Interfacing Analog Signals to the AnadigmApex (3.3v) Family of dpASP's

Introduction

The AnadigmApex (3.3volt) family of dpASPs use analog signals that are referenced to +1.5 V (VMR) and are limited to the range 0 to +3 V. This application note describes a number of methods for interfacing these dpASPs to signals that are biased at voltages other than +1.5 V and/or whose amplitude exceeds the range 0 to +3 V.

This application note complements the older application note AN205 (Application Note 205) which describes a large number of ways to interface to the AnadigmVortex (5.0 volt) family of dpASPs. All of the methods described in App Note 205 also apply to the Apex dpASPs.

Input and Output Signals

First of all it is necessary to explain in more detail the kind of signals that can be handled by the dpASP. The following discussion applies to Apex with references to Vortex in brackets.

All dpASPs are single supply devices, that is to say they work from a positive voltage supply (Vdd) and ground. There is no negative supply which means that the dpASP cannot handle signals that are negative, either on its inputs or its outputs. It is an obvious point, but worth stressing, that the dpASP can only handle signals that are between ground and its positive supply. For Apex that supply is +3.3V (+5.0V for Vortex).

For this reason, the dpASP has an internal signal ground that is fixed at a positive voltage just below half the supply voltage. This signal ground is set to +1.5V for Apex (+2.0V for Vortex). Note that the user does not need to supply this signal ground, it is generated within the dpASP and is output to a pin called VMR.

All the analog signals paths within and at the I/O of the dpASP are differential, that is to say they consist of 2 equal and opposite signals, both centered on VMR, both restricted to the range of ground and Vdd. The maximum signal that the dpASP can handle is +/-3V, or 6V peak to peak (for Vortex +/-4V, 8V peak to peak). It is important to understand that this is differential amplitude, not a single ended amplitude.

How is this maximum amplitude calculated?

If the signal (input or output) is at +3V then this means that there is +3V on the positive side and 0V on the negative side (must be equal and opposite centered about VMR). When the signal is at -3V then there is 0V on the positive side and +3V on the negative side. (for Vortex max signal is +/-4V with each side of the differential signal between 0V and +4V).

To fully utilize the dpASP (and maximize the performance) in a system with single ended analog signals, it is necessary to convert input signals to VMR referenced differential signals, and to convert the output VMR referenced differential signal into whatever form the user requires (typically ground referenced and single-ended).

This application note provides two simple methods for interfacing to the Apex dpASP using ground referenced single-ended signals. One applies to input signals, the other to output signals.

Signal Input Using the Rauch Filter

The Apex dpASP provides an optional input OpAmp, available within IOs 1-4 (this is not provided on Vortex). This I/O OpAmp allows the user to construct a circuit, using only passive components, that performs 4 tasks:-
1) level shifts an input signal bias voltage to VMR,
2) converts a single-ended signal to differential signal (if required),
3) performs a 2-pole (2nd order) low-pass anti-aliasing filter function on the input signal in order to reduce noise,
4) it can amplify or attenuate an input signal in order to best match it to the input range of the dpASP.
This circuit used is called a Rauch filter (or low-pass multiple feedback filter), and is shown in figure 1 below:

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Figure   1.   Rauch   Filter
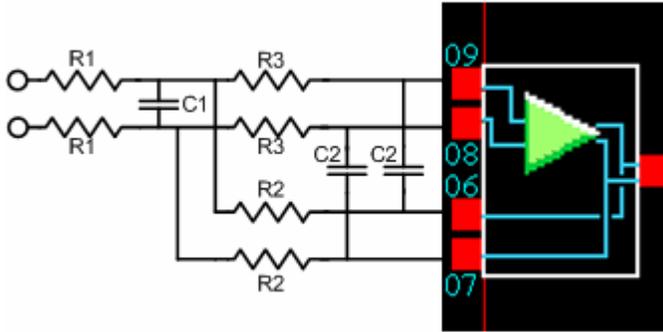
The values of the components can be calculated from the required values of Fo (low-pass corner frequency), Q (the filter Q, use 0.707 for optimum flat response in pass-band), and G (the pass-band gain). The equations are shown below.

First choose a convenient value of R1. Then we have:

R2 = R1 * G
R3 = R1 * G / (G + 1)
C1 = Q * (G + 1) / (G * Fo * R1 * 2 * π)
C2 = 1 / (G * Fo * R1 * Q * 4 * π)

The signal applied to the Rauch filter can be single-ended or differential and centred on any voltage. It can also be any amplitude provided the gain G is set to provide the correct amplitude at the dpASP pins. The corner frequency Fo should be set to a value just above the working range of the input signal. If a ground referenced single-ended signal is input to the Rauch, then the other input should be tied to ground.

Let us consider an example: suppose we wish to input a single-ended ground referenced signal of +/-10V to the dpASP. Also let us suppose that this signal ranges in frequency up to 10kHz. We need to set the parameters as follows:

G = 0.3 (10V ampl divide by 3V max ampl for dpASP)
Q = 0.707 (optimum flat response)
Fo = 12kHz (just above the freq range)

This gives component values of:

R1 = 10k (choose this)
R2 = 3k
R3 = 2.3k
C1 = 4.1n
C2 = 3.1n

Obviously the user will choose preferred component values that are as close as possible to these values. The user can then reverse calculate the filter parameters from the following equations:

G = R2 / R1
Fo = 1/(2 * π * R2) * sqrt[(R1+R2)/(2 * C1 * C2 * R1)]
Q = sqrt[C1 * R1/(2 * C2 * (R2+R1))]

For example: the user might choose the following component values:

R1 = 10k
R2 = 3.3k
R3 = 2.2k
C1 = 4.7n
C2 = 3.3n

In this case we can reverse calculate the filter parameters to get:
G = 0.33
Fo = 9.99kHz
Q = 0.73

Signal Output Using an Opamp
Figure 2 shows how a single opamp can be used to not only level-shift the dpASP output but also do a differential to single-ended conversion. Furthermore, this circuit can be used to amplify or attenuate the dpASP output by any desired amount. The gain of this circuit is given by:
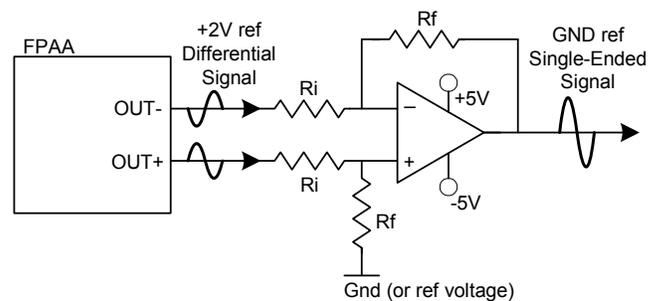
Gain = Rf / Ri

Figure 2. Level-Shift & Diff2Single on the Output

Note: The circuit in Figure 1 shows level shifting of the dpASP output to ground and it is the resistor Rf connected to ground that provides the reference for the level-shifted signal. However, this circuit can be used to level-shift the dpASP output to any desired voltage simply by connecting the resistor Rf to that voltage instead of ground.

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In addition to level-shifting and amplifying/attenuating the dpASP output, the circuit can also be turned into a simple one-pole low-pass filter by adding capacitors in parallel with the two resistors marked Rf. The corner frequency of this filter would be givien by:

$$Fo = 1 / (2 * \pi * Rf * C)$$

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