DEMO MANUAL DC2191A

RF Transmitter Using LTC2000 16-Bit, 2.5Gsps to 2.7Gsps DAC

DESCRIPTION

Demonstration circuit 2191A supports the LTC®2000, a high speed, high dynamic range DAC driving the LT5579 upconverting mixer.

The circuitry on the DAC IF output is optimized for analog frequencies from DC to 500MHz. The circuitry on the LO input is optimized for frequencies from 1000MHz to 4300MHz.

The circuitry on the RF output is optimized for frequencies from 2200MHz to 2600MHz.

Design files for this circuit board are available at http://www.linear.com/demo/DC2191

PERFORMANCE SUMMARY

Specifications are at T_A = 25°C

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage – DC2191	This supply must provide up to 1100mA	4.8	5.0	5.2	V
Sampling Frequency (Sample Clock Frequency)*		300		2500 or 2700	MHz
Sample Clock Level (Single-Ended)	Use a 50Ω Source	0		15	dBm
LVDS Inputs	Differential Input Voltage Range Common Mode Voltage Range	±0.2 0.4		±0.6 1.8	V V
LO Input Frequency Range		750		4300	MHz

*DC2191A-A Features the LTC2000-16, 16-Bit, 2.5Gsps DAC

QUICK START PROCEDURE

DC2191 is easy to set up to evaluate the performance of the LTC2000 + LT5579. Refer to Figure 1 for proper measurement equipment set-up and follow the procedure below.

SOFTWARE

The software for the DC2191, LTDACGen is available at www.linear.com/LTDACGEN free of charge. It simplifies the creation of complex waveforms and loading them into the FPGA to test the DC2191. For more information about how to use the LTDACGen software, refer to the help files that come with the software.

APPLYING POWER AND SIGNALS TO THE DC2191 DEMONSTRATION CIRCUIT

If a Stratix IV demo board is used to supply data to the DC2191, the two boards should first be bolted together and a proper connection should be made. If Linear Technology provided the Stratix IV board the proper bit file is already installed in flash memory and will begin to operate when the board is powered on. If an unprogrammed FPGA board is used, refer to the Stratix IV GX Development Board Reference Manual on how to program it.

Power should be applied to the system in this order:

1. Connect the Altera board to the provided power supply.
2. Connect the USB cable to J7.
3. Apply a clock to J4.
4. Connect an LO source to J6.
5. Turn on the voltage to the Altera board.
6. Connect the 5V from a bench supply to the +5V turret on the DC2191.
7. Open the LTDACGen software and hit connect.

LTDACGen should report back that it is connected to the FPGA. See Figure 2:

QUICK START PROCEDURE

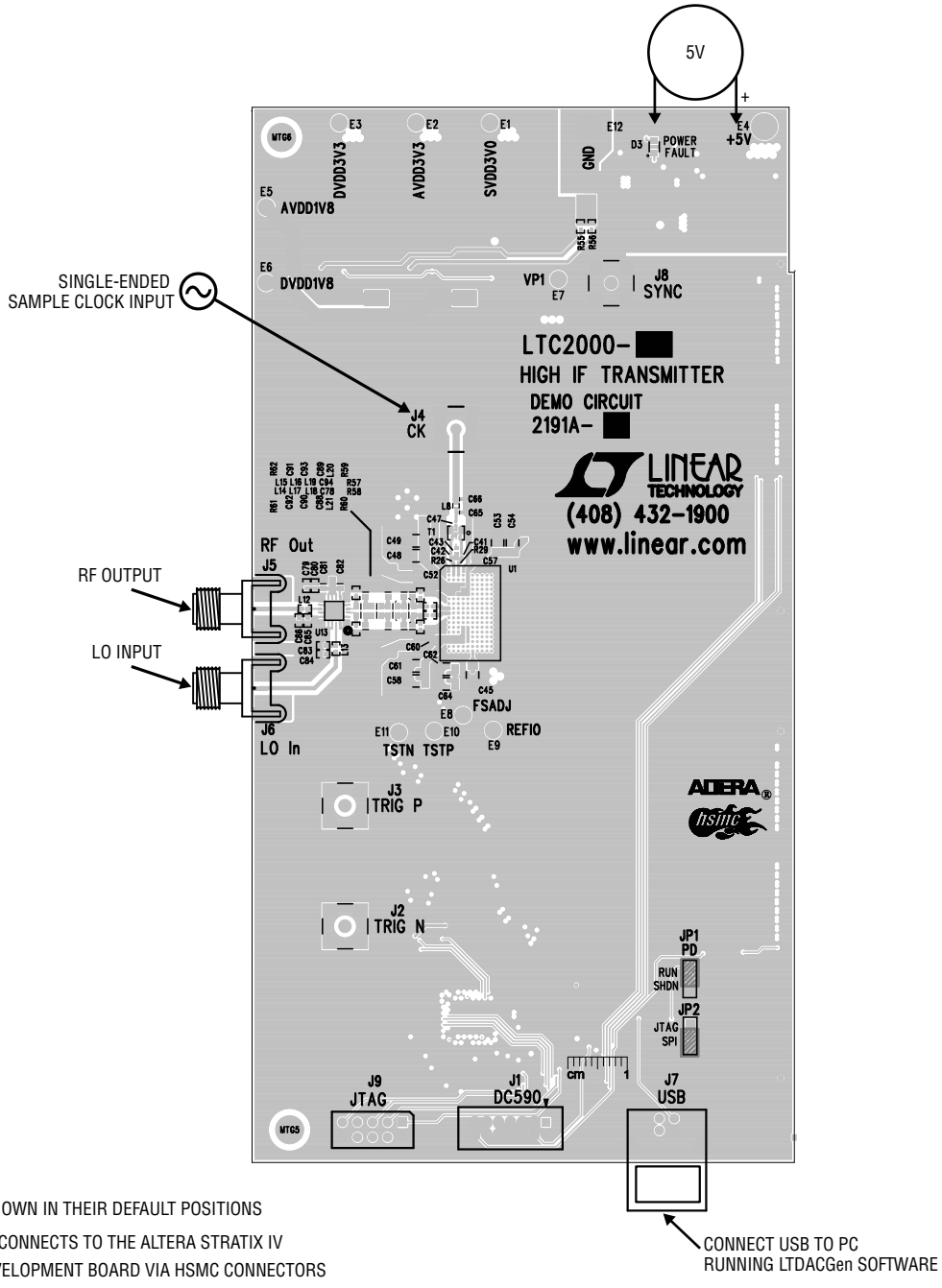

Figure 1. DC2191 Setup (zoom for details)

