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1 Introduction

The highly integrated CMX7031 Two-Way Radio Baseband Processor IC is an ideal product for professional, semi-professional and leisure radios. In addition to its extensive feature set, the CMX7031 also offers two flexible PLL frequency synthesisers.

A Microsoft Excel™ spreadsheet, "CMX7031 Synthesiser Calculator", has been developed by CML to assist in configuring the CMX7031's on-board Synthesisers. The purpose of this application note is to describe the use of this spreadsheet.

The "CMX7031 Synthesiser Calculator" spreadsheet contains two worksheets. The first worksheet (Worksheet 1) assists in Synthesiser configuration by calculating N & R values, and the second worksheet (Worksheet 2) calculates component values for an external third order passive loop filter.

Since Worksheet 2 uses values from Worksheet 1 as part of its calculation, **Worksheet 1 should be completed and free of errors before entering data on Worksheet 2.**

This application note should be used alongside the CMX7031 Datasheet and the CMX7031 User Manual.
The worksheet file (CMX7031_Synthesiser_Calculator.XLS) should be downloaded from the (MyCML) CMX7031 portal area.

2 Worksheet 1 – Setting of the PLL Synthesiser Frequency

Worksheet 1 includes seven user-specified input terms, shaded in yellow, that are used to calculate the PLL Synthesiser frequency:

1. **Use Xtal? (Y or N):** this box allows the user to select either the CMX7031 crystal-derived clock ("Y") or an external RF Synthesiser clock ("N") as the source of the RF reference clock signal.

2. **Xtal Frequency**: This refers to the timing source connected to the CMX7031 XTALN and XTAL/CLK pins. Valid range is 4.0MHz – 12.288MHz. This term will be used in the calculations only if the "Use Xtal?" box is "Y".

3. **RF Synth Input Frequency:** This refers to the external RF reference clock source, such as a TCXO. Valid range is 5.0MHz – 40.0MHz. This term will only function if the "Use Xtal?" box is "N".

4. **Desired Reference Frequency**: This term normally refers to the channel spacing.

5. **VCO Frequency**: This term refers to the VCO signal that is connected to the RF1- (or 2-) and RF1+ (or 2+) pins. Valid range is 150MHz – 600MHz.

6. **Channel 1?:** a "Y" in this box causes Channel 1 register values to be calculated, while "N" causes Channel 2 register values to be calculated.

7. **Tx?:** a "Y" in this box causes Tx register values to be computed, while "N" causes Rx register values to be selected.

Error messages are generated if out-of-range values are entered, or if the entered values do not result in integer relationships between the desired reference frequency and the other signals.

If the reference frequency is set to the channel spacing then the VCO can be switched to any channel by changing the "**N**" counter value alone. If the system is required to work on a restricted set of channels then the reference frequency may be set to the HCF "Highest Common Factor" of the restricted set, which could be greater than the channel spacing.

It is also possible to achieve individual channel steps by offsetting an external temperature compensated crystal oscillator (TCXO) that provides the RF Synth Input Frequency, if this is providing the reference. This approach could yield improved noise performance due to a reduced division ratio from the VCO frequency to the reference frequency.

The user should try both the maximum and minimum of any spread of VCO frequencies to check than no error messages are flagged on the worksheet. The center of the VCO frequency range (or the nearest channel to that frequency) should be entered into the VCO frequency cell when using the Worksheet 2 to calculate suitable components for the loop filter.

The output cells in the large box named “RF Channel Data Register Instructions” show the data that must be written to the RF Channel Data ($B2) register to achieve the desired settings. The desired channel (1 or 2) and register (Tx or Rx) can be selected with the associated check boxes.

Channel 1 and Channel 2 each have Tx and Rx settings. Eight C-BUS transactions are required to fully program one Synthesiser; sixteen C-BUS transactions are required to configure both Synthesisers.

As an example, the following scenario describes how to use this spreadsheet to determine all register values for Channel 1 and Channel 2:

1. Enter parameters for xtal frequency (or RF synth input frequency), reference frequency, and VCO frequency.
2. Enter “Y” in the “Channel 1?” box and “Y” in the “Tx?” box.
3. The Channel 1 Tx N & R values (the first four RF Channel Data ($B2) register writes) are now displayed in the “RF Channel Data Register Instructions” box. Record these settings.
4. Enter “N” in the “Tx?” box so that the Channel 1 Rx N & R values are displayed. Record these settings.
5. Enter “N” in the “Channel 1?” box and “Y” in the “Tx?” box. The Channel 2 Tx N & R values should now be displayed. Record these settings.
6. Finally, enter “N” in the “Tx?” box so that the Channel 2 Rx N & R settings are displayed, and record these settings.

