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| Additional Resources | Scilab scripts – Download from the CML website using the link that accompanied this document.<br>ProgCustomTxFilter.pes – An example PE0002 script to load coefficients into the custom Tx filter of the CMX7861 |
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## 1 Introduction

The CMX7861 uses compensation to provide a maximally flat response approaching half the selected user sample rate when operating in Codec mode. It also provides a user-programmed FIR filter that allows relatively simple implementation of transmit filters with no further compensation required. There is a similar filter in the receive path but, this document discusses the design of custom transmit filter for Codec mode.

Good mathematical modelling of the required filter response is no trivial task and DSP engineers generally use a tool to approximately model the filter response. The actual response is then tested and the filter parameters trimmed iteratively until the desired response is achieved. This document looks at the application of Scilab for the generation of filter co-efficients and provides some automation of the task.

Although independent filters are required in each channel of the CMX7861 transmit path, the filters cannot be individually programmed or selected. That is, the selected transmit filter response will be applied to both transmit channels. The same is true for both receive channels.

## 2 History

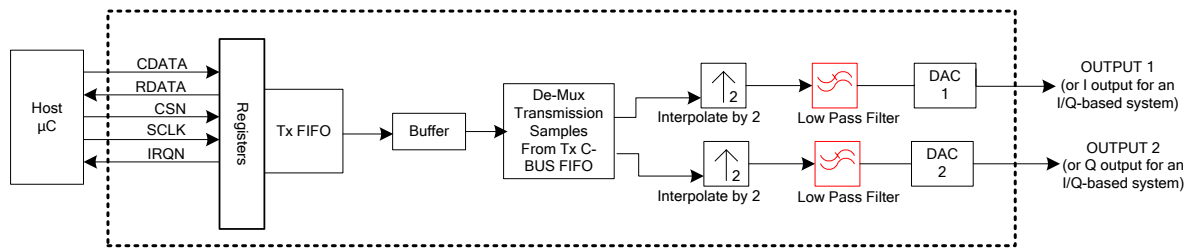
| Version | Changes       | Date     |
|---------|---------------|----------|
| 1       | First release | 12-01-12 |
|         |               |          |

## 3 About Scilab

Scilab is a numerical computational package that has been designed to provide efficient matrix handling. At the time of writing, Scilab has its own domain on the web at [www.scilab.org/](http://www.scilab.org/). The current version is 5.3. Versions prior to 5.x do not support the current GUI controls and may not support the graphic tools. Scilab is an interpreted language and runs scripts that use many familiar 'C' constructs. Where possible, matrices should be used in preference to for-next loops as the former are many times more efficient in the Scilab environment.

## 4 CMX7861 Codec Mode

The following diagram shows transmit processing chain when CMX7861 is in Codec Mode.



**Figure 1 Tx Processing Chain in Codec Mode**

Codec mode provides sampling at rates up to 72kHz and a signal bandwidth of 30.96kHz at that sample rate. With this bandwidth constraint, the *FirmCODEC*<sup>®</sup> provides ADCs and DACs to sample or reproduce any arbitrary waveform, for example, left/right stereo or control signals.

In Codec mode, the CMX7861 provides optional user-programmable filtering on the input and output signals. Filter design is straightforward, requiring only an understanding of normal filter design and interpolation by 2. ADC and DAC roll-off can be ignored because compensation is automatic.

Limited filter choices are possible when in Codec mode. When in transmit either the Codec mode filter or a user-programmable filter must be selected using Program Register P4.1.

The remainder of this document will describe the use of a Scilab script to design a Codec mode custom transmit filter (the Low Pass Filter in Figure 1). The final section covers programming the custom transmit filter into the CMX7861.

## 5 Filter Example

As can be seen in Figure 1, samples are taken from the internal FIFO and fed to an interpolator where a value of zero is inserted between each sample. The resulting signal is a digital impulse chain with spectral duplication up to twice the sample rate. If no more than half the available sample bandwidth is used then only a simple RC on the DAC output is required to remove spectral duplication efficiently. Typically, interpolating allows only around 40% of the lower bandwidth to be available without additional filtering.

So the sample rate,  $F_s$ , seen by the transmit filter is twice the user sample rate,  $user\_F_s$ . This yields a flat pass band up to approximately 0.43 of  $user\_F_s$ .

