WHITE PAPER

TELEDYNE e2v's EV10AS940 "SILVER BULLET" RF/Microwave ADC

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TELEDYNE e2v | Semiconductors
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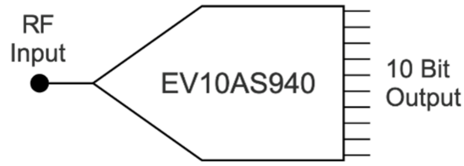
EXECUTIVE SUMMARY



Every RF/Microwave system level design engineer searches for the "silver bullet" component solution that will be the key enabler for ALL performance specification requirements. A "silver bullet" can be defined as the single perfect solution to many complicated problems. For today's RF/Microwave receiver system design engineers, Teledyne e2v's EV10AS940 10 Bit, 12.8 GSPS ADC (with internal DDC) is the ultimate "silver bullet." An ADC singularly converts the electromagnetic world for digital signal processing [1]. The EV10AS940 10 Bit ADC directly converts RF/Microwave input frequencies (requiring no analog mixing) from L to Ka-Band (1Ghz-40Ghz), and then digitally down converts (DDC) and conditions the signal to include: quadrature detection, frequency hopping and beam forming (so an external DSP engine can then perform additional output computations).

RF/Microwave systems must be designed and procured to meet one of five basic quality levels: Consumer, Commercial, Industrial, Military or Space. In ascending order, each of these quality levels require higher performance/reliability and endurance/lifespans that corresponds with increasing component costs. In addition, with higher quality levels, per RF/Microwave application, a system usually benefits from ever increasing capabilities for softwarization/reconfigurations on-the-fly which in-turn dramatically lowers overall system costs. Again, the EV10AS940 is the "silver bullet" for all of the above considerations including cost minimization within SWaP constraints (16 x 17.6 mm FCBGA package at 2.5W (@ Fsamplemax=12.8 GSPS)).

Teledyne e2v's EV10AS940 ADC was designed for all RF/Microwave applications such as: Military/Defense (Aerospace, Avionics, Radar/SAR, EW, Communications), Space (Satellites, SATCOM, Spacecraft, Earth Observation, Edge Computing, Navigation (GNSS), Next Gen. GPS), Telecommunications/Cellular, Industrial/Manufacturing, Medical/Healthcare, Oscilloscopes/Digitizers, Radioastronomy, Energy, Quantum Navigation and Computing, Automotive, etc. This list of applications represents only a fraction of potential usages for the EV10AS940 (all available at the required quality levels previously mentioned).

RF/MICROWAVE RECEIVER SYSTEM DEVELOPMENTS

Traditionally, RF/Microwave receiver systems have always required basic electronic components that are common to all applications: Antennas, Filters, Mixers, Oscillators, and the most critical component being the ADC. An electromagnetic RF/Microwave signal is received by the antenna, filtered, mixed and converted into a digital code so the DSP can then perform system computations. The signal processing between the antenna and the DSP is called frequency down conversion. Receiver down conversion occurs when the received signal (from the antenna) is frequency translated from RF to IF (Intermediate) to Base Band. The RF frequency range is a function of the transmitter application. The IF frequency range is highly variable and is selected based on a number of factors required to improve frequency selectivity (transmission lines, filter/mixer/oscillator specifications, etc.). The Base Band frequency is a function of the ADC input sampling bandwidth. In addition to frequency down conversion, quadrature detection is often used to demodulate the signal into a two-dimensional signal whose instantaneous value (in time) can be specified by a single complex number having two parts (I represents amplitude of the in-phase signal and Q represents the quadrature signal (90o offset). Figure 1 (below) shows a traditional dual-down convertor RF receiver. This receiver is a fundamentally narrowband analog system that requires the most circuitry, which in-turn introduces base band channel mismatches and phase distortion. Software reconfigurations are also very limited (i.e. frequency hopping, beam forming, etc.) [2].

