



QF1Da512 SavFIRE®

Implementing Multiple Filters in One Device

1) Introduction

The SavFIRE digital filter processor can easily be configured to apply multiple filters to a single digital input data stream. This application note describes the methodology for designing the desired filters (using the QF1Da512-DK development kit), creating the configuration data for download to the device, and defining the control of the input data stream to obtain the desired results.

This same technique can be used in both the QF1D512 and also the QF1Da512.

2) Summary

Step 1:

Setup the configuration of the SavFIRE as if you were using just one filter.

For a dual-filter implementation, it is preferable to use symmetric filters (which is what our tool builds anyway). The use of symmetric filters is only possible in this dual-filter application if one of the filters is an odd length symmetric filter (i.e. there will be a center tap) and the other is implemented as an even length symmetric filter.

For implementations using more than two filters, use asymmetric filters. Asymmetric filters will allow for only half as many taps as are available with symmetric filters.

For sample rate, use the rate your data would come in for each channel. Don't multiply up. For example, if you have four filters designed for a 1 KHz sample rate, build the filters with a 1 KHz sample rate, not 4 KHz.

Refer to Table 1 for examples of allowable filter lengths.

Step 2:

Save the coefficients to separate text files. You will be opening them in an Excel spreadsheet.

Step 3:

Interleave the coefficients of the various filters, alternating between them. The first coefficient for the first filter is placed in location 0, the first coefficient for the second filter is placed in location 1, ..., the first coefficient for Mth filter is placed in location M-1, the second coefficient for the first filter is placed in location M, etc.

Save these as a text file and use the import function of our tool to bring them back in. Ignore the representation of the new "filter" you see on the screen. The software is assuming only one filter is present, but this is not the case in your application.

Step 4:

Data sent to the chip must have zeros interleaved into the data stream. Thus you would send a data sample one on the first clock, a zero on subsequent clocks (for the next $M - 1$ clocks), then a data sample on the next clock followed by $M - 1$ zeros, and so forth.

3) Concept

As an example consider Figure 1 where a QF1Da512 device is configured to simultaneously process an input data stream with three separate filters. At time n , where n is the input sample number, sample $x(n)$ is in the “newest” location in the input sample buffer, and sample $x(n-k)$ is the “oldest” location. The current output, $y(n)$, corresponds to filter 1, which is defined by the coefficients $h_1(k)$. When the next input arrives, which in this example is an inserted zero, the data values shift in the buffer and the calculated output, $y(n+1)$, corresponds to filter 2, which is defined by the coefficients $h_2(k)$. A similar shifting of the input buffer and calculation yields $y(n+2)$ corresponding to filter 3, which is defined by the coefficients $h_3(k)$. Then the cycle repeats, beginning with a new input data sample and computing the next output corresponding to filter 1.

Note that the coefficient space is m times the number of taps of the longest filter. For smaller filters, coefficients with zero value are inserted at the end of the coefficient vector to equal the number of taps of the longer filter.

