ClockMatrix

Translating Non-Integer Frequencies

Abstract

The ClockMatrix family of devices is designed to support exact translation for non-integer frequencies. Very often applications such a forward-error correction (FEC) in 10GB Ethernet LAN/WAN transport require clock rates that are expressed as a base frequency multiplied by a ratio (e.g., 156.25MHz *66/64=161.1328125). The issue is that some ratios, such as OTU1 (255/238*2,488.320kHz) result in very long decimal numbers that are often truncated. This application note discusses how to configure a ClockMatrix device for non-integer frequencies in order to obtain zero translation errors.

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1. ClockMatrix M/N Architecture

The format for representing a frequency in the registers of a ClockMatrix device is:

$$f = \frac{M}{N} \qquad\qquad (Eq.1)$$

where M is a 48-bit integer and N is a 16-bit integer. M/N is a fraction that allows for the creation of non-integer frequencies. For example:

$$133.\overline{333}MHz = \frac{400MHz}{3} \qquad\qquad (Eq.2)$$

2. The Need for Precision

Since the architecture of a ClockMatrix device provides for precise frequency generation, it is important to provide exact frequencies for the configuration. For example, it is common to receive a request for a 133.3MHz output. This is easily supported by the device and the GUI as this ratio:

$$\frac{M}{N} = \frac{1333,000,000}{10} \qquad\qquad (Eq.3)$$

However, it may be that the system actually requires $133.\overline{333}MHz$. That means that 133.3MHz is actually -250ppm offset from the required frequency.

Even a parts-per-trillion error is sufficient to negatively impact phase lock in a 1588 system or cause an occasional line across the screen in video applications. So, an exact configuration is critical.

3. Arithmetic Expressions in the ClockMatrix GUI

In order to support exact translation, the ClockMatrix GUI supports arithmetic expressions for the input and output frequency fields. Figure 1 shows the location of the input and output frequency fields.

Figure 1. GU Input and Output Frequency Fields

These fields support addition, subtraction, division, and multiplication. They also support fractional frequency offsets (ffo) such as adding 1ppm. Finally, they support absolute offsets, such as adding 1kHz. The following are examples of valid inputs:

- 400/3
- 100+10K
- 156.25+1ppm

Note: The input/output default unit is MHz.

This is how it looks in the GUI:

Figure 2. Output Frequency with PPM Offset

4. Input Frequency M/N Configuration

Here is an example configuration for an input frequency of $133.\overline{333}MHz$. The input is entered as "400/3" (since the default unit is MHz).
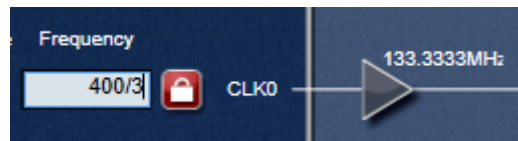

Figure 3. Arithmetic Expression as Frequency Input

Clicking on the "buffer" symbol for CLK0 brings up the "CLK0 Config" dialog which shows details for the M/N settings (see Figure 4). The GUI recognized the ratio and set M (Numerator) as 400,000,000 and N (Denominator) as 3.
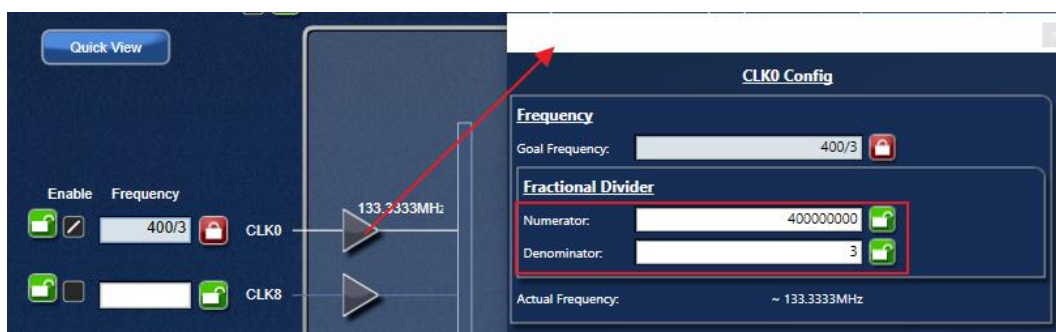

Figure 4. 133.333MHz Input Frequency Setting

In another example, a system such as OTU4 may need a clock such as 2.6660571428MHz. The exact rate, which was included in the introduction, is (255/238)*2,488.320 and the decimal representation of this fraction is 2.666057142857142857142857142857142857142857142857… (this is truncated due to the limits of the 64-bit system used to convert the ratio to decimal).