In the example, a  $user\_F_s$  of 60kHz has been selected giving a flat pass band up to  $0.43 \times 60k = 25.8kHz$ . A filter having a stop band at 25kHz will remove the spectral duplicates. The filter in the CMX7861 is a 250 tap FIR, a linear filter that convolves the input signal with the impulse response of the filter. The default filter has a raised cosine impulse response and is typically used in RF systems. The example also allows user-selection of the Scilab function `wfir()` to create a windowed sinc filter using a selection of windowing functions. The user can then compare the response of this filter with different windows. Note that the Scilab `wfir()` function calls the same windowing function used to generate the raised cosine filter coefficients.

To run the coefficient generator either:

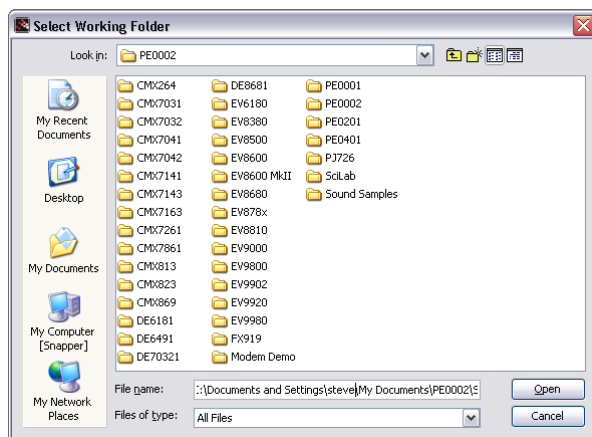
1. Start Scilab and type, “exec CMX7861\_Tx\_Filter\_Codec\_Mode.sce” at the console command prompt.
2. Start Scilab and then open SciNotes from the Applications menu. Open “CMX7861\_Tx\_Filter\_Codec\_Mode.sce” in SciNotes. Select “..file with no echo” from the Execute menu. SciNotes allows you to browse the algorithms used including function calls supplied with the Scilab environment.

It is also possible to view and modify the scripts and function calls by starting SciNotes as above and then opening the following files:

```
CMX7861_Tx_Filter_Codec_Mode.sce
myRC.sci
disp_coeffs.sci
getWindow.sci
```

## 6 Using the Coefficient Generator

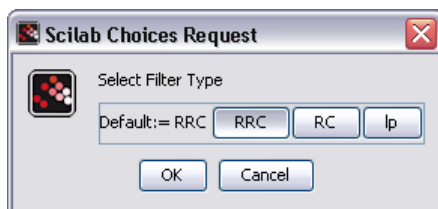
The Scilab script has been written to provide a simple user interface. This eliminates the need to modify the script although the user is free to do so if they wish. Scilab runs in its own working directory which, in Windows, is the Temp folder. The opening dialog allows the user to specify a more useful folder.



Select a convenient working folder or create one from this dialogue.

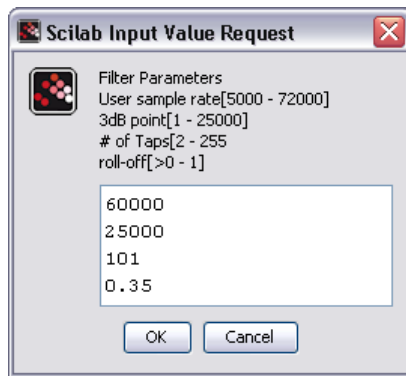
When done click the **Open** button and this will become the current working directory. Any output files created will be written to this folder.

Scilab will now give the option for creating a sample of filter types. Only low-pass responses are offered as they are likely to be most useful.



RRC or RC filters are very common in RF communication as they have good flat passband response and a fast roll-off. The high bandstop ripple occurs at the sample rate with crossing points at zero resulting in an acceptably flat stop band.

The **lp** option selects a sinc filter, which are universally used due to good performance and simplicity. The filter types can be compared by re-running the script and comparing the resulting plots. Click on **OK** to accept the selection.



