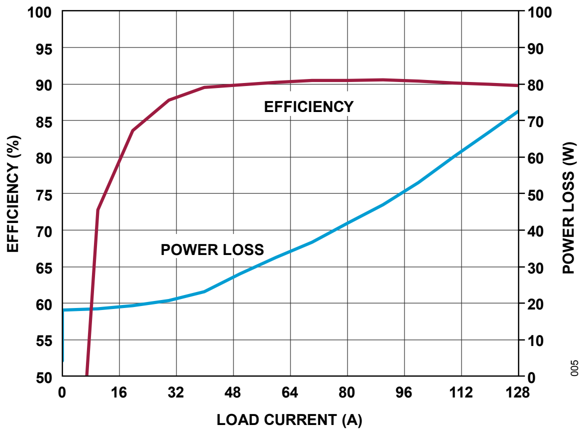


Figure 5. Sourcing Current Efficiency vs. Power Loss

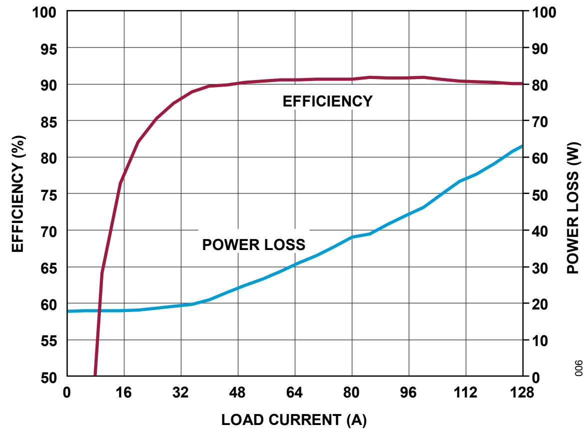


Figure 6. Sinking Current Efficiency vs. Power Loss

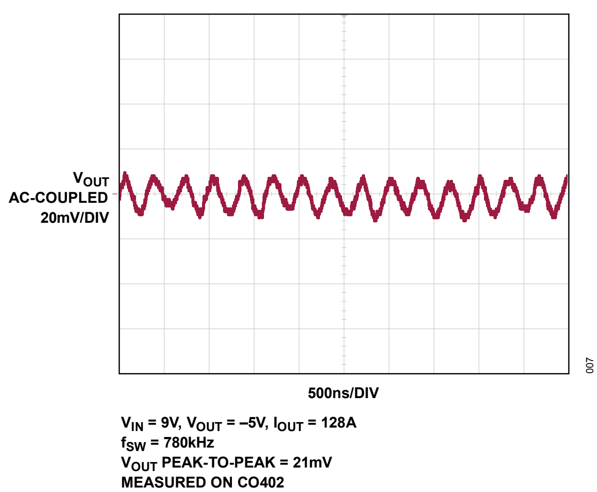
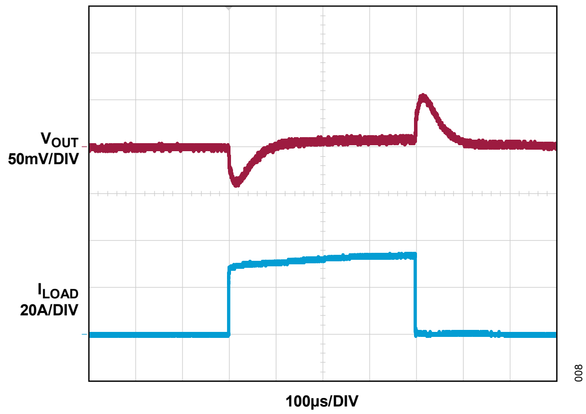
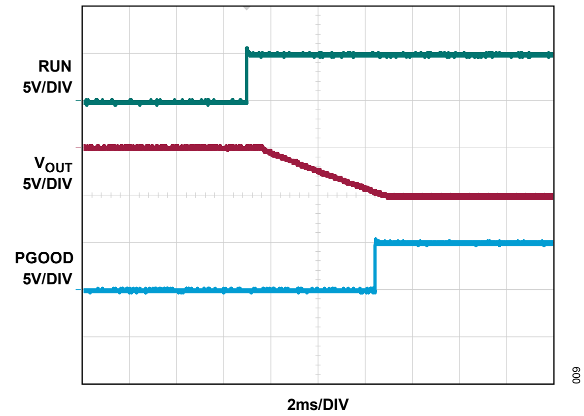


