AN-1309
APPLICATION NOTE

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A Range Extension Reference Design Using the ADF7023 and RFFM6901 915 MHz ISM Band Transmit Receive Module with Diversity Switch

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INTRODUCTION

For situations where customers want to extend the range of the ADF7023 ISM band transceiver, this application note describes a reference design that enables an improvement of almost 20 dB on the overall link budget. In a line of sight scenario that is not interference limited, this equates to a range increase of approximately 6 to 7 times.

This design consists of an ADF7023 transceiver from Analog Devices, Inc., and an RFFM6901 front-end module (FEM) from RFMD, Inc. The design is suitable for operation in the 902 MHz to 928 MHz ISM band and complies with FCC regulations.

About the ADF7023

The ADF7023 is a very low power, high performance, highly integrated 2FSK/GFSK/OOK/MSK/GMSK transceiver. It is designed for operation in the 862 MHz to 928 MHz and 431 MHz to 464 MHz frequency bands, which cover the worldwide license-free ISM bands at 433 MHz, 868 MHz, and 915 MHz.

This transceiver is suitable for circuit applications that operate under the European ETSI EN300-220, the North American FCC (Part 15), the Chinese short-range wireless regulatory standards, or other similar regional standards. Data rates from 1 kbps to 300 kbps are supported

About the RFFM6901

The RFFM6901 is a single chip front-end module for application in the 868 MHz and 915 MHz ISM bands. The RFFM6901 addresses the need for aggressive size reduction for typical portable equipment RF front-end designs and greatly reduces the number of components outside of the core chipset thus minimizing the footprint and assembly cost of the overall solution. The RFFM6901 contains an integrated 1 W PA, dual port diversity antenna switch, LNA with bypass mode, and matching components. The RFFM6901 is packaged in a 32-pin, 6.0 mm × 6.0 mm × 1.2 mm over-molded laminate package.

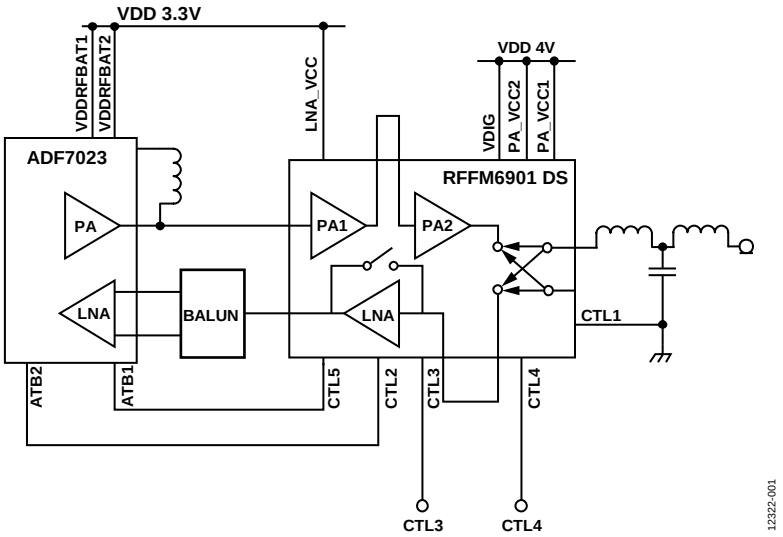

Figure 1. Functional Block Diagram

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REVISION HISTORY

5/14—Rev. 0 to Rev. A

Changes to Table 2 3

5/14—Revision 0: Initial Version

GENERAL OPERATION AND PERFORMANCE DATA

This section describes the general operating conditions and typical performance realized when using these devices together. Further details regarding the performance of each device are available in the product data sheets.

Typical performance data is taken as an average of eight different EVAL-ADF7023-RFFM6901 Revision C evaluation boards tested at room temperature with 3.3 V applied to the ADF7023 and 4 V applied to the RFFM6901.

GENERAL OPERATING CONDITIONS

Table 1. General Operation Conditions

Parameter	Min	Typ	Max	Unit
Frequency Range	902		928	MHz
Supply Voltage, ADF7023		3.3		V
Supply Voltage, RFFM6901		4.0		V
Temperature Range	−40		+85	°C

TYPICAL PERFORMANCE DATA

All test results were carried out on a test board, the EVAL-ADF7023-RFFM6901 Revision C evaluation board.