Figure 5. Complicated Example of Arithmetic Expression as Frequency Input

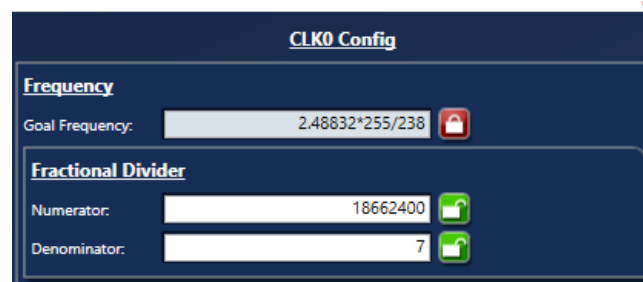The GUI recognized the ratio and simplified it as 18662400/7, as shown in Figure 6.

Figure 6. CLK0 M/N Calculations

Some basic math shows that this is an exact equivalent of the original input ratio:

$$\frac{2443200 * 255}{238} = \frac{(1244160 * 2) * (15 * 17)}{(2 * 17 * 7)} = \frac{1244160 * 15}{7} = \frac{18662400}{7} \qquad (Eq. 4)$$

5. Output Frequency M/N Configuration

The output frequency also supports an M/N configuration. For this example, let's use the frequency of 10.3125GHz/256 which is used in a popular PHY. Enter the frequency into the field for Q0 and then open up the Q0 configuration window, as shown in Figure 7.
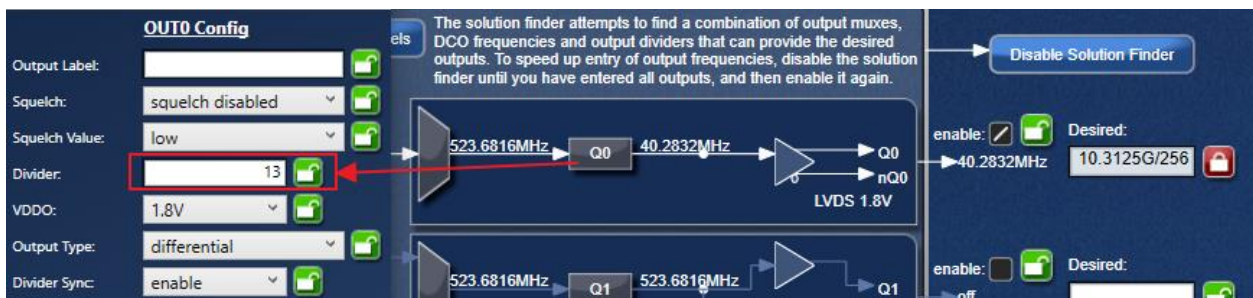

Figure 7. Q0 Output Divider

Note that there is a divide-by-13 setting in the output path. That means that the ideal DPLL0 frequency is (10.3125GHz/256)*13. The reduced ratio calculation is as follows:

$$\frac{10,312,500,000 * 13}{256} = \frac{322,265,625 * (32) * 13}{(32) * 2 * 2 * 2} = \frac{322,265,625 * 13}{8} = \frac{4,189,453,125}{8} \qquad (Eq.5)$$

Next, open up the Channel 0 DPLL configuration window, by pressing the Config button as shown in Figure 8.

Figure 8. Arithmetic Express as Output Frequency

Opening up the DCO configuration, is shows the "Goal" and "Actual" DCO frequencies. They are rounded, and should only be used for approximations of the frequency.
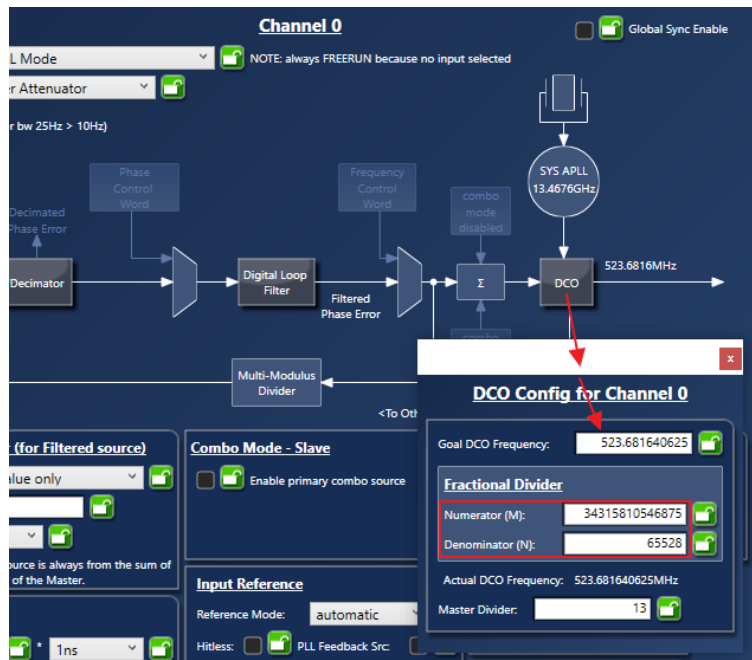
Figure 9. DCO M/N Configuration

