ANALOG DEVICES

EVAL-ADRF6820 User Guide
UG-652

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Evaluating the ADRF6820—a 695 MHz to 2700 MHz Quadrature Demodulator with Integrated Fractional-N PLL and VCO

FEATURES

Full featured evaluation board for the ADRF6820
On-board USB for SPI control
Dual supply: 5 V and 3.3 V operation
C# software interface for serial port control

EVALUATION KIT CONTENTS

ADRF6820 evaluation board
USB cable

ADDITIONAL EQUIPMENT NEEDED

Analog signal sources
Power supply (6.0 V, 2.5 A)
PC running Windows 98 (2nd ed.), Windows 2000, Windows ME, Windows XP, or Windows 7
USB 2.0 port, recommended (USB 1.1 compatible)

SOFTWARE NEEDED

ADRF6820 control software (download from ADRF6820 product page)

GENERAL DESCRIPTION

The ADRF6820 is a highly integrated quadrature demodulator and synthesizer ideally suited for next generation communication systems. The feature rich device consists of a high linearity, broadband quadrature demodulator; an integrated fractional-N phase-locked loop (PLL); and a low phase noise multicore voltage controlled oscillator (VCO). In addition, the ADRF6820 integrates a 2:1 RF switch, an on-chip tunable RF balun, a programmable RF attenuator, and two low dropout (LDO) regulators. This highly integrated device fits within a small 40-pin, 6 mm × 6 mm footprint.

This user guide describes the evaluation board for the ADRF6820, which provides all of the support circuitry required to operate the ADRF6820 in its various configurations. The application software used to interface with the device is also described.

The ADRF6820 data sheet, available at www.analog.com, provides additional information and should be consulted in conjunction with this user guide when using the evaluation board.

PHOTOGRAPH AND FUNCTIONAL BLOCK DIAGRAM OF EVALUATION BOARD

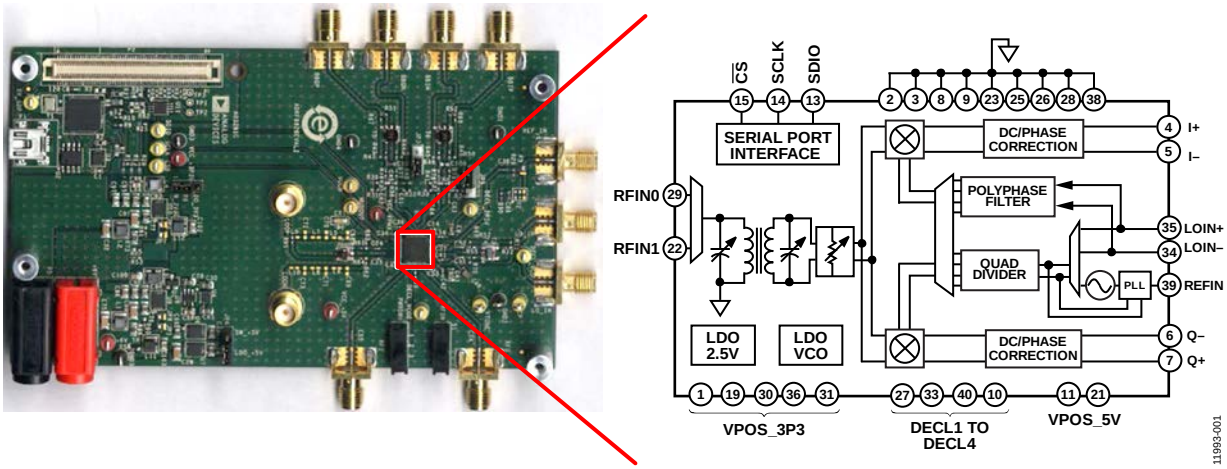


Figure 1.

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REVISION HISTORY

2/14—Revision 0: Initial Version

EVALUATION BOARD HARDWARE

The ADRF6820 evaluation board provides all of the support circuitry required to operate the ADRF6820 in its various modes and configurations. Figure 2 shows the typical bench setup used to evaluate the performance of the ADRF6820.

POWER SUPPLY

The ADRF6820 evaluation board requires a quiet 6 V power source. This 6 V power source feeds the power supply design on the ADRF6820 evaluation board that consists of switches and dc regulators. Via the switches and/or dc regulators, 3.3 V and 5.0 V power rails are provided to the main IC.

RF INPUTS

The high isolation 2:1 RF switch and on-chip tunable RF balun enable the ADRF6820 to support two single-ended, 50 Ω terminated RF inputs. The 2:1 RF switch can be controlled serially via the SPI port or in parallel via Switch S1. The default configuration is parallel control using the switch. The operational frequency range of the RF inputs is from 695 MHz to 2700 MHz; these inputs should be ac-coupled.

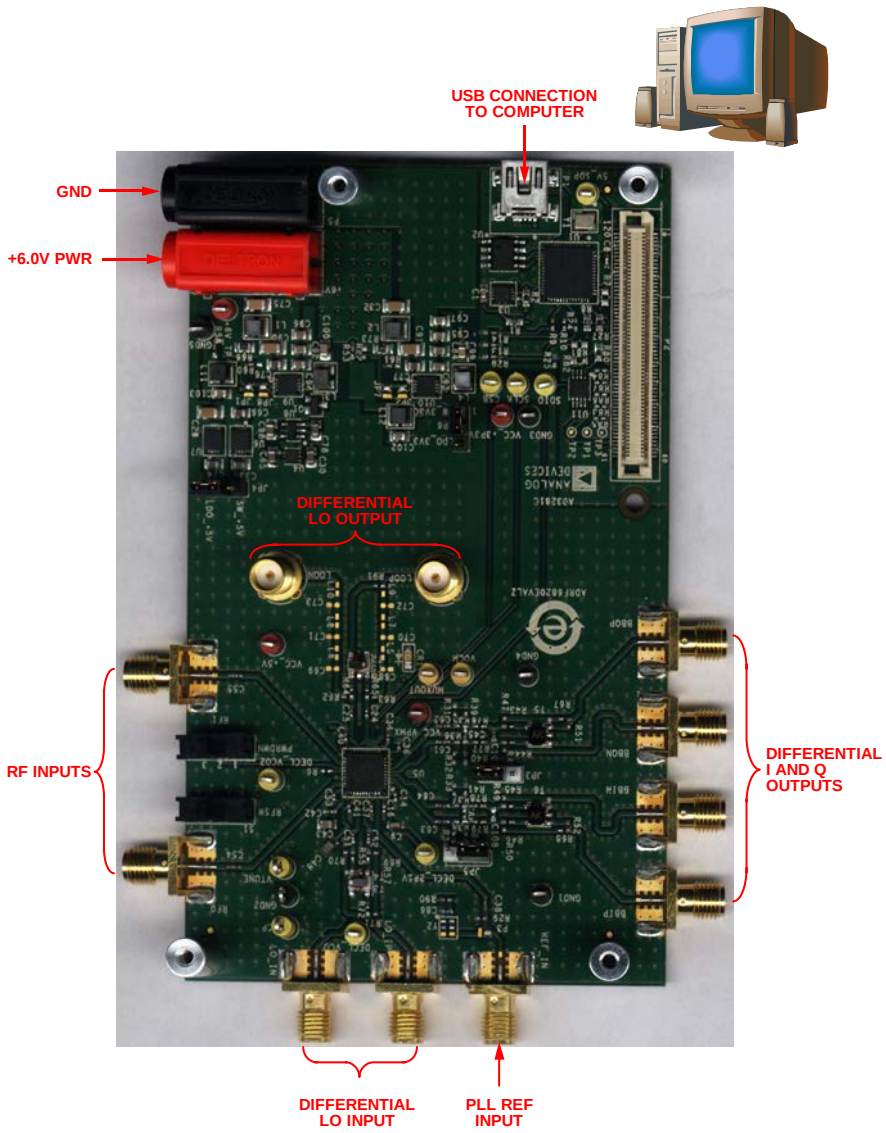


Figure 2. ADRF6820 Typical Measurement Setup

LO INPUT/OUTPUT

The ADRF6820 offers two alternatives for generating the differential local oscillator (LO) input signal:

- Generate the signal externally via a high frequency, low phase noise LO signal.
- Generate the signal internally via the on-chip Fractional-N synthesizer.