Figure 7. Output Voltage Ripple



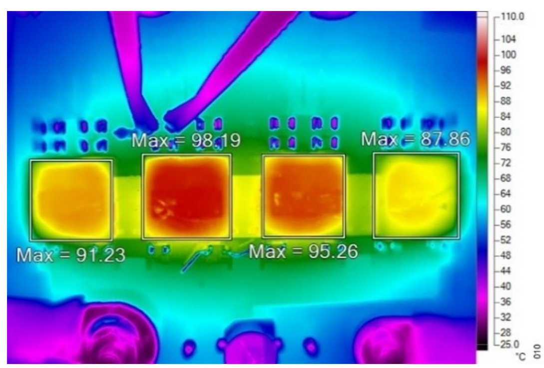
V_{IN} = 9V, V_{OUT} = –5V, I_{OUT} = 0A TO 32A, f_{SW} = 780kHz
V_{OUT} PEAK-TO-PEAK = 99mV
MEASURED ON CO402

Figure 8. Load Transient Response



V_{IN} = 9V, V_{OUT} = –5V, f_{SW} = 780kHz
C_{OUT} = 38 × 220µF CERAMIC
C_{SS} = 0.1µF

Figure 9. Startup with No Load



V_{IN} (V)	V_{OUT} (V)	I_{OUT} (A)	MAX CASE TEMP (°C)
9	–5	75	98

Figure 10. Thermal Capture with 400LFM Airflow, T_A = 25°C

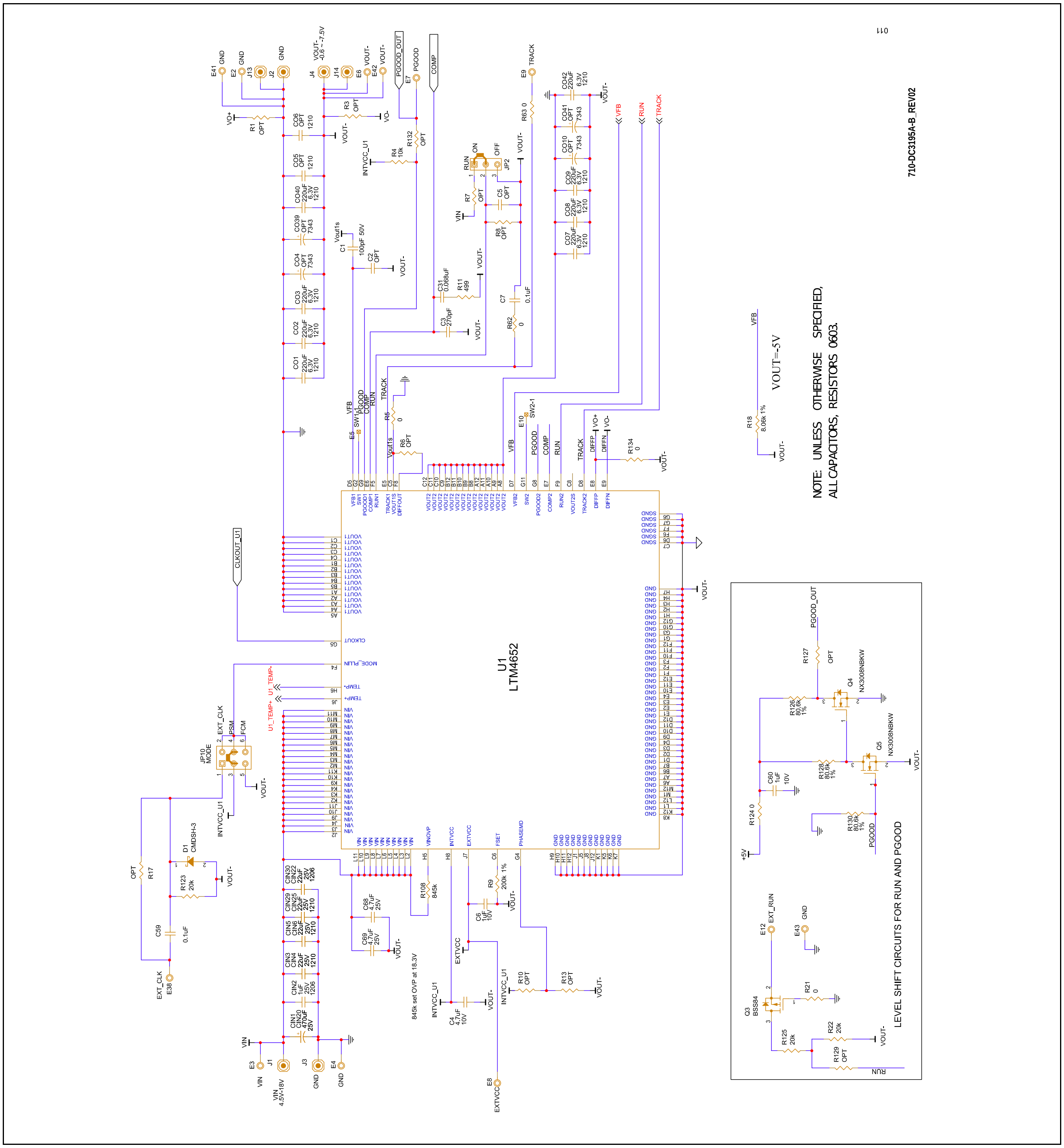
DC3195A-B Evaluation Board Bill of Materials