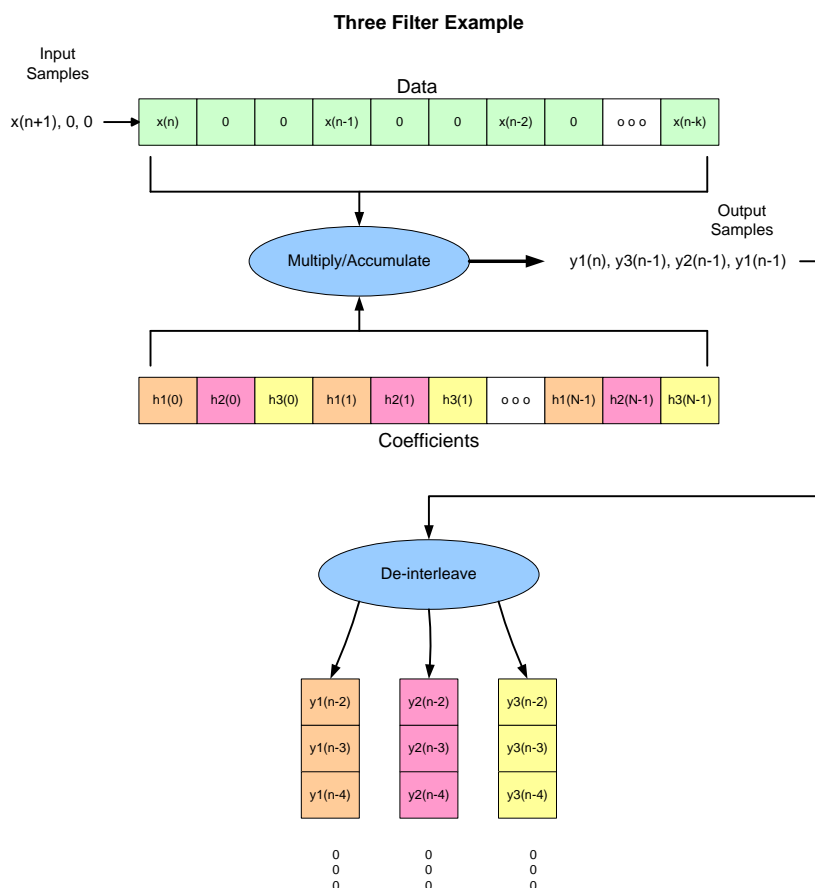


Figure 1. Three-filter example flow chart

4) Design Considerations

The SavFIRE can be programmed to execute multiple filters on the same input sample stream if the following conditions are met:

- 1) When using asymmetric filters, the total coefficient space of 256 coefficients must not be exceeded. Thus, m times the number of coefficients of the longest filter must be ≤ 256 , where m is the number of filters. This value is input as the number of taps (NUM_TAPS) in register address 06h, bits 0-7. Register address 07h must be zero.
- 2) Symmetric and asymmetric filters cannot be mixed. Either one or the other must be used exclusively.
- 3) When using symmetric filters, the total coefficient space of 512 coefficients is not to be exceeded. In this case, the maximum number of filters is two. One filter must use an odd number of taps (maximum of 255) while the other filter uses an even number of taps (maximum of 254). The total number of taps used is input (NUM_TAPS) in register address 06h, bits 0-7, and Register address 07h, bit 0. Note: the even tap filter will have a null at $F_s/2$.
- 4) For asymmetric filters, the shorter filter(s) must be appended with zero value coefficients to have the same number of taps (coefficients) as the longest filter.
- 5) The coefficients, $h_f(k)$, where f is the filter identifier ($0, 1, 2 \dots m-1$), and k is the coefficient number ($0, 1, 2 \dots N-1$), are placed in coefficient memory at address $(m \times n + f)h$. Thus the filter coefficients for filter 0 are placed in addresses $0, m, 2m$, etc.; coefficients for filter 1 are at $1, m+1, 2m+1$, etc.
- 6) The effective input sample rate (m times the original data sample rate) cannot exceed the maximum input sample rate of the device.
- 7) For each sample out of the ADC, the system must insert $m-1$ zero-valued samples. This is readily implemented with the SavFIRE operating in the co-processor configuration where the system's micro-controller inputs samples to the SavFIRE device. The micro-controller must also sort the output sample stream into the appropriate filter sample space, as it will receive alternating samples for each filter.
- 8) The following table illustrates the maximum number of taps per filter, the maximum sample rate per filter, and the latency of each filter for multiple filter configurations.

Number of Filters	Max Taps (per filter)	Max Sample Rate Per Filter
1 symmetric	512	500 KHz
1 asymmetric	256	500 KHz
2 symmetric	255	250 KHz
2 asymmetric	128	250 KHz
4 asymmetric	64	125 KHz
<i>m</i> asymmetric	256 / <i>m</i>	500 KHz / <i>m</i>

Table 1. Number of filters, maximum number of taps and maximum sample rate.

