

RD-179: High-IF Sub-sampling Receiver Subsystem

National Semiconductor
RD-179
High Speed Signal Path Applications
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1.0 Design Description

The SP16160CH1RB demonstrates a high-IF sampling receiver subsystem that provides signal amplification, digitization and clocking as used in wireless infrastructure systems. The subsystem includes the ADC16DV160 analog-to-digital converter (ADC), LMH6517 Digitally-controlled Variable-Gain Amplifier (DVGA) and LMK04031B precision clock conditioner.

In the signal path, the subsystem provides impedance-matched, single-to-differential conversion through a 1:4 transformer and a 31.5 dB amplification gain range in 0.5 dB steps through the DVGA. The anti-aliasing filter at the output of the DVGA provides noise filtering and over 40 dB harmonic suppression by selecting the 20 MHz signal band centered at 192 Hz. The signal is then sampled and quantized by the ADC into 16-bit words using a 153.6 MHz CMOS clock.

In the clock path, a LMK04031B clock conditioning circuit operates with a 61.44 MHz reference oscillator and 76.8 Hz VCXO to provide the 153.6 MHz CMOS sampling clock. The clock output is also filtered and buffered to provide very low broadband noise for less than 200 fs total jitter over the clock input bandwidth of the ADC.

The measured system performance demonstrates a large signal SNR of 71 dBFS and SFDR greater than 80 dBFS for a -1 dBFS, 192 MHz input signal and a sampling frequency of 153.6 MSPS. For signals less than -6 dBFS, the SNR is greater than 72.7 dBFS and the SFDR is greater than 92 dBFS.

In a channel bandwidth of 200 kHz the subsystem achieves a small signal channel SNR greater than 99 dBFS enabling use in MC-GSM wireless communications receiver applications. In the presence of a -4 dBFS blocking signal that is 800 kHz from the channel center, the SP16160CH1RB achieves a SNR of 94 dBFS and SFDR of 90 dBFS in the channel.

Evaluation of this reference board is simplified with the WaveVision 5.1 Data Capture Board and WaveVision 5 software which enables data capture and analysis, as well as complete programmable configuration of the ADC16DV160 and LMH6517 via a common SPI bus. The LMK04031B is easily configured using a PIC Loader board that is included with the reference kit.

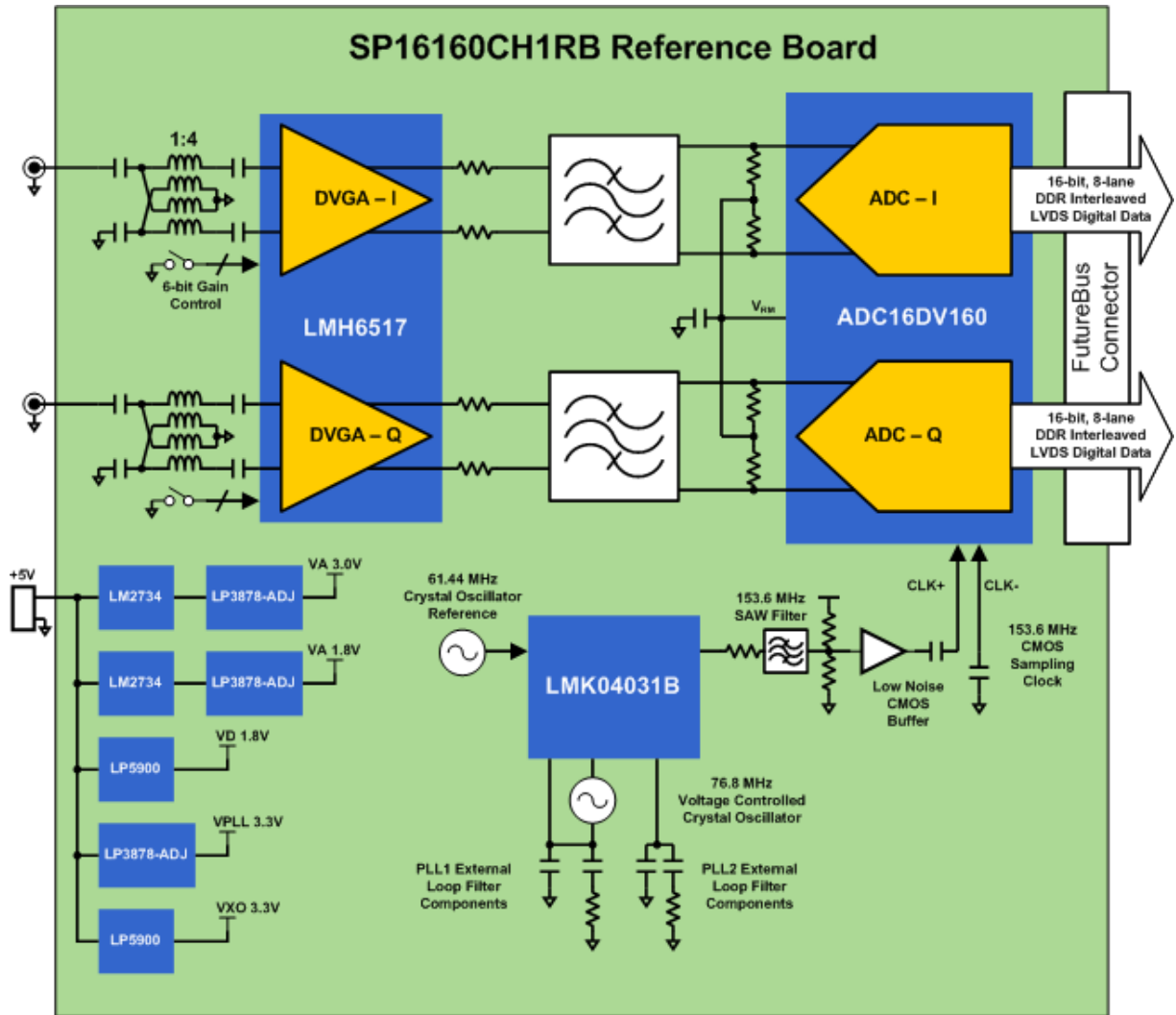
The reference design comes complete with the SP16160CH1RB board, the PIC Loader board to program the LMK04031B, and a WaveVision 5.0 software CD. Design documents such as the schematic, BOM and Gerber files are available on the web at www.national.com.