Table 2. Typical Performance Data

Parameter	Typ	Unit	Test Conditions
Maximum Transmit Power	30	dBm	
Harmonics at 30 dBm Tx Power			
2nd Harmonic	−18	dBm	Conducted
3rd Harmonic	−43	dBm	Conducted
4th Harmonic	−56	dBm	Conducted
5th Harmonic	−65	dBm	Conducted
Receiver Sensitivity			
200 kbps	−106.7	dBm	10^{-3} BER FSK (f_{DEV} 50 kHz), 915 MHz
Current Consumption			
Tx Current at 30 dBm	650	mA	
Rx	21	mA	
Bypass			
Sleep	0.5	mA	

FCC COMPLIANCE

Frequency hopping systems in the 902 MHz to 928 MHz frequency band in the United States are subject to FCC Part 15 regulations. FCC Part 15.247 allows for transmission at up to 1 W (30 dBm) provided at least 50 frequency hopping channels are used, the 20 dB bandwidth of the hopping channel is less than 250 kHz, and the average time of occupancy on any frequency is no greater than 0.4 seconds in a 20 second period.

The reference design described in this application note passed FCC Part 15.247 radiated harmonics precompliance testing at +30 dBm output power. Testing was carried out at both 100 kbps and 300 kbps for a 255-byte packet transmitted every 100 ms. No external SAW filter was used. RF shielding may be required for other data rates, packet lengths, or if layout changes are made to the reference design.

REFERENCE DESIGN DESCRIPTION

The reference design consists of an ADF7023 from Analog Devices and an RFFM6901 front-end module from RFMD. This design is applicable for the 915 MHz ISM band and is capable of delivering +30 dBm output power and increasing receive sensitivity. This specific configuration enables you to select a number of modes.

In this reference design, the default power supply connections for +30 dBm operation in transmit are as follows:

- The ADF7023 is supplied at 3.3 V via the VDDBAT1 and VDDBAT2 pins.
- The LNA_VCC pin of the RFFM6901 is also supplied at 3.3 V.
- The VDIG, PA_VCC1, and PA_VCC2 pins of the RFFM6901 are supplied at 4 V.

However, if +27 dBm transmit power is required, a common 3.0 V to 3.3 V supply can be connected to both the ADF7023 and RFFM6901 power supply pins. For further information on the operation of the RFFM6901 in this mode of operation, consult the RFFM6901 data sheet.

For this reference design, it is recommend to use the RFFM6901 high bias mode in Receive and the low bias mode in Transmit. Refer to the following subsection for how to configure the reference design for these modes of operation. Other modes of operation are also available (see Table 3) and are described in the RFFM6901 data sheet.

MODE CONTROL OF RFFM6901 WITH ADF7023

The reference design is capable of a number of modes dependent on specific user requirements. Table 3 summarizes these modes and settings. The primary operation of the RFFM6901 is controlled via the ADF7023 ATB ports thus easing the load on the host processor. CTL 5 selects low or high bias while CTL2 is the Tx/Rx select. These are controlled via ATB 1 and ATB 2, respectively. CTL3 powers on or off the LNA and CTL4 is the power-down pin; these pins can be controlled via your host processor GPIO. If Rx bypass is not required, then CTL 3 can be tied to CTL2 via a resistor. CTL1 is the antenna select pin and is tied to ground in this design which is configured for single antenna operation. Table 3 describes the different modes and how they are controlled including register writes from the ADF7023 where appropriate.

CTL2 and CTL5 are controlled via the ADF7023 ATB 1 and ATB 2 GPIOs. The configuration of these pins is described in the ADF7023 data sheet. In summary, Register 0x139, Bit 7 controls the logic level drive at these pins. For this design, it is recommended to set this to 3.3 V; this is established by writing 0x139 = 0x00. Register 0x11A configures the logic table for ATB1 and ATB2 and, once set, the ADF7023 state controls the logic high or low at these pins. Thus, once Register 0x139 and Register 0x11A of the ADF7023 are configured, then the state of the RFFM6901 is controlled by the ADF7023. This is summarized in Table 3.

Table 3. Mode Control

System State	RFFM 6901 State	ADF7023 State	ADF7023 Register Settings	CTL2 and CTL5 (Controlled via Register Settings and ADF7023 State)	CTL3	CTL4
Power-Down/Sleep	Power down	Sleep	Don't care	Don't care	Don't care	Low
Tx 1 (High Gain)	Tx high bias	PHY_Tx	0x139 = 0x00 and 0x11A = 0x43	CTL2 = Low; CTL5 = High	Low	High
Tx 2 (Low Gain)	Tx low bias	PHY_Tx	0x139 = 0x00 and 0x11A = 0x42	CTL2 = Low; CTL5 = Low	Low	High
Rx 1 (High Gain)	Rx high bias	PHY_Rx	0x139 = 0x00 and 0x11A = 0x42/43	CTL2 = High; CTL5 = Low	High	High
Rx Bypass	Rx bypass	PHY_Rx	0x139 = 0x00 and 0x11A = 0x42/43	CTL2 = High; CTL5 = Low	Low	High

REFERENCE DESIGN SCHEMATICS AND ARTWORK

A full reference design package is available from the Analog Devices website that consists of Gerber files, circuit schematic, fabrication notes, and the bill of materials (BOM).