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	C1	CAP., 100pF, X7R, 50V, 10%, 0603	AVX, 06035C101KAT2A
2	1	C3	CAP., 270pF, C0G, 50V, 5%, 0603	AVX, 06035A271JAT2A
3	4	C4, C10, C18, C22	CAP., 4.7µF, X5R, 10V, 10%, 0603	TDK, C1608X5R1A475K080AC
4	7	C6, C11, C19, C23, C42, C56, C60	CAP., 1µF, X7R, 10V, 10%, 0603	MURATA, GRM188R71A105KA61
5	3	C7, C57, C59	CAP., 0.1µF, X7R, 25V, 10%, 0603	MURATA, GRM188R71E104KA01D
6	1	C31	CAP., 0.068µF, X5R, 25V, 10%, 0603	AVX, 06033D683KAT2A
7	2	C41, C48	CAP., 100µF, X5R, 10V, 20%, 1210	MURATA, GRM32ER61A107ME20L
8	38	C44, C45, C52–C55, CO1-CO3, CO7–CO9, CO11, CO13–CO17, CO20–CO22, CO26–CO28, CO30, CO32–CO36, CO40, CO42, CO45, CO46, CO48, CO50, CO52, CO54	CAP., 220µF, X5R, 6.3V, 20%, 1210, NO SUBS ALLOWED	MURATA, GRM32ER60J227ME05K
9	1	C46	CAP., 10µF, X5R, 16V, 20%, 1210	WURTH ELEKTRONIK, 885012109009
10	1	C47	CAP., 220pF, X7R, 50V, 10%, 0603	AVX, 06035C221KAT2A
11	1	C49	CAP., 0.047µF, X7R, 50V, 10%, 0603	MURATA, GRM188R71H473KA61D
12	1	C58	CAP., 470pF, X7R, 50V, 10%, 0603	MURATA, GRM188R71H471KA01D
13	8	C61, C62–C66, C68, C69	CAP., 4.7µF, X5R, 25V, 10%, 0603	MURATA, GRM188R61E475KE15D
14	2	CIN1, CIN20	CAP., 470µF, ALUM POLY HYB, 25V, 20%, 10mm × 10.2mm, G, SMD, RADIAL, AEC-Q200	PANASONIC, EEHZK1E471P
15	2	CIN2, CIN11	CAP., 1µF, X7R, 25V, 10%, 1206	MURATA, GRM31MR71E105KA01L
16	24	CIN3-CIN10, CIN12–CIN19, CIN23, CIN25, CIN27–CIN29, CIN32, CIN34, CIN36	CAP., 22µF, X7R, 25V, 10%, 1210, NO SUBS ALLOWED	MURATA, GRM32ER71E226KE15L
17	8	CIN21, CIN22, CIN24, CIN26, CIN30, CIN31, CIN33, CIN35	CAP., 22µF, X6S, 25V, 20%, 1206	MURATA, GRM31CC81E226ME11L
18	1	D1	DIODE, SCHOTTKY, 30V, 250mW, 100mA, SOD-323	CENTRAL SEMI., CMDSH-3 TR LEAD FREE

