

Evaluating the LT4322, Floating, High-Voltage Active Rectifier Controller**FEATURES**

- ▶ Fully featured evaluation board for the [LT4322](#)
- ▶ High voltage full-wave rectification
- ▶ Ideal Diode bridge
- ▶ Schottky diode bridge replacement

EVALUATION KIT CONTENTS

- ▶ DC3137A evaluation board

DOCUMENTS NEEDED

- ▶ LT4322 data sheet

EQUIPMENT NEEDED

- ▶ AC power supply
- ▶ Voltmeter
- ▶ Constant current or resistive load
- ▶ Oscilloscope

GENERAL DESCRIPTION

Demonstration circuit DC3137A features the floating, high voltage active rectifier controller LT4322 in a full-wave rectifier configuration. It is suitable for applications that require high voltage line rectification with DC outputs up to 170V. While components were chosen to optimize performance at 60Hz, the LT4322 is capable of operating at frequencies up to 100kHz.

The LT4322 drives an N-Channel MOSFET to perform functionally like a diode but with much lower power dissipation. This topology eases thermal constraints and increases the usable output voltage. An N-Channel topology has multiple benefits over a P-Channel topology, including lower $R_{DS(ON)}$, a smaller footprint, lower cost, and a wider selection of MOSFETs. In this full-wave rectifier, four LT4322 circuits replace four diodes.

Only a few essential components are required to operate each LT4322: a single N-Channel MOSFET (M1x), a reservoir capacitor (C1xB), a gate capacitor (C5x), and in applications where the peak-to-peak input voltage exceeds 60V, an N-Channel depletion mode MOSFET (M2x). In most applications, only a single output capacitor C2 is needed to smooth the output voltage and ensure the output voltage ripple stays below a user-determined maximum value.

Design files for this circuit board are available at: <http://www.analog.com>

TABLE OF CONTENTS

Features.....	1	M1x – Ideal Diode MOSFETs.....	6
Evaluation Kit Contents.....	1	M2x – Depletion Mode MOSFETs.....	6
Documents Needed.....	1	C1x and C1xB – V_{DDA} Reservoir Capacitors.....	6
Equipment Needed.....	1	C5x – GATE Capacitor.....	6
General Description.....	1	C2, C2-2, C2-3 – Output Capacitors.....	6
DC3137A Evaluation Board Photograph.....	3	Optional Component Pads.....	7
Performance Summary.....	4	Voltage, Current, Frequency Modifications.....	7
Quick Start Procedure.....	5	Evaluation Board Schematic.....	8
Board Description.....	6	Ordering Information.....	9
Overview.....	6	Bill of Materials.....	9
U1 to U4 – The Diode Controllers.....	6		

