HYPERLABS' HL9334 HARMONIC DOWNCONVERTER/SAMPLER IC DESCRIPTION AND FUNCTIONALITY

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OVERVIEW

The HL9334 is a high-precision sampler/harmonic mixer integrated circuit (IC) offering excellent linearity, low noise, and flat frequency response up to 20 GHz (RF). Starting with a functional block diagram, this application note will describe the sub-components that make up HL9334 including the front-end RF linear amplifier, the LO comb generator, and the IF linear amplifier.

Following the description of the functionality of the IC, a couple use cases will be presented including the use as a tuned receiver or a Nyquist folding receiver.

Founded in 1992, HYPERLABS sells an array of ultra-broadband components including baluns, bias tees, DC blocks, power dividers, pick-off tees, samplers and more operating up to 110 GHz. HYPERLABS' growing instrumentation line includes pulse generators, TDRs/TDTs, impedance analyzers, and more.

HL9334 DESCRIPTION

HL9334 is a DC-20 GHz harmonic downconverter/sampler IC packaged in a 28-pin 4mm QFN. A functional block diagram is shown below in *Figure 1*. Each function is described in the following paragraphs.

RF Linear Amplifier

The RF front-end of HL9334 features direct coupled 50 Ω terminations to ground and a low noise, high linearity, differential RF amplifier with >20 GHz bandwidth and excellent reverse isolation. This RF amplifier configuration minimizes input reflections and enables HL9334 to receive broadband signals from DC-20 GHz. The combined -3 dB bandwidth of the RF amplifier and sampling mixer is typically DC-17 GHz. At f_{LO} = 2 GHz and 0 dBm, the LO-RF isolation is typically 70 dB (measured on an evaluation board containing the recommended LO limiting amplifier).

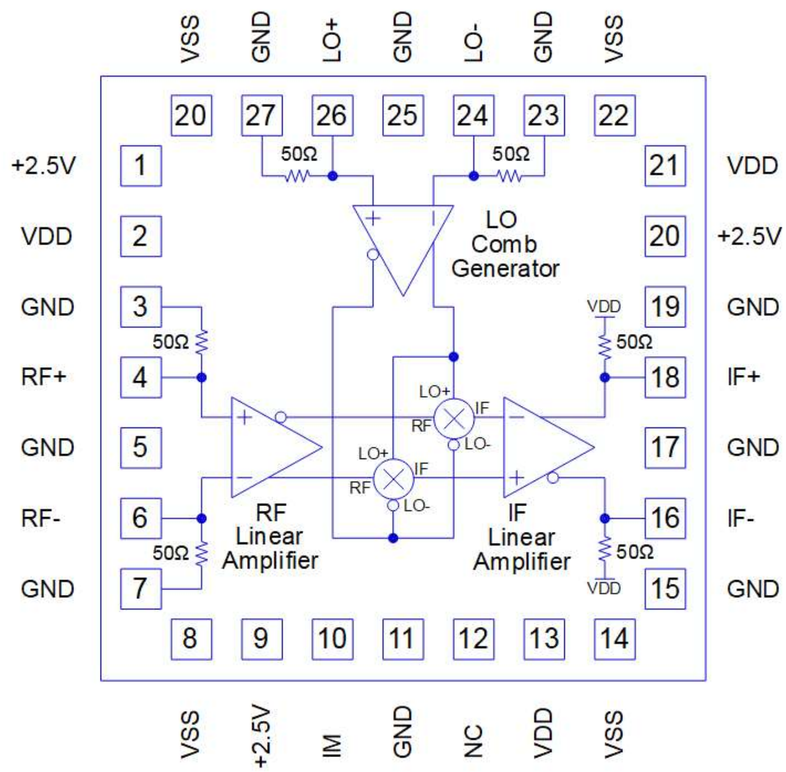

Figure 1. Functional Block Diagram of HL9334

LO Comb Generator

The feature that distinguishes a harmonic downconverter/sampler from a conventional mixer is the LO comb generator. The LO comb generator produces a broad spectrum of even and odd harmonics. Each harmonic converts 2 Nyquist zones worth of information from RF to IF baseband. For example, when HL9334 is operated at f_{LO} = 2 GHz, the 10th harmonic of the LO mixes with signals in the 19 GHz to 21 GHz range, thus down-converting them to 0-1000 MHz IF baseband. At the same time, signals in lower Nyquist zones are down-converted by mixing with lower order LO harmonics. The resulting IF signal contains all of the information from DC-20 GHz. 20 Nyquist zones worth of information from the RF spectrum are "folded" and aliased into the 0-1000 MHz IF baseband. See *Figure 2* below. Note

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that information from even Nyquist zones appears in the IF baseband as a mirror image whereas information from odd Nyquist zones is translated directly to baseband without spectral inversion. A variety of methods are available to prevent aliasing or otherwise "unfold" the aliased information (See the applications section). HYPERLABS recommends using a tunable preselector bandpass filter and an IF reconstruction lowpass filter.