In either case, the differential LO signal can be routed off chip to SMA connectors labeled LOOP and LOON for the purpose of daisy-chaining multiple ICs requiring LO signals.

For an internal LO configuration using the on-chip Fractional-N synthesizer, apply a low phase noise reference signal to the REF_IN connector. The PLL reference input can support a wide frequency range because the divide or multiplication block can be used to increase or decrease the reference frequency to the desired value before the signal is passed to the phase frequency detector (PFD). The integrated synthesizer enables continuous LO coverage from 356.25 MHz to 2850 MHz.

For optimum performance using an external LO source, the LO input pins (LOIN– and LOIN+) should be driven differentially. The wide input range of the external LO inputs span from 350 MHz to 6000 MHz. Unless an ac-coupled balun/transformer is used to generate the differential LO, the inputs must be ac-coupled. The input impedance of the differential LO signals is 50 Ω.

QUADRATURE I/Q OUTPUTS

On the evaluation board, the quadrature I/Q outputs are terminated with 200 Ω differential. This is achieved by using a 1:1 transformer and an L-impedance matching network. The 1:1 transformer, TC1-1-13M+ from Mini-Circuits, is a very wide bandwidth (4.5 MHz to 3000 MHz) transformer that allows a flat pass-band response of up to 1 GHz. Using a wide bandwidth transformer is necessary to accurately evaluate the wideband pass-band response of the ADRF6820 without the effects of the transformer/balun roll-off. However, to terminate the ADRF6820 with 200 Ω and also match the output impedance of the transformer with 50 Ω, an L network is placed between the I/Q outputs and the transformer. This introduces some power loss because the L network acts as a voltage divider (see Figure 3). The power loss due to the L network is approximately 17 dB.

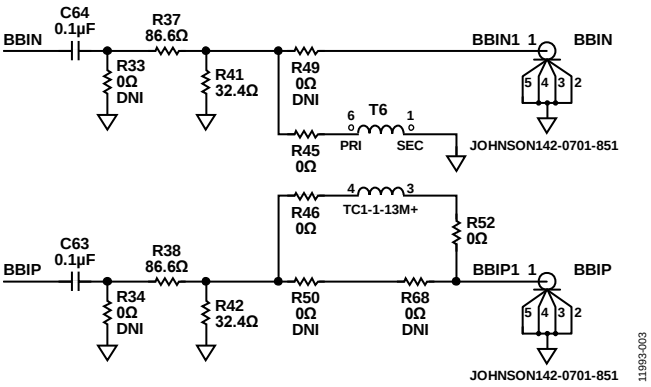


Figure 3. I/Q Output Matching Network

To avoid the power loss from the L network while achieving the proper impedance matching, a 4:1 impedance transformer, such as the TC4-1W+ from Mini-Circuits can be used in place of the TC1-1-13M+. This 4:1 impedance transformer allows the primary side of the transformer to be terminated with 200 Ω and the secondary side to be terminated with 50 Ω. The L network then becomes unnecessary and can be shorted out by replacing R35, R36, R37, and R38 with 0 Ω while R31, R32, R33, R34, R39, R40, R41, and R42 can all be DNI (do not install). Attention needs to be paid to the bandwidth of the transformer because impedance transformation transformers tend to have narrower bandwidths. The TC4-1W+ has a listed bandwidth of 3 MHz to 800 MHz; however, the 1 dB bandwidth is limited to 100 MHz. As a result, the roll-off of the transformer may distort the pass-band flatness of the ADRF6820, depending on which bandwidth configuration is used for the ADRF6820.

EVALUATION BOARD CONTROL SOFTWARE

The ADRF6820 evaluation board is configured with a USB friendly interface to allow programmability of the ADRF6820 registers.

SOFTWARE INSTALLATION PROCEDURES

The following instructions describe how to install the ADRF6820 control software, as well as the Cypress generic USB driver, on a computer running a Windows XP, Windows Vista, or Windows 7 (32- or 64-bit) operating system.

Warning

Install the necessary software before plugging the USB cable into the computer.

Installing the Evaluation Software

1. From the extracted folder, **ADI_RFG_Drivers**, double-click the **ADI_RFG_Drivers.exe** file. Running this file allows the installation of the Cypress CyUSB.sys driver as a verified, signed driver.
2. From the extracted .zip file, double-click the **ADRF6820_install.exe** file. An icon should appear on your desktop with the ADI logo, titled **ADRF6820**.
3. After the installer is finished, install the USB driver.

Installing the Driver

1. Connect the USB connector on the evaluation board to the PC using the USB cable that was included in the box.
2. In either Windows XP or Windows Vista, right-click **My Computer** and then select **Properties**.
3. Open the **Device Manager**.
   a. In Windows Vista or Windows 7, select the **Device Manager** option.
   b. In Windows XP, select the **Hardware** tab and then click **Device Manager**.
4. In **Device Manager**, select the last category, **Universal Serial Bus Controllers**. You should see an entry that either has a yellow flag (indicating an unknown device) or an entry labeled **ADF4xxx USB Driver** (if you have installed a previous ADRF6x0x or ADI Limerick PLL software).
5. Right-click on the appropriate device and select **update driver**.
6. Browse to select the directory **C:\Program Files\ADRF6820_customer_software**.
7. Click **Next**. Windows completes the driver installation.

USING THE ADRF6820 EVALUATION SOFTWARE

ADRF6820 Tab

The main window of the ADRF6820 evaluation software includes a block diagram that shows how the registers affect the major functional blocks of the ADRF6820 (see Figure 4). Within this window, the green boxes indicate that user input is required, and the yellow boxes indicate read only information.

To use the ADRF6820 evaluation software,

1. Before reading or writing to the registers, validate the USB connection by reading the USB indicators located in the lower left corner of the main window.
2. Click **Update GUI** to read the register values from the device and update the user interface. (An automatic write to the chip is initiated every time a register value is changed from the user interface.)
3. Specify the PLL reference and the desired LO frequency by typing the appropriate values into the designated boxes. Press ENTER after each input, and the software (via the PLL synthesizer blocks) calculates and sets the INT, FRAC, and MOD values accordingly.

Engineering Tab

The **Engineering** tab (see Figure 5) allows specific reads and writes to individual registers. Be sure to type values into the **Address (decimal)** and **Write Data (decimal)** boxes in decimal format.