2.0 Features

Key Features of the SP16160CH1RB High-IF Sub-Sampling Receiver Reference Design Board

- Demonstrates a high-IF sub-sampling subsystem architecture used in wireless infrastructure systems
- Configured for a 20 MHz input bandwidth centered at 192 MHz
- Configured with a low-noise, 153.6 MSPS CMOS sampling clock
- **Featured Products Include:**
 - ADC16DV160 dual 16-bit, 160 Megasample per second (MSPS) ADC with parallel LVDS outputs
 - LMH6517 Digitally-controlled, Variable Gain Amplifier (DVGA) with 31.5 dB gain range in 0.5 dB steps
 - LMK04031B low-jitter precision clock conditioner consisting of cascaded phase locked loops (PLLs), an internal voltage controlled oscillator (VCO) and a distribution stage
 - Several energy-efficient power management ICs
- Large-signal (-1 dBFS) performance for a 192 MHz input signal:
 - SNR = 71 dBFS
 - SFDR > 80 dBFS
- Small-signal (-6 dBFS) performance for a 192 MHz input signal:
 - SNR = 72.7 dBFS
 - SFDR > 92 dBFS
- 200 kHz channel performance for base-station receiver applications:
 - SNR = 99 dBFS under normal conditions
 - SNR = 94 dBFS under blocking conditions
 - SFDR > 90dBFS under blocking conditions
- Total integrated jitter < 200 fs
- PIC Loader board included with reference board for quick and easy configuration of the LMK04031B
- Compatible with the WaveVision 5.1 Data Capture Board and WaveVision 5 software for simplified evaluation
- All internal register ADC and DVGA features can be exercised using the WaveVision 5 software
- Board comes fully assembled and tested
- Operates from a single (+5V) supply