A close inspection of the N value in Figure 9 shows that it is not 8, rather it is 65528, which is 8 * 8191. This is because the GUI always maximizes the denominator value in order to improve the phase noise performance of the device. Multiplying the reduced fraction from Equation 5 by 8191 shows that the GUI result is equivalent:

$$\frac{4,189,453,125 * 8191}{8 * 8191} = \frac{34315810546875}{65528} \qquad (Eq.6)$$

Another way to check the result is to set the N value and allow the GUI to calculate the M value (see Figure 10), which results in the same reduced ratio that was calculated in Equation 5.
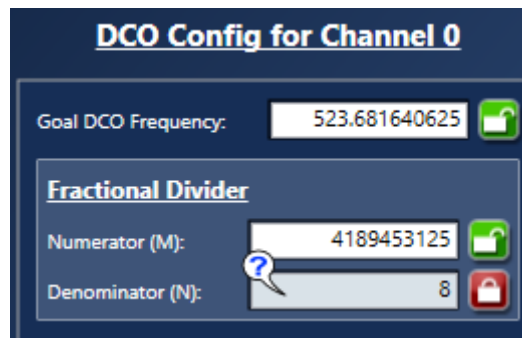

Figure 10. DCO Denominator Override

It is wise to always check the M/N ratio to ensure that the values are exact. A quick, lazy way to check is to use a website that supports either simplification of fraction or decimal calculations with very high accuracy.

6. One-Step Calculation Recommendation

When calculating translations, it is recommended to always use a single calculation step, rather than calculating one step at a time. Intermediate steps can results in rounding errors that carry through into the next step of the calculation. A single calculation helps avoid that extra error.

Table 1 shows several examples for M/N calculations for standard applications.

Table 1. Example Calculations

Rate	Data	Units	MHz	CLK Freq. (MHz)	M	N	DCO	OutDiv	Freq. (MHz)	Error
OTU4	111.8099736	kb/s	111.8099736	111.8099736	5590498678	10	559049867.8	5	111.8099735680	0
OTU3	43.018	kb/s	43.018	155.52*255/236	155520000*255*4	236	672162711.8….	4	168.0406…	0
OTU2	10.70922532	kb/s	10.70922532	10.70922532	5354612658	10	535461265.8	50	10.7092253160	0
OTU2	11.09572785	kb/s	11.09572785	155.52*(255/237)	155,520,000*255*4	237	669326582.27….	4	167.33164….	0
OTU2e	11.09572785	kb/s	11.09572785	11.09572785	5547863924	10	554786392.4	50	11.0957278480	0
OTU2e	11.09572785	kb/s	11.09572785	156.25*66/64*255/237	156250000*66*255*4	64*237	693482990.5…	4	173.37074…	0
OTU1	2.666057143	kb/s	2.666057143	2.666057143	6665142858	10	666514285.8	250	2.6660571430	0
OTU1	166.62857…	kb/s	155.52*255/238	155.52*(255/238)	4*155520000*255	238	666514285.8	4	166.62857…	0
1 GbE	1250	kb/s	1250	312.5	625000000	1	625000000	2	312.5000000000	0
10 GbE	10312.5	kb/s	10312.5	412.5	825000000	1	825000000	2	412.5000000000	0
FC100	10,625	Gb/s	10625	425	850000000	1	850000000	2	425.0000000000	0
FC200	2,125	Gb/s	2125	85	595000000	1	595000000	7	85.0000000000	0
FC400	4,250	Gb/s	4250	170	680000000	1	680000000	4	170.0000000000	0
FC800	8,500	Gb/s	8500	340	680000000	1	680000000	2	340.0000000000	0
FC1600	14,025	Gb/s	14025	561	561000000	1	561000000	1	561.0000000000	0
STM1	155.52	kb/s	155.52	155.52	622080000	1	622080000	4	155.5200000000	0
STM4	622.08	kb/s	622.08	622.08	622080000	1	622080000	1	622.0800000000	0
STM16	2.48832	kb/s	2.48832	2.488320	622080000	1	622080000	250	2.4883200000	0
STM64	9.95328	kb/s	9.95328	9.953280	597196800	1	597196800	60	9.9532800000	0
25GbE	25.78125	kb/s	25.78125	25.781250	515625000	1	515625000	20	25.7812500000	0

7. Conclusion

This document has shown how to configure a ClockMatrix device for non-integer frequency translation. The device's M/N architecture, along with the GUI's support for arithmetic inputs, provide exact frequency translation. For questions regarding this feature, please contact Renesas Application Support at idt.com.

8. Revision History

Revision	Date	Description
1.0	May.7.20	Initial release.

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