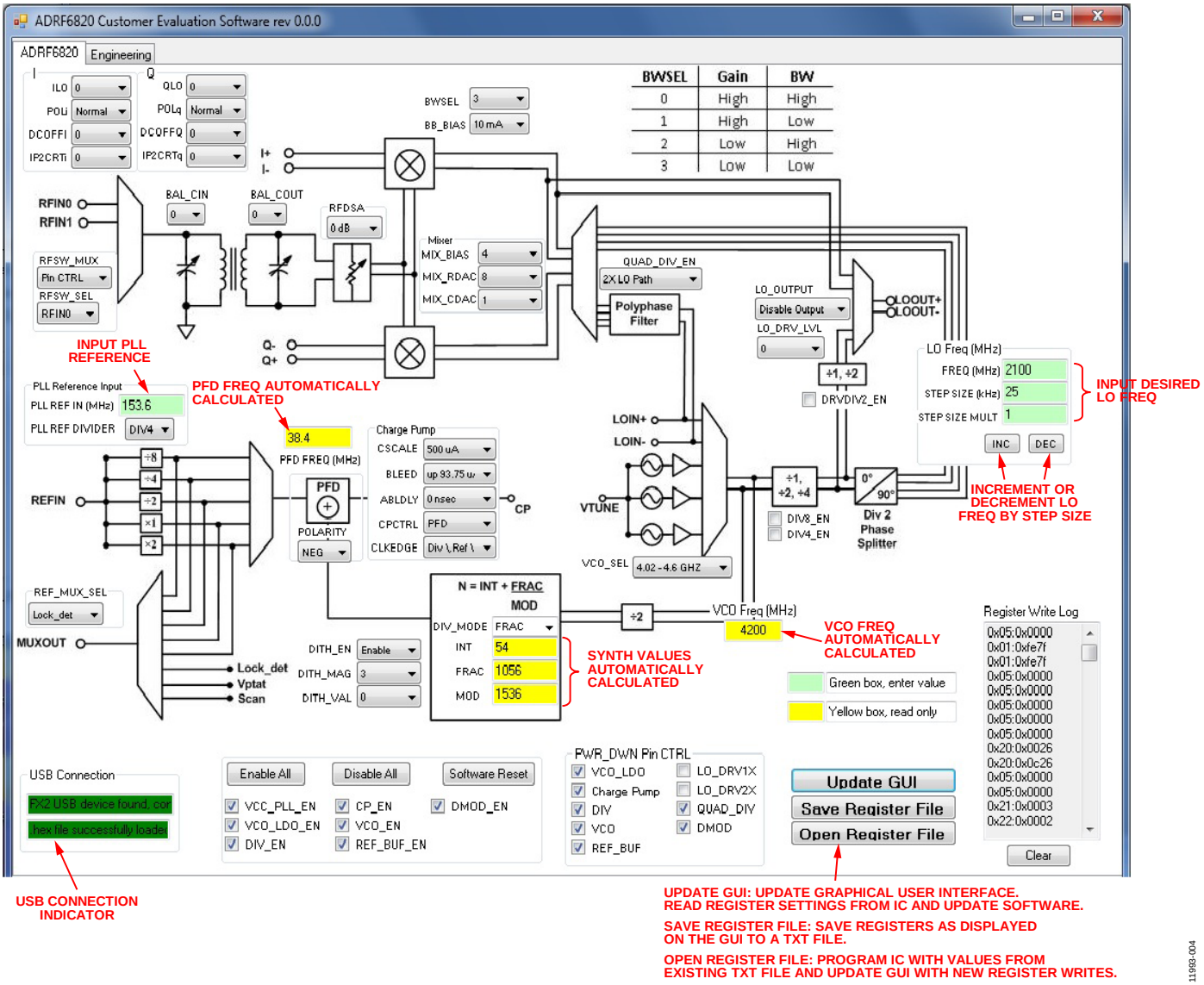


Figure 4. Main Window of the ADRF6820 Control Software

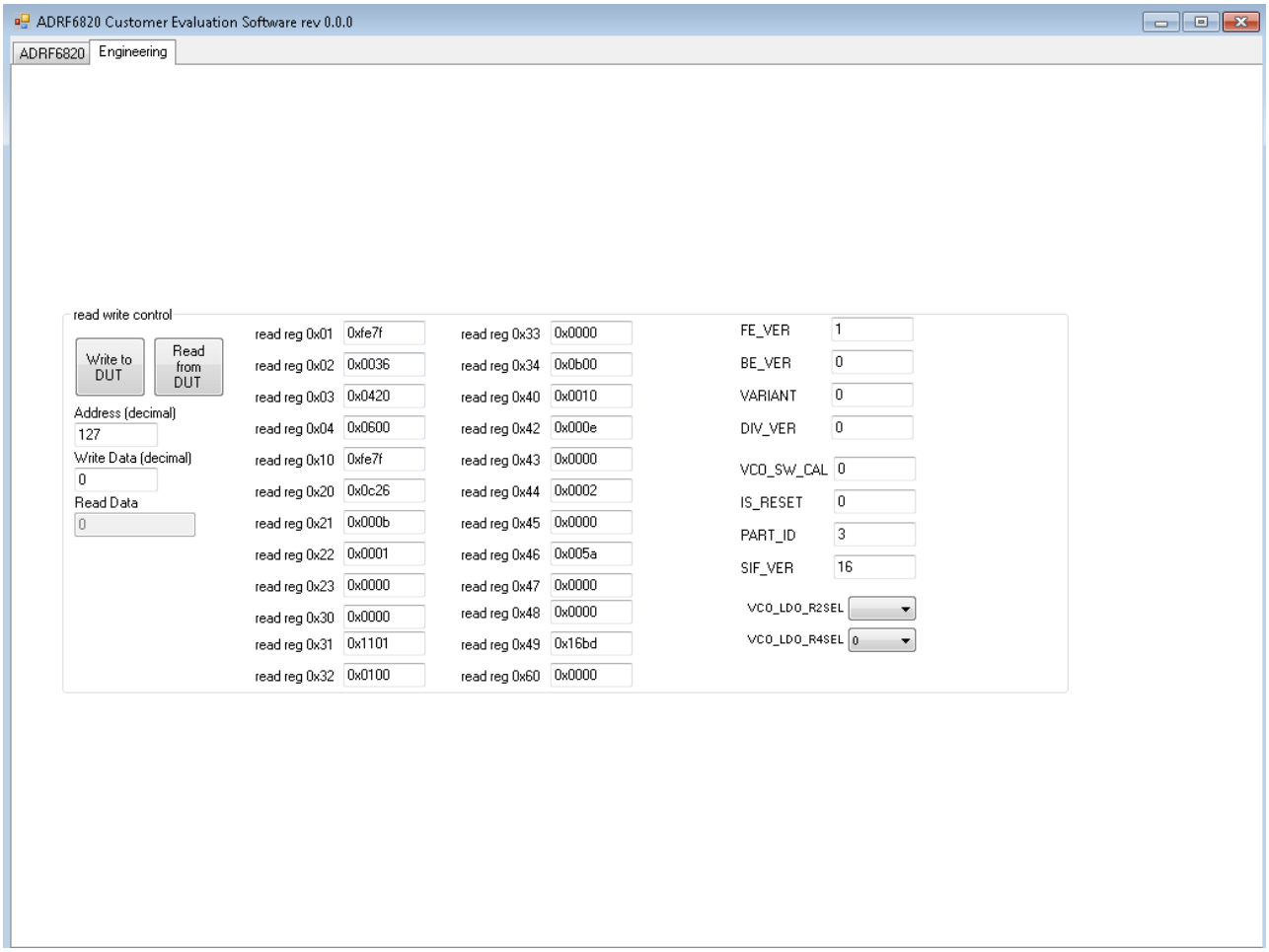


Figure 5. Engineering Tab of the ADRF6820 Control Software

EVALUATION BOARD SCHEMATICS AND ARTWORK

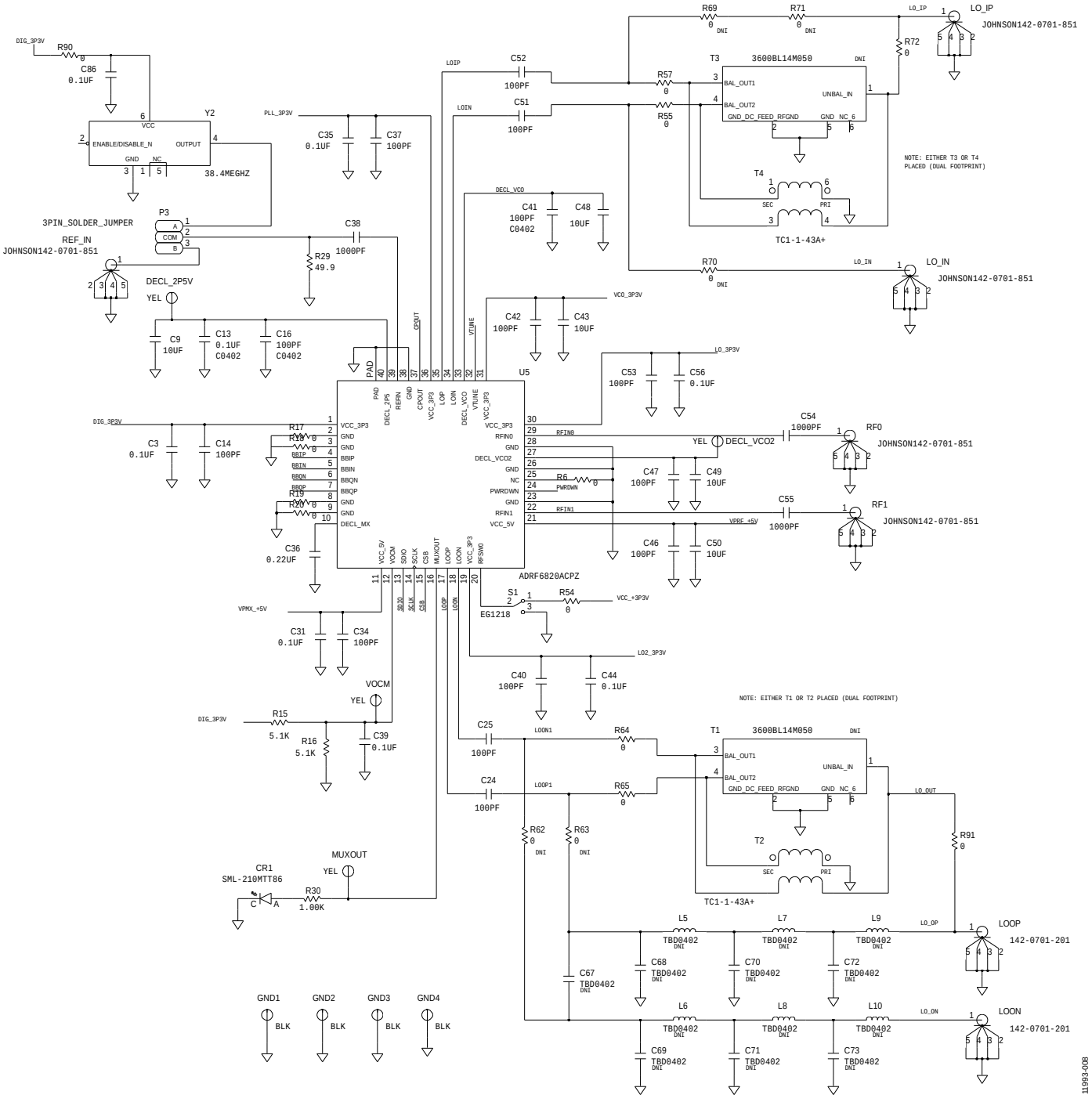


Figure 6. ADRF6820 Schematic

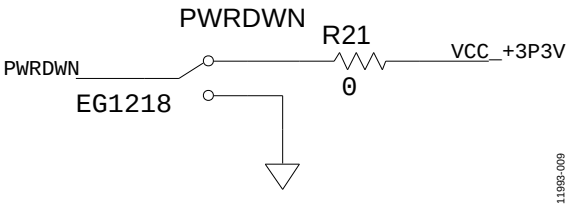


Figure 7. Power-Down Switch

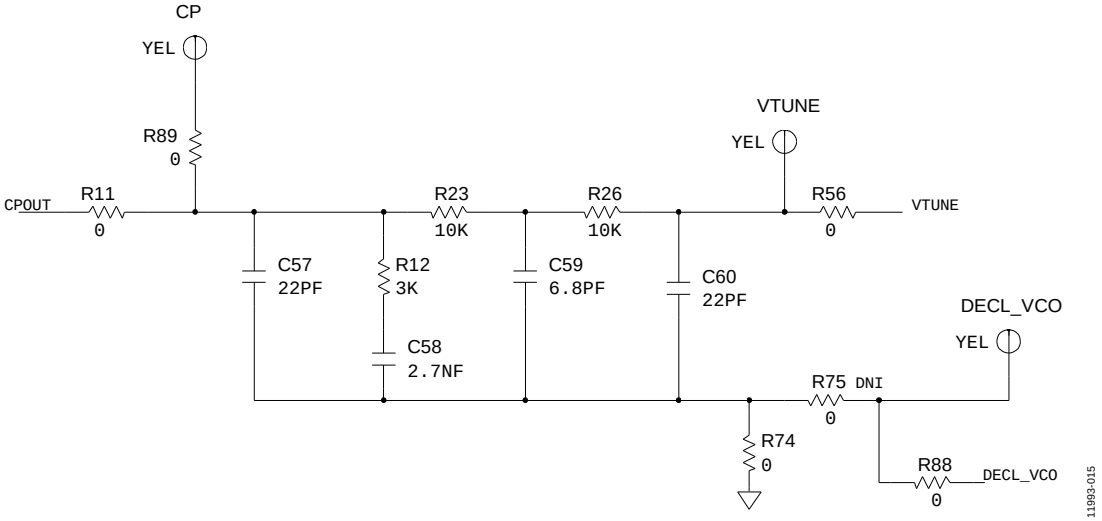


Figure 8. External Loop Filter

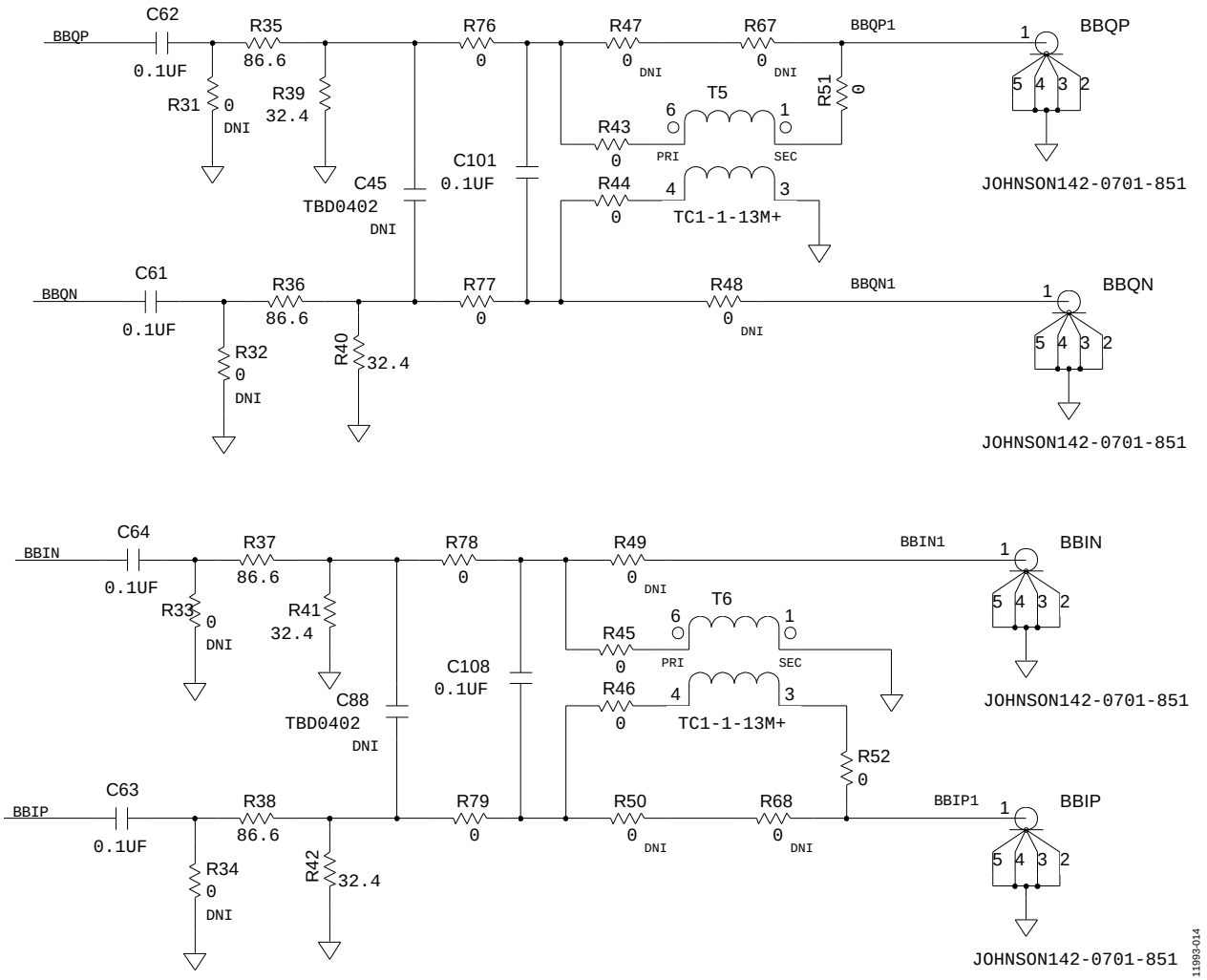


Figure 9. I/Q Output Termination

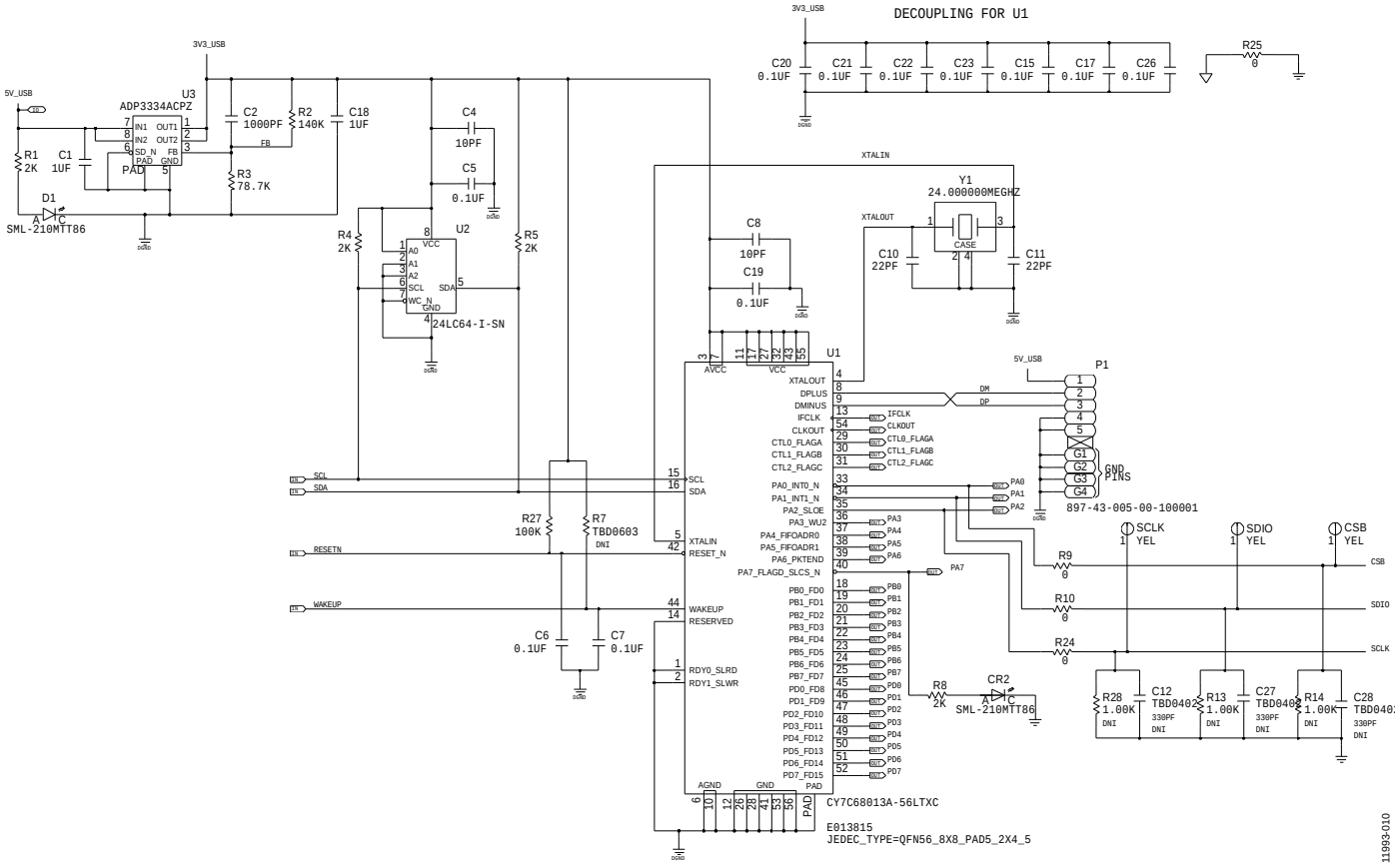


Figure 10. Serial Port Schematic

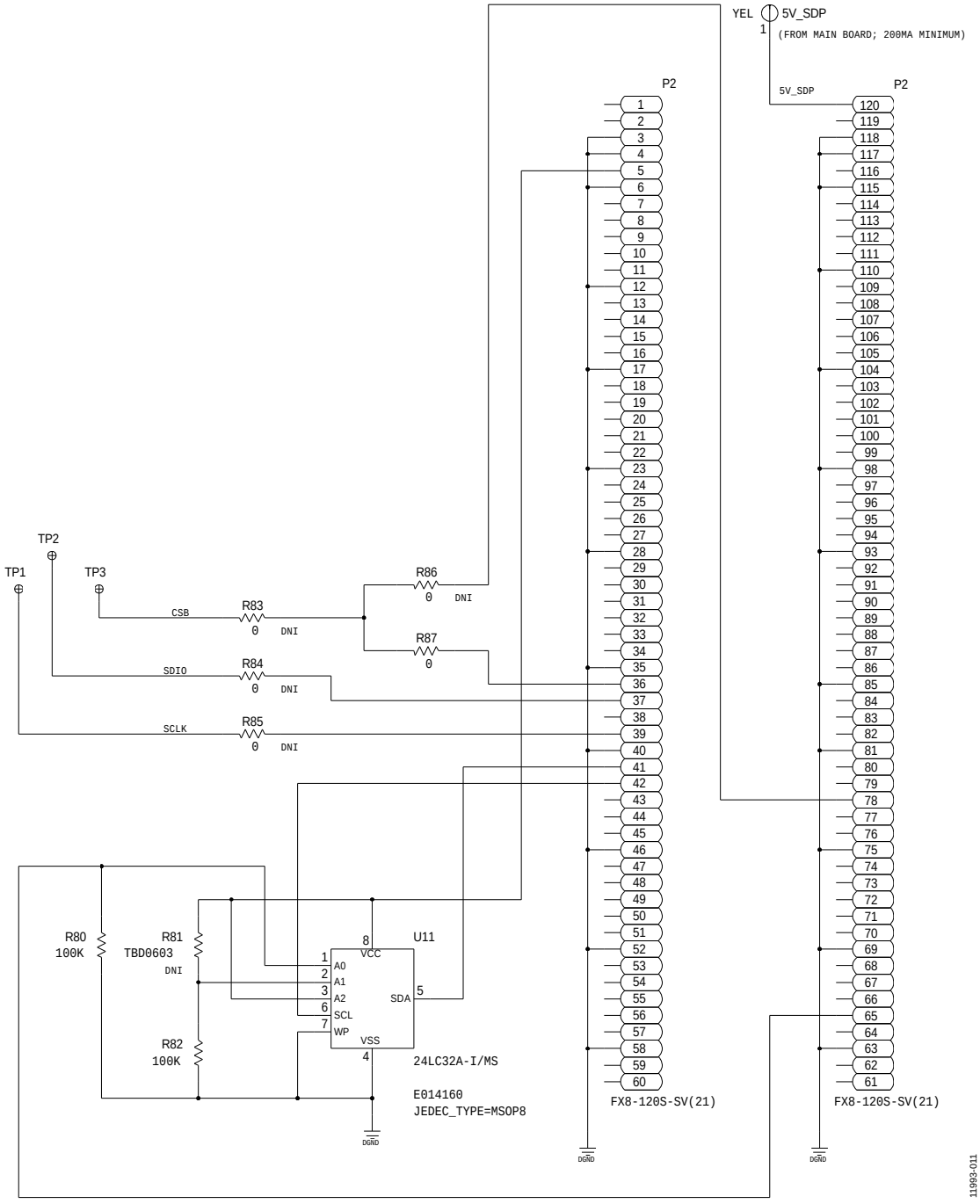


Figure 11. SDP Connector

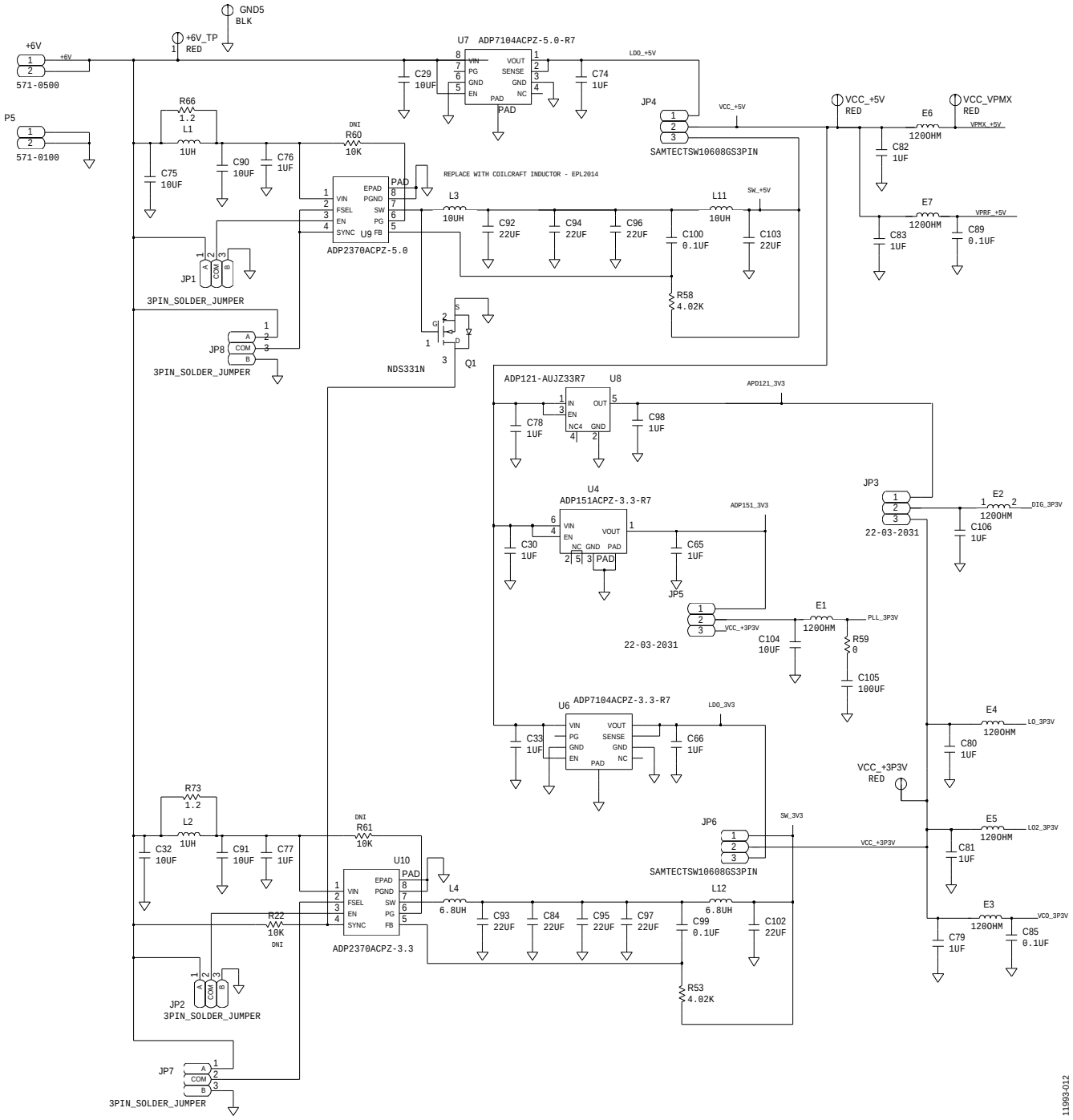


Figure 12. Power Management