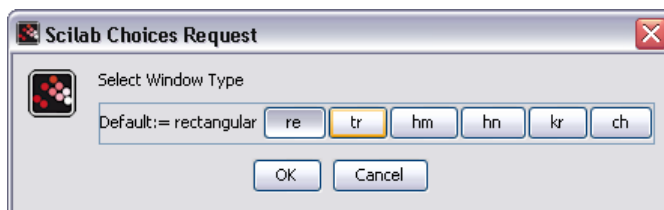
This will open another dialog to set the available filter parameters. The actual parameters will vary depending on the chosen filter type. This example is for the simple low pass case.

The **User sample rate** is the sample rate set in the CMX7861 Program Block 1. The sample rate at the analogue output will be twice this rate due to interpolation.

Enter the other filter parameters or use the defaults.

Click on **OK** to accept the selection.

If the **lp** option has been selected for the filter type, Scilab will prompt for a window type.



Rectangular and triangular windows are unlikely to be of any use as they allow a lot of energy to leak into adjacent windows.

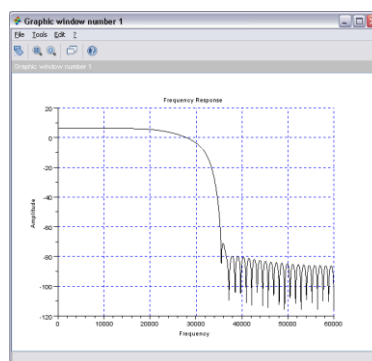
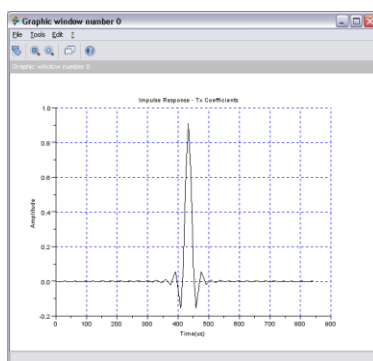
The Hanning (or Hann) or the Hamming windows give good narrow responses that result in increased stop-band rejection and a gentle roll-off. Both windows give a raised cosine response but the Hamming

is optimized to minimize the maximum (nearest) side lobe, giving it a height of about one-fifth that of the Hanning window - another raised cosine type but with simpler coefficients.

The Kaiser and Chebychev windows allow the main lobe and side lobes of the window to be adjusted to trade off the gain loss against spectral leakage. Scilab help gives a description of these parameters.

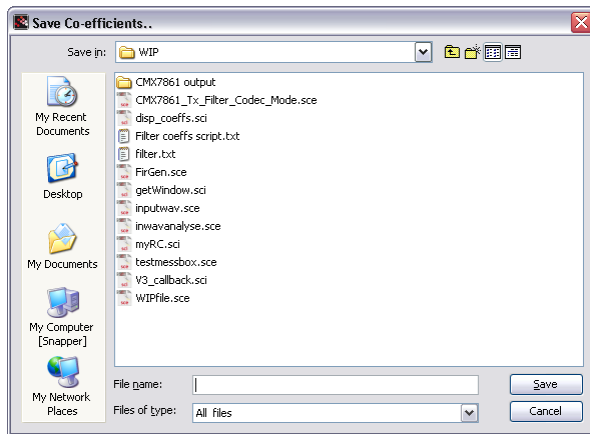
If the RC or RRC filter type was selected, then the window is fixed as a Hamming type with an alpha of 0.54.

See the References section for more information on windowing and its applications.



Having chosen the filter type and specified its parameters, Scilab now offers to display the response. Two windows are opened, the first displaying the impulse response of the coefficients and the second the frequency response of the filter. These graphic windows allow for zooming, printing and other graphic functions. The images can be saved as jpegs to compare different

filter options. The graphic windows can be closed if not required. If the script is re-run, it will automatically close the graphic windows so remember to save the content if required.



Having generated a set of coefficients, Scilab now offers to save these. The default operation of the script is to save the coefficients in a file. Use the dialog to navigate to a suitable folder and to determine the file name. The file type is unrestricted so ensure one is specified; ie save as coefficients.txt not just coefficients. Click on **Save** when done.

The script offers a number of alternative ways of saving coefficients and a number of different formats. This includes saving to the clipboard or the Scilab console, from where they can be copied into other documents or code. See the comments in the scripts; “CMX7861\_Tx\_Filter\_Codec\_Mode.sce” and “disp\_coefs.sci” for further details.