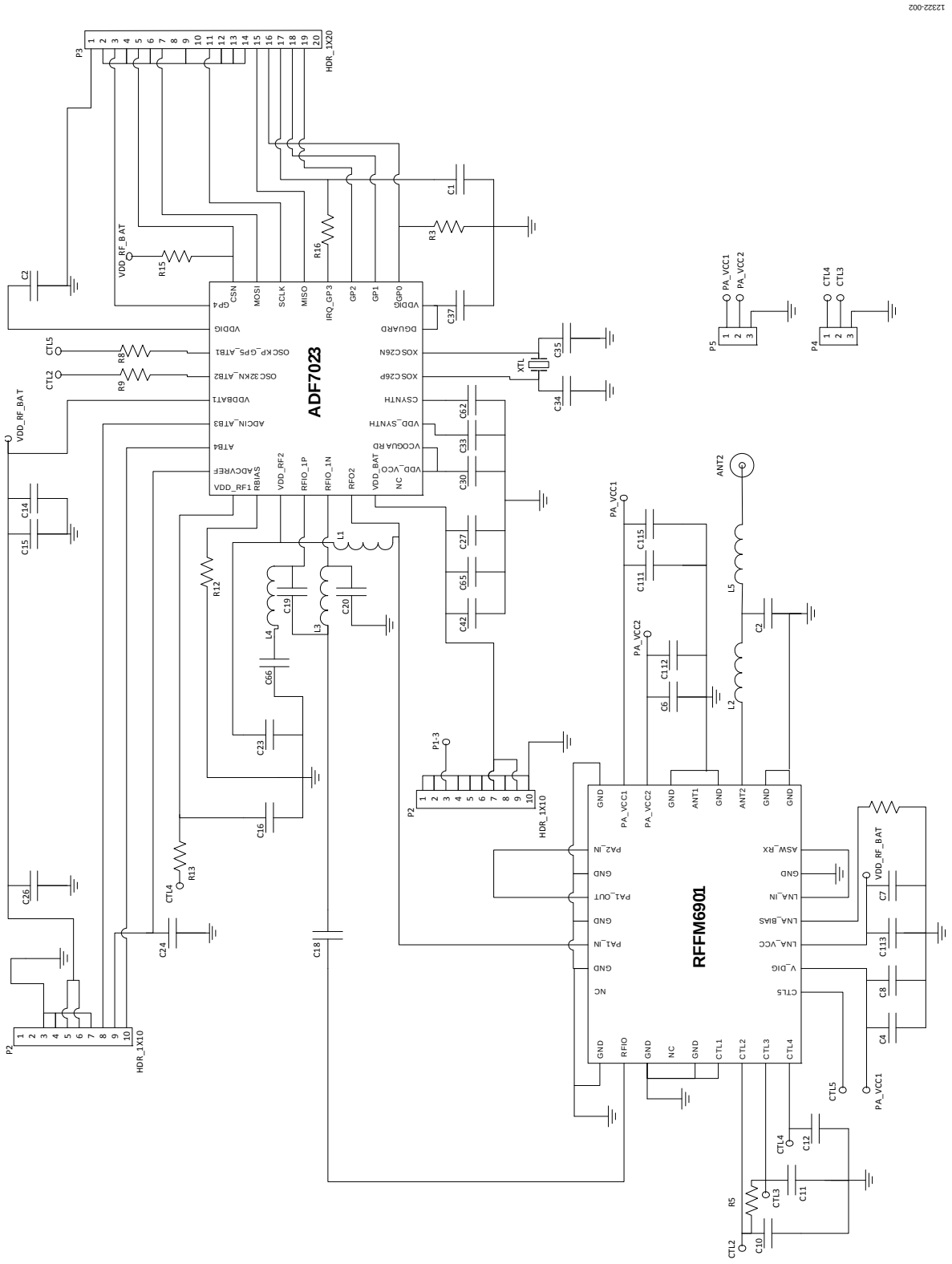

Figure 2. Schematic

RECOMMENDED PCB LAYOUT

Figure 3 and Figure 4 show the recommended PCB layout. The Gerber files are available from the Analog Devices website.