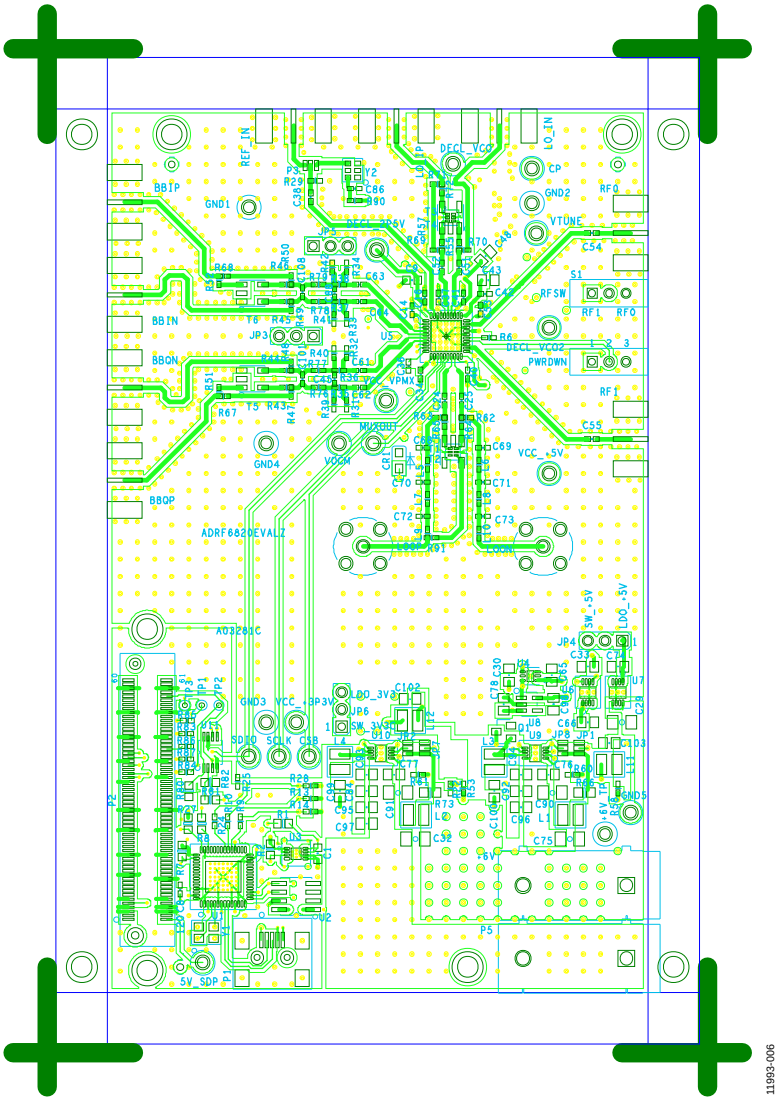


Figure 13. ADRF6820 Evaluation Board Top Silkscreen

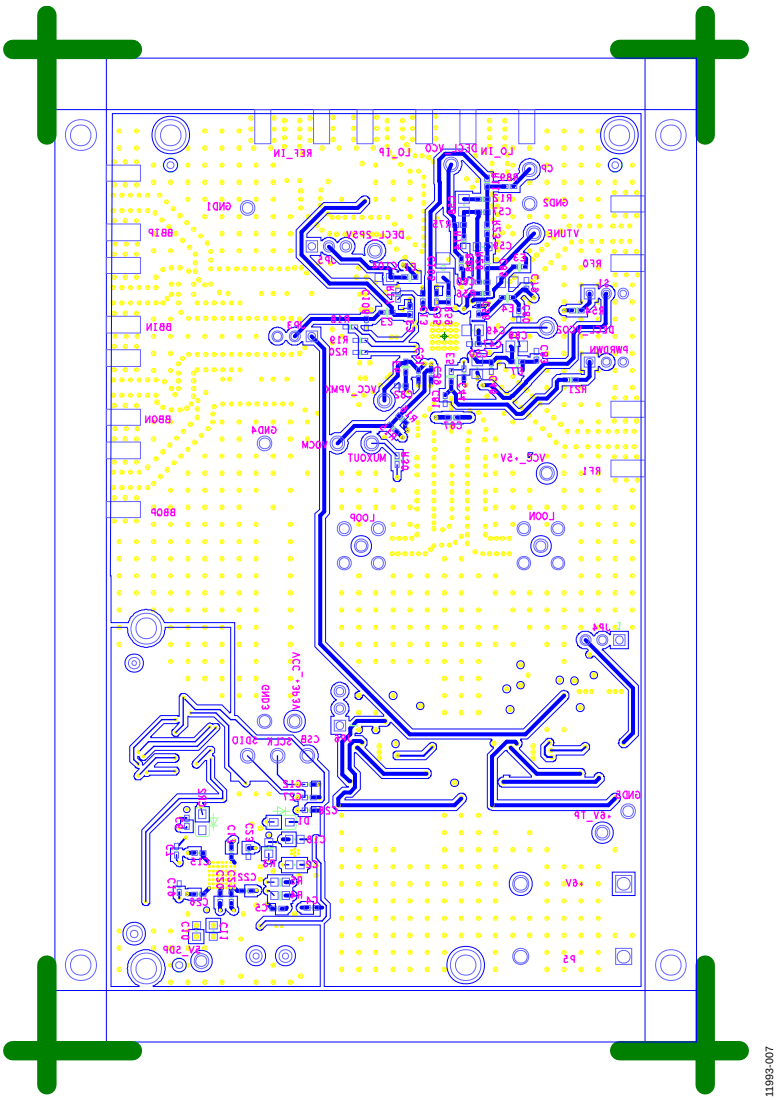


Figure 14. ADRF6820 Evaluation Board Bottom Silkscreen

BILL OF MATERIALS

Table 1. ADRF6820 Evaluation Board Bill of Materials

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part No.
1	+6V	Connector-PCB single socket red, CNDELTRON-571	Deltron	571-0500
4	+6V_TP, VCC_+5V, VCC_VPMX, VCC_+3P3V	Connectors-PCB test point red, CNLOOPTP	Components Corporation	TP-104-01-02
11	CP, CSB, SCLK, SDIO, VOCM, VTUNE, 5V_SDP, MUXOUT, DECL_VCO, DECL_2P5V, DECL_VCO2	Connectors-PCB test point yellow, CNLOOPTP	Components Corporation	TP-104-01-04
9	RF0, RF1, BBIN, BBIP, BBQN, BBQP, LO_IN, LO_IP, REF_IN	Connectors-PCB coax SMA end launch, CNJOHNSON142-0701-851	Johnson	142-0701-851
