Application Note
Digital IF Receiver Megafunction

Introduction

The Digital IF Receiver Megafunction provides all the functionality needed to convert a sampled IF signal into complex base band data samples, ready for demodulation. The primary functions of the Digital IF Receiver Megafunction include frequency down conversion, decimation, and narrowband filtering. The Digital IF Receiver can significantly reduce the processing requirements of DSP-based receivers by pre-selecting the signals of interest and reducing the sample rate.

QPSK Example

In Quadrature Phase Shift Keying (QPSK) the modulator encodes two bits of data, into each QPSK symbol. The di-bit symbol is transmitted using one of four phase relationships between two quadrature carriers. In our example, the QPSK modulator uses the encoding shown in Table 1. The quadrant refers to the vector projection of the complex carrier; $\cos(w_c t \pm n\pi) + j \sin(w_c t \pm n\pi)$ where n is either 0 or 1.

Table 1 QPSK Modulator Encoding

Symbol	Sin Phase Shift	Cos Phase Shift	Quadrant
00	0°	0°	I
01	0°	180°	II
10	180°	180°	III
11	180°	0°	IV

In addition, the modulator in our example will use a clock rate of 100MHz, a digital IF of 10MHz and a symbol rate of 100ksymb/s, while repeatedly transmitting the data sequence shown in Table 2. The FIR filter uses 64 taps for this example, and non-optimized coefficients. Carrier phase lock, between the transmitter and the receiver, has been artificially resolved for this simulation.

Table 2 QPSK Modulator Data Sequence

Tx Data	Tx Symbol	Quadrant
0	00	I
1	01	II
2	10	III
3	11	IV
3	11	IV
2	10	III
1	01	II
0	00	I

The Digital IF Receiver Megafunction simulation uses QPSK Modulated data samples as input. The output samples taken directly from the functional simulation are plotted in Figure 1.

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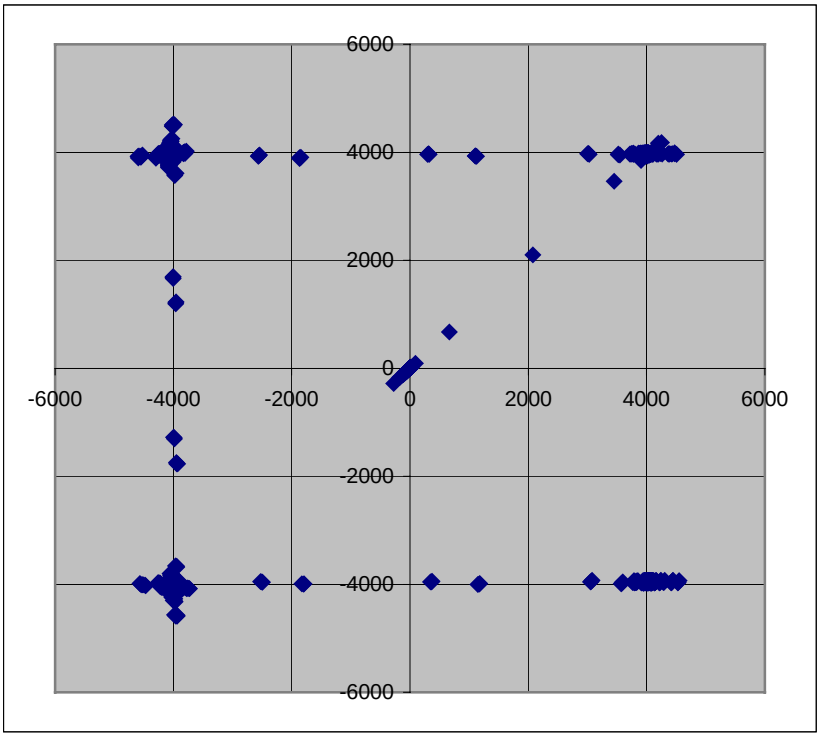
Figure 1 Digital IF Receiver Output from QPSK Modulation



In Figure 1, the data points are sampled at the decimated sample rate of 3.125MHz. This rate is determined by the high speed clock rate of 100MHz and the CIC decimation rate of 32. The high speed clock produces samples every 10nsec, but the CIC decimates this rate to produce samples at 1/32nd of that rate, yielding samples every 320nsec. This sample rate still exceeds the data rate, 100ksymb/s, by a factor of 31.25.