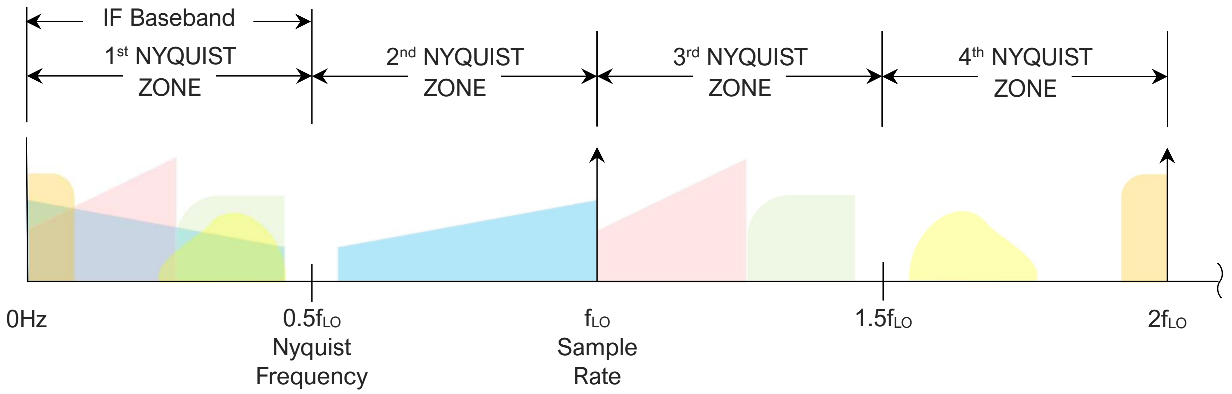

Figure 2. Aliased down-conversion of RF information from 2nd, 3rd and 4th Nyquist zones to IF baseband.

For illustration purposes, all image frequencies above 0.5f LO and below 0 Hz are neglected.

The LO port of HL9334 is designed to be driven by a logic-level square wave from a low cost, commercially available, differential limiting amplifier. Unlike traditional mixers, the conversion loss and linearity of HL9334 are insensitive to variations in LO drive level applied at the input of the LO limiting amplifier. However, HL9334 conversion loss is directly influenced by LO frequency. (See the applications section).

The recommended LO operating frequency range is 2 - 4 GHz. This is more than enough tuning range to successfully digitize the full DC - 20 GHz spectrum (See the applications section). HL9334 is capable of operating at LO frequencies as high as 7 GHz with little effect on RF bandwidth. For time domain applications, it is not recommended to operate at Nyquist frequencies above the -3 dB IF bandwidth (typically 1 GHz). Operating at Nyquist frequencies above the IF bandwidth results in excessive ripple or "holes" in the frequency response of the receiver as illustrated in *Figures 3* and *Figure 4*. For RF applications, the LO frequency may be tuned so the preselected Nyquist zone of interest falls within the appropriate IF baseband range. In this case, good performance can be achieved at Nyquist frequencies above 1 GHz.

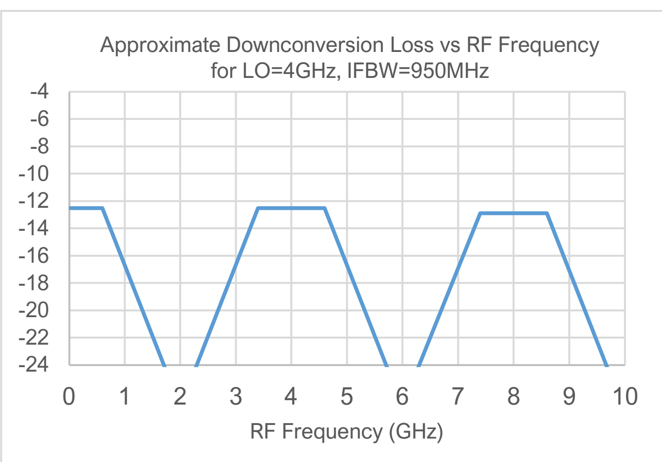

Figure 3. Holes in the frequency response result from operation at fNyquist ≥ IFBW