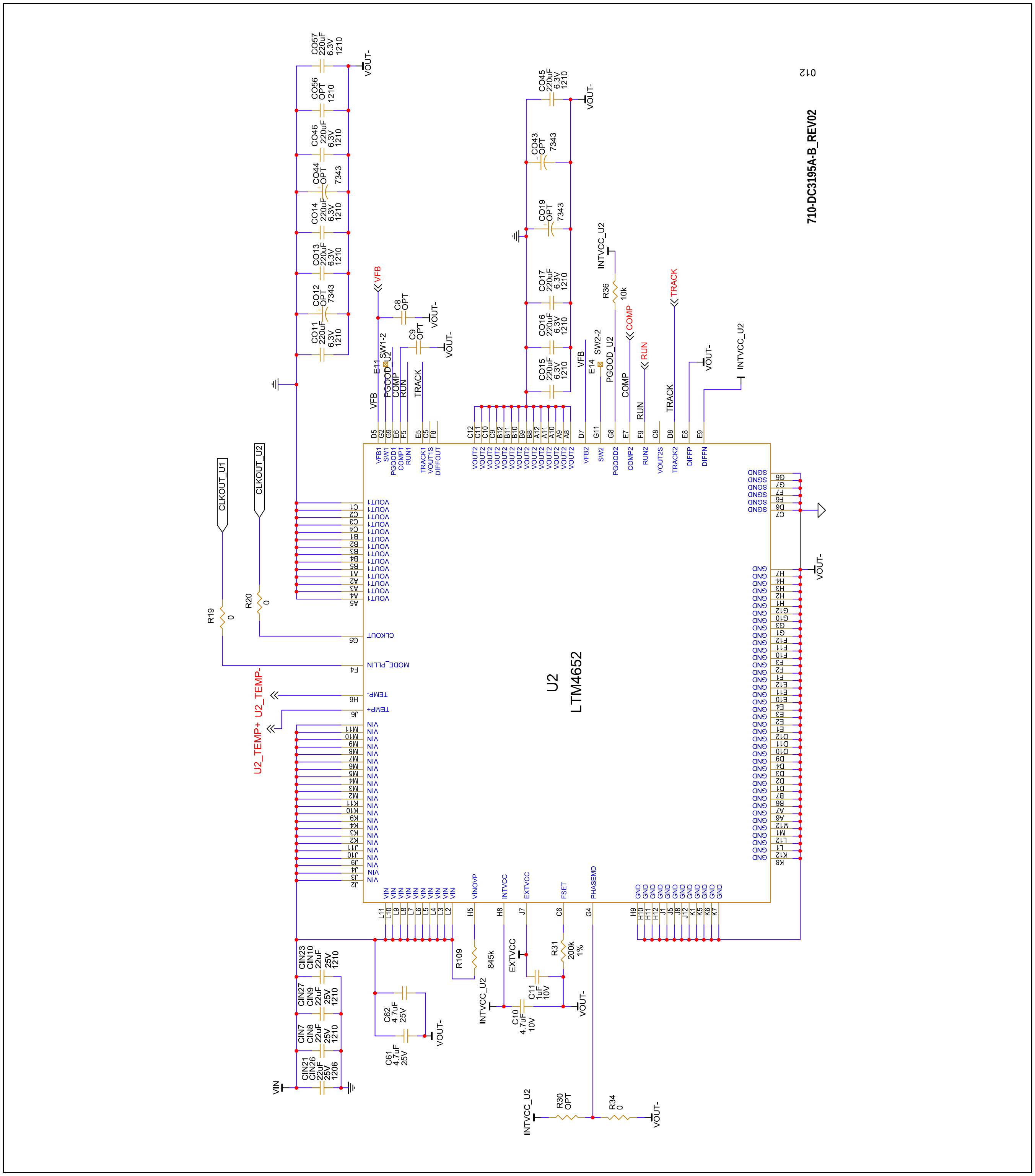
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
19	2	J11, J12	CONN., RF, BNC, RCPT, JACK, 5-PIN, ST, THT, 50Ω	AMPHENOL RF, 112404
20	1	L1	IND., 33µH, PWR, SHIELDED, 20%, 3.6A, 105mΩ, 6.56mm × 6.36mm, AEC-Q200, XAL6060	COILCRAFT, XAL6060-333MEB
21	2	Q1, Q2	XSTR., MOSFET, N-CH, 40V, 14A, DPAK (TO-252)	VISHAY, SUD50N04-8M8P-4GE3
22	1	Q3	XSTR., MOSFET, P-CH, 50V, 130mA, SOT23-3	DIODES INC., BSS84-7-F
23	2	Q4, Q5	XSTR., MOSFET N-CH, 30V, 350mA, SOT-323	NEXPERIA, NX3008NBKW, 115
24	5	R4, R36, R41, R98, R112	RES., 10kΩ, 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060310K0JNEA
25	13	R5, R19–R21, R34, R40, R45, R62, R63, R114, R115, R124, R134	RES., 0Ω, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06030000Z0EA
26	4	R9, R31, R43, R51	RES., 200kΩ, 1%, 1/10W, 0603	VISHAY, CRCW0603200KFKEA
27	1	R11	RES., 499Ω, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603499RFKEA
28	1	R18	RES., 8.06kΩ, 1%, 1/10W, 0603	YAGEO, RC0603FR-078K06L
29	3	R22, R107, R125	RES., 20kΩ, 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060320K0JNEA
30	2	R101, R102	RES., 0.01Ω, 1%, 1W, 2512, PWR, METAL, SENSE, AEC-Q200	VISHAY, WSL2512R0100FEA
31	1	R105	RES., 105kΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603105KFKEA
32	4	R106, R126, R128, R130	RES., 80.6kΩ, 1%, 1/10W, 0603	VISHAY, CRCW060380K6FKEA
33	4	R108–R111	RES., 845kΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603845KFKEA
34	1	R113	RES., 10Ω, 1%, 1/10W, 0603	VISHAY, CRCW060310R0FKEA
35	1	R123	RES., 20kΩ, 1%, 1/10W, 0603	VISHAY, CRCW060320K0FKEA
36	4	U1-U4	IC, SOURCE/SINK DUAL ±25A OR SINGLE ±50A µModule REGULATOR WITH INPUT OVERVOLTAGE PROTECTION, BGA-144	ANALOG DEVICES, LTM4652EY#PBF
37	1	U7	IC, SYNCHR. STEP-DOWN CONVERTER, MSOP-16	ANALOG DEVICES, LTC3630EMSE#PBF
38	1	U8	IC, REMOTE/INTERNAL TEMPERATURE SENSOR, DFN-6	ANALOG DEVICES, LTC2997IDCB#TRMPBF