5) Implementation

The *QFPro* QF1Da512 software can aid the development of the SavFIRE configuration file for executing multiple filters. However, the development board cannot be used to display the FFT results of the multiple filters, since the on-board controller is not programmed to support the insertion of zeros into the input stream, or to sort the output stream into the individual filter samples. The following steps are used to create the configuration file:

1. Design the filters using the *QFPro* filter editor (or other filter design tool of your choice), and save the coefficients for each filter. Save the coefficients by selecting **Filter Data** under the **Window** menu and then pressing the **Save to File** button at the bottom of the coefficient display (as shown in Figure 2). Select the file location, name the file, and press **Save**.
2. *Interleave* the coefficients into a single file per rule 4 above as shown in Figure 3. If some filters have fewer taps than others, append coefficients of zero value to make all filters have a number of coefficients equal to the number of coefficients of the filter with the most taps. The total coefficient space of the newly created coefficient file will be equal to the number of filters times the number of taps in the maximum tap filter. The completed file format must be a single column of floating point coefficients.
3. Import the new coefficients into the *QFPro* filter editor using the asymmetric or symmetric filter import capability as appropriate (as shown in Figure 4). The appropriate screen (Create Filter) is reached by selecting **New Filter** under the **File** menu. Select the **ASYM** (or **SYM**) icon on the **Imported Filters** line, and then select the file to import from the file selection dialog.
4. Press the **Design Filter** button, and when complete, press the **Done** button to enter the configuration dialog page.
5. Select the **Coprocessor** configuration in the **Data Input Source** field, and set up the chip per your application using the **Data Format Editor** and the **Pins Settings Editor** under the **Chip** menu.

6. Press **Start** to download the configuration to the QF1Da512 on the development kit. You may then use the **Read/Write** screen on the **Chip** menu to display and verify the chip settings.
7. Save the configuration using the **Save Configuration** selection in the **File** menu, and export the download image via the **Export Image** selection in the **File** menu. The Export Image dialog will permit the file to be saved as a text file, an Intel Hex file, or as C code files (as shown in Figure 5).
8. Develop the code for capturing the ADC samples and transferring these samples to the QF1Da512 co-processor, and capturing the filtered samples. Insert $m-1$ zero valued samples, where m is the total number of filters, between each ADC sample input to the device. You may feed samples to the device at a maximum rate of 500ksp/s. You may also select to sort the samples from the QF1Da512 into m separate files as they are collected for independent filter analysis.

