App Note: Simplified Baseband Design for Amplification and Filter Stage

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Introduction:

In order to have optimal data for signal processing, a good portion of focus should be spent on the baseband. The objective of this application note is to outline the process of how to design the baseband system. While the Digital Signal Processing (DSP) depends on the baseband system, DSP will not be discussed for this app note. Instead, emphasis will be put on the amplification and filtering aspect of the baseband.

Amplification:

Background

The down converted signal from the mixer provides data on how far the reflective object is from the radar system. Since the signal from the Voltage Controlled Oscillator (VCO) is transmitted over some distance within free space, there is a large amount of attenuation before the signal is received. This is known as the free space path loss. The power of a traveling wave within free space is inversely proportional to the R^2 (where R is the distance traveled). Without sufficient amplification, the signal to noise ratio will be low and undesirable since the power of the interested signal will be comparable to the surrounding noise generated from the environment and the RF system. Even with amplification from the RF board and antennas, it is almost required that the down converted signal should be amplified again to have sufficient amplitude for signal processing.

Design

For amplification, you may choose whichever topology to achieve the necessary amount of gain. We will examine the common non-inverting amplifier topology for simplicity sake.

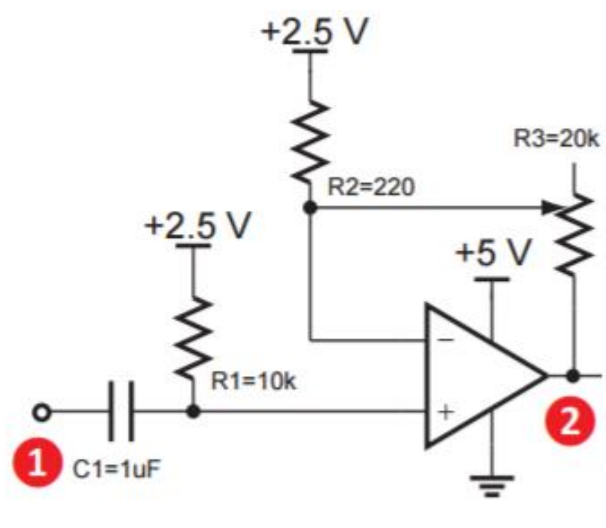

Figure 1. Non-inverting Amplifier Schematic

From figure 1, the gain of the amplifier is determined by R2 and R3

$$A_V = 1 + \frac{R_3}{R_2}$$

It would be a good idea that the R3 be switched with a potentiometer to have an easily adjustable gain. Examining the schematic, the role of C1 is to DC couple the input signal so as to eliminate any DC components from the signal. The +2.5 Volt reference in conjunction with the +5 Volt supply rail merely sets the maximum output swing if only a +5 Volt source is used to power the amplifier. This can be modified depending on the users intended application. From our experience, it may be a good idea to cascade another non-inverting amplifier to add versatility to the gain stage. You may need to increase the gain substantially than what was calculated from the link budget analysis in order to obtain a desirable signal for DSP. However, since amplifying the signal also amplifies the noise, it is important to find a good balance between the two, which is easily achieved with potentiometers as the gain controller.

Filtering:

Background

Filtering is one of the most important factors to signal processing. Filtering removes unwanted components from a signal of interest. After a signal is downconverted from the mixer and amplified by the baseband amplifier, there are many unwanted components that must be filtered out. Since the desired signal is of very low frequency, the easiest method to attenuate the unwanted signal is to use a low pass filter. With a reasonably low cutoff frequency.

Design

Like the baseband amplifiers, there are numerous ways to implement a low pass filter. One of the easiest method is to use an IC from companies such as Analog Devices or MAXIM Integrated. We used MAX7408 (datasheet) since the typical operating circuit was easy to build. The MAX7408 provides a stopband rejection of approximately 53 dB with cutoff frequencies between 1 Hz to 15 KHz.

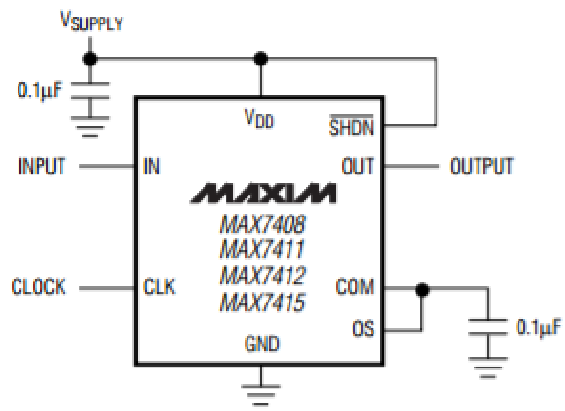

Figure 2. Typical Operating Circuit for MAX7408

Since an external clock cannot be utilized, the MAX7408 can be internally clocked by shorting the CLK pin to GND with a capacitor value to yield the desired cutoff frequency. The relationship between the cutoff frequency and oscillation frequency of the internal clock can be expressed as:

$$f_C = \frac{f_{CLK}}{100}$$

The necessary clock frequency can directly be calculated by the cutoff frequency. With these parameters, the expression to determine the capacitor value is given as

$$f_{CLK}(KHz) = \frac{k}{C_{OSC}(pF)} \qquad where\ k = 27 * 10^3$$

The cutoff frequency for the low pass filter should carefully be chosen depending on how accurate you would like your DSP. In principle, the cutoff frequency should be as low as necessary that unwanted components from the amplified signal be filtered out, but as high as possible for the DSP to improve on the resolution.

Conclusion

The baseband subsystem is one of the most important aspect for the whole system since it determines how well the signal can be digitally processed. In this app note, the discussed stages for the baseband were amplification and filtering. Since there are many topologies for the amplifier, the non-inverting amplifier was used due to simplicity as the gain is controlled by two resistors. Next, the filtering can be done using a low pass filter since the interested frequency component from the downconverted signal is very low. It would be a good idea that students first attempt to purchase a low pass filter IC rather than building one from transistors and lumped elements to reduce weight. A good tip is to build these stages on the breadboard for easy testing and troubleshooting. I hope that this will help students in the future as they attempt to build the baseband portion of their design.