2	C1, C18	Capacitor monolithic ceramic X5R, 1 µF, 10%, 25 V, C0603	Murata	GRM188R61E105KA12D
2	C10, C11	Capacitor ceramic NP0, 22 pF, 5%, 50 V, C0603	Phycomp (Yageo)	CC0603JRNP09BN220
4	C85, C89, C99, C100	Capacitor ceramic X7R 0805, 0.1 µF, 10%, 25 V, C0805	Murata	GRM21BR71E104KA01L
23	C3, C5 to C7, C13, C15, C17, C19 to C23, C26, C31, C35, C39, C44, C56, C61 to C64, C86	Capacitor ceramic X7R 0402, 0.1 µF, 10%, 16 V	Murata	GRM155R71C104KA88D
9	C84, C92 to C97, C102, C103	Capacitor ceramic chip, 22 µF, 20%, 6.3 V, C0805	Murata	GRM21BR60J226ME39L
2	C9, C104	Capacitor ceramic X5R 0603, 10 µF, 20%, 6.3 V	Murata	GRM188R60J106ME47D
1	C105	Capacitor ceramic X5R, 100 µF, 20%, 6.3 V, C1206H71	Murata	GRM31CR60J107ME39L
6	C79 to C83, C106	Capacitor monolithic ceramic 0402 SMD X5R, 1 µF, 10%, 10 V, C0402	Murata	GRM155R61A105KE15D
14	C14, C16, C24, C25, C34, C37, C40 to C42, C46, C47, C51 to C53	Capacitor chip monolithic ceramic C0G 0402, 100 pF, 5%, 50 V, C0402	Murata	GRM1555C1H101JD01D
1	C2	Capacitor ceramic C0G 0603, 1000 pF, 5%, 100 V, C0603	TDK	C1608C0G2A102J
5	C29, C32, C75, C90, C91	Capacitor ceramic monolithic X5R, 10 µF, 10%, 25 V, C1206	Murata	GRM31CR61E106KA12L
9	C30, C33, C65, C66, C74, C76 to C78, C98	Capacitor ceramic 0805 X7R, 1 µF, 10%, 16 V, C0805	Murata	GRM21BR71C105K
1	C36	Capacitor ceramic Y5V, 0.22 µF, −20%, +80%, 16 V, C0402	Murata	GRM155F51C224ZA01D
3	C38, C54, C55	Capacitor ceramic C0G 0402, 1000 pF, 5%, 50 V, C0402	Murata	GRM1555C1H102JA01
2	C4, C8	Capacitor ceramic multilayer NP0 0402, 10 pF, 5%, 50 V, C0402	Phycomp (Yageo)	CC0402JRNP09BN100
4	C43, C48 to C50	Capacitor ceramic monolithic, 10 µF, 10%, 16 V, C0805	Murata	GRM21BR61C106KE15L
2	C57, C60	Capacitor ceramic, 22 pF, 5%, 50 V, C0402	Phycomp (Yageo)	0402CG220J9B200
1	C58	Capacitor ceramic monolithic, 2.7 nF, 5%, 50 V, C0805	Murata	GRM2165C1H272JA01D
1	C59	Capacitor ceramic NP0, 6.8 pF, 5%, 50 V, C0603	Phycomp (Yageo)	2238 867 15688
3	D1, CR1, CR2	LED 570 nm WTR clear 0805 SMD (green), 2.2 V, LED0805	Rohm Semiconductor	SML-210MTT86
7	E1 to E7	Bead core chip, 120 Ω, L0603	Panasonic	EXC-3BP121H
5	GND1 to GND5	Connectors-PCB test point black, CNLOOPTP	Components Corporation	TP-104-01-00

