Application Note

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Using Dither in PXI 3030 Series RF Digitizers

When performing measurements of small signals at levels in proximity to noise dither can be used to improve performance of the Digitizer. Dither is a technique where a noise-like signal, uncorrelated with the wanted signal is added to the Analog-to-Digital Converter (ADC) input. This has the effect of smoothing out nonlinearities and can give improvements in ADC noise floor, distortion products and level linearity.

This application note covers the use of dither in Aeroflex 3030A and 3035 PXI RF Digitizers. Firstly, the implementation of dither is explained. Secondly, typical performance of dither using PXI is demonstrated. Finally, recommendations on the use of dither are provided.

USING DITHER IN PXI 3030A AND 3035 RF DIGITIZER MODULES

The 3030A and 3035 PXI RF digitizers enable a dither signal to be added to the IF. The frequency of the dither is designed to lie outside of the IF bandwidth. This dither signal will be removed when the signal is digitally downconverted to I&Q data and decimated. To prevent interference with the triggering system, and for those using no decimation, the dither signal is also removed with a dedicated digital dither removal filter. (See Figure 1).

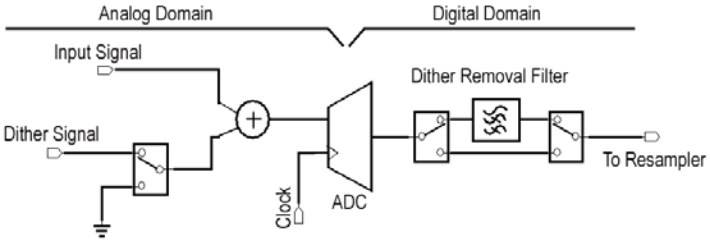

Figure 1: 3030A and 3035 Dither Implementation

The addition of dither results in a very small decrease in dynamic range (around 0.2 dB) and a slightly longer latency due to the dither removal filter. To ensure 100% compatibility with existing applications, the default state for dither is disabled. The table below shows the dither enable functions to use for both the af3030 and afDigitizer programming interfaces.

DLL	Dither Function Call
af3030	af3030_setDitherEnable
afDigitizer	afDigitizerDll_RF_DitherEnable_Set

By default, when dither is enabled, the dither removal filter is also enabled. The dither removal filter can be disabled if reduced latency is required. This is accomplished using the existing function call for DC offset* removal:

DLL	DC Offset Removal Function Call
af3030	af3030_setDcOffsetFilter
afDigitizer	afDigitizerDll_RF_RemoveDCOffset_Set

The above function call has the following effect:

DC Offset Removal State	Effect with Dither Off	Effect with Dither On
TRUE	DC offset tracked out	Dither removal filter is enabled DC offset is removed.
FALSE	DC offset is not removed.	Dither removal filter is disabled DC offset is not removed.

* DC offset relates to the DC component resulting from IF sampling

Additionally, the digitizer soft front panels provide access to the above functions through the control shown in Figure 2, accessed via the "DC offset" button.

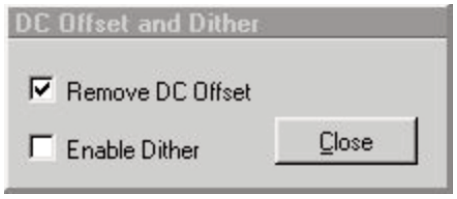

Figure 2: Dither controls in the SFP accessed via the "DC offset" button

Note that the extra latency due to the dither removal filter is automatically compensated for when using internal triggering.

Expected FFT Spectrum

The effects of dither on the spectrum can be demonstrated through an example.

Figure 3 illustrates the typical residual noise spectra expected from a 3030A with dither and DC offset removal enabled/disabled.

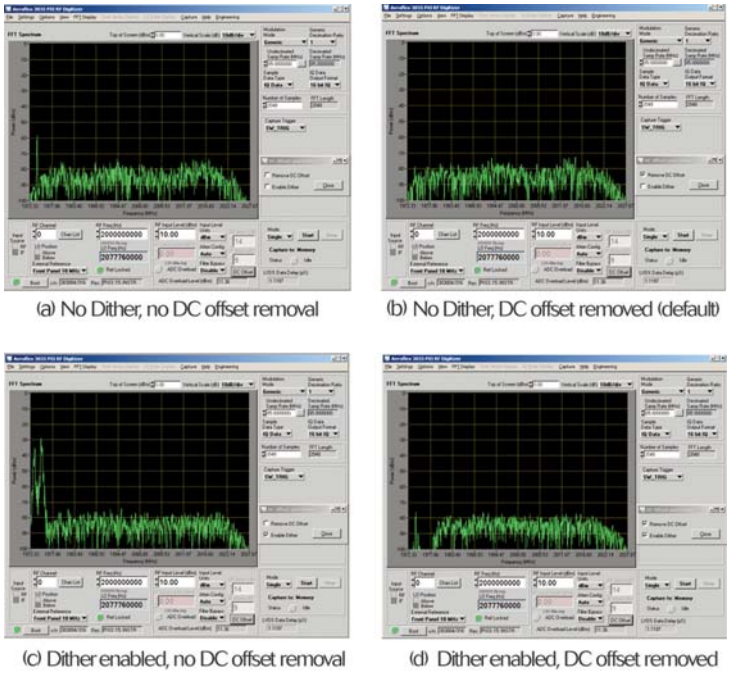

Figure 3: Typical spectra expected with and without dither and DC removal

The spike in the figure 3(a) is due to the DC offset. This is removed by default by having DC offset remove enabled, see Figure 3(b).