REVISION HISTORY

2/2023—Revision 0: Initial Version

DC3137A EVALUATION BOARD PHOTOGRAPH

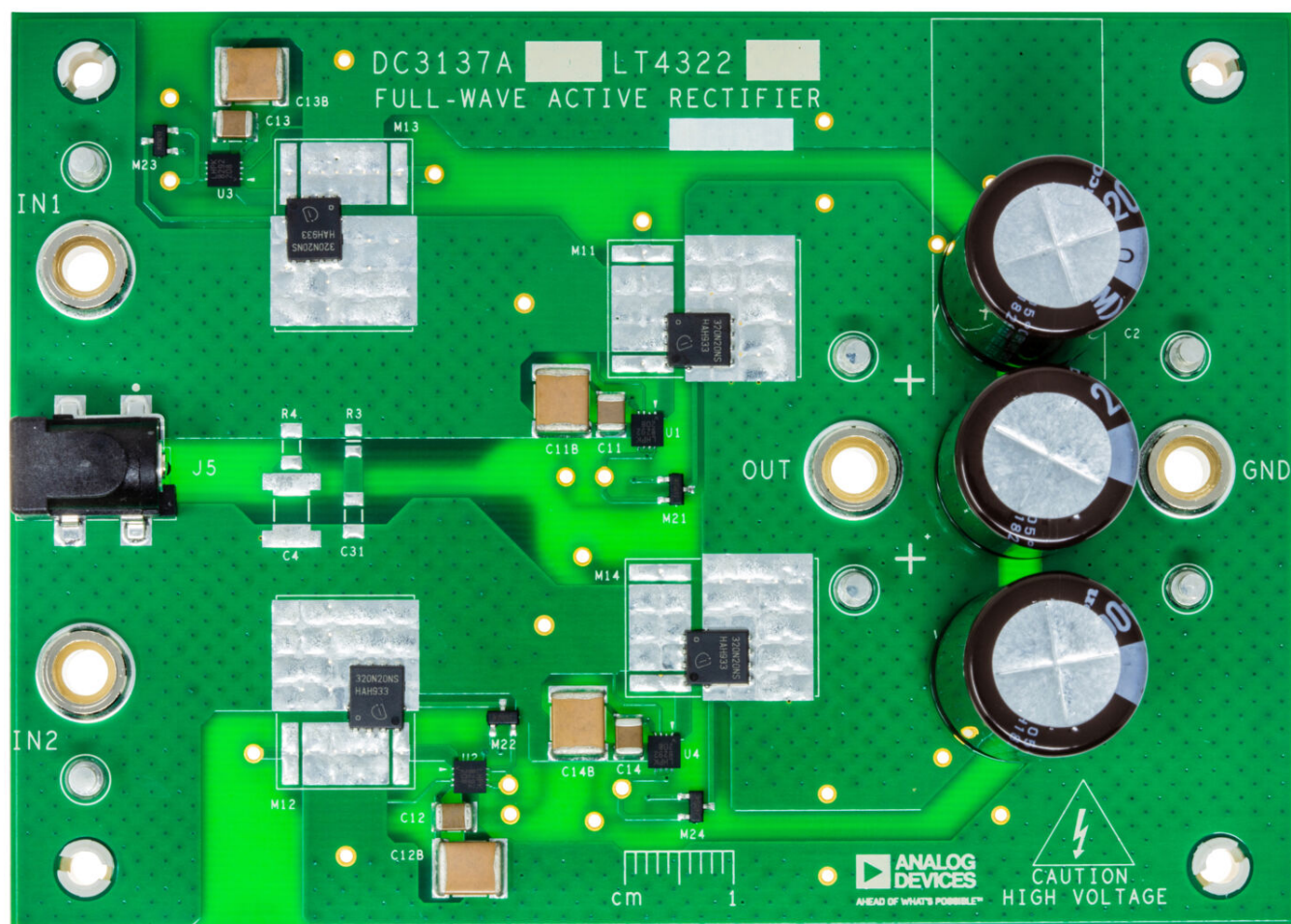


Figure 1. DC3137A Evaluation Board Photograph

PERFORMANCE SUMMARY

Specifications are at $T_A = 25^\circ\text{C}$, unless otherwise noted.

Table 1. Performance Summary¹

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
AC Input Voltage	Shorting Resistors R11, R12, R13, and R14 Installed	7		42	$V_{AC(RMS)}$
	No Shorting Resistors	7	120	140	$V_{AC(RMS)}$
Output Voltage	Shorting Resistors R11, R12, R13, and R14 Installed	9.5		60	V
	No Shorting Resistors	9.5	170	200	V
Output Current	With C2, C2-2, and C2-3 Installed (660 μF total), resistive load			5.2	A_{RMS}
	With only C2 installed (220 μF total), resistive load			2.9	A_{RMS}

¹ Generated using default components from the Parts List.

QUICK START PROCEDURE

WARNING! High voltage testing should be performed by qualified personnel only. As a safety precaution, at least two people should be present during high voltage testing. There are exposed conductors on the bottom of the board, and any banana plugs present will protrude through the bottom of the board. The underlying surface should be non-conductive and clear of any wire, solder, and other conductive debris.

A simple demonstration of DC3137A operation is as follows:

1. Connect an AC power supply between IN1 and IN2, as shown in Figure 2. Make sure that the output voltage of the supply is within the input voltage range of the DC3137A, as shown in Table 1. Verify that shorting resistors R11 to R14 have been removed before exceeding $42V_{AC(RMS)}$. Take care not to exceed 24V or 5A when using the barrel jack. Use the turrets (E1 to E6) and banana jacks (J1 to J4) in all valid current/voltage ranges.
2. Connect a load and voltmeter across OUT and GND, as shown in Figure 2. Turn down the load current to zero. Put the voltmeter in DC volt measurement mode.
3. Raise the AC input power supply voltage to the desired level. Check the output voltage with the voltmeter. For cases where the input supply is a $120V_{AC}$ line voltage, the voltmeter reads $\sim 170V_{DC}$.
4. Raise the load current to the desired level. Make sure that the load current is less than or equal to the maximum load current, as shown in Table 1. The output smoothing capacitors' (UCY2D221MHD capacitors C2, C2-2, and C2-3) combined value is equal to $660\mu F$ with a ripple current rating that allows for a load up to $5.2A_{(RMS)}$ at $25^{\circ}C$. C2-3 can be removed for

loads ranging from $2.9A_{(RMS)}$ to $4.6A_{(RMS)}$. Both C2-2 and C2-3 can be removed for output load currents below $2.9A_{(RMS)}$.