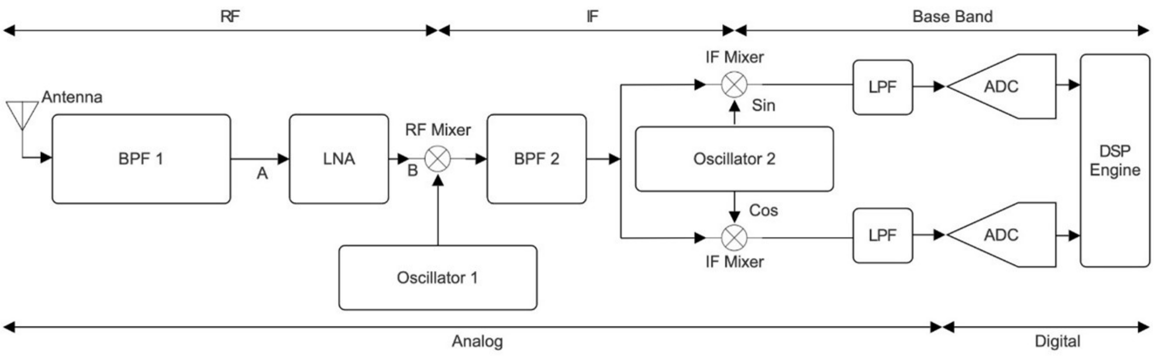


Figure 1: Traditional Dual Down Convertor

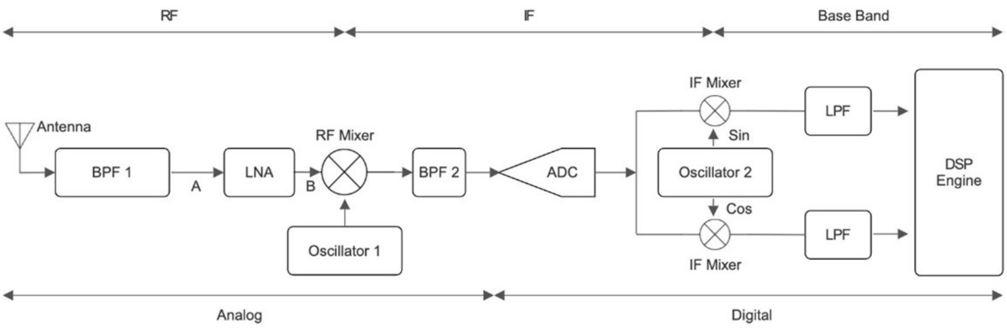


Figure 2: IF Down Convertor with external DDC

Figure 2 (above) depicts a significant upgrade to Figure 1. This requires an ADC to have a higher input signal bandwidth, and corresponding sample rate, that is capable of processing the signal at a specified IF range. In addition, IF to Base Band frequency translation, quadrature detection, and filtering is performed by a digital down convertor (DDC) external to the ADC. The DDC eliminates I/Q channel imbalances and can be easily programmed and reconfigured on-the-fly. The DDC could also be incorporated into the DSP engine, but this places a significant burden on the ADC to drive lengthy digital lines to an offboard DSP computer. Therefore, incorporating the DDC function (see Figure 3) into the ADC, would produce the highest possible overall performance and softwarization options.

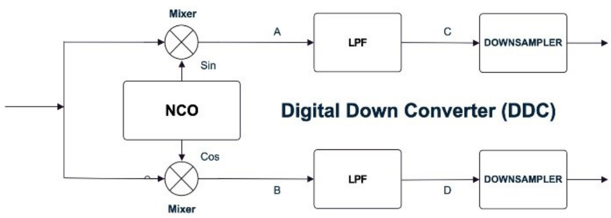


Figure 3

Figure 4 represents the "silver bullet" solution for RF/Microwave receiver designers utilizing Teledyne e2v's EV10AS940 10 Bit, 12.8 GSPS, single channel ADC capable of directly sampling/processing RF input signals from L to Ka-Band (1Ghz-40Ghz) at 2.5 W power dissipation. With a small form factor, single-ended RF and clock inputs, internal/programmable DDC and Numerically Controlled Oscillators/ NCOs (for I/Q detection, fast frequency hopping and beam forming), the EV10AS940 is capable of being co-located with the antenna for implementation in multi-channel ADC arrays with internal synchronization capabilities.