At this point, all sixteen register values required to configure the CMX7031 Synthesisers have been calculated.

Writes to the RF Channel Data ($B2) register should only be performed when the relevant synthesiser is disabled or is working from a register not being updated. **There are no interlocks to enforce this intention.**

3 Worksheet 2 – Passive Loop Filter Calculation

Worksheet 2 calculates useful values for a third order passive filter based on three capacitors and two resistors. Since Worksheet 2 reads the "*N*" value from Worksheet 1 as part of its calculation, Worksheet 1 should be completed and free of errors before entering data on Worksheet 2.

Worksheet 2 calculates a natural frequency based on:

- *fstep* (maximum frequency change to a new frequency)
- *ts* (desired time for the carrier to reach the new frequency to a tolerance of *fa*).

In practice, the natural frequency is the frequency at which the loop bandwidth is unity. Since the PLL built into the CMX7031 is a phase/frequency discriminator that runs at the reference frequency, it is strictly a sampled data system, and this natural frequency must be much less than the reference frequency. The worksheet checks that it is less than one tenth of the reference frequency. The calculation of the resistor and capacitor values follows a method published by Applied Radio Labs, www.radiolab.com.au.

The frequency/voltage characteristic of the VCO is called *Kvco*. In the case where a VCO is designed from discrete components the designer should take care that the *Kvco* is reasonably accurate and represents the gain averaged over the operating range of channels.

The gain of the charge pump, (*Icp)*, may be set to any value between 230uA and 2.5mA. The worksheet will calculate a suitable value for the external resistor to connect between the Iset pin and ground.

Note that the gain setting bit written to the RF Channel Control Register ($B3, b3 or b11) must match the value stated in the box below the "External Resistor Value" (Iset resistor) box. For two useful values, Icp=2.5mA and Icp=625uA, the calculated resistor value is 0. This means the Iset pin should be connected to ground (Vss).

The worksheet gives component values printed to four significant digits. In practice these should be rounded to the nearest values for the desired tolerance. In the case of C3 (capacitor in parallel with the VCO tuning input), the actual input capacitance of the VCO should be subtracted from the worksheet value before rounding to take account of that input capacitance. The layout of the circuit should take care that the earthy ends of C1,C2 and C3 are positioned close to the VCO.

The component solution will provide a phase margin of about 45 degrees at the natural frequency. This will yield a useful phase margin of better than 30 degrees at an octave above and below this natural frequency, and hence enough margin to cover a spread of channels as long as the spread of channels are somewhat less than an octave.

The resulting circuit design and component values should be verified with a suitable circuit simulation tool such as Spectre or Spice.

Worksheet 2 also determines the expected thermal noise contribution from the calculated resistance values. These thermal noise estimates are calculated for 100Hz, 1kHz, 10kHz, and 1MHz offsets from the carrier at a temperature of 25°C (the temperature can be changed). These figures only represent the thermal noise generated by the resistors; many other noise sources are present in any RF system.

This is not the only method that can be used to design a passive loop filter. Other tools include the "Easy-PLL" software at www.national.com. Good references on loop filter design include "PLL Performance Simulation and Design" written by Dean Banerjee, and "RF Microelectronics" (section 8.2) written by Behzad Razavi.

4 Conclusion

The CMX7031 contains many features that allow it to serve a wide variety of two-way radio applications, and two flexible PLL Synthesisers are included in the CMX7031's extensive feature set. CML has developed a spreadsheet, the "CMX7031 Synthesiser Calculator", to assist an engineer in configuring these Synthesisers. The purpose of this application note was to explain the use of this spreadsheet. It is hoped that the information in this document will help designers successfully implement the CMX7031 into their two-way radio designs.

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For FAQs see: http://www.cmlmicro.com/products/faqs/index.htm

For a full data worksheet listing see: http://www.cmlmicro.com/products/dataworksheets/download.htm

For detailed application notes: http://www.cmlmicro.com/products/applications/index.htm

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