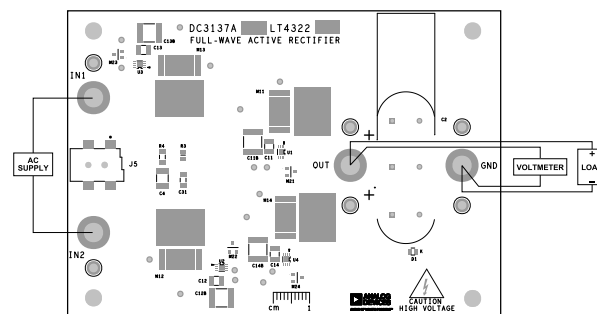


Figure 2. Measurement Equipment Setup

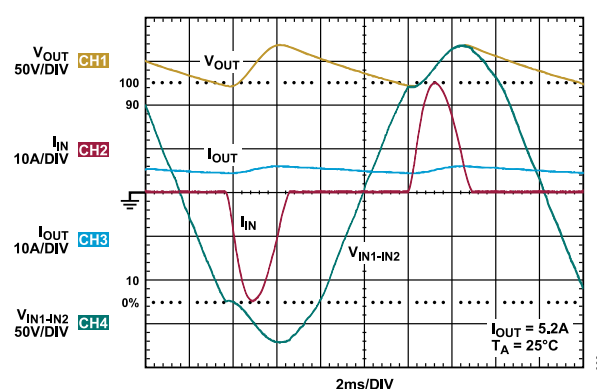


Figure 3. Typical Performance Under $5.2A_{RMS}$ Resistive Load

BOARD DESCRIPTION

OVERVIEW

DC3137A features four [LT4322s](#), each controlling an N-Channel MOSFET to provide a highly efficient, compact, and low-profile solution for full-wave rectification. Careful attention has been paid to the board layout to provide at least 104mil (2.6mm) clearance between the larger copper planes and as much clearance as possible between components and traces to ensure DC3137A operation up to the maximum voltages of the chosen components.

DC3137A is a 2-layer board with 2oz copper on each layer. The copper in the power path can carry 20A continuously, depending on ambient conditions. Furthermore, all copper planes in the power path are doubled on the bottom copper layer where possible. With the default components, however, the load current is limited to $5.2A_{(RMS)}$ by the power MOSFETs.

For ease of evaluation probe points have been provided for the LT4322 pins.

The following is a brief description of the main components of DC3137A.

U1 TO U4 – THE DIODE CONTROLLERS

U1 to U4 are LT4322 controllers, each in an 8-pin, 3mm x 3mm side-wettable DFN package. For more details, refer to the LT4322 data sheet on its operation.

M1X – IDEAL DIODE MOSFETS

M1x (M11 to M14) is the Infineon N-Channel MOSFET BSC320N20NS3 in a SuperSO8 package. It was selected for its 200V drain-to-source breakdown voltage, $\pm 20V V_{GS(MAX)}$, and 27m Ω drain-to-source on-state resistance (at 10V V_{GS}). M1x's $\pm 20V V_{GS(max)}$ is compatible with the 12V limit on the LT4322's gate drive. During the peaks of the AC input, the drain-to-source voltage reaches 170V. This is comfortably below M1x's 200V drain-to-source breakdown voltage specification.

M2X – DEPLETION MODE MOSFETS

M2x (M21 to M24) is the Microchip N-Channel depletion mode MOSFET DN3135 in a TO-236AB (SOT-23) package. It was selected for its 350V drain-to-source breakdown voltage and 180mA I_{DSS} . During the peaks of the AC input, M2x's drain-to-source voltage is close to 170V, safely below its 350V breakdown. M2x's 180mA I_{DSS} allows the 50mA to 100mA peak current required by the LT4322 V_{DDC} pin while refreshing its V_{DDA} reservoir capacitor.