QUICK START PROCEDURE

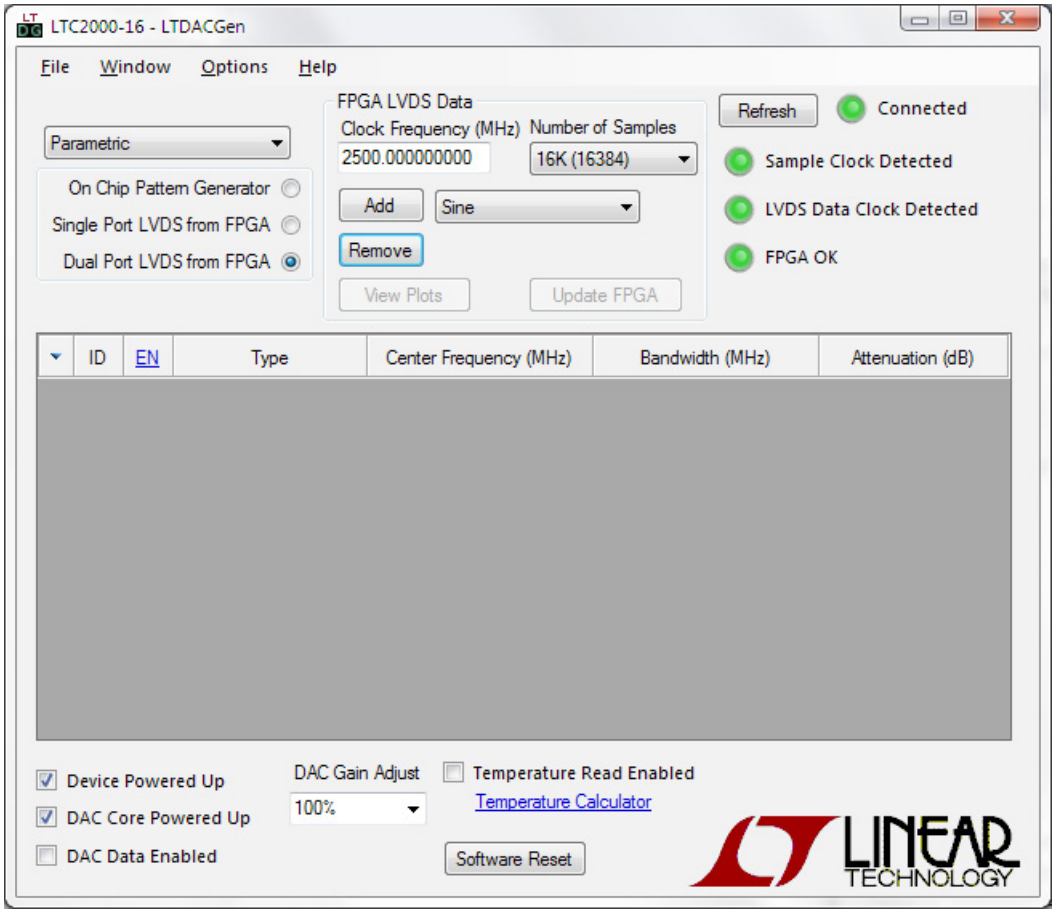

Figure 2. LTDACGen Connected to FPGA

QUICK START PROCEDURE

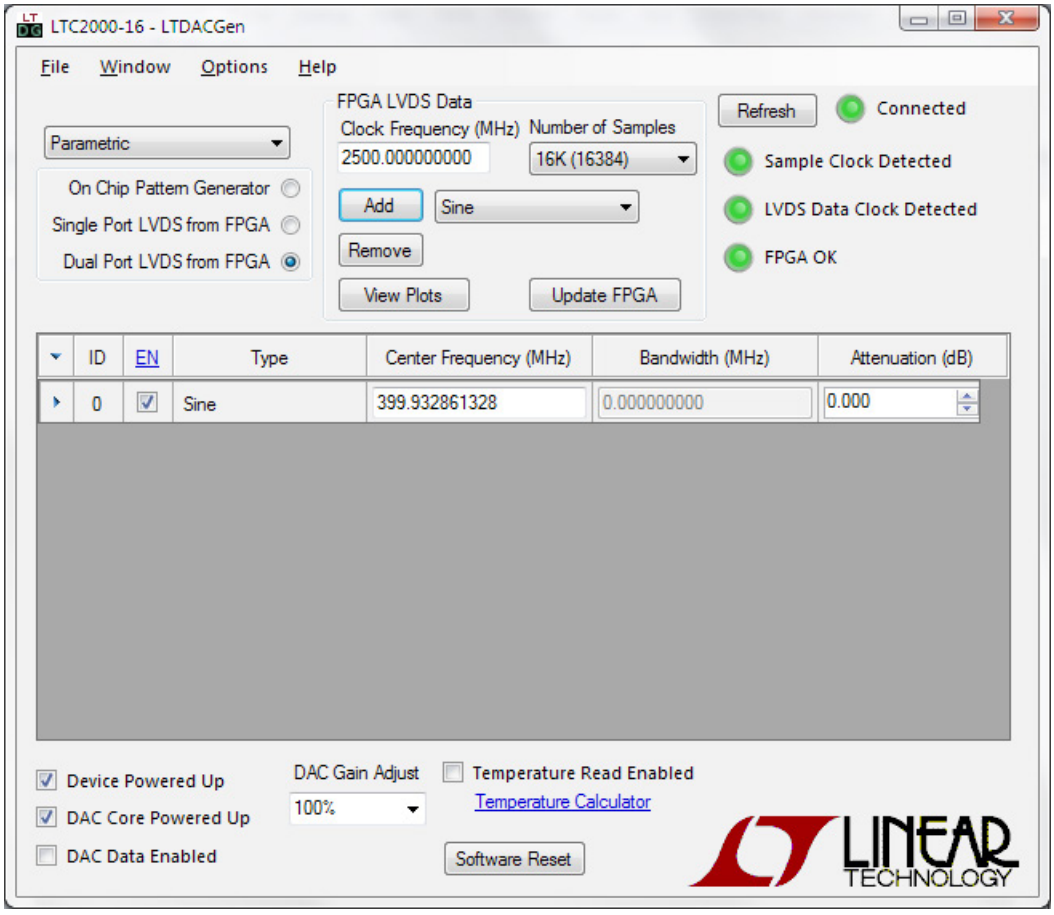

Figure 3. Default Frequency

QUICK START PROCEDURE

ANALOG OUTPUT NETWORK

The analog output network of the DC2191 has been designed to maximize the performance of the LTC2000. The LTC2000 drives a chebyshev lowpass filter with a corner at 500MHz.

SAMPLE CLOCK

The sample clock to the DC2191 demonstration circuit board is marked J4. As a default it is a single-ended 50Ω input port. There is an onboard balun that does a single-ended to differential translation.

For the best noise performance, the sample input must be driven with a very low jitter signal generator source. The amplitude should be as large as possible up to ±1.8V or 9dBm.

RESULTS

After everything is set up and the software is connected to the DAC demo system, a sine wave can be added to the output waveform. The default frequency is 399.932861328MHz (Figure 3). By clicking Update FPGA, the data is sent to the FPGA and is then used to program the DAC. A spectrum analyzer can then be used to view the results at J5.

HARDWARE SETUP

SMAs

J2 & J3: Differential Trigger Input. Apply a signal to J2 from a 50Ω driver. Absorptive filters are required for data sheet performance. Use J2 and J3 if the trigger is a differential signal.

J4: Sample Clock Input. Apply a clock signal to this SMA connector from a 50Ω driver. A 0dBm clock source should be sufficient, but for best phase noise and jitter performance, use the highest possible amplitude and slew rate.

J5: RF Output Signal. This is the upconverted output of the DAC if the output impedance is 50Ω. Connect to a spectrum analyzer.

J6: LO Input Signal. This is the local oscillator input to the upconverting mixer. Nominal power level is 0dBm.

J8: SYNC. This SMA is to provide access to the sync pin of the LT8614. It is not used in normal use.

Turrets

+5V: Positive Input Voltage for the DAC, Mixer, and Digital Circuits. This voltage feeds a series of regulators that supply the proper voltages for the DAC. The voltage range for this turret is 4.8V to 5.2V. Note: For close-in phase noise plots, driving this voltage is not ideal. There is a known 20kHz noise hump in the spectrum that is generated by the regulators. For the best phase noise performance, back drive the onboard regulators with the provided turrets from a low noise supply.

GND: Ground Connection. This demo board has only a single ground plane. This turret should be tied to the GND terminal of the power supply being used.

SVDD3V0: Optional 3.0V Input. This pin is connected directly to the SV_{DD} pin of the DAC. It requires a supply that can deliver up to 100mA. Driving this pin will shut down the onboard regulator.

AVDD3V3: Optional 3.3V Input. This pin is connected directly to the AV_{DD33} pin of the DAC. It requires a supply that can deliver up to 450mA. Driving this pin will shut down the onboard regulator.

DVDD3V3: Optional 3.3V Input. This pin is connected directly to the DV_{DD33} pin of the DAC. It requires a supply that can deliver up to 50mA. Driving this pin will shut down the onboard regulator.

AVDD1V8: Optional 1.8V Input. This pin is connected directly to the AV_{DD18} pin of the DAC. It requires a supply that can deliver up to 1A. Driving this pin will shut down the onboard regulator.

DVDD1V8: Optional 1.8V Input. This pin is connected directly to the DV_{DD18} pin of the DAC. It requires a supply that can deliver up to 500mA. Driving this pin will shut down the onboard regulator.

VP1: This is a test point that is at the output of the on-board switching regulator. It is meant for test purposes. It can also be driven to 2.5V to shut down the output of the switching regulator.

TSTP & TSTN: These pins are tied directly to the TSTP and TSTN pins of the DAC. They can be used to measure the internal temperature and timing of the LVDS inputs.