3.0 Block Diagram



diagram

FIGURE 1. SP16160CH1RB Block Diagram

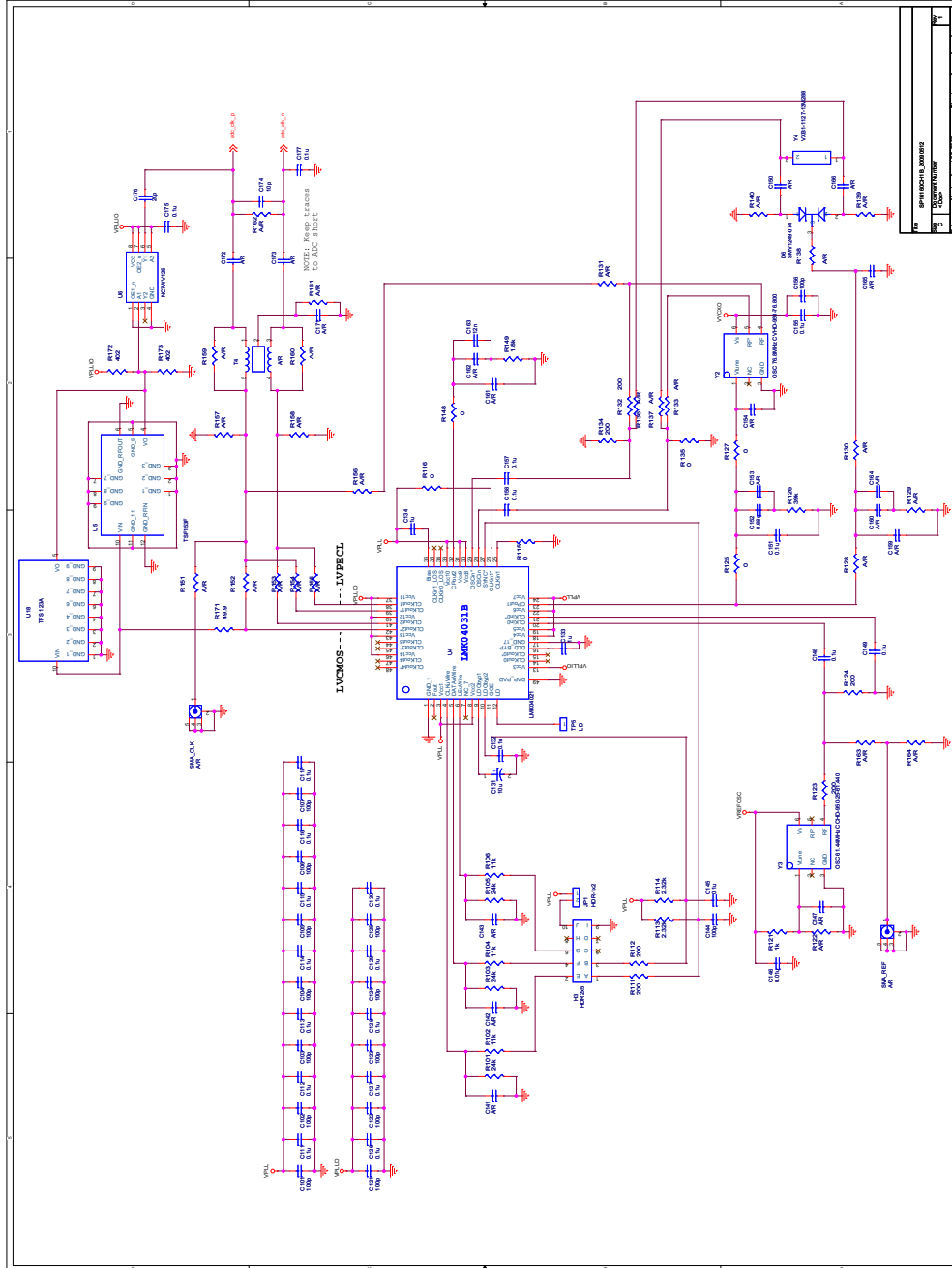
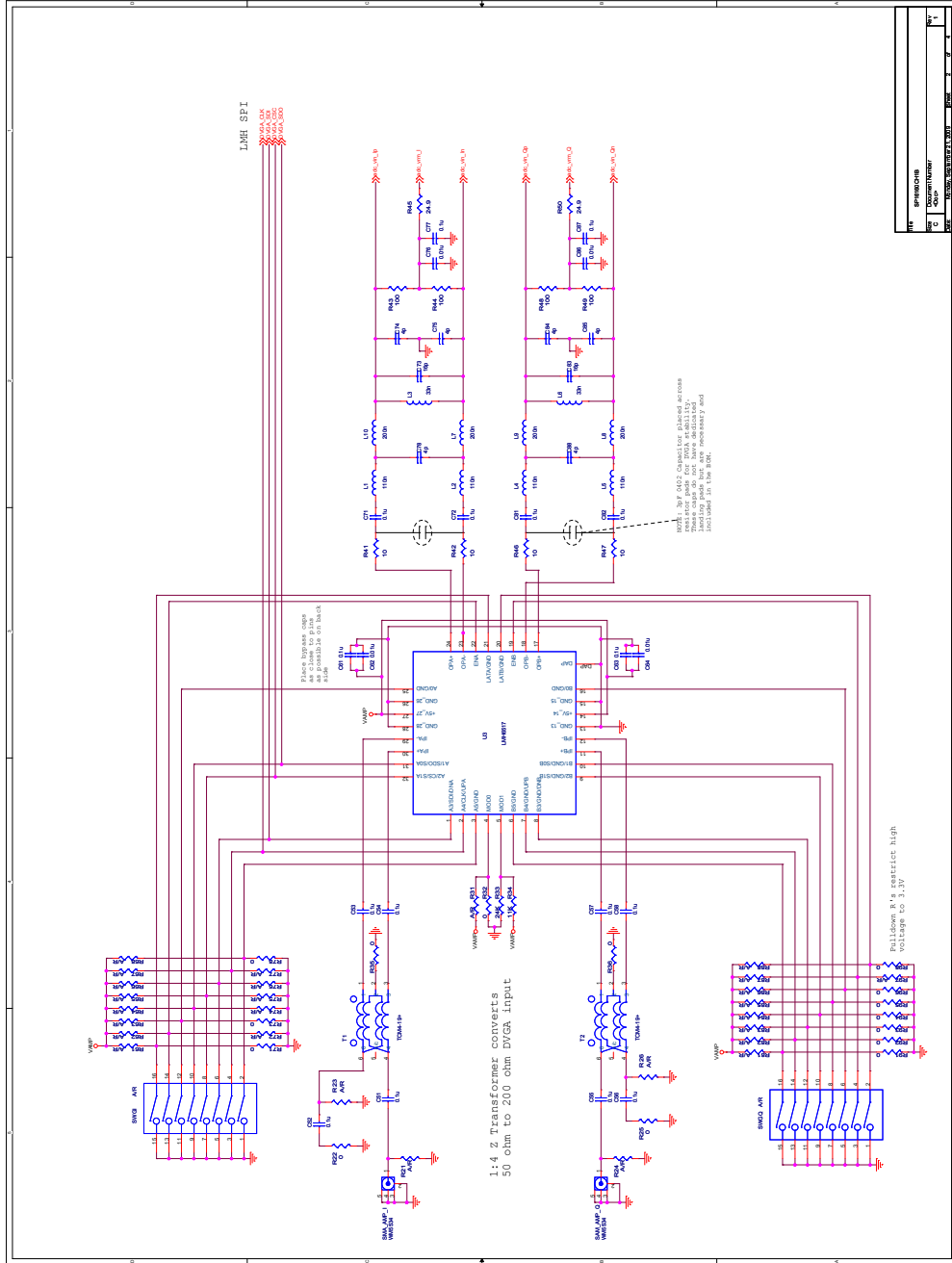