C1X AND C1XB – V_{DDA} RESERVOIR CAPACITORS

Due to their strong voltage coefficient, the actual value of multilayer ceramic capacitors is often significantly less than what is stated, especially at voltages close to the capacitor's maximum voltage rating. Additionally, the voltage coefficient is a function of the capacitor's physical size. A 2220, 25V-rated ceramic capacitor is chosen for C1xB to achieve a true value of 22 μ F at the 12V operating voltage for this 60Hz application.

Alternatively, for 60Hz applications, users can populate C1x with a 0.1 μ F ceramic capacitor and solder a 22 μ F aluminum electrolytic capacitor between each LT4322's V_{DDA} and V_{SSA} pins instead of populating C1xB. For input frequencies ≥ 200 Hz, users can leave C1xB unpopulated and populate only C1x.

C5X – GATE CAPACITOR

The LT4322 is optimally compensated with a 10nF capacitance between the gate and source of the external power MOSFET. The necessity of C5x is dependent on the choice of M1 and its inherent C_{ISS} value. In the case of the BSC320N20NS3, CG1 is populated with a 10nF capacitor to improve stability in forward regulation. For more details, refer to the Gate Capacitor Selection section of the LT4322 data sheet.

C2, C2-2, C2-3 – OUTPUT CAPACITORS

Output capacitors C2, C2-2, and C2-3 provide the output load current for the majority of the AC period. For more details, refer to the Output Capacitor C_{OUT} Selection section of the LT4322 data sheet on selecting the capacitance value as a function of output load current, AC period, and maximum allowed output voltage droop. [Figure 3](#) shows the output voltage droops from 170V to 122V for a 5.2A $_{(RMS)}$ resistive load and 16.7ms period (60Hz) when $C2 = C2-2 = C2-3 = 220\mu$ F.

The user must make sure the RMS current in the capacitors does not exceed the maximum ripple current rating. This ensures the capacitor lifetime is not compromised. An electrolytic capacitor's ripple current rating is a function of RMS current, frequency, and ambient temperature. Consult the manufacturer's specifications and ensure that the selected device is suited to operate within the required frequency, temperature, and load current conditions of the application.

The user can choose to populate only one or two of these output capacitors if the output voltage droop and ripple current requirements of their application allow.

BOARD DESCRIPTION

OPTIONAL COMPONENT PADS

Some components (M1x, M2x, C2, and C22) are provided with extra unstuffed pads to try out different values and sizes or other circuits from the [LT4322](#) data sheet. Some of these extra pads are on the backside of the board.

M1 has a universal MOSFET footprint on both outer layers to accommodate power-SO8, DPAK, D2PAK, HSOF, and LFPACK packages. The user can populate the top and bottom M1 footprints simultaneously to connect two power MOSFETs in parallel, thereby reducing the total MOSFET power loss by a factor of two. M2x has footprints for SOT-23 and SOT-89.

While the board is populated with three electrolytic capacitors on the output voltage by default, there is also a footprint for a multilayer ceramic capacitor C22 on the output. The user can populate various combinations of the ceramic capacitor and aluminum electrolytic capacitors to try various combinations of total output capacitance and ESR with various output current loads.

Components R3, R4, C31, C32, and C4 are provided to facilitate optional snubbing networks. Although they are populated by default, they are unnecessary in most applications. For more details, refer to the Input Snubber section of the LT4322 data sheet.

VOLTAGE, CURRENT, FREQUENCY MODIFICATIONS

For higher voltage operation, see [Table 2](#) and ensure that the stated components meet or exceed the minimum voltage requirement for the desired input/output voltages.

To modify the board for higher current, try the following in this order, while still ensuring all board components meet the voltage requirements in [Table 2](#):

1. Add matching FETs in parallel using the backside MOSFET footprints.
2. Select an M1x replacement with a lower $R_{DS(ON)}$ value.
3. After modifying the MOSFETs, raise the C2, C2-2, and C2-3 values and ripple current capacities.

For applications using an AC input supply less than $42V_{RMS}$, R1x can be installed to short M2x from the circuit. For higher frequency AC input, it is optimal to pick a lower value C1x even though the installed value works. For frequencies below 60Hz, C1x must be increased. For more details, refer to the V_{DDA} Capacitor Selection section of the LT4322 data sheet.