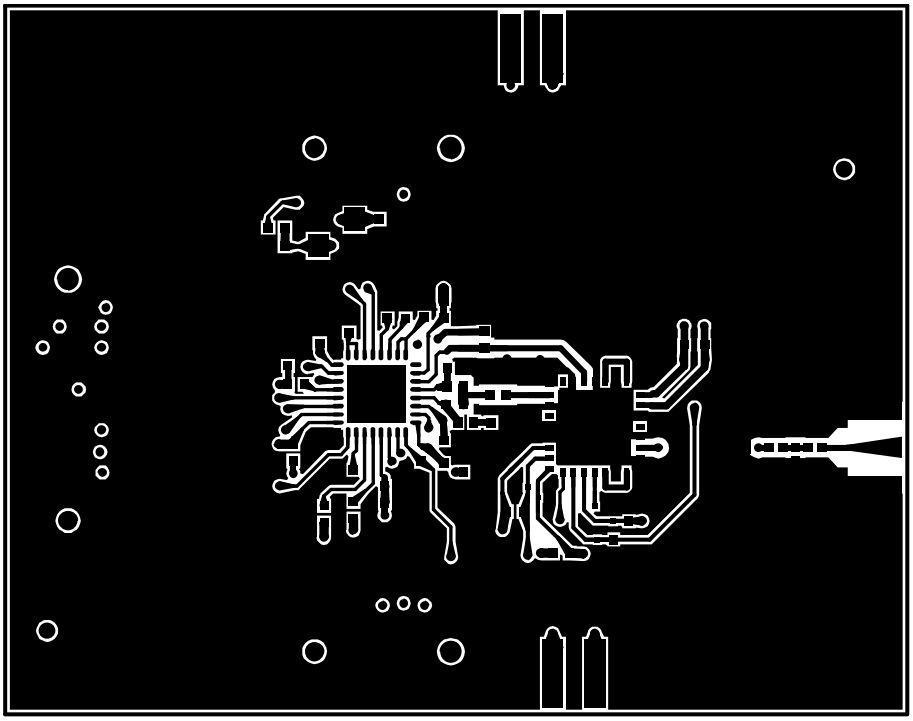

Figure 3. PCB Layout Diagram

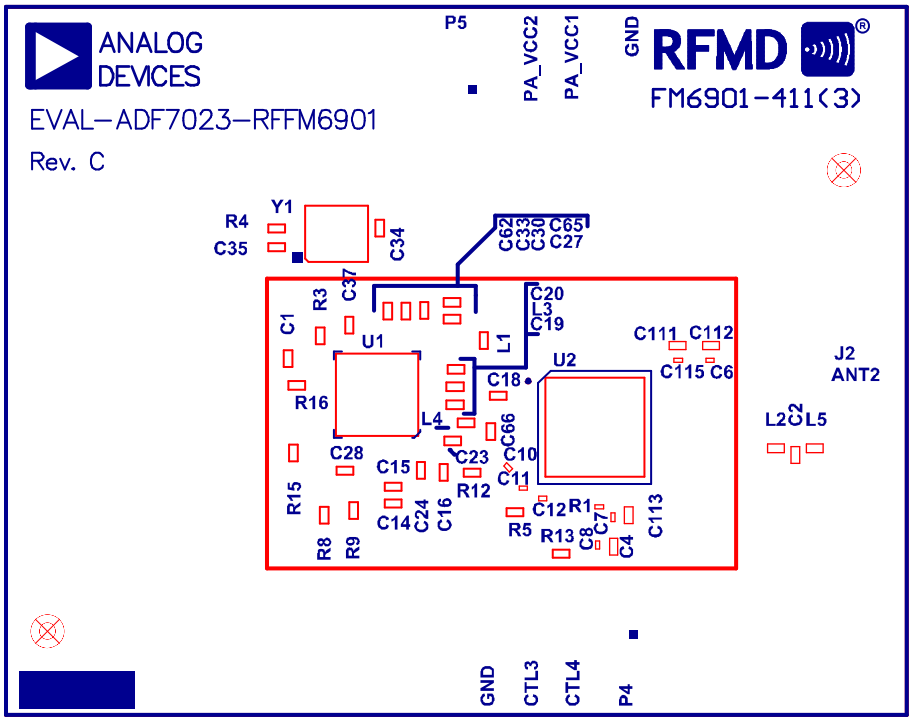

Figure 4. Component Placement Diagram

BILL OF MATERIALS

Table 4. Components Listing

Name	Value	Tolerance	PCB Decal	SMD	Layer	Manufacturer	Part Number
C1	DNI	N/A	C0402	Yes	Top	N/A	N/A
C2	3.3 pF	N/A	C0402	Yes	Top	Murata	GRM1555C1H3R3CA01D
C4	0.1 µF	±5%	C0402	Yes	Top	Murata	GRM155R71C104KA88D
C6	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
C7	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
C8	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
C10	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
C11	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
C12	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
C15	100 pF	±5%	C0402	Yes	Top	Murata	GRM1555C1H101JZ01D
C16	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C18	56 pF	±5%	C0402	Yes	Top	Murata	GRM1555C1H560JD01D
C19	2.7 pF	±0.25	C0402	Yes	Top	Murata	GRM1555C1H2R7CZ01D
C20	1.2 pF	±0.25	C0402	Yes	Top	Murata	GRM1555C1H1R2CZ01D
C23	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C24	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C26	10 µF	±20%	C0603	Yes	Bottom	Johanson	6R3R14X106MV4T
C27	100 pF	±5%	C0402	Yes	Top	Murata	GRM1555C1H101JZ01D
C28	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C30	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C33	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C34	18 pF	±5%	C0402	Yes	Top	Murata	GRM1555C1H180JZ01D
C35	18 pF	±5%	C0402	Yes	Top	Murata	GRM1555C1H180JZ01D
C37	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C42	10 µF	±20%	C0603	Yes	Bottom	Johanson	6R3R14X106MV4T