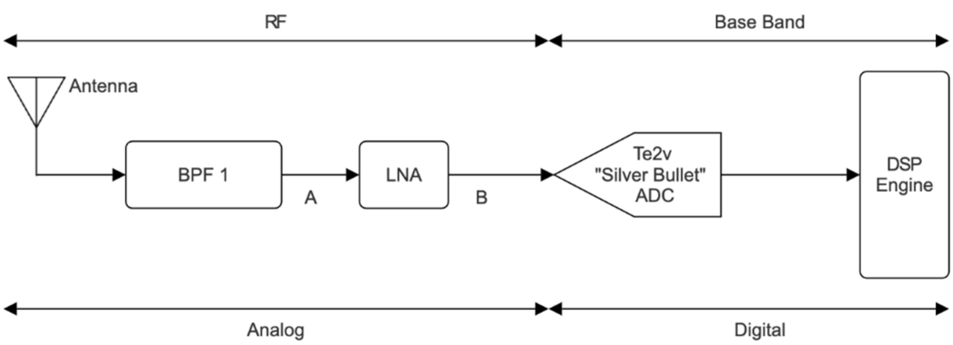
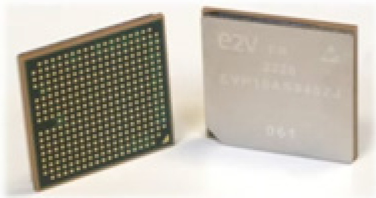


Figure 4: Direct Sampling RF ADC with Internal DDC

RF/MICROWAVE RECEIVER SYSTEM SIGNAL MANAGEMENT UTILIZING THE EV10AS940



Extensive Digital Features

- DDC frrom 2 to 1024
- X4 NCO allow multi-channel management
- Fast frequency Hopping
- Beamforming / Digital Delays
- Automatic background calibration
- Easy muti-chip synchronization

In the pursuit of advanced RF/Microwave Receiver Systems, Radars, and Software Defined Microwave Radios (SDMRs), etc.; Teledyne e2v's EV10AS940 ADC isn't just a component, it is the future. The EV10AS940's software defined flexibility and agility (on-the-fly) allows for dynamic frequency plans which include simultaneous sampling/multi-band and cross-band service operations from the L to Ka-Band (1Ghz-40Ghz) range. The EV10AS940's 33 Ghz-3dB input bandwidth (at 12.8 GSPS and 2.5W power dissipation (.195 mW/GSPS)) make it the best choice for Direct RF/Microwave receiver architectures thereby eliminating any requirements to implement dedicated mixers between the antenna and the ADC. Digitally, it also features 11 ESIstream output serial links that operate synchronously with the sampling clock in order to achieve deterministic data transfer. The ADC onboard Digital Down Conversion functionality has multiple options for decimation rates (2 to 1024) with up to 4 independent NCOs (4 DDC channels) to support multi-channel management including deterministic I/Q detection, Fast Frequency Hopping (with RTZ, Continuous, and Coherent Modes) in multi-band operations. Fractional digital delays enable Beam Forming capability allowing the EV10AS940 to be used in Phased Array applications. Coherent Frequency Hopping and Beam Forming is made possible with digital delays due to multiple phase accumulators on each NCO, and deterministic dedicated hopping trigger I/Os. Other features include: Background and Temperature calibration, Temperature monitoring, ESIstream 62/64b, HSSL reach selection, and HSSL impedance control (2x50Ω+/-20).

Figure 4 (above) represents the real-life elegance and simplicity of implementing the EV10AS940 into RF/ Microwave receivers. For simultaneous sampling multi-band/service receiver systems (we will look at performance later), it all begins with the RF antenna. Linear polarized antennas receive signals in only one plane but generally have a longer read range. Circular polarized antennas receive signals in every possible plane. Therefore, if the received signal is in the same plane, linear polarized antennas are used, if not, then circular polarized antennas are the necessary choice. The antenna output (L through Ka-Band) is then filtered (BPF1) for specific frequency selections, and interference rejection, that is picked up by the antenna. This in-turn relaxes the linearity requirements when amplified by a RF low noise amplifier (LNA) which then drives the single-ended input of the EV10AS940. The LNA converts and amplifies a very low power RF signal from the antenna. This amplification reduces the noise contributed by the ADC in comparison to the desired signal. In this way, the receiver becomes less sensitive to the noise stages after the LNA. Because the LNA drives a 50 ohm single-ended input of the ADC, it eliminates the need for a differential balun. Baluns have inherent bandwidth limitations, high cost, and create PCB size and weight issues. A balun free design provides an ultra-wide broadband input bandwidth to the ADC which also has an integral DC blocking and 50-ohm effective input impedance. That's a major enhancement to the front end, enabling a denser design layout. Of course the ADC clock input is configured the same as the RF input (single ended, DC blocking and 50 input impedance) as well (see Figure 5) [3].