FSADJ: This is an optional pin that is tied directly to the FSADJ pin of the DAC. It can be used to set the full-scale output current of the DAC. In normal operation this pin is tied to GND through 500Ω to set a current of 40mA at the output.

REFIO: This pin is tied directly to the REFIO pin of the DAC and is used to set the reference voltage for the DAC. Normally it is internally set to 1.25V but can be overdriven with an external voltage from 1.1V to 1.4V.

Jumpers

The DC2191 demonstration circuit should have the following jumper settings as default positions.

JP1: PD. In the RUN position this pin results in normal operation of the DAC. In the SHDN position the DAC is powered down. (Default: RUN or up)

JP2: SPI and JTAG. This jumper selects how the FPGA is programmed. In the SPI position the FPGA is programmed from the onboard FTDI chip and the LTDACGen software. In the JTAG position the J9 is used with a JTAG programmer to program the FPGA. (Default: SPI or down)

Connectors

J1: DC590. This is an optional header that can be used to program the DAC with the DC590. (Default: removed)

J9: JTAG. This is an optional header that can be used to program the FPGA through a JTAG programmer. (Default: removed)

J7: USB. Connect a USB cable from J7 to a computer with the LTDACGen software installed.

J10 & J11: HSMC Connectors. These connectors are designed to connect to the Altera Stratix IV development board. All of the communication between the FPGA and the DAC is routed through these connectors.

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	13	C1, C25, C26, C29, C31, C32, C33, C34, C35, C36, C37, C71, C72	CAP., X7R, 0.1µF, 16V 10% 0402	AVX, 0402YC104KAT2A
2	4	C2, C3, C8, C19, C78, C94	CAP., NPO, 0.01µF, 25V, 5%, 0603	TDK, C1608C0G1H103J
3	9	C4, C6, C9, C11, C14, C18, C67, C68, C69, C76, C77, C81	CAP., X7R, 1µF, 16V 10% 0603	AVX, 0603YC105KAT2A
4	5	C5, C7, C10, C12, C15	CAP., TANT., 47µF, 16V, 10%, 7343	AVX, TAJD476K016RNJ
5	6	C13, C16, C27, C28, C73, C74	CAP., X5R, 4.7µF, 16V, 20%, 1206	TDK, C3216X5R1C475M
6	3	C17, C40, C82	CAP., X5R, 10µF, 10V, 20%, 0603	AVX, 0603ZD106MA2T
7	1	C20	CAP., C0G, 4.7pF, 50V ± 0.25pF, 0603	AVX, 06035A4R7CAT2A
8	2	C21, C24	CAP., X7R, 0.1µF, 16V, 10%, 0603	TDK, C1608X7R1C104K
9	1	C22	CAP., X7R, 1µF, 25V, 10%, 0603	TDK, C1608X7R1E105K
10	2	C23, C70	CAP., X7R, 47µF, 10V, 10%, 1210	MURATA, GRM32ER71A476KE15L
11	1	C30	CAP., X5R, 3.3µF, 16V, 10%, 0603	TDK, C1608X5R1C335K
12	2	C38, C39	CAP., COG, 27pF, 50V, 5%, 0402	TDK, C1005C0G1H270J
13	2	C89, C88	CAP., COG, 5.6pF, 50V, 5%, 0402	TDK, C1005C0G1H5R6J
14	2	C90, C93	CAP., COG, 22pF, 50V, 5%, 0402	TDK, C1005C0G1H220J
15	1	C83	CAP., COG, 2.7pF, 50V, 5%, 0402	TDK, C1005C0G1H2R7J
16	1	C85	CAP., COG, 1.2pF, 50V, 5%, 0402	TDK, C1005C0G1H1R2J
17	1	C79	CAP., COG, 10pF, 50V, 5%, 0402	TDK, C1005C0G1H100J
18	1	C80	CAP., COG, 100pF, 50V, 5%, 0402	TDK, C1005C0G1H101J
19	2	C41, C42	CAP., COG, 100pF, 25V, 5%, 0201	TDK, C0603C0G1E101J
20	1	C43	CAP., X5R, 0.01µF, 16V, 10%, 0402	MURATA, GRM155R61C103KA01D
21	1	C44	CAP., X7R, 47nF, 25V, 10%, 0402	MURATA, GRM155R71E473KA88D
22	9	C45, C48, C49, C53, C54, C58, C61, C62, C64	CAP., X5R, 100µF, 6.3V, 20%, 1206	TDK, C3216X5R0J107M
23	10	C46, C50, C51, C52, C55, C56, C57, C59, C60, C63	CAP., X7S, 2.2µF, 4V, 20%, 0306	MURATA, LLL185C70G225ME01L
24	1	C47	CAP., COG, 10pF, 25V, 5%, 0201	MURATA, GRM0335C1E100JA01D
25	0	C65, C84, C86, C91, C92	CAP., OPT, 0402	OPTION
26	1	C66	CAP., NP0, 1pF, 25V ±.25pF, 0402	AVX, 04023A1R0CAT2A
27	1	C75	CAP., X7R, 10µF, 50V, 10%, 1210	MURATA, GRM32ER71H106KA12L
28	1	D1	DIODE, TVS, 70V, SMA	DIODES INC./ ZETEX, SMAT70A-13-F
29	1	D2	DIODE, TVS, 24V, SMA	DIODES INC./ ZETEX, SMAJ24A-13-F
30	1	D3	LED,RED, WATERCLEAR, 0805	WURTH, 150080RS75000
31	10	E1, E2, E3, E5-E11	TEST POINT, TURRET, .061, PBF	MILL-MAX, 2308-2-00-80-00-00-07-0
32	2	E4, E12	TEST POINT, TURRET, .094, PBF	MILL-MAX, 2501-2-00-80-00-00-07-0
33	2	JP1, JP2	HEADER, 3 PIN, .079	SULLINS, NRPN031PAEN-RC
34	1	J1	HEADER, 2 × 7 DUAL ROW	MOLEX 87831-1420
35	3	J2, J3, J8	CON.,SMA JACK, STRAIGHT, THRU-HOLE	AMPHENOL CONNEX, 132134
36	1	J4	CON., SMA PCB TOP MOUNT	AEP, 9650-1113-005
37	2	J5, J6	CON., SMA 50 OHM EDGE-LAUNCH	EMERSON, 142-0701-851