The quadrature base band samples are plotted on an X-Y chart in Figure 1. Notice the grouping of sample points in each of the four quadrants. Also note that there are sample points starting at (0,0) that make a trail to quadrant I, II, III, and IV. The samples at (0,0) indicate the response of the system at startup.

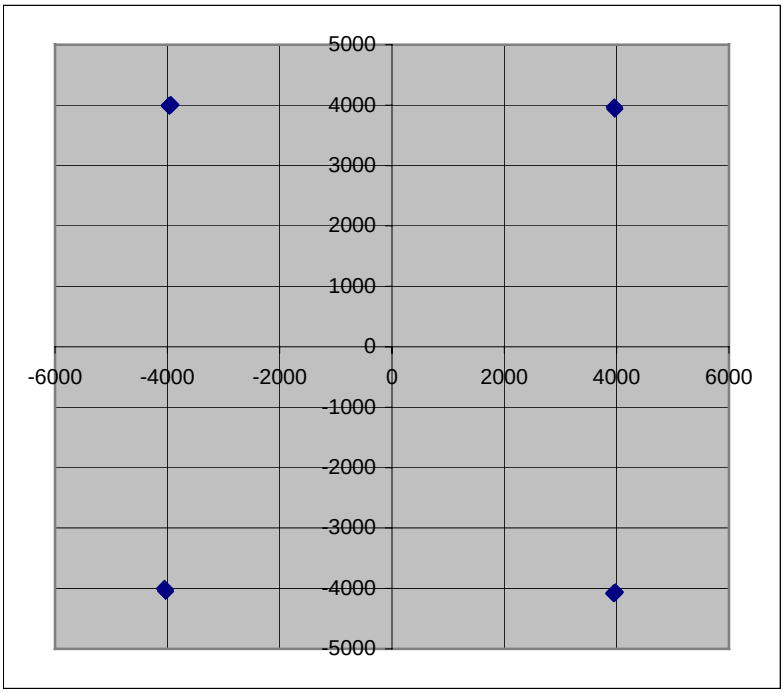
All the sample points do not fall in a tight grouping, within each quadrant, because we still have not "sampled" the received data at the optimum timing point. We have merely plotted the raw data flowing out of the receiver without the benefit of timing synchronization. In this plot there are 31.25 samples per symbol, since the symbols are 10usec each and the samples occur every 320nsec. Table 3 shows the time-sampled data, where I and Q are the actual time-sampled data taken directly from the functional simulation. The sampled data is then mapped into one of four quadrants according to the sign of the sample pair. Comparing Table 2 and Table 3, we can see the Rx data matches the Tx data. Also note that there are no data transitions from quadrant IV to quadrant I. This is apparent by examination of the Tx data as well as the graphical illustration in Figure 1.

Figure 2 is an X-Y plot of the I,Q data taken from Table3. Figure 2 illustrates the constellation of QSPK modulated data.

Table 3 Time Sampled Receive Data

I sampled	Q sampled	Rx Data	Quadrant
3955	3971	0	I
3980	-4066	1	II
-4036	-4035	2	III
-3973	3992	3	IV
-3968	3976	3	IV
-4027	-4051	2	III
3980	-4054	1	II
3965	3968	0	I
3967	3946	0	I
3962	-4087	1	II
-4054	-4011	2	III
-3963	4005	3	IV
-3959	3989	3	IV
-4033	-4023	2	III
3973	-4067	1	II
3973	3943	0	I
3967	3928	0	I
3941	-4089	1	II
-4054	-3996	2	III
-3935	4017	3	IV
-3933	4001	3	IV
-4041	-4014	2	III
3946	-4066	1	II

Figure 2 Receiver QPSK Constellation



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