C62	150 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A154KE9D
C65	220 nF	±10%	C0402	Yes	Top	Murata Electronics	GRM155R61A224KE19D
C66	100 pF	±5%	C0402	Yes	Top	Murata	GRM1555C1H101JZ01D
C111	0.1 µF	±5%	C0402	Yes	Top	Murata	GRM155R71C104KA88D
C112	0.1 µF	±5%	C0402	Yes	Top	Murata	GRM155R71C104KA88D
C113	0.1 µF	±5%	C0402	Yes	Top	Murata	GRM155R71C104KA88D
C115	1 nF	±10%	C0201	Yes	Top	TDK	C0603X7R1E102K030BA
J2			SMA_CARD_EDGE_RF	Yes	Top	Johnson Components	142-0711-821
L1	47 nH	±5%	L0402	Yes	Top	Coilcraft	0402CS-47NXJL
L2	7.5 nH	±5%	L0402	Yes	Top	Coilcraft	0402CS-7N5XJL
L3	12 nH	±5%	L0402	Yes	Top	Coilcraft	Coilcraft 0402CS-12NXJL
L4	6.2 nH	±5%	L0402	Yes	Top	Coilcraft	Coilcraft 0402CS-6N2XJL
L5	7.5 nH	±5%	L0402	Yes	Top	Coilcraft	Coilcraft 0402CS-7N5XJL
P1			SKT10_1.27MM	No	Bottom	Samtec	SFM-105-02-S-D-A
P2			SKT10_1.27MM	No	Bottom	Samtec	SFM-105-02-S-D-A
P3			SKT20_1.27MM	No	Bottom	Samtec	SFM-110-02-S-D-A
P4			SIP-3P-RA_SMD	Yes	Top	Sullins	GEC36SGSN-M89
P5			SIP-3P-RA_SMD	Yes	Top	Sullins	GEC36SGSN-M89
R1	DNI	±1%	R0201	Yes	Top	N/A	N/A
R3	DNI	±1%	R0402	Yes	Top	N/A	N/A
R4	DNI	±1%	R0402	Yes	Top	N/A	N/A

Name	Value	Tolerance	PCB Decal	SMD	Layer	Manufacturer	Part Number
R5	0 r	±1%	R0402	Yes	Top	Rohm	MCR01MRTJ000
R8	0 r	±1%	R0402	Yes	Top	Rohm	MCR01MRTJ000
R9	0 r	±1%	R0402	Yes	Top	Rohm	MCR01MRTJ000
R12	36 k	±1%	R0402	Yes	Top	Rohm	MCR01MZPF3602
R13	DNI	N/A	R0402	Yes	Top	N/A	N/A
R15	100 k	±1%	R0402	Yes	Top	Rohm	MCR01MZPF1003
R16	0 r	±1%	R0402	Yes	Top	Rohm	MCR01MRTJ000
U1			LFCSP-32	Yes	Top	Analog Devices	ADF7023-LFCSP32
U2			LGA, 32-Pin, 6 mm × 6 mm			RFMD	RFFM6901
Y1	26 MHz		XTAL-SMD-3_2-2_5MM	Yes	Top	NDK	NX3225SA-26.000000MHZ-G2