FIGURE 3. SP16160CH1RB Clock Schematic

schematic3



schematics

FIGURE 5. SP16160CH1RB DVGA Schematic

5.0 Bill of Materials

Item	Quantity	Schematic Reference	Part Name	Description	Manufacturer
1	2	-	3p	CAP CER 3PF 50V COG 0402	Murata Electronics
2	6	C74, C75, C78, C84, C85, C88	4p	CAP CERAMIC 4PF 50V COG 0402	Murata Electronics
3	1	C174	10p	CAP CER 10PF 50V 5% COG 0402	Murata Electronics
4	2	C73, C83	16p	CAP CER 16PF 50V S 0402 UHI Q	Johanson Technology Inc.
5	1	C176	20p	CAP CER 20PF 50V 5% COG 0402	Murata Electronics
6	14	C101, C102, C103, C104, C105, C106, C107, C121, C122, C123, C124, C125, C144, C156	100p	CAP 100PF 50V CERAMIC X7R 0402	Panasonic - ECG
7	3	C214, C248, C268	2.2n	CAP CERM 2200PF 5% 100V X7R 0603	AVX Corporation
8	1	C163	12n	CAP .012UF 16V CERAMIC X7R 0402	Panasonic - ECG
9	19	C21, C23, C25, C27, C31, C33, C35, C62, C64, C71, C72, C76, C81, C82, C86, C146, C213, C247,	0.01u	CAP .01UF 25V CERAMIC X7R 0402	Panasonic - ECG
10	2	C242, C262	0.01u	CAP CER 10000PF 50V X7R 10% 0603	
11	2	C1, C11	0.1u	CAP CERAMIC .1UF 6.3V X5R 0201	Panasonic - ECG
12	61	C2, C4, C5, C6, C7, C8, C9, C12, C14, C15, C16, C17, C18, C19, C22, C24, C26, C28, C30, C32, C34, C36, C39, C41, C42, C44, C45, C51, C52, C53, C54, C55, C56, C57, C58, C61, C63, C77, C87, C111, C112, C113, C114, C115, C116, C117, C126, C127, C128, C129, C130, C132, C145, C148, C149, C151, C155, C157, C168, C175, C177, C182,	0.1u	CAP .1UF 10V CERAMIC X5R 0402	Panasonic - ECG
13	10	C202, C204, C206, C217, C219, C226, C236, C238, C251, C271	0.1u	CAP .1UF 16V CERAMIC X7R 0603	Panasonic - ECG
14	1	C152	0.68u	CAP CER .68UF 6.3V Y5V 0402	Murata Electronics
15	2	C133, C134	1u	CAP 1UF 6.3V CERAMIC Y5V 0402	Panasonic - ECG
16	7	C212, C222, C224, C232, C234, C246, C266	1u	CAP 1UF 16V CERAMIC Y5V 1206	Panasonic - ECG
17	23	C3, C13, C29, C43, C46, C131, C201, C203, C205, C211, C216, C218, C221, C223, C225, C231, C233, C235, C237, C245, C250, C265, C270	10u	CAP TANTALUM 10UF 6.3V 20% SMD	Kemet
18	7	C215, C241, C243, C249, C261, C263, C269	10u	CAP CER 10UF 6.3V X5R 20% 1206	TDK Corporation
19	2	D2, D4	BAT54WS	DIODE SCHOTTKY 30V 200MW SOD-323	Diodes Inc
20	2	D3, D5	MBR0530	DIODE SCHOTTKY 30V 0.5A SOD123	ON Semiconductor
21	2	L3, L6	33n	33nH Chip Inductor 0603CS Series	Coilcraft
22	4	L1, L2, L4, L5	110n	110nH Chip Inductor 0603CS Series	Coilcraft
23	4	L7, L8, L9, L10	200n	200nH Chip Inductor 0603CS Series	Coilcraft
24	1	L11	EXC-CL4532U1	BEAD CORE 4.5X3.2X1.8 SMD	Panasonic - ECG
25	2	L12, L13	100u	INDUCTOR UNSHIELDED 100UH SMD	API Delevan
26	2	L21, L23	4.7u	4.7uH LPS3008 Series Low Profile Power Inductor	Coilcraft
27	25	R22, R25, R32, R34, R35, R36, R71, R73, R78, R91, R92, R93, R94, R95, R96, R98, R115, R116, R125, R127, R135, R148, R202,	0	RES ZERO OHM 1/16W 5% 0402 SMD	Panasonic - ECG
28	4	R212, R232, L22, L24	0	RES 0.0 OHM 1/8W 5% 0805 SMD	Panasonic - ECG
29	10	R1, R2, R3, R4, R5, R7, R41, R42, R46, R47	10	RES 10 OHM 1/10W 5% 0402 SMD	Panasonic - ECG
30	2	R45, R50	24.9	RES 24.9 OHM 1/16W 1% 0402 SMD	Panasonic - ECG
31	1	R171	49.9	RES 49.9 OHM 1/16W 1% 0402 SMD	Panasonic - ECG
32	4	R43, R44, R48, R49	100	RES 100 OHM 1/16W 1% 0402 SMD	Panasonic - ECG
33	6	R111, R112, R123, R124, R132, R134	200	RES 200 OHM 1/16W 1% 0402 SMD	Panasonic - ECG
34	2	R172, R173	402	RES 402 OHM 1/16W 1% 0402 SMD	Panasonic - ECG