Table 2. Voltage Requirements

Part Reference	Minimum Voltage Requirement
C1x, C1xB, C5x	16V
C2, C2-2, C2-3, C4, C22, C31, C32	$V_{IN(PEAK)}$ or Desired $V_{OUT(MAXDC)}$
M1x, M2x	$BV_{DSS} \geq V_{IN(PEAK-PEAK)}$

EVALUATION BOARD SCHEMATIC

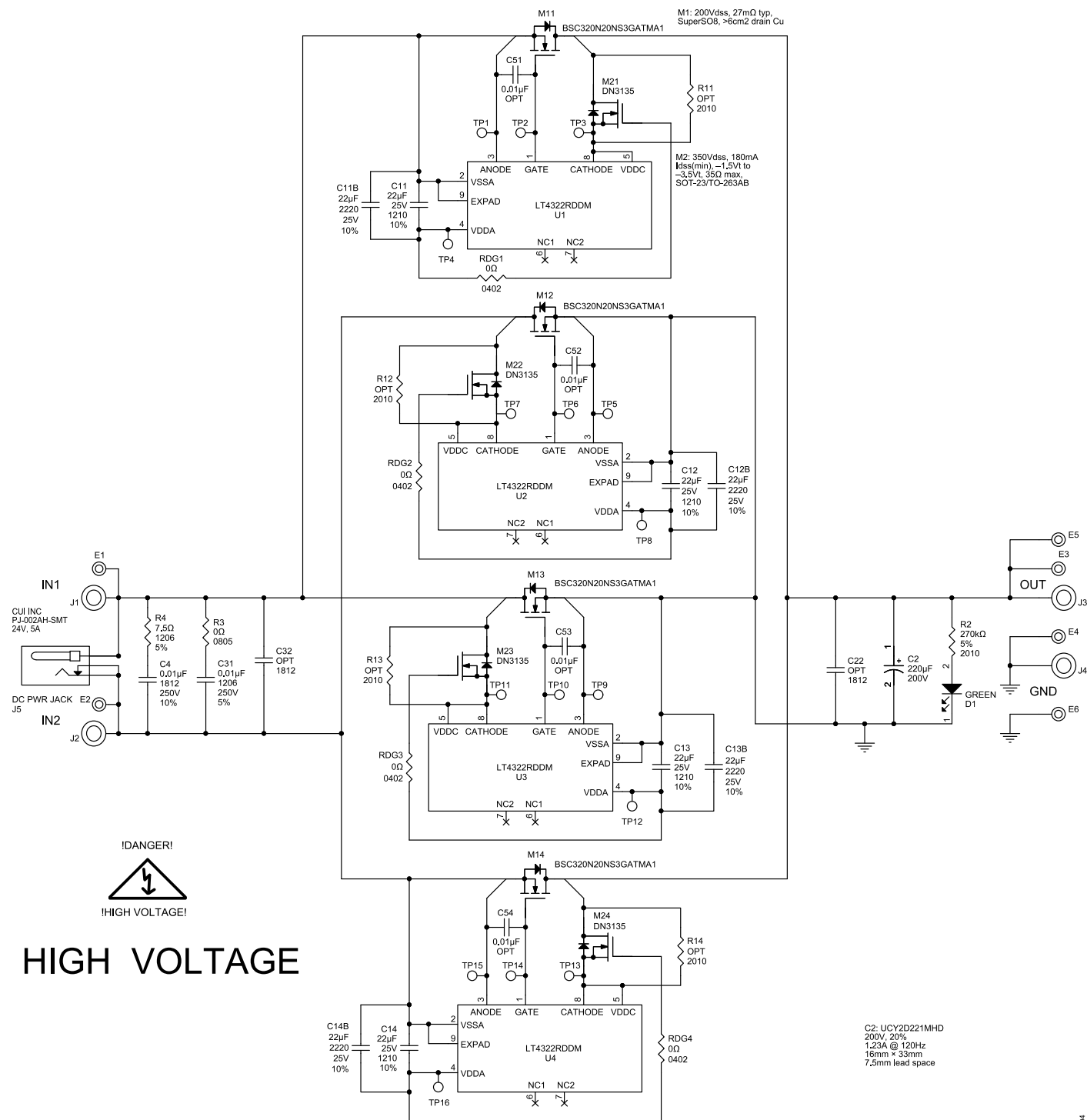


Figure 4. DC3137A Schematic Diagram

ORDERING INFORMATION

BILL OF MATERIALS

Table 3. DC3137A Bill of Materials

Item	Quantity	Reference Designator	Part Description	Manufacturer, Part Number
Required Circuit Components				
1	3	C2, C2-2, C2-3	Capacitors, 220 μ F, Aluminium 200V, 20%, 16 x 31.5mm, AEC-Q200	Nichicon, UCY2D221MHD AVX, 12103C226KAT2AC1 Kemet, 210C226K3RACTU Murata, GRM32ER71E226KE1 Samsung, 5LCL32B226KAJNNNE
2	4	C11, C12, C13, C14	Capacitors, 22 μ F, X7R, 25V, 10%, 1210	Kemet C2220C226K3RAC78 Kyocera 0022203C226KAZ2A AVXCAL-CHIP
3	4	C11B, C12B, C13B, C14B	Capacitors, CER 22 μ F 25V X7R 2220	Electronics, GMC55X7R226K25NT
4	4	C51, C52, C53, C54	Capacitors, 0.01 μ F, X7R, 16V, 10%, 0805	Würth Elektronik, 885012207039
5	4	M11, M12, M13, M14	Transistors, MOSFET, N-Channel, 200V, 36A, TDSO-8	Infineon, BSC320N20NS3 Infineon, GBSC320N20NS3GATMA1
6	4	M21, M22, M23, M24	Transistors, MOSFET N-Channel Depletion Mode, 350V, 72mA, 3-PIN SOT-23, DN3135	Microchip Technology, DN3135K1-G
7	4	RDG1, RDG2, RDG3, RDG4	Resistors, 0 Ω , 1/16W, 0402	Nicrohm, NRC04ZOTRFMCR0 Vishay, 1MZIPJ000CRCW040 , Yageo, 20000Z0EDRC0402JR-070RL
8	4	U1, U2, U3, U4	IC, Active Bridge Ideal Diode Controller, DFN-8	Analog Devices Inc., LT4322RDDM#PBF
Additional Demo Board Circuit Components				
9	1	C4	Capacitor, 0.01 μ F, X7R, 250 V, 10%, 1812	Kemet, C1812C103KARACTU
10	0	C22, C32	Capacitor, Option, 1812	