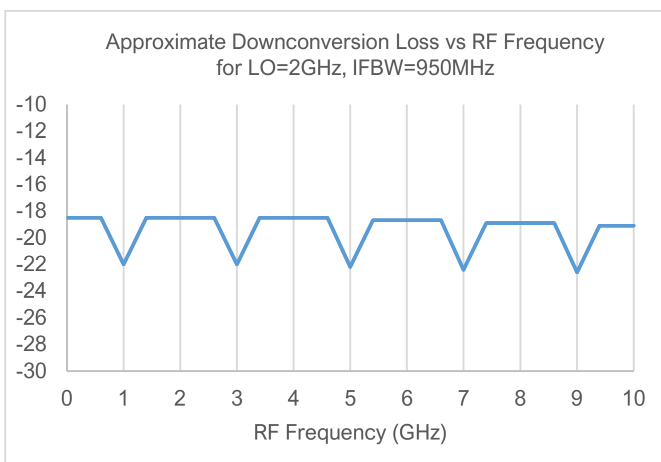

Figure 4. Ripple is minimized by operating at fNyquist ≤ IFBW

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IF Linear Amplifier

The IF output of HL9334 features direct coupled 50 Ω terminations to VDD (+6 V) and a high linearity common source differential IF amplifier. The IF bandwidth of HL9334 is typically 1 GHz. *Figure 3* and *Figure 4* illustrate the effect of Nyquist frequency and IF bandwidth on RF frequency flatness.

HL9334 APPLICATIONS

Now that an understanding of the block diagram and integral sub-systems are understood, a couple use cases will be presented in this applications section.

The initial application is a 2-18 GHz tuned receiver followed by a Nyquist folding receiver application. Other uses of the HL9334 include being used as a high-speed front-end for A/D converters, as a component in a network analyzer, sampling oscilloscope, or spectrum analyzers.

2-18GHz Tuned Receiver

HL9334 offers unique advantages over traditional mixers when used in tuned receiver systems. An example receiver block diagram is shown below in *Figure 5.* As shown below, the integrated LO comb generator simplifies LO design, requiring a much narrower tuning range and lower drive power than a traditional superheterodyne receiver. The conversion loss and linearity of the receiver is insensitive to variations in LO drive power. The LO power is spread over a wide spectrum of integer harmonics ranging from the fundamental LO frequency to more than 20GHz thus reducing LO coupling to the RF port of the mixer. The excellent reverse isolation of the on-chip RF amplifier further enhances LO - RF isolation. HL9334 is a very quiet receiver.

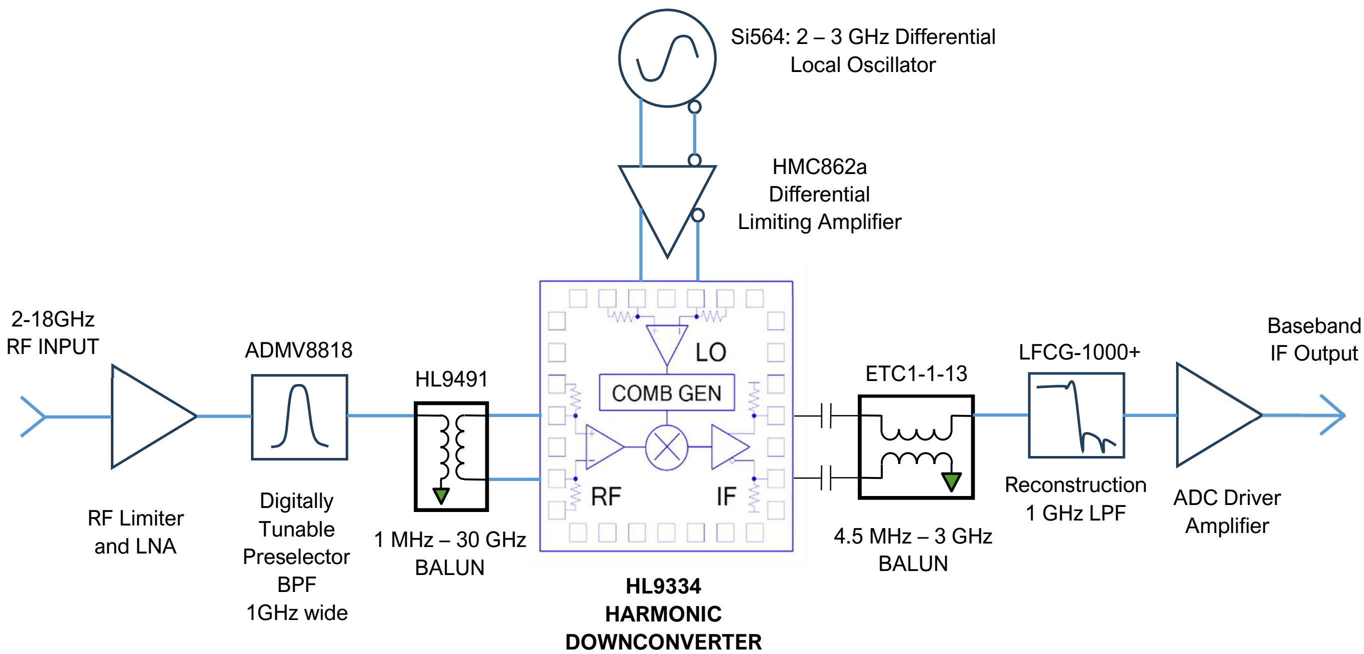

Figure 5. 2-18 GHz Tuned Receiver using HL9334 Harmonic Downconverter. LO Tuning range is 2 – 3 GHz