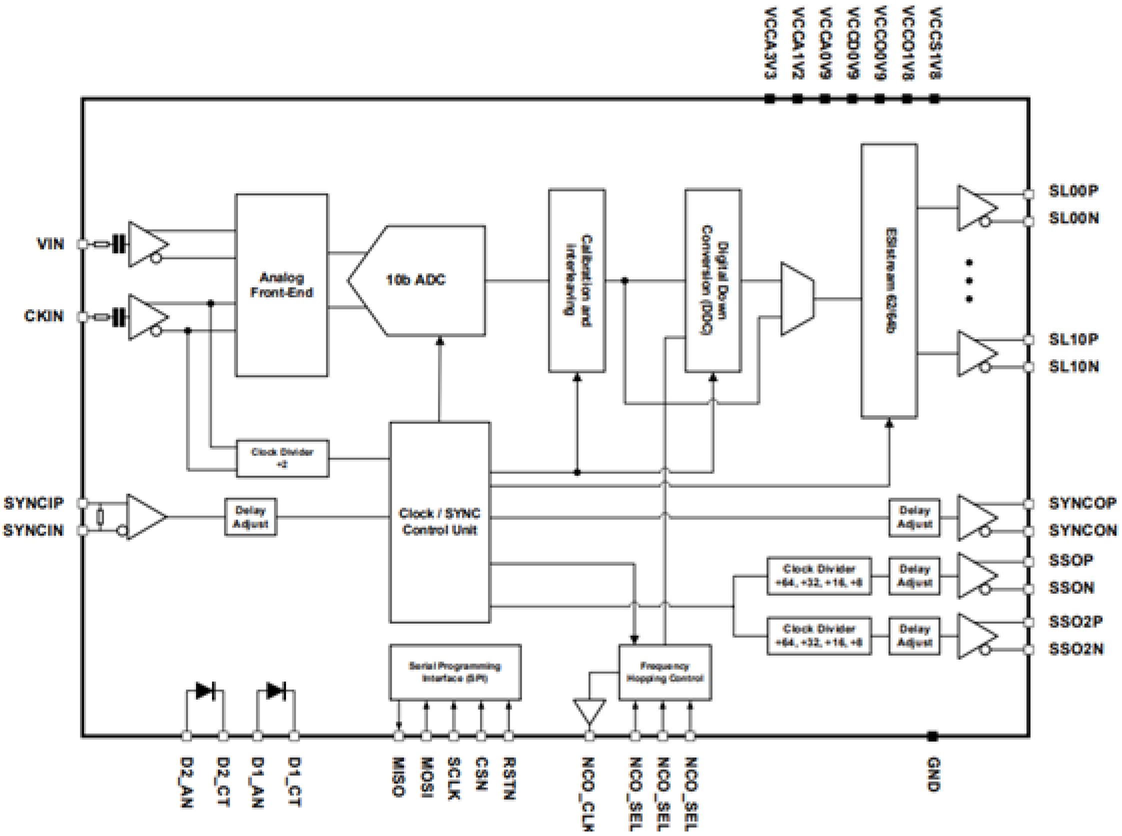


Figure 5: EV10AS940 ADC Block Diagram

The EV10AS040 provides state-of-the-art analog RF input signal sampling synchronized with comprehensive digital signal frequency controls designed for multi-band/service, fast frequency hopping, and beam forming applications (see Figure 6). Coherent fast frequency hopping is achieved utilizing dedicated phase accumulators on each fine control NCO channel, which are then coupled to deterministic and dedicated frequency hopping trigger signals. This provides four independent configuration channels supporting multi-band systems. Phase continuity is achieved across all four channels. A 4-bit fine phase control is implemented in each NCO channel enabling a wide degree of flexibility in managing cross channel phase delays. A fifth NCO channel delivers coarse phase setting that gates the fine control outputs of the quad NCOs to handle the relative phase offsets between separate RF channels in a large array antenna environment. Determinism is one of the value advantages of this integrated ADC architecture [4] [5].