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
38	1	J7	CONNECTOR, USB TYPE B, RIGHT ANGLE PCB MOUNT	FCI, 61729-0010BLF
39	1	J9	HEADER, 2 × 5, 0.100	SAMTEC, TSW-105-07-L-D
40	2	J10, J11	CONNECTOR, HSMC	SAMTEC, ASP-122952-01
41	6	L1, L2, L3, L4, L6, L7	FERRITE BEAD, 33Ω at 100mhz, 1206	MURATA, BLM31PG330SN1L
42	1	L5	INDUCTOR, 2.2µH, 20% HIGH CURRENT, SMT	VISHAY, IHLP2020BZER2R2M11
43	1	L8	INDUCTOR, CERAMIC CHIP, 1nH, 5%, 0402	COILCRAFT, 0402CS-1N0XJLU
44	1	L9	FERRITE BEAD, 30Ω at 100Mhz, 0805	TDK, MPZ2012S300A
45	1	L10	INDUCTOR, 6.8µH, 20% HIGH CURRENT, SMT	VISHAY, IHLP2020BZER6R8M11
46	2	L18, L19	IND, 3.3nH, 5%, 0402	TOKO, LL1005-FHL3N3S
47	2	L16, L17	IND, 3.9nH, 5%, 0402	TOKO, LL1005-FHL3N9S
48	1	L13	IND, 1.8nH, 5%, 0402	TOKO, LL1005-FHL1N8S
49	1	L12	IND, 2.7nH, 5%, 0402	TOKO, LL1005-FHL2N7S
50	2	L20, L21	IND, 560nH, 5%, 0603	COILCRAFT, 0603HL-561XJR
51	2	L14, L15	RES., CHIP, 0Ω, JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
52	5	MP1-MP5	MACHINE SCREW, NYLON, #4-40 × 1/2 IN., SLOTTED	EAGLE PLASTIC DEVICES, 561-J440.5
53	2	MP6-MP7	HEX STANDOFF, NYLON, #4-40 × 1/2 IN., THREADED	KEYSTONE, 1902C
54	4	MP8-MP11	SPACER, NYLON, 5mm L × 3.2mm DIA.	BIVAR, 9908-5MM
55	2	MP12-MP13	STANDOFF, NYLON, 3/4 IN.	KEYSTONE, 8834
56	4	MP14-MP17	STANDOFF, NYLON, #4-40 × 1/4 IN.	MICROPLASTICS, #14HTSP101
57	2	MP18, MP19	STANDOFF, NYLON 3/4"	KEYSTONE, 8834
58	2	Q1, Q2	TRANSISTOR, N-CH. POWER MOSFET, SOIC 8L	FAIRCHILD, FDS8870
59	6	R1, R2, R3, R13, R17, R30	RES., CHIP, 1k, 1/16W, 5%, 0402	VISHAY, CRCW04021K00JNED
60	1	R4	RES., CHIP, 4.7k, 1/16W, 5%, 0402	YAGEO, RC0402JR-074K7L
61	4	R5, R14, R15, R16	RES., CHIP, 10k, 1/16W, 5%, 0402	YAGEO, RC0402JR-0710KL
62	2	R6, R8	RES., CHIP, 2k, 1/16W, 5%, 0402	VISHAY, CRCW04022K00JNED
63	0	R7, R10, R36, R37, R38, R39	RES., CHIP, DNI, 0402	OPTION
64	1	R9	RES., CHIP, 39Ω, 1/16W, 1%, 0402	VISHAY, CRCW040239R0FKED
65	3	R11, R57, R58	RES., CHIP, 0Ω JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
66	1	R12	RES., CHIP, 12k, 1/16W, 5%, 0402	VISHAY, CRCW040212K0JNED
67	1	R18	RES., CHIP, 2.2k, 1/16W, 5%, 0402	VISHAY, CRCW04022K20JNED
68	2	R19, R20	RES., CHIP, 3.24k, 1/16W, 1%, 0402	VISHAY, CRCW04023K24FKED
69	1	R21	RES., CHIP, 1k, 1/16W, 1%, 0402	YAGEO, RC0402FR-071KL
70	1	R22	RES., CHIP, 7.15k, 1/16W, 1%, 0402	VISHAY, CRCW04027K15FKED
71	2	R26, R29	RES., CHIP, 49.9Ω, 1/6W, 1%, 0201	VISHAY, CRCW020149R9FNED
72	7	R31, R32, R33, R34, R35, R41, R42	RES., CHIP, 10Ω, 1/16W, 1%, 0402	VISHAY, CRCW040210R0FKED
73	1	R45	RES., CHIP, 499Ω, 1/16W, 1%, 0402	VISHAY, CRCW0402499RFKED
74	1	R49	RES., CHIP, 41.2k, 1/10W, 1%, 0603	VISHAY, CRCW060341K2FKEA
75	1	R50	RES., CHIP, 309k, 1/10W, 1%, 0603	VISHAY, CRCW0603309KFKEA
76	1	R51	RES., CHIP, 243k, 1/10W, 1%, 0603	VISHAY, CRCW0603243KFKEA