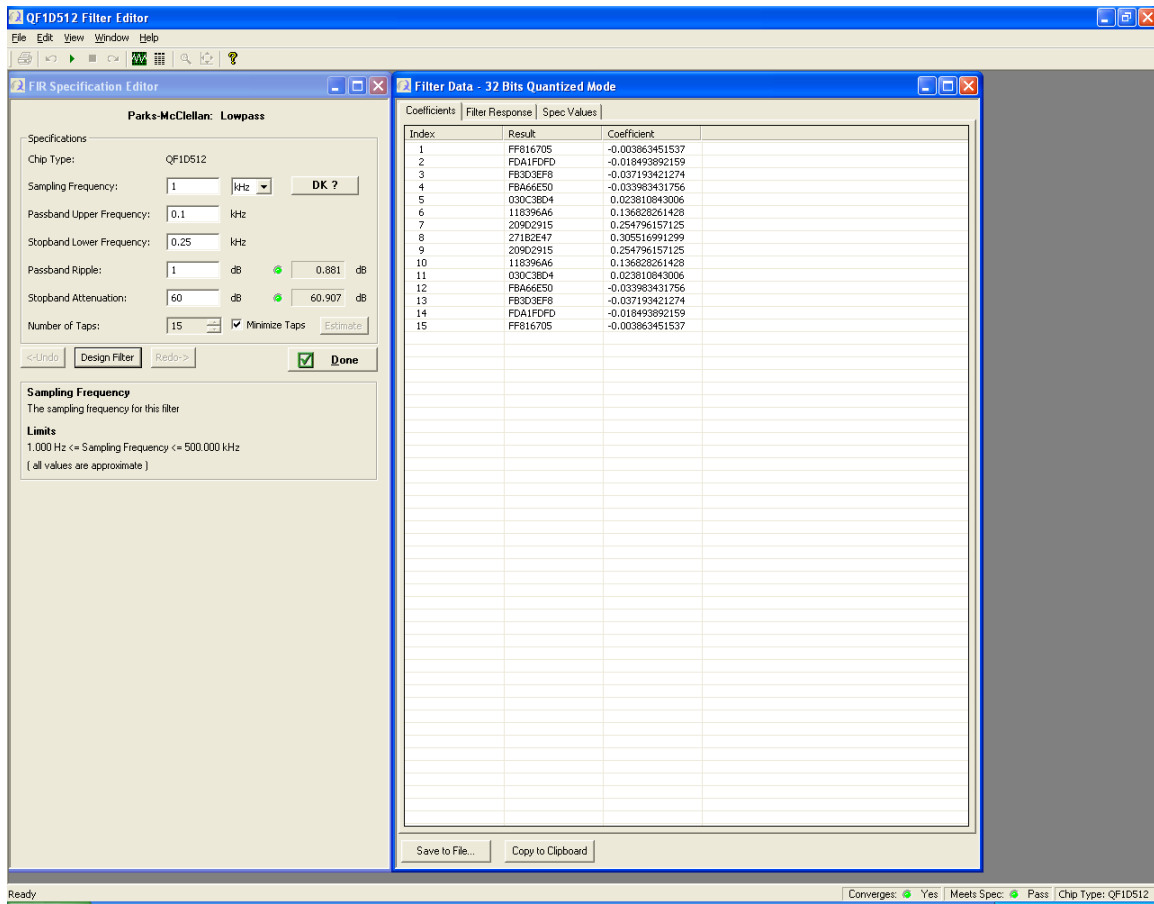


Figure 2. Export coefficients for each filter via the "Save to File" button



```
File Edit Format View Help
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Figure 3. Interleaved coefficients from three filters