An example frequency tuning plan is shown in *Table 1* below. Only odd Nyquist zones are received, thus avoiding spectral inversion. Crosstalk between adjacent frequency bands can be minimized by operating at higher LO frequencies than shown in *Table 1*. The trade-off is conversion loss flatness. As shown in *Figure 3* and *Figure 4* above, conversion efficiency increases with sample rate (LO frequency) by roughly 6dB/octave. Higher LO frequencies result in less spreading effect and greater LO signal coupling to the RF port.

Table 1. Frequency tuning plan for 2 – 18 GHz tuned receiver using HL9334 Harmonic Downconverter.

LO Freq (GHz)	RF Pre-selector Filter Band (GHz)	LO Order Utilized	Nyquist Zone
2	2-3	1	3
3	3-4	1	3
2	4-5	2	5
2.5	5-6	2	5
3	6-7	2	5
2.333	7-8	3	7
2.667	8-9	3	7
3	9-10	3	7
2.5	10-11	4	9
2.75	11-12	4	9
3	12-13	4	9
2.6	13-14	5	11
2.8	14-15	5	11
3	15-16	5	11
2.667	16-17	6	13
2.833	17-18	6	13

Nyquist Folding Receiver

The HL9334 is suitable for use in Nyquist Folding Receiver (NyFR) applications. More information on this application can be found in various IEEE journals such as the following: https://ieeexplore.ieee.org/document/6355638. Numerous patents are held by L3Harris for this technology. The NyFR is able to determine the frequency of a received signal without having first pre-selected a specific band and without tuning the LO near the received signal.

To determine the frequency of any arbitrary RF tone received, it is necessary to identify the Nyquist zone. This is done by frequency modulating the LO and measuring the modulation index of the received IF tone. The modulation index of the received IF tone indicates the order of the LO harmonic adjacent to the RF tone. For example, RF tones in the 4th and 5th Nyquist zones produce IF tones exhibiting 2x modulation index because RF tones in this range are adjacent to the 2nd harmonic of the LO. Similarly, RF tones adjacent to the 5th harmonic of the LO are converted into IF tones with 5x modulation index.

The operating principals described above were demonstrated in the lab. A Picosecond Pulse Labs comb generator driven at 1.02 GHz was used to generate a broad-spectrum RF signal. The 20th harmonic (20.4GHz) of the RF was measured to be approximately -20 dBc. The 1.00 GHz LO was modulated with .04% ramp wave FM. As shown in *Figure 6*, the modulation index observed on the IF output directly indicates the Nyquist zone of each RF tone. This demonstration clearly illustrates compression of a broad and sparse 1.02 - 20.4 GHz RF spectrum into 400 MHz IF bandwidth. The resulting IF spectrum could be readily digitized and real time processed with DSP.

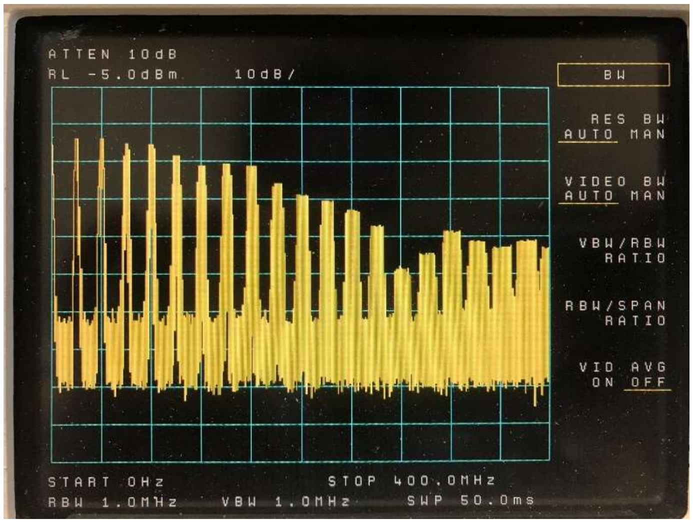

Figure 6. IF Output Spectrum of HL9334
(1.02GHz-20.4GHz RF Comb, 1.00GHz LO with .04% ramp wave FM)