The dither signal may be observed in Figure 3(c). This is mirrored about the DC offset component. Note that the dither signal falls outside of the normal digitizer operating bandwidth. The dither signal is large relative to the noise floor and its presence would limit the dynamic range available for triggering from IF signal power. Applying decimation will remove the dither signal.

IF trigger detection dynamic range is restored by applying a dither removal filter. This is enabled when both DC offset removal and dither are both enabled. The effect of this can be seen in Figure 3(d). The level of the dither signal is now reduced to not exceed the noise floor. This prevents false triggering.

TYPICAL PERFORMANCE OF DITHER IN 3030A AND 3035 PXI RF DIGITIZER MODULES

Latency

By design, the additional latencies compared to driver software 6.9.0 and earlier are as follows:

Configuration	Additional Latency (clock cycles)	Additional Delay (3030A/3035)
6.9.0 driver or earlier	0	0
6.10.0+ Dither removal filter disabled	1	Approx 10 ns
6.10.0+ Dither removal filter enabled	41	Approx 400 ns

When using internal triggering, these latencies are automatically compensated. When using external LVDS output, the above latencies are included in the value reported by the af3030_getLvdsDataDelay function.

Noise floor flatness

A common characteristic of high speed analog to digital converters is that the noise floor can be non-white. The noise floor flattens once a signal is applied. However, for aesthetic reasons or when measuring signals very close to the noise floor, dither can be enabled to significantly improve noise floor flatness. Typical improvement seen on one 3030A unit is shown in Figure 4. In this example, noise floor ripple of around 3 dB peak-peak is improved to <1 dB when dither is enabled.

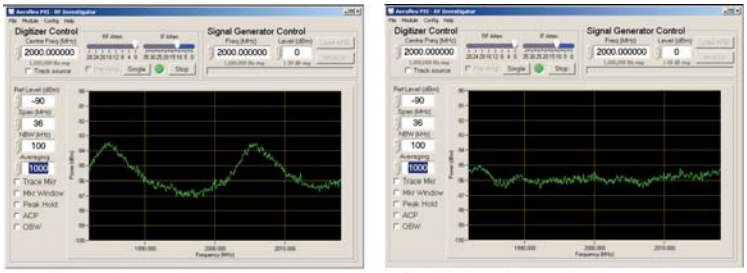

Figure 4: Noise floor flatness improvement with dither. Span=36 MHz, Y axis 1 dB per division

Level linearity

Enabling dither ensures consistent and accurate measurement of small signals. This is important in applications such as level calibration of transmitters. Figure 5 shows typical measured level accuracy relative to full scale with dither enabled. The flatness is excellent. Without dither, degraded performance can be expected at levels below -40 dB with respect to full scale.

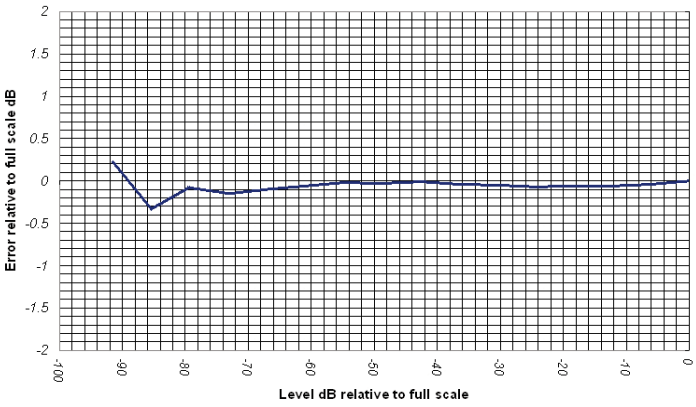

Figure 5: Typical relative level accuracy with dither enabled. The deviation at low levels is due to noise floor.

Effects on other parameters

Dither has little impact on the Third Order Intercept point (IP3) or Adjacent Channel Leakage Ratio (ACLR) as these are limited by the RF circuitry. A small degradation (approx 0.1%) in EVM measurement may be seen when dither is enabled, so lowest residual EVM users should consider testing with dither off.

In general, spurious signals levels under single tone excitation are reduced with dither enabled.

Requirements

Dither is available for use with the 3030A and 3035 modules when using PXI Module Software version 6.10.0 onwards.

Recommendations

It is particularly recommended that dither be enabled on 3030A/3035 in the following applications:

- Accurate measurement of signal levels below -30 dBFS (Where FS is the full scale level).
- Noise measurements (Improvement in noise floor flatness will be seen.

In general enabling dither is recommended. The default dither state has only been set to off for compatibility with legacy applications, requiring unchanged latencies.

CONCLUSIONS

Dither is a useful technique for reducing quantization distortion. PXI 3030 Series modules that implement this feature provide improved noise floor flatness and level linearity. This translates to improved characterization of low level signals.

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