Lattice Semiconductor Corporation

Using the ispPAC30 as a Programmable Lowpass Filter

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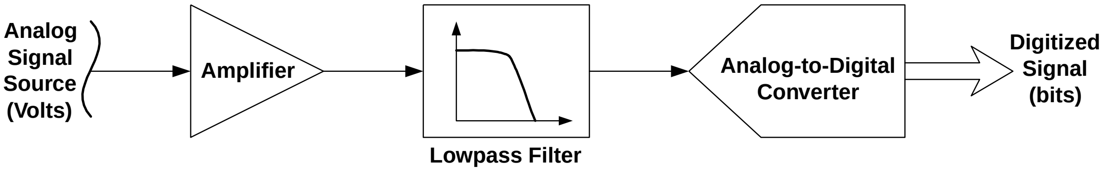
Lowpass filters are often used for anti-aliasing and general noise reduction in the signal path leading to an Analog-to-Digital Converter, as shown in Figure 1.

Figure 1. Data Acquisition Signal Path

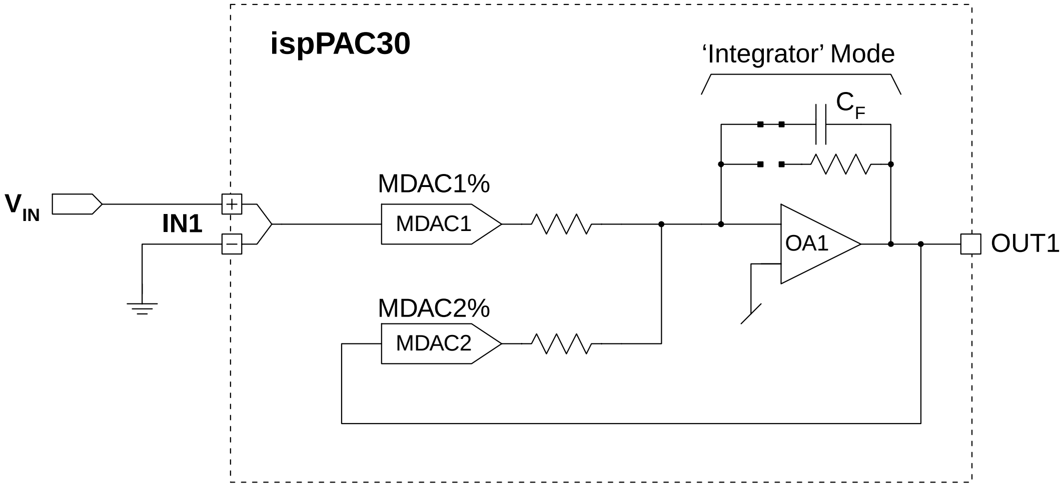


While a filter with a fixed corner frequency is often used, this can be a problem when the system must accommodate signals with varying spectral characteristics. In these cases the one-size-fits-all approach provided by a fixed filter may not be desirable. While there are many potential reasons for wanting to vary a filter's corner frequency, two common cases are noise reduction and alias attenuation.

When the noise in a signal is distributed over a wide frequency range and the signal is near DC it is often possible to improve a system's signal-to-noise ratio (SNR) by reducing the bandwidth of the filter. If one uses too low a corner frequency, signal information is lost. Conversely, if one uses too high a corner frequency, more interfering noise is allowed through. For this reason, it can be useful to be able to adjust the signal path bandwidth to strike the appropriate balance between noise and signal bandwidth.

Another situation benefiting from adjustable corner frequency is where one wants to vary the sampling rate of an analog-to-digital converter to accommodate the characteristics of different signals. For optimal operation, an ADC sampling at a variable rate will also require an anti-aliasing filter with a corner frequency that tracks the sampling rate.

Figure 2. Using the ispPAC30 as a Variable Lowpass Filter



The ispPAC®30 can be used to implement 1st-order tunable precision lowpass filters over a range of 5kHz to over 600kHz. Figure 2 shows the circuit for doing so. This circuit operates by using MDAC2 to simulate a programmable feedback resistor around output amplifier OA1. In this technique, the effective feedback resistance is inversely proportional to MDAC2's gain. Although C_F can only be set to one of seven values, this technique makes it possible to implement hundreds of corner frequencies. Because negative feedback is essential to maintaining a stable loop, MDAC2's gain must be set to only negative values.

In addition to affecting the corner frequency, the value of MDAC2 also affects the input-to-output gain of the circuit. Because there are two MDACs in an ispPAC30, one way to do this is to attenuate the input signal through MDAC1 by the same amount the feedback signal is attenuated by MDAC2. To maintain signal polarity, however, MDAC1 should be set to a positive gain. Deliberately changing the values of MDAC1 and MDAC2 also allows one to alter the gain dynamically, providing a variable gain control feature. The following expressions can be used to estimate the resulting corner frequency (F_C) and gain, where FCAP is the frequency associated with the feedback capacitor.:

$$F_C = \left| F_{CAP} \text{ x MDAC2\%} \right| \tag{1}$$

$$\text{Gain} = \left| \frac{\text{MDAC1\%}}{\text{MDAC2\%}} \right| \tag{2}$$

Note that MDAC2% must be negative, and that MDAC1% should normally be positive for the single-ended system shown in Figure 2.

Although this technique can be used to control the corner frequency over a range of 128:1, the attenuation caused by a very low MDAC1 setting can reduce the filter's overall signal-to-noise ratio and increase effective DC offset and gain errors to unacceptable levels. Table 1 shows the ranges of corner frequencies that can be realized with this technique when limiting MDAC2 settings between -10.16% and -100%.

Table 1.

Feedback Capacitor #	OA1 Feedback Capacitor Value (pF)	Minimum Corner Frequency (kHz)	Maximum Corner Frequency (kHz)	Frequency Step (kHz)
1	5.88pF	63	622	4.86
2	8.68pF	41	401	3.13
3	13.48pF	25	250	1.95
4	19.65pF	17	168	1.31
5	28.81pF	11	113	0.88
6	43.93pF	7	74	0.58
7	65.64pF	5	49	0.38

As an example, assume MDAC = +75%, MDAC2 = -25% and C_F is chosen for 74kHz (43.9pF). The resulting DC gain will be 3 $\left(\left| \frac{75\%}{25\%} \right| \right)$ and the corner frequency will be 18.5kHz (74kHz x 25%).

Technical Support Assistance

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