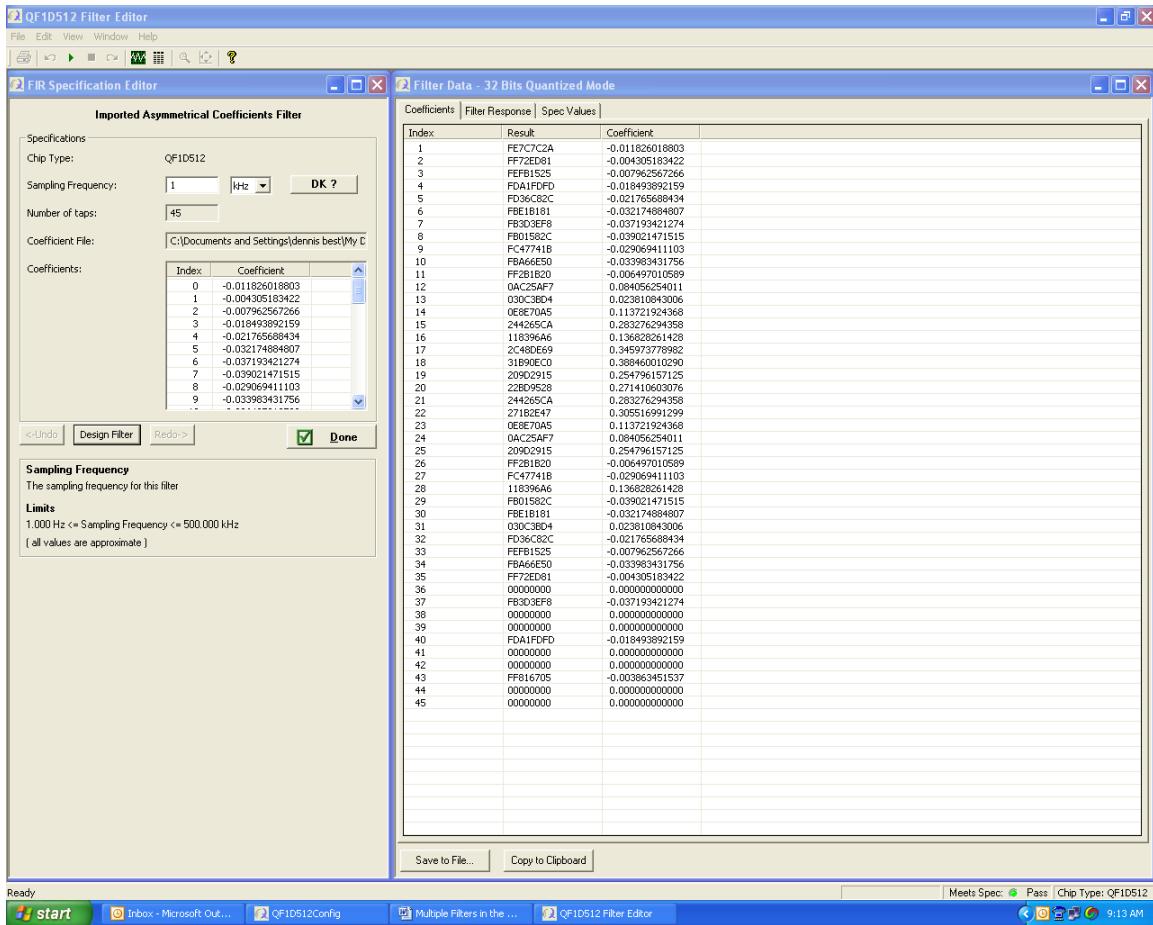


Figure 4. Asymmetric filter import of interleaved coefficient file

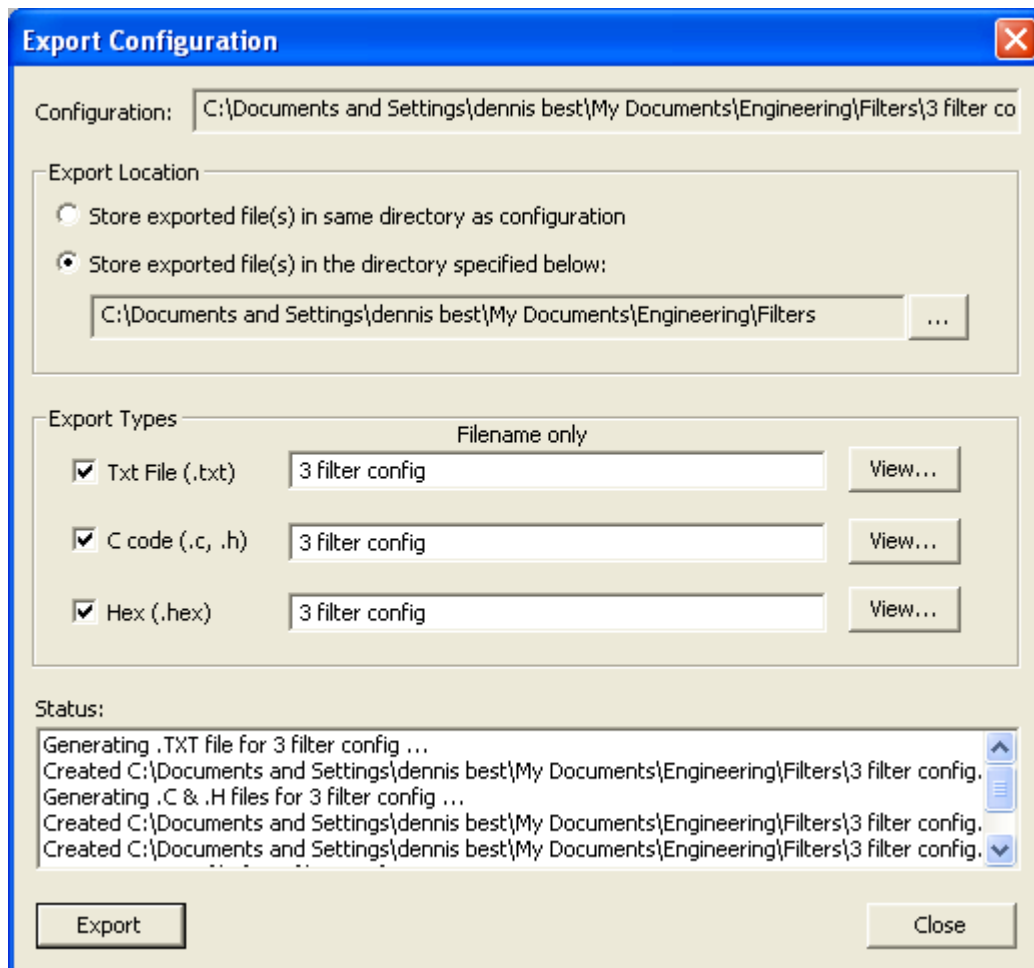


Figure 5. Export configuration as text, C code, or Intel hex file



Application Brief

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