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
77	1	R52	RES., CHIP, 50Ω, 1/8W, 5%, 0603	VISHAY, FC0603E50R0JST1
78	1	R53	RES., CHIP, 560Ω, 1/10W, 5%, 0603	VISHAY, CRCW0603560RJNEA
79	1	R54	RES., CHIP, 10k, 1/10W, 1%, 0603	VISHAY, CRCW060310K0FKEA
80	4	R55, R56, R59, R60	RES., CHIP, 20Ω, 1/16W, 1%, 0402	VISHAY, CRCW040220R0FKED
81	2	R61, R62	RES., CHIP, 11Ω, 1/16W, 1%, 0402	VISHAY, CRCW040211R0FKED
82	1	T1	TRANSFORMER, BALUN	ANAREN, B0430J50100AHF
83	1	U2	IC, USB TO MULTIPURPOSE UART/FIFO, TQFP	FTDI, FT2232HL
84	1	U3	IC, QUAD MUX/DEMUX, TSSOP-16	FAIRCHILD, FST3257MTCX
85	1	U4	IC, EEPROM 1KBIT 3MHz, 8TSSOP	MICROCHIP, 93LC46C-I/ST
86	1	U5	IC, MICROPOWER REGULATOR, SO-8	LINEAR TECH., LT1763CS8-3#PBF
87	2	U6, U7	IC, MICROPOWER REGULATOR, SO-8	LINEAR TECH., LT1763CS8-3.3#PBF
88	1	U8	IC, BUCK REGULATOR, QFN	LINEAR TECH., LT8614IUDC#PBF
89	1	U9	IC, VOLTAGE REFERENCE, MSOP	LINEAR TECH., LTC6655CHMS8-2.048#PBF
90	2	U10, U11	I.C., LOW DROPOUT REGULATOR, 3mm × 3mm, DFN	LINEAR TECH., LT3080EDD#PBF
91	1	U12	I.C., 80V IDEAL DIODE, DFN-6L	LINEAR TECH.,LTC4359HDCB#TRPBF
92	1	U13	IC, MIXER	LINEAR TECH, LTC5579IUH
93	2	XJP1, XJP2	SHUNT, 2mm	SAMTEC, 2SN-BK-G
94	1	Y1	CRYSTAL, 12.0MHz, SMT	ABRACON, ABMM2-12.000MHZ-E2-T
DC2191A-A Required Circuit Components				
1	1		GENERAL BOM	DC2191A
2	1	U1	IC, 16-BIT 2.5Gsps DAC	LINEAR TECH. LTC2000IY-16