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Additional Evaluation Board Circuit Components				
1	0	C2, C5, C8, C9, C16, C17, C20, C21, C51	CAP., OPTION, 0603	
2	0	CO4, CO10, CO12, CO19, CO23, CO29, CO31, CO37, CO39, CO41, CO43, CO44, CO47, CO49, CO51, CO53	CAP., OPTION, 7343	
3	0	CO5, CO6, CO24, CO55-CO59	CAP., OPTION, 1210	
4	0	R1, R3, R6, R7, R8, R10, R13, R17, R30, R42, R44, R50, R52, R87, R116, R117, R118, R119, R120, R121, R127, R129, R132	RES., OPTION, 0603	
Hardware: For Evaluation Board Only				
1	15	E2-E4, E6-E9, E12, E36, E38, E39, E41–E44	TEST POINT, TURRET, 0.064" MTG. HOLE, PCB 0.062″ THK	MILL-MAX, 2308-2-00-80-00-00-07-0
2	2	E33, E34	TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062″ THK	MILL-MAX, 2501-2-00-80-00-00-07-0
3	6	J1-4, J13, J14	RING, LUG, #10, CRIMP, 16-14 AWG, NON-INSULATED, SOLDERLESS TERMINALS	KEYSTONE, 8205
4	6	J1-J4, J13, J14	WASHER, FLAT, #10, STEEL, ZINC PLATE, OD: 0.437 [11.1]	KEYSTONE, 4703
5	6	J1-J4, J13, J14	STUD, FASTENER, #10-32	PENNENGINEERING, KFH-032-10ET
6	12	J1-J4, J13, J14	NUT, HEX, #10-32, STEEL, ZINC PLATE	KEYSTONE, 4705
7	2	JP2, JP9	CONN., HDR, MALE, 1×3, 2mm, VERT, ST, THT, NO SUBS. ALLOWED	WURTH ELEKTRONIK, 62000311121
8	1	JP10	CONN., HDR, MALE, 2×3, 2mm, VERT, ST, THT	WURTH ELEKTRONIK, 62000621121
9	1	LB2	LABEL SPEC, DEMO BOARD SERIAL NUMBER	BRADY, THT-96-717-10
10	4	MP9-MP12	STANDOFF, NYLON, SNAP-ON, 0.25" (6.4mm)	KEYSTONE, 8831 WURTH ELEKTRONIK, 702931000
11	1	PCB1	PCB, DC3195A	ANALOG DEVICES APPROVED SUPPLIER, 600-DC3195A
12	3	XJP2, XJP9, XJP10	CONN., SHUNT, FEMALE, 2-POS, 2mm	WURTH ELEKTRONIK, 60800213421
13	1	STNCL1	TOOL, STENCIL, DC3195A	ANALOG DEVICES APPROVED SUPPLIER, 830-DC3195A