The next section deals with loading the coefficients into the CMX7861. An example is given below in pseudo code or the PE0002 script, “ProgCustomTxFilter.cbs”, that accompanied this document can be downloaded from the CML website.

## 7 Loading the coefficients into the CMX7861

Coefficients are loaded into the CMX7861 Program Blocks ( $P_n$ ). Loading can only be done while the device is in idle mode, Mode register \$6B, b1-0 = 00.

Program Block P9 is selected by writing the desired Program Block value, 0x09, to the Mode register b7-4 with all other bits set to 0. The majority of Program Blocks are tables and each row entry is sequentially numbered from zero. In this case, a specific table entry can be directly selected by writing the desired Program Block value to the Mode register b7-4 at the same time as the desired table entry number to b15-8. For example, to skip Program Block 9.0, which is reserved, write 0x0190 to the Mode register.

Values to be written are loaded into the Programming register \$6A but only if the PRG flag is set high, Reg Done Select register \$69, b0. The state of the PRG flag cannot be read directly but is inferred from the state of the Reg Done bit, Status register \$7E. The Reg Done bit can be set by any of the flags in the Reg Done Select register going high so only the PRG flag should be unmasked in this register when the Program Blocks are to be written.

To start entering data, write the required data to Programming register \$6A. Wait for the Reg Done flag to signal that the write is successful. The internal table pointer will automatically increment so that the Mode register does not have to be set to point to every table entry.

This example writes the tx co-efficients generated by the Scilab script into the Custom Tx Filter Program Block, P9.

```
Write 0x0000 to Mode register $6B      // select idle mode
Write 0x0190 to Mode register $6B      // select P9.1 (skip 9.0)
Write <number of coefficients> to Programming register $6A      //inform the
                                                                    //CMX7861 how many sequential values to expect
Wait for Reg Done
Write 2 to Programming register $6A    // Interpolation factor
Wait for Reg Done
For n = 1 to <number of coefficients>
    Write <coefficient1 to Programming register $6A
    Wait for Reg Done
Next n
```

All the coefficients are now loaded to the Custom Tx filter. To enable the filter a write to P4.1 is required. Continuing the pseudo code above:

```
Write 0x0140 to Mode register $6B      // select P4.1 (skip 4.0)
Write 0x0102 to Programming register $6A      // select Custom Tx filter and
                                                                    //ADC compensation filter for Rx
Wait for Reg Done
```

## 8 References

1. The Mathworks, R2011B documentation – Communications System Toolbox: pulse shaping, lower-level filters, rcosfir.
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4. Introduction to Scilab. Michael Baudin. The Scilab Consortium.
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9. An introduction to the treatment of neurophysiological signals using Scilab Jesus Olivan Palacios. <http://www.neurotraces.com/scilab/scilab2/>
10. Scilab Code for Digital Signal Processing Principles, Algorithms and Applications by J. G. Proakis & D. G. Manolakis
11. Scilab Textbook Companion for Digital Signal Processing. P. Ramesh Babu
12. Equalis Community. <https://www.equalis.com/>
13. Wickipedia, Window functions.
14. <http://www.scilab.in/>
15. The Scientist and Engineer's Guide to Digital Signal Processing. 2<sup>nd</sup> Edition. Steven W. Smith California Technical Publishing.
16. Consortium Scilab - Digiteo (2011). Scilab: Free and open source software for numerical computation (OS, Version 5.XX) [Software]. Available from: <http://www.scilab.org>

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| <b>Tel:</b><br>+44 (0)1621 875500<br><b>Fax:</b><br>+44 (0)1621 875600<br><b>Sales:</b><br>sales@cmlmicro.com<br><br><b>Tech Support:</b><br>techsupport@cmlmicro.com    | <b>Tel:</b><br>+1 336 744 5050<br>800 638 5577<br><b>Fax:</b><br>+1 336 744 5054<br><b>Sales:</b><br>us.sales@cmlmicro.com<br><b>Tech Support:</b><br>us.techsupport@cmlmicro.com | <b>Tel:</b><br>+65 62 888129<br><b>Fax:</b><br>+65 62 888230<br><b>Sales:</b><br>sg.sales@cmlmicro.com<br><br><b>Tech Support:</b><br>sg.techsupport@cmlmicro.com                     |
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