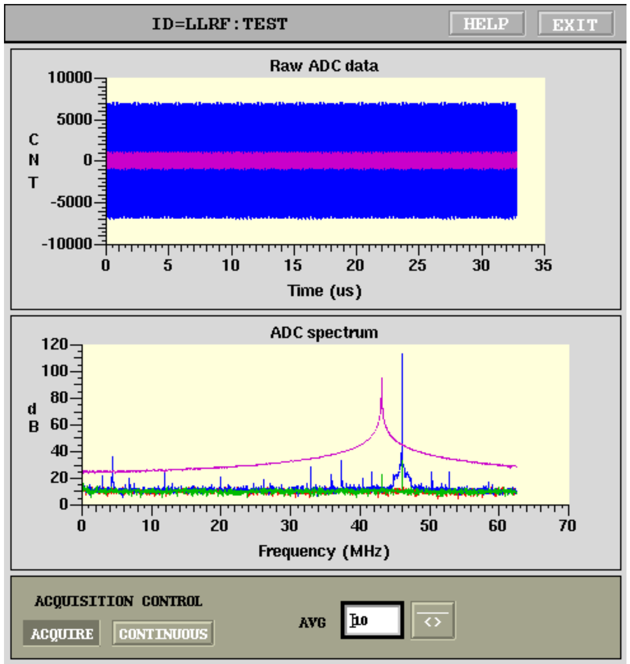

ADC Familiarization

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1 Introduction

In this lab we will spend some time measuring ADC signals using the LLRF4 board. You should have the ”LLRF4 Evaluation Board: USPAS Lab Reference” document handy — we will refer to it quite often.

Our basic setup will use two N5181A signal generators. One generator will be used as the 250 MHz clock source (shared with the DAC lab). You do not need to adjust that generator. The second generator will provide you with the input signal.

Set things up as described in Section 1.1 of the LLRF4 reference. Connect 250 MHz clock (the cable will be labeled as such) to the clock input. Connect the signal generator to ADC0 input.

2 Exercises

2.1 Measuring 48 MHz signal

Set the signal generator to 48 MHz and 9 dBm. Turn on ADC0 power on the main experimental physics and industrial control system (EPICS) control panel. Bring up the waveform window — you should see rapidly updating waveforms both on the top and bottom plots. Measure and record the time-domain amplitude of the signal. Next, record the spectral peak frequency and magnitude.

2.2 Finding FFT Bin

The spectral plot you see is obtained from 4096 sample record of the signal motion. This plot can uniquely resolve discrete frequencies at multiples of

$f_{\text{bin}} = f_s/4096$. This step is typically called fast Fourier transform (FFT) bin. If your input signal is exactly at a multiple of f_{bin}, the spectral peak will be quite narrow. With 48 MHz signal the signal is not at a bin frequency, so it has significant width.

Compute the FFT bin multiple frequency closest to 48 MHz[1]. Set the signal generator to that frequency — the spectral peak should get very narrow. Experiment with the frequency by moving it in 100/10/1 Hz steps, trying to make the peak as narrow as possible. Record the final frequency:

Now you should see several additional peaks in the spectrum. Record the frequencies and amplitudes of the three largest peaks (including the main signal):

2.2.1 After Dinner Questions

Was the frequency you optimized above the same as your computed value? If not, think and explain in a few words why it was different.

[1]You can use "octave" or just a calculator. Find f_{bin}, then the nearest integer to $48e6/f_{\text{bin}}$. Multiply that by the bin frequency

Try to identify all three frequencies you found in the spectrum. Hint: think of harmonics of the input signal and their aliasing. For example, if $2f_0 > f_s/2$ it will appear at $f_s - 2f_0$.

2.3 Finding ADC Full-Scale

Now let's determine the full-scale sensitivity of the analog-to-digital converter (ADC) in dBm. To do that, increase the output of the generator in small steps (0.1 dB). When you reach and exceed the full scale, harmonic distortion level will rise significantly[2]. Reduce the source level just below that point - that is your full-scale sensitivity. Record that level:

Now repeat this with ADC1:

[2] This will also help you identify the harmonics

2.4 Characterizing IF Filter Bandwidth

In this exercise we will determine the 3 dB bandwidth of the intermediate frequency (IF) filter in front of ADC0. Set the signal generator level 6 dB below the full-scale you found earlier. Move the generator frequency down in 0.5 MHz steps to find the point where the response drops by 3 dB. Record that frequency. Go back to 48 MHz and now increase the frequency in 0.5 MHz steps. Find the upper 3 dB point.

Lower cutoff frequency: ____________________

Upper cutoff frequency: ____________________

Bandwidth: ____________________

2.4.1 Extra Credit

You could get more precise bandwidth measurement if you searched for the center frequency first. If you have time and energy, repeat the bandwidth measurement above, but first search across frequency band for maximum response. Use that level as your reference for -3 dB search.

Center frequency: ____________________

Lower cutoff frequency: ____________________

Upper cutoff frequency: ____________________

Bandwidth: ____________________

3 Glossary

Glossary

analog-to-digital converter (ADC)

An electronic circuit that converts continuous analog signals to discrete digital numbers. 4

experimental physics and industrial control system (EPICS)

A set of software tools and applications used to develop distributed soft real-time control systems. 2

fast Fourier transform (FFT)

An efficient algorithm to compute the discrete Fourier transform 2, 3

intermediate frequency (IF)

RF signal processing is often performed at a frequency significantly below the frequency of operation. Signal at an intermediate frequency is typically produced by mixing the high-frequency signal with an offset local oscillator. 4