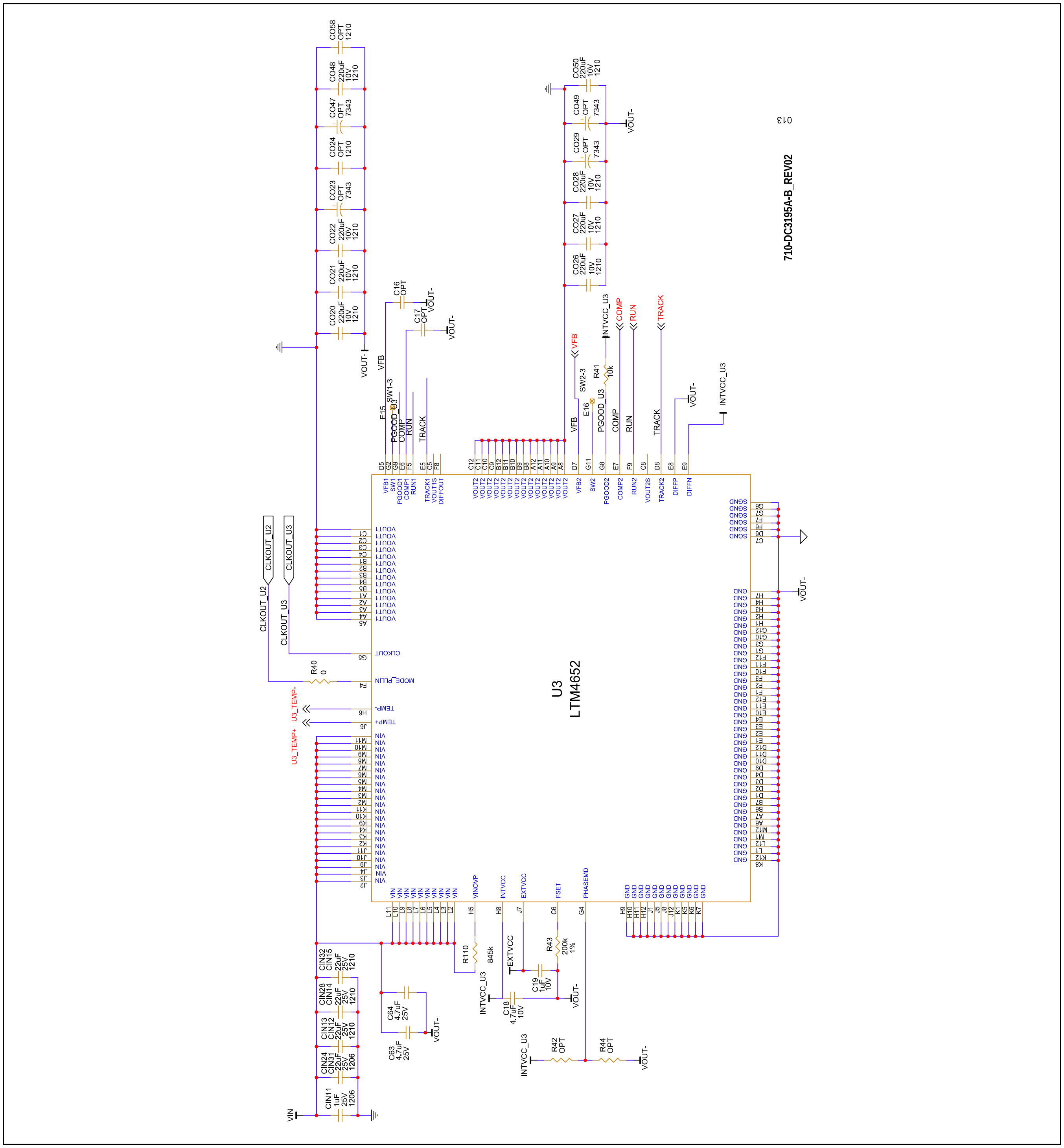
DC3195A-B Evaluation Board Schematic



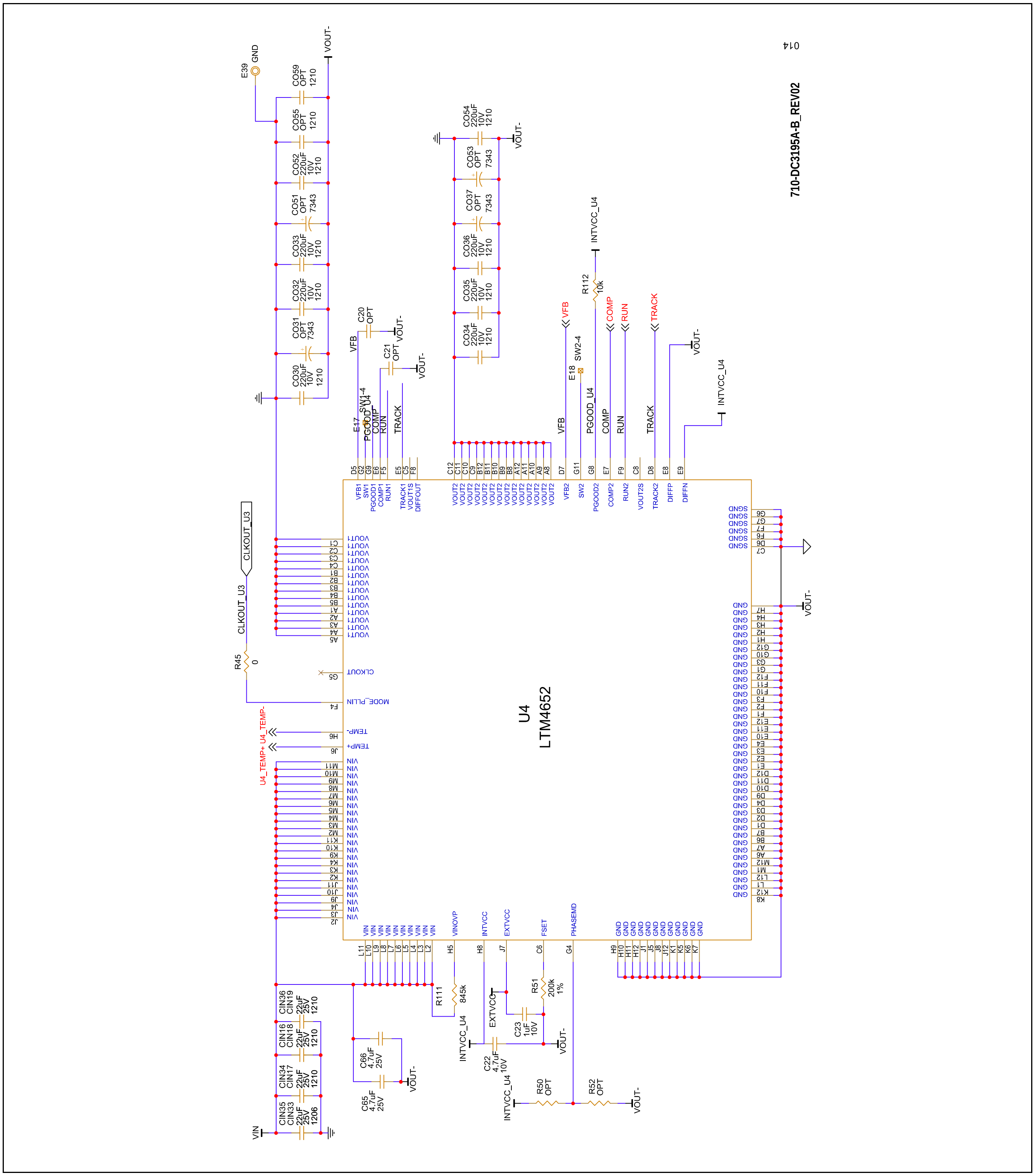