11	1	C31	Capacitor, 0.01 μ F, U2J, 250V, 5%, 1206	Murata, GRM31B7U2E103JW31
12	1	D1	LED, Green, Water-Clear, 0805	Würth Elektronik, 150080GS75000
13	0	M11B, M12B, M13B, M14B	Transistors, MOSFET, N-Channel, 200V, 36A, TDSO-8	Infineon, BSC320N20NS3 Infineon, GBSC320N20NS3GATMA1
14	0	M21-2, M22-2, M23-2, M24-2	Transistors, MOSFET N-Channel Depletion Mode, 350V, 0.135A, 4pin(3 + tap) SOT-89	Microchip Technology, DN3135N8-G
15	1	R2	Resistor, 270k Ω , 5%, 3/4W, 2010, AEC-Q200	Panasonic, ERJ-12ZYJ274U
16	1	R3	Resistor., 0 Ω , 1/8W, 0805	Yageo, RC0805JR-070RL
17	1	R4	Resistor, 7.5 Ω , 5%, 1/4W, 1206	Yageo, RC1206JR-077R5L
18	0	R11, R12, R13, R14	Resistors, Option, 2010	
Hardware: For Demo Board Only				
19	6	E1, E2, E3, E4, E5, E6	Test Point, Turret, 0.094" MTG. Hole, PCB 0.062" THK	Mill-Max, 2501-2-00-80-00-00-07-0
20	4	J1, J2, J3, J4	Connectors, Banana Jack, Female, THT, Non-Insulated, Swage, 0.218"	Keystone, 575-4
21	1	J5	Connector, DC PWR Jack, Female, 3Term, 1Port, 2mm ID, 6.5mm OD, Horizontal, R/A, SMT, 24V _{DC} , 5A	Cui Inc., PJ-002AH-SMT-TR
22	1	LB1	Label Spec, Demo Board Serial Number	Brady, THT-96-717-10
23	4	MP1, MP2, MP3, MP4	Standoff, Nylon, Snap-on, 0.25" (6.4mm)	Keystone, Würth Elektronik, 8831702931000
24	1	PCB1	PCB, DC3137A	ADI Approved supplier, 600-DC3137A
25	0	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9,	Test point, 0.044", 0.275 L x 0.093 W, TH	Keystone, 1036

ORDERING INFORMATION

Table 3. DC3137A Bill of Materials (Continued)

Item	Quantity	Reference Designator	Part Description	Manufacturer, Part Number
		TP10, TP11, TP12, TP13, TP14, TP15, TP16		

**ESD Caution**

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

Legal Terms and Conditions

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.