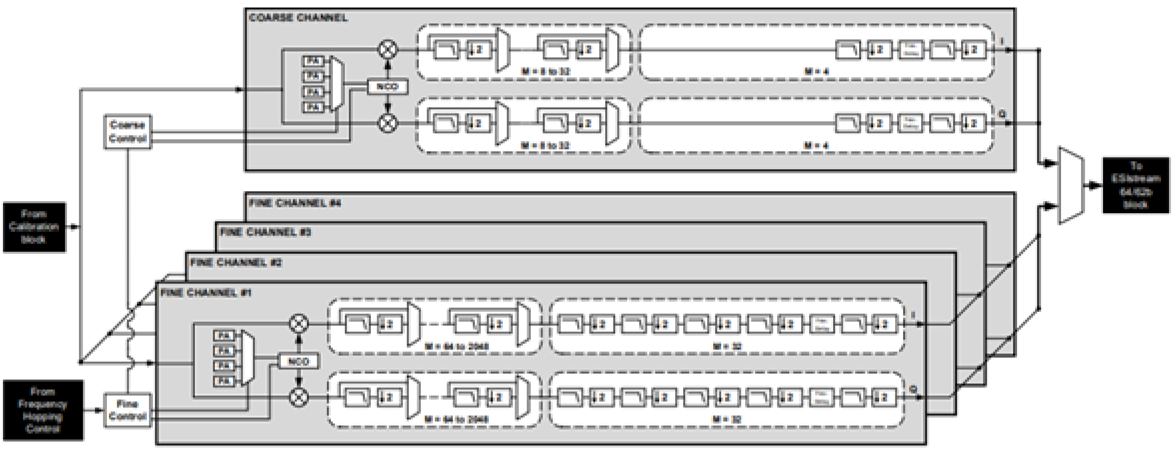


Figure 6: EV10AS940 DDC Block Diagram

As sample clock frequencies increase, it is essential, particularly in beam forming systems, that the signal sample clock edge is deterministically applied across the system – thus establishing the spatial accuracy limit of the system. Sample clock phase accuracy places significant demands on clock system precision (especially for example in a SAR system). In this regard, the EV10AS940 incorporates what Teledyne e2v refers to as "Sync-Chain" capability. This allows each individual ADC, in a phased array, to eliminate digital metastability since each device on the chain "retimes" its received Sync signal to be subsequently shared by all other ADCs further down the timing chain. This method ensures each device samples at a precise instant in time. As a result, unlimited channel parallelization is made possible which essentially eliminates channel phase misalignment issues.