SCHEMATIC DIAGRAM

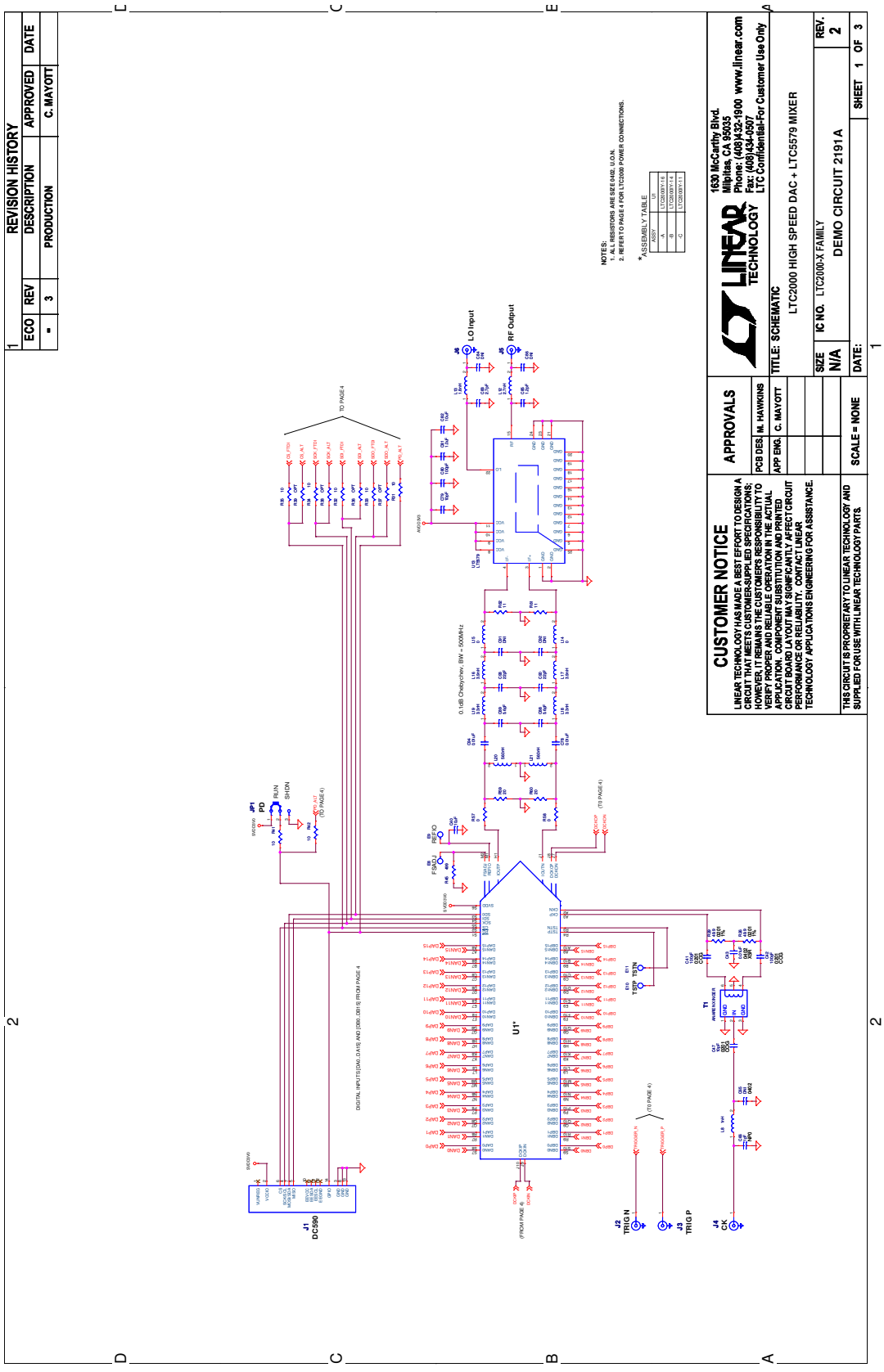

Figure 4. DC2191 Demo Circuit Schematic (Sheet 2)

SCHEMATIC DIAGRAM

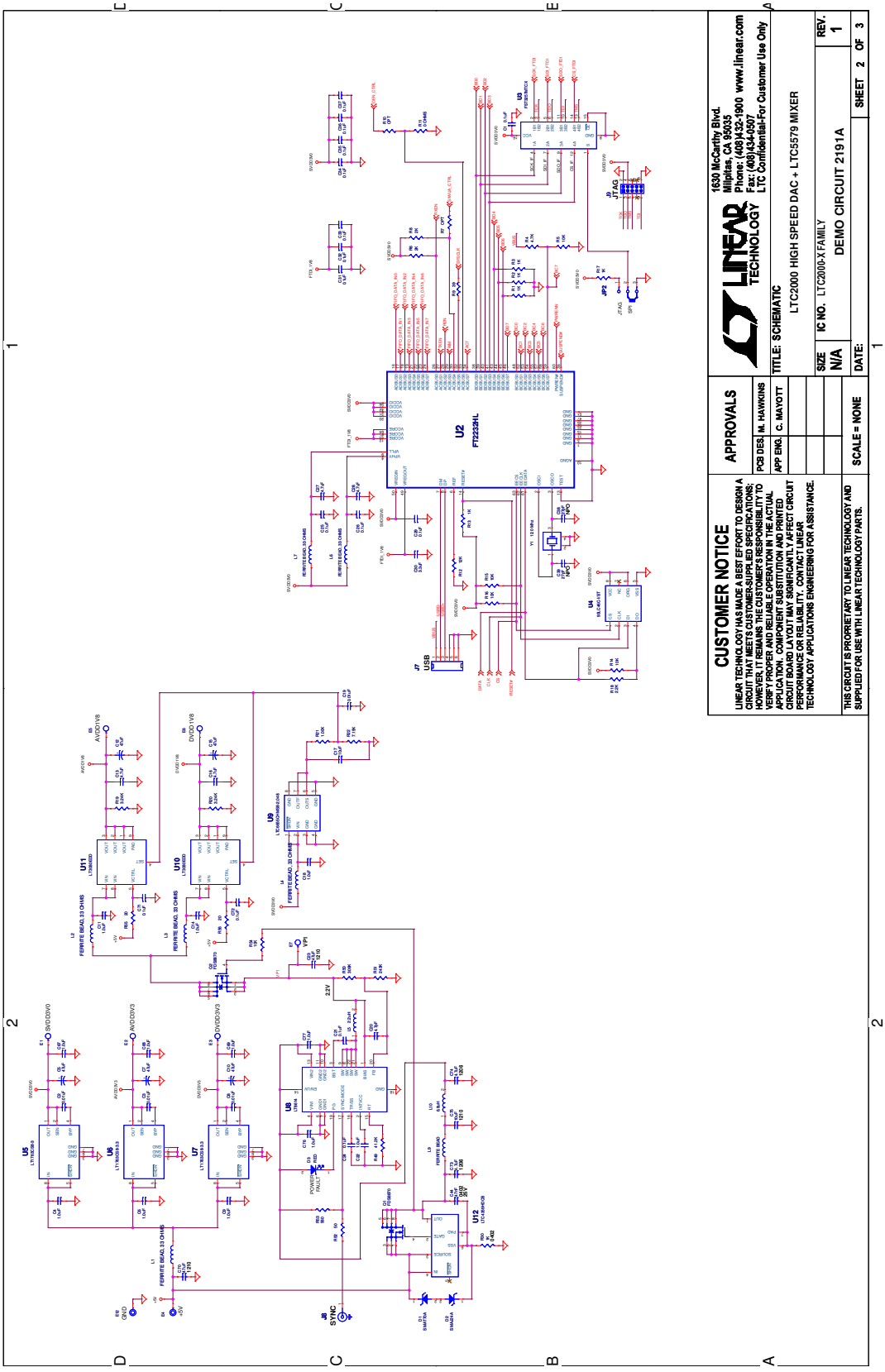

Figure 5. DC2191 Demo Circuit Schematic (Sheet 3)