DC3195A-B Evaluation Board Schematic (continued)



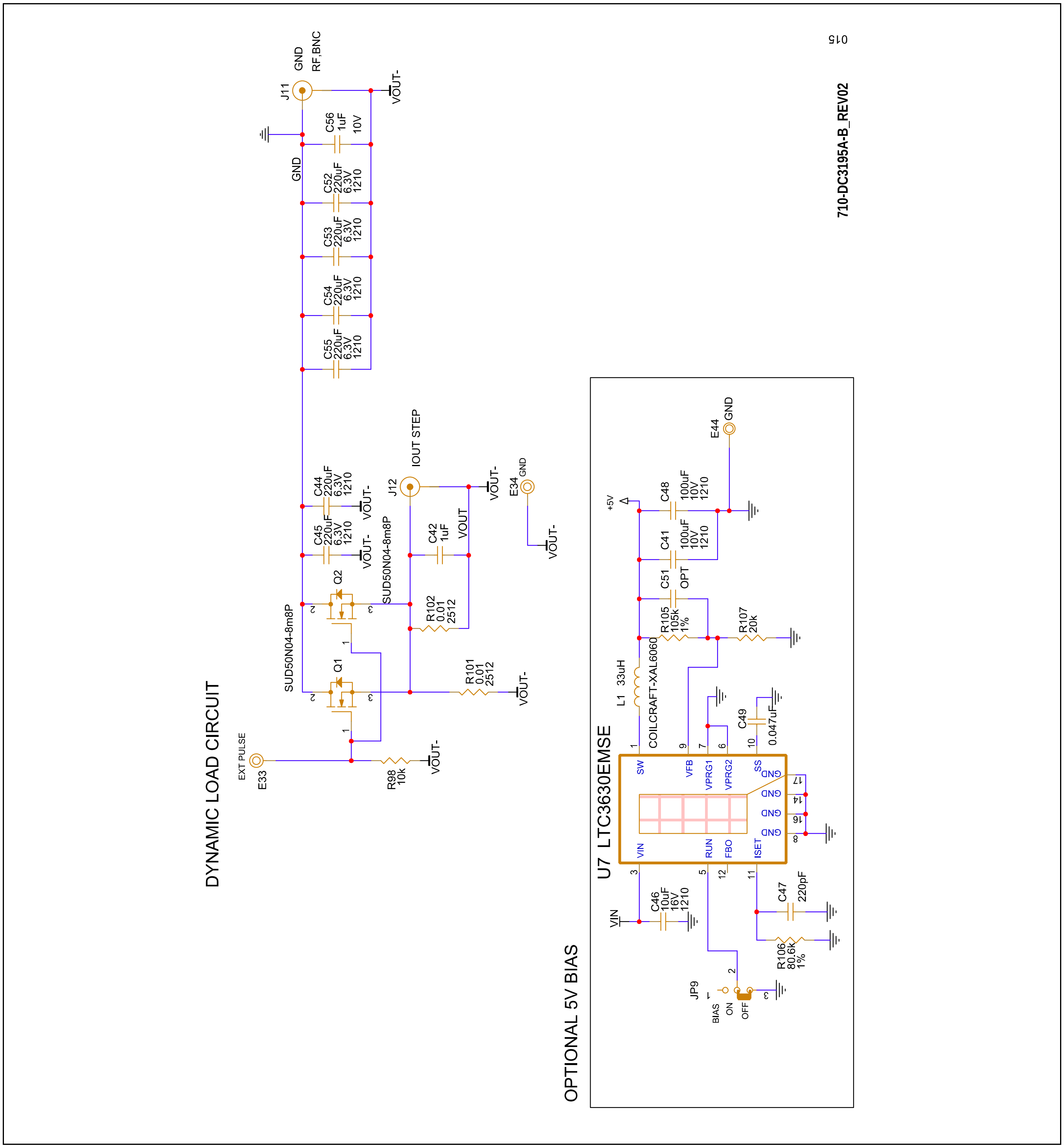
DC3195A-B Evaluation Board Schematic (continued)