SYSTEM PERFORMANCE

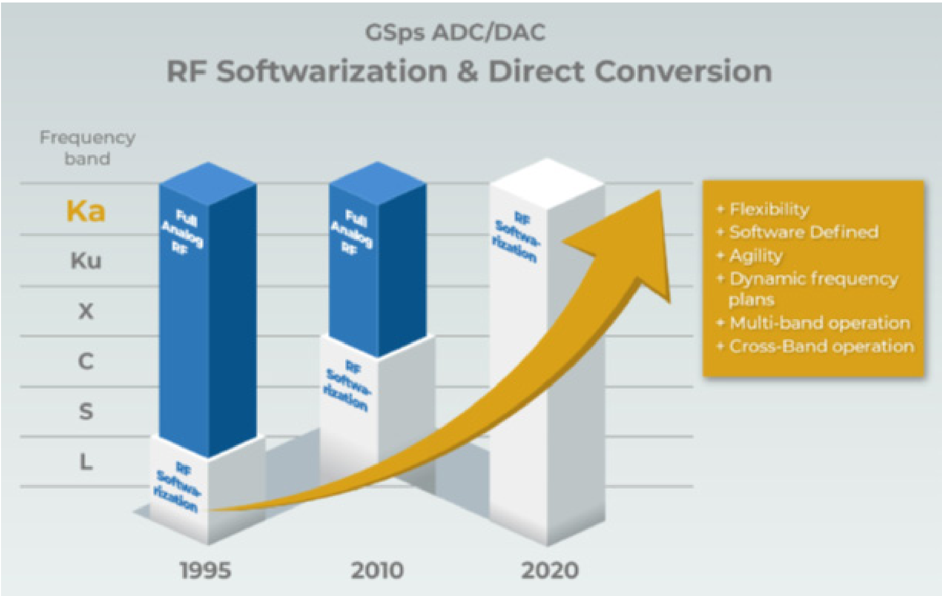


Figure 7

Teledyne e2v has been providing microwave RF receiver products for over 29 years (since 1995). As RF processing frequencies increase over the decades, and become more commonplace industry wide (i.e. Ka-Band); the incremental softwarization capabilities of the system have also needed to increase. Eventually, reaching a point that tops out, and it simply becomes a softwarable receiver (see Figure 7). Teledyne e2v's EV10AS940 ADC is the "silver bullet" that tops out a completely softwarable (dynamically software reconfigurable) receiver (see previous Figure 4). This single chain receiver is capable of converting Multi-Bands (L-Ka Band) simultaneously (not sequentially) for implementing Multi-Service operations with seamless connectivity including handovers (e.g. LEO/MEO, etc.). The receiver is reconfigurable on-the-fly (i.e. frequency adjustable). Direct RF conversion (with no mixing) allows the receiver module to be co-located to the antenna together with all the required circuitry for digital frequency conversion, I/Q detection, frequency hopping, and beam forming. Digital data routing on the RF receiver PCB must be minimized because it becomes a significant impediment to accomplish multi-service system capability [6]. Figure 8 shows a representative RF transmitter output spectrum driven by a Teledyne e2v EV12DD700 DAC when simultaneously transmitting X & Ku band output signals. The DAC simultaneously transmits the multi-bands while the EV10AS940 ADC RF receiver (Figure 4) would then simultaneously receive and process these signals as well [7].

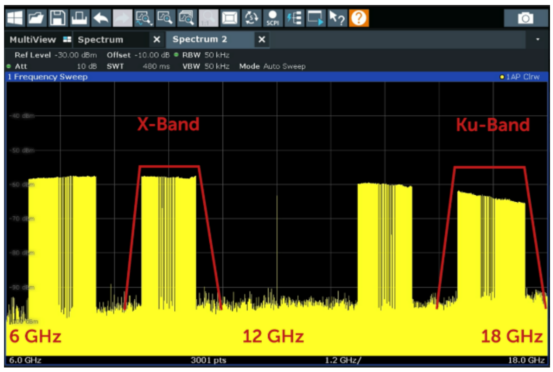


Figure 8

Snapshot of key EV10AS940 dynamic characteristics

- 33GHz (-3dB) analog bandwidth
- SFDR with Fs = 12.8GHz, POUT = - 6dBFS
- Fin = 4.1GHz -> -54.5dBc
- Fin = 14.1GHz -> -50.2dBc
- Fin = 17.4GHz -> -50.4dBc
- Fin = 28.4GHz -> -50.5dBc
- Fin = 40.5GHz -> -32.1dBc

Figure 9

Optimal Multi-Band SFDR and Phase/Noise performance is also realizable (see Figures 9 and 10). In regards to receiver system frequency planning, once the hardware implementation is set (Antenna, BPF1, LNA and EV10AS940), the only design variable (besides software reconfigurations) is the sample clock frequency. Therefore, a completely softwarable system allows for continuous dynamic RF/Microwave system reconfigurations (ultimately utilizing AI technology).