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part No.
2	JP3, JP5	Connectors-PCB wire to board hardware, CNMOLEX22-03-2031	Molex	22-03-2031
2	JP4, JP6	Connectors-PCB BERG header ST male 3-pin, CNBERG1X3H205LD36	Samtec	TSW-103-08-G-S
2	L1, L2	Inductor SMT power, 1 µH, 20%, LSML126W110H95	Coilcraft	ME3220-102MLB
2	L3, L11	Inductor SMT power, 10 µH, 10%, LSML126W110H95	Coilcraft	ME3220-103KLB
2	L4, L12	Inductor SMT power, 6.8 µH, 20%, LSML126W110H95	Coilcraft	ME3220-682MLB
2	LOON, LOOP	Connectors-PCB coax SMA ST, CNJOHNSON142-0701-201	Johnson	142-0701-201
1	P1	Connector-PCB receptacles mini-USB Type B SMT, CNTYCO-1734035-2	Mill-Max	897-43-005-00-100001
1	P2	Connector-PCB vertical type receptacles SMD, CNHRSFX8-120S-SV	Hirose	FX8-120S-SV(21)
1	P5	Connector-PCB single socket black, CNDELTRON-571	Deltron	571-0100
2	S1, PWRDWN	SW PC mount slide switch, SWEG1218	E-Switch	EG1218
1	Q1	Transistor N-channel LLE mode FET, SOT23	Fairchild	NDS331N
4	R1, R4, R5, R8	Resistor film SMD 0603, 2 kΩ, 1%, 1/10 W, R0603	Phycomp (Yageo)	9C06031A2001FKHFT
35	R6, R9 to R11, R17 to R21, R24, R25, R43 to R46, R51, R52, R54 to R57, R59, R64, R65, R72, R74, R76 to R79, R87 to R91	Resistor film SMD 0402, 0 Ω, 5%, 1/16 W, R0402	Panasonic	ERJ-2GE0R00X
1	R12	Resistor thick film chip, 3 kΩ, 5%, 1/16 W, R0402	Panasonic	ERJ-2GEJ302X
2	R15, R16	Resistor film SMD 0402, 5.1 kΩ, 5%, 1/16 W, R0402	Multicomp	CR10B512JT
1	R2	Resistor precision thick film chip 0603, 140 kΩ, 1%, 50 V, 1/10 W, R0603	Panasonic	ERJ-3EKF1403V
2	R23, R26	Resistor precision thick film chip R0402, 10 kΩ, 1%, 1/16 W, R0402	Panasonic	ERJ-2RKF1002X
3	R27, R80, R82	Resistor precision thick film chip, 100 kΩ, 1%, 50 V, 1/10 W, R0603	Panasonic	ERJ-3EKF1003V
1	R29	Resistor ultra-precision ultra-reliability MF chip, 49.9 Ω, 0.1%, 1/16 W, R0402	Susumu	RG1005P-49R9-B-T5
1	R3	Resistor precision thick film chip 0603, 78.7 kΩ, 1%, 50 V, 1/10 W, R0603	Panasonic	ERJ-3EKF7872V
1	R30	Resistor precision thick film chip R0402, 1.00 kΩ, 1%, 1/10 W, R0402	Panasonic	ERJ-2RKF1001X
4	R35 to R38	Resistor chip SMD 0402, 86.6 Ω, 1%, 1/16 W, R0402	Panasonic	ERJ-2RKF86R6X
4	R39 to R42	Resistor precision thick film chip R0402, 32.4 Ω, 1%, 1/16 W, R0402	Panasonic	ERJ-2RKF32R4X
2	R53, R58	Resistor precision thick film chip 4.02 kΩ, 1%, 1/16 W, R0402	Panasonic	ERJ-2RKF4021X
2	R66, R73	Resistor thick film chip, 1.2 Ω, 5%, 1/8 W, R0805	Panasonic	ERJ-6GEYJ1R2V
2	T2, T4	Transformer RF SMT, AT224-1	Mini-Circuits	TC1-1-43A+
2	T5, T6	Transformer RF 1:1, AT224-1	Mini-Circuits	TC1-1-13M+
1	U1	IC HS USB peripheral, 3 V to 3.6 V, QFN56_8X8_PAD5_2X4_5	Cypress Semiconductor	CY7C68013A-56LTXC
1	U10	IC low quiescent current buck regulator 3.3 V output, QFN8_3X3_PAD2_44X1_7	Analog Devices	ADP2370ACPZ-3.3
1	U11	IC 32-kbit serial EEPROM, MSOP8	Microchip	24LC32A-I/MS

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part No.
1	U2	IC 64-kbit EEPROM, SO8	Microchip	24LC64-I-SN
1	U3	IC high ACC, low quiescent current adjustable low drop regulator, QFN8_3X3_PAD1_75X1_45	Analog Devices	ADP3334ACPZ
1	U4	IC CMOS linear regulator LDO 3.3 V, DFN6_2X2_PAD1_6X1	Analog Devices	ADP151ACPZ-3.3-R7
1	U5	IC wideband demodulator, QFN40_6X6_PAD4_6X4_6	Analog Devices	ADRF6820ACPZ
1	U6	IC low noise, CMOS LDO, QFN8_3X3_PAD2_44X1_7	Analog Devices	ADP7104ACPZ-3.3-R7
1	U7	IC low noise, CMOS LDO, QFN8_3X3_PAD2_44X1_7	Analog Devices	ADP7104ACPZ-5.0-R7
1	U8	IC 150 mA, CMOS linear regulator, 2.3 V to 5.5 V, TSOT-5	Analog Devices	ADP121-AUJZ33R7
1	U9	IC low quiescent current buck regulator 5.0 V output, QFN8_3X3_PAD2_44X1_7	Analog Devices	ADP2370ACPZ-5.0
1	Y1	IC crystal SMD, 24.000000 MHz, XTALNX3225	NDK	NX3225SA-24.000000MHZ

Table 2. ADRF6820 Evaluation Board Bill of Materials—Do Not Install[1]

Qty	Reference Designator	Description	Manufacturer[2]	Manufacturer Part No.
12	C12, C27, C28, C45, C67 to C73, C88, C101, C108	Do not install (TBD_C0402)	N/A	TBD0402
6	L5 to L10	Do not install (TBD_L0402)	N/A	TBD0402
3	R13, R14, R28	Resistor precision thick film chip R0402, 1.00 kΩ, 1%, 1/10 W	Panasonic	ERJ-2RKF1001X
3	R22, R60, R61	Resistor thick film chip, 10 kΩ, 5%, 1/10 W	Panasonic	ERJ-2GEJ103X
20	R31 to R34, R47 to R50, R62, R63, R67 to R71, R75, R83 to R86	Resistor film SMD 0402, 0 Ω, 5%, 1/16 W	Panasonic	ERJ-2GE0R00X
2	R7, R81	Do not install (TBD_R0603)	N/A	TBD0603
2	T1, T3	Transformer 3.6 GHz balun	Johanson Technology	3600BL14M050
1	Y2	IC crystal oscillator, 38.4 MHz, 3.3 V, YSML98W79H35_A	Rakon	IT2200AQ

[1] These components are part of the printed circuit board (PCB) or should not be installed.
[2] N/A = not applicable.

NOTES

NOTES



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 One Technology Way, Norwood, MA 02062, USA. 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 NONINFRINGEMENT 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.

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