SCHEMATIC DIAGRAM

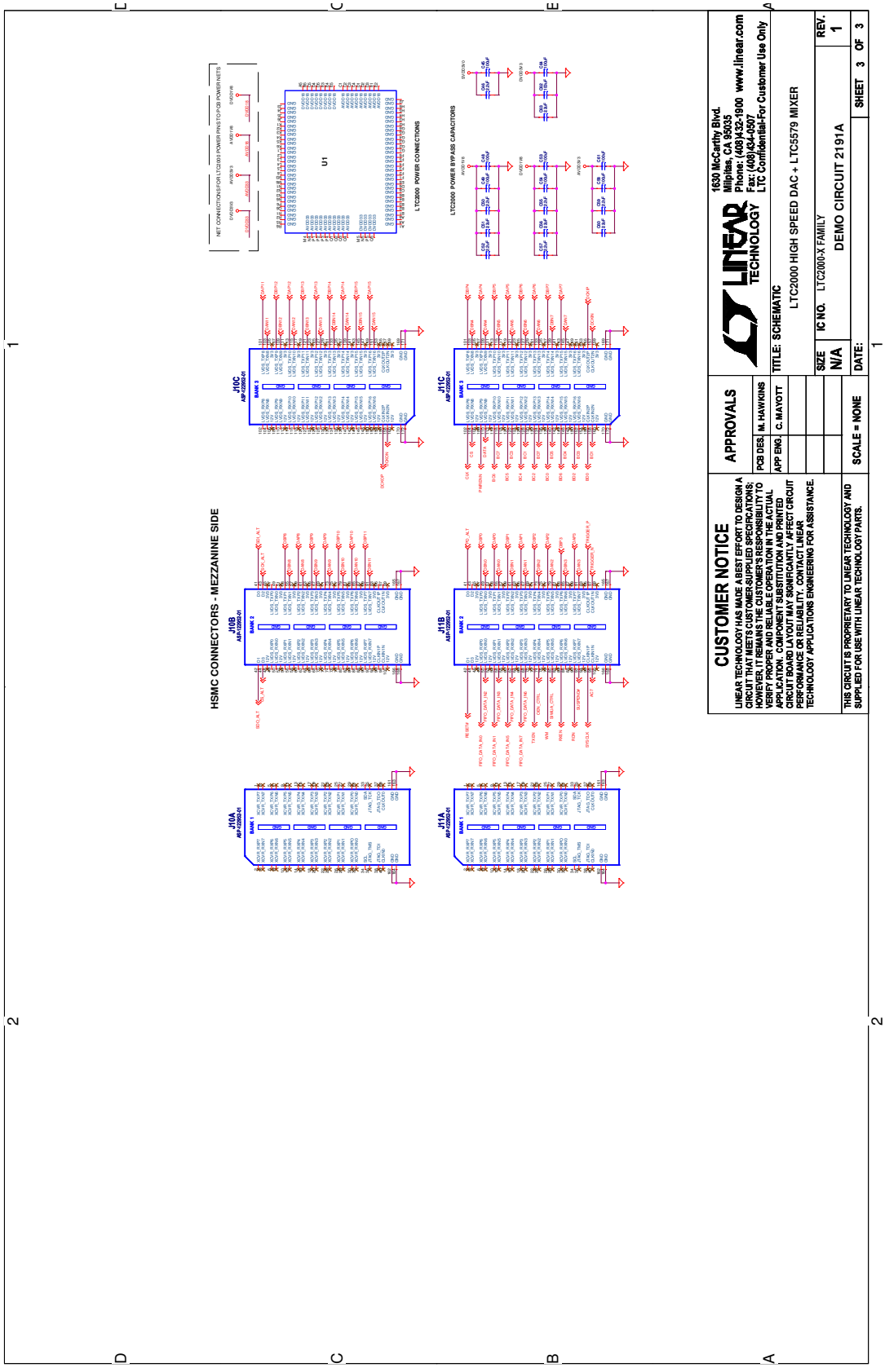

Figure 6. DC2191 Demo Circuit Schematic (Sheet 4)

DEMONSTRATION BOARD IMPORTANT NOTICE

Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

This demonstration board (DEMO BOARD) kit being sold or provided by Linear Technology is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not provided by LTC for commercial use. As such, the DEMO BOARD herein may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including but not limited to product safety measures typically found in finished commercial goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may or may not meet the technical requirements of the directive, or other regulations.

If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

No License is granted under any patent right or other intellectual property whatsoever. **LTC assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or any other intellectual property rights of any kind.**

LTC currently services a variety of customers for products around the world, and therefore this transaction **is not exclusive**.

Please read the DEMO BOARD manual prior to handling the product. Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged**.

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

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OCEAN CHIPS
Океан Электроники
Поставка электронных компонентов

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Наши преимущества:

- Поставка оригинальных импортных электронных компонентов напрямую с производств Америки, Европы и Азии, а так же с крупнейших складов мира;
- Широкая линейка поставок активных и пассивных импортных электронных компонентов (более 30 млн. наименований);
- Поставка сложных, дефицитных, либо снятых с производства позиций;
- Оперативные сроки поставки под заказ (от 5 рабочих дней);
- Экспресс доставка в любую точку России;
- Помощь Конструкторского Отдела и консультации квалифицированных инженеров;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Поставка электронных компонентов под контролем ВП;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

Компания «Океан Электроники» является официальным дистрибьютором и эксклюзивным представителем в России одного из крупнейших производителей разъемов военного и аэрокосмического назначения «**JONHON**», а так же официальным дистрибьютором и эксклюзивным представителем в России производителя высокотехнологичных и надежных решений для передачи СВЧ сигналов «**FORSTAR**».

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(Применяются в телекоммуникациях гражданского и специального назначения, в средствах связи, РЛС, а так же военной, авиационной и аэрокосмической отраслях промышленности).

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