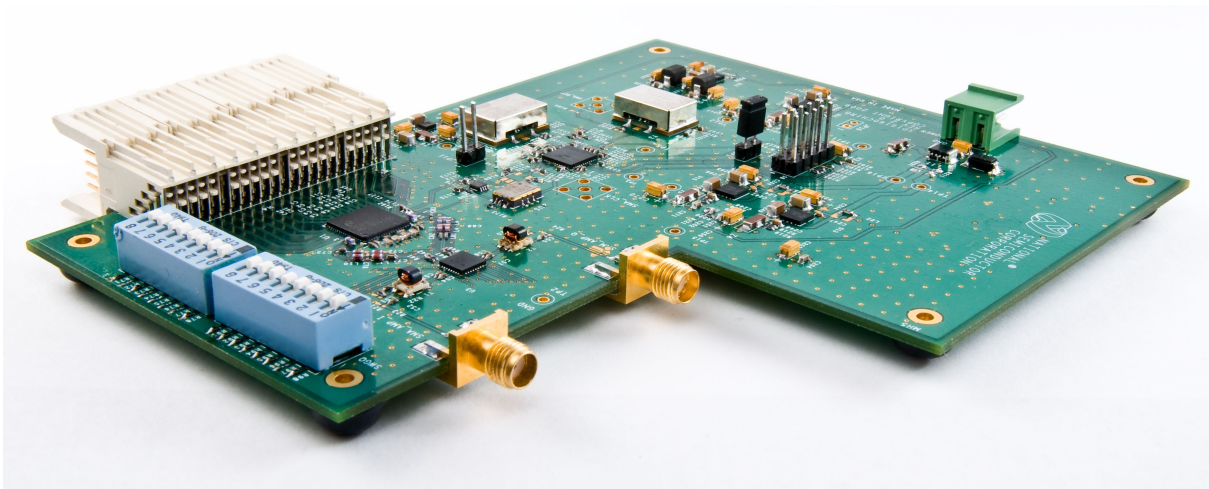
FIGURE 6. Bill of Materials 1 of 2

bom4

Item	Quantity	Schematic Reference	Part Name	Description	Manufacturer
35	1	R238	806	RES 806 OHM 1/16W 1% 0402 SMD	Panasonic - ECG
36	4	R121, R203, R219, R239	1k	RES 1.00K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
37	1	R149	1.8k	RES 1.80K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
38	1	R218	2k	RES 2.00K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
39	3	R113, R114, R204	2.32k	RES 2.32K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
40	7	R34, R102, R104, R106, R216, R220, R236	11k	RES 11.0K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
41	6	R33, R101, R103, R105, R221,	24k	RES 24.0K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
42	2	R126, R215	39k	RES 39.0K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
43	2	R213, R233	100k	RES 100K OHM 1/16W 1% 0402 SMD	Panasonic - ECG
44	2	SAM_AMP_Q, SMA_AMP_I	WM5534	CONN JACK SMA 50 OHM EDGE MOUNT	Molex/Waldom Electronics
45	2	T1, T2	TCM4-19+	SURFACE MOUNT RF TRANSFORMER 50 OHM 10 TO 1900 MHz	MINI-CIRCUITS
46	1	U1	ADC16DV160	Dual 16-bit 160 MSPS ADC with LVDS outputs	National Semiconductor
47	1	U2	24C02/S08	2K SERIAL EEPROM	ATMEL
48	1	U3	LMH6517	Multi Standard, IF and Baseband Dual DVGA	National Semiconductor
49	1	U4	LMK04031B	IC CLOCK CONDITIONER W/PLL 48LLP	National Semiconductor
50	1	U5	TSF153F	153.6 MHz SAW Filter	Vectron
51	1	U6	NC7WV125	Tinylogic Buffer 3-STATE Out	Fairchild Semiconductor
52	3	U11, U13, U15	LP3878SD-ADJ	IC VREG 800MA ADJ 8-LLP	National Semiconductor
53	2	U12, U14	LM2734Y	IC PWM STP-DWN REG 1A TSOT23-6	National Semiconductor
54	1	U16	LP5900SD-1.8	IC REG 1.8V LDO 100MA RF/ANLG 6-LLP	National Semiconductor
55	1	U17	LP5900SD-3.3	IC REG 3.3V LDO 100MA RF/ANLG 6-LLP	National Semiconductor
56	1	Y2	OSC 76.8MHz CVHD-950-76.800	76.8 MHz Voltage Controlled Crystal Oscillator	Crystek
57	1	Y3	OSC 61.44MHz CCHD-950-25-	61.44 MHz Crystal Oscillator	Crystek
58	6	Z1, Z2, Z3, Z4, Z5, Z6	NFM41PC204F1H3	FILTER LC HIGH FREQ .2UF 1806	Murata Electronics
59	1	H3	HDR2x5	2X5 JUMPER BLOCK HEADER	Samtec
60	1	H4	4 - 6x4 FutureBus Connector	Z-PACK 2mm FB (Futurebus+) RIGHT ANGLE HEADER CONNECTOR	AMP
61	1	JP1	HDR-1x2	1X2 JUMPER BLOCK HEADER	Samtec
62	1	POWER	Power Connector Terminal Block	CONN HEADER RT ANG 2POS 5.08MM	Phoenix Contact
63	1	-	Power Connector Plug	CONN TERM BLOCK PLUG 2POS 5.08MM	Phoenix Contact
64	1	-	2-position Jumper	2-POSITION JUMPER	FCI Electronic
65	5	-	Rubber Bump-ons	PLACE BUMP ONS AT THE 4 CORNERS, ON BOTTOM OF BOARD	3M