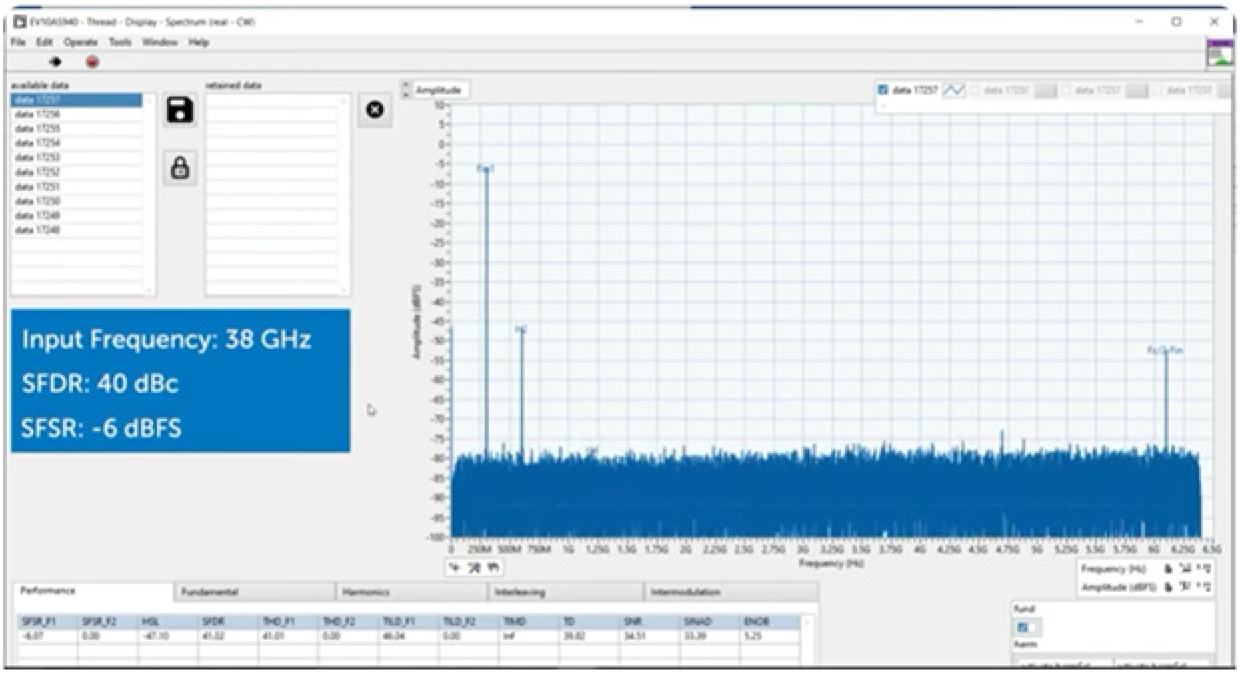


Figure 10

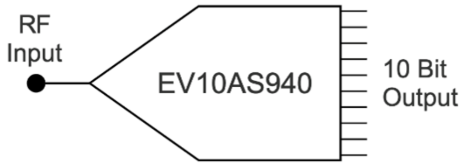
Noise Power Ratio (NPR) testing measures how quiet unused channels/bands are within a multi-band system when adjacent channels/bands are energized. NPR is measured by driving the RF receiver with a Gaussian noise source (representing all multi-band frequencies) in conjunction with various notch filters emulating selective frequency bands. With the notch filter out, the rms noise power of the signal inside the notch bandwidth is measured by the receiver. The notch filter is then switched in and the residual noise inside the notch is measured. The ratio of these two readings expressed in dB is the NPR. Figure 11 shows preliminary NPR measurements which is helpful in assessing simultaneous sampling multi-band RF/Microwave receiver performance utilizing the EV10AS940 ADC.

Parameter	Test Level	Symbol	Min	Typ	Max	Unit
Noise Power Ratio (NPR) @ -14 dB LF (with 5.1GHz pattern width, 50MHz notch located at $F_s/4$) 1st Nyquist 2nd Nyquist 3rd Nyquist 4th Nyquist 5th Nyquist 6th Nyquist 7th Nyquist		NPR		35.5 35.0 35.0 34.5 34.0 33.5 33.0		dB

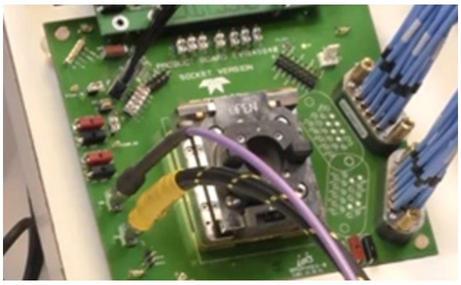
Figure 11: EV10AS940 Typical NPR Performance Specifications

CONCLUSION AND NEXT STEPS

RF/Microwave system developers want to design broadband receiver systems that are:
- L to Ka-Band/Direct RF Simultaneous Sampling
- Multi-Band
- Multi-Service/Application
- Single Ended (Balun free)
- Low Cost
- Low Power
- Small Form Factor
- Expandable to unlimited multi-channel implementations with deterministic phase sampling
- Softwarable (Dynamically Software Reconfigurable On-the-Fly)
- Internal DDC: I/Q detection, Triple Mode Fast Frequency Hopping, Beam Forming
- Available in the Quality Levels for every application (from consumer to space).



This seems like an impossible wish list to fulfill, and yet Teledyne e2v's EV10AS940 10 Bit, 12.8 GSPS ADC does just that. It is the "silver bullet" solution for all RF/Microwave system level developers.



So, what's the next step? Download Teledyne e2v's EV10AS940 data sheet, compare with any other RF ADC on the world-wide market, verify for yourself that it is the "silver bullet," and then contact Teledyne e2v for an evaluation board (please see Figure 12) [8]. We look forward to working with you on your next steps to develop your next generation RF/Microwave receiver.

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