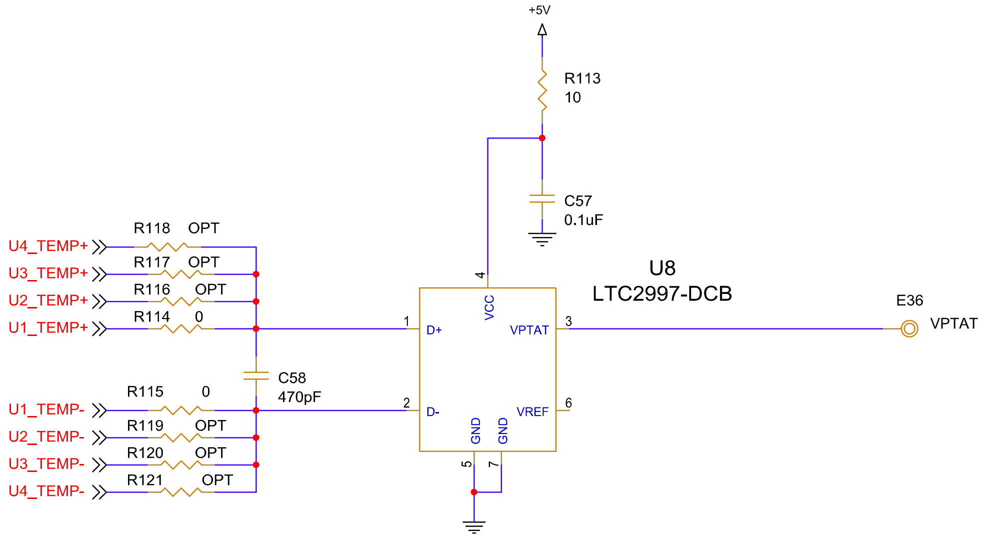
DC3195A-B Evaluation Board Schematic (continued)



DC3195A-B Evaluation Board Schematic (continued)



DC3195A-B Evaluation Board Schematic (continued)



PCA ADDITIONAL PARTS

MP9	STANDOFF, NYLON, SNAP-ON, 0.25" (6.4mm)
MP10	STANDOFF, NYLON, SNAP-ON, 0.25" (6.4mm)
MP11	STANDOFF, NYLON, SNAP-ON, 0.25" (6.4mm)
MP12	STANDOFF, NYLON, SNAP-ON, 0.25" (6.4mm)
LB2	BOARD S/N LABEL 895-0154
STNCL	TOOL, STENCIL, DC3195A, REV02
PCB	PCB, DC3195, REV02

710-DC3195A-B_REV02

016

Ordering Information

PART	TYPE
DC3195A-B	The DC3195A-B evaluation board features the LTM4652, a source/sink dual ±25A or single ±50A µModule regulator with input overvoltage protection.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	08/24	Initial release.	—

Notes