FIGURE 7. Bill of Materials 2 of 2

6.0 Board Photos



boardphoto

FIGURE 8. SP16160CH1RB

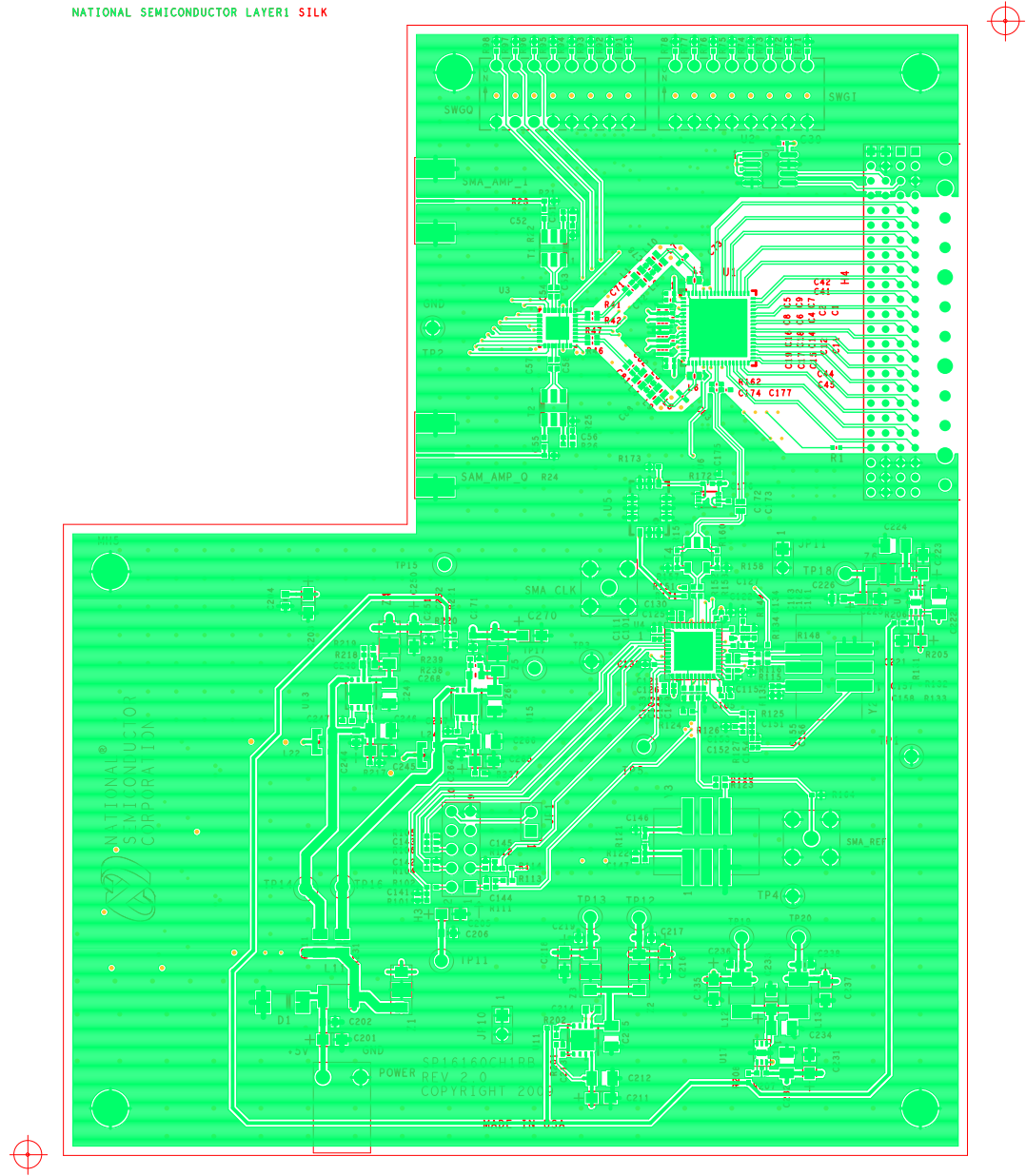
7.0 Hardware Description

A comprehensive discussion of this design is within in the **SP16160CH1RB High IF Receiver Reference Design Board ADC16DV160 + LMH6517 + LMK04031B User's Guide**. The user guide can be found in the **Design Resources** section on the RD-179 reference design folder:

<http://www.national.com/rd/RDhtml/RD-179.html>

8.0 Layouts

NATIONAL SEMICONDUCTOR LAYER1 SILK



layout2

FIGURE 9. SP16160CH1RB L1 Signal Layer

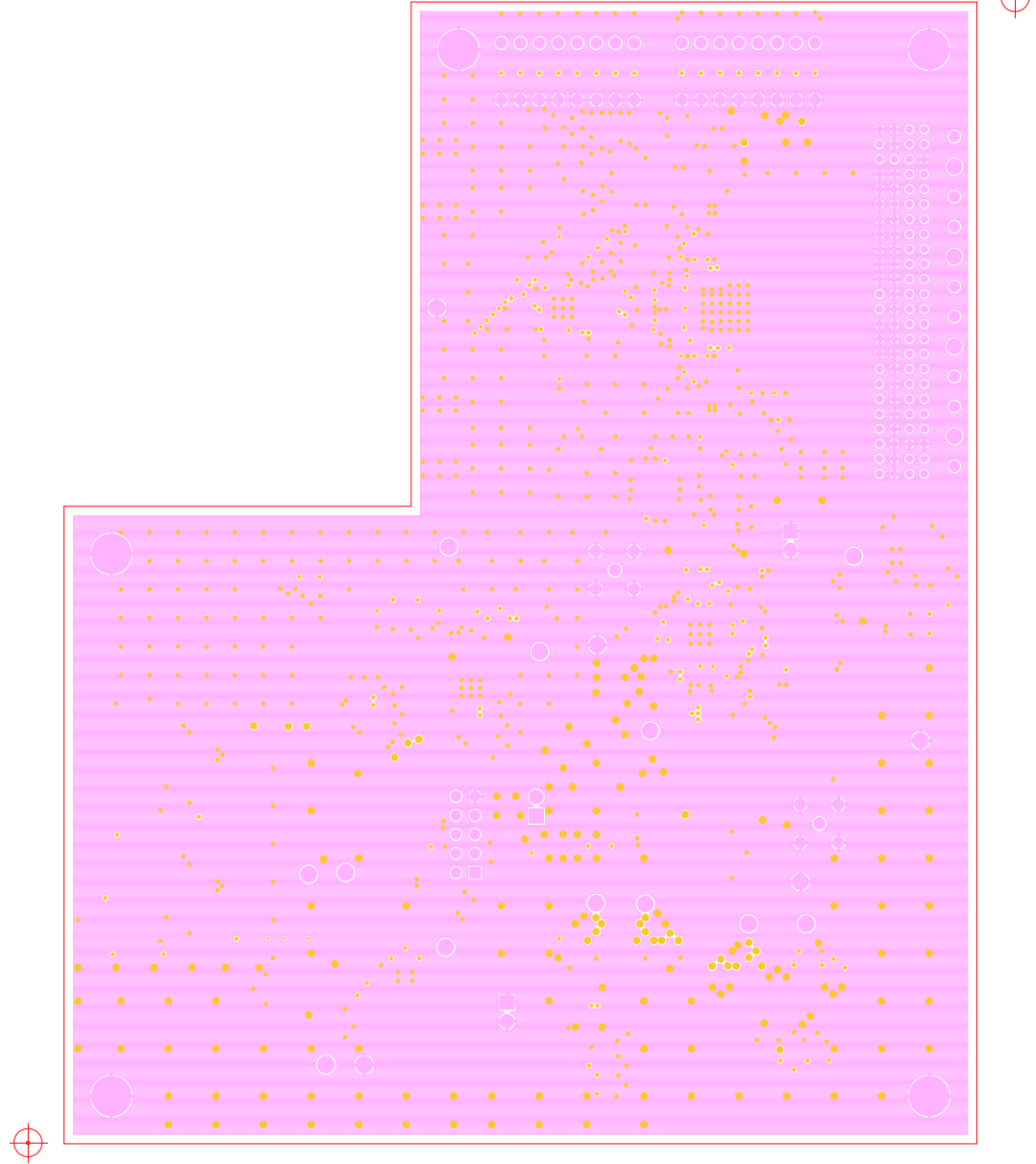
NATIONAL SEMICONDUCTOR LAYER2



layout3

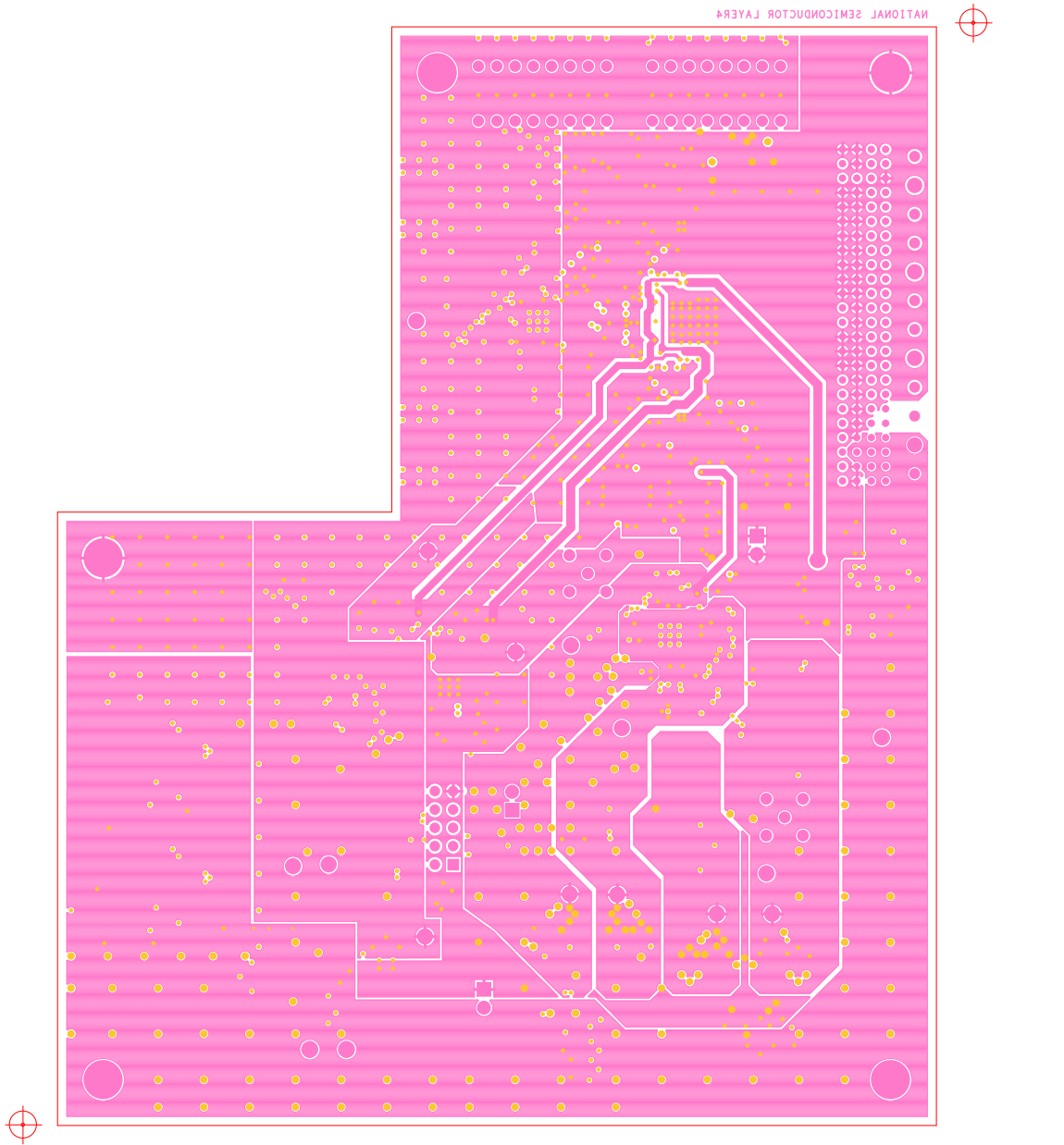
FIGURE 10. SP16160CH1RB L2 Ground Layer

NATIONAL SEMICONDUCTOR LAYERS



layout4

FIGURE 11. SP16160CH1RB L3 Ground Layer



layout5

FIGURE 12. SP16160CH1RB L4 Power Layer



FIGURE 13. SP16160CH1RB L5 Ground Layer

layout6



FIGURE 14. SP16160CH1RB L6 Signal Layer

layout7

Notes

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