

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 as 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:

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

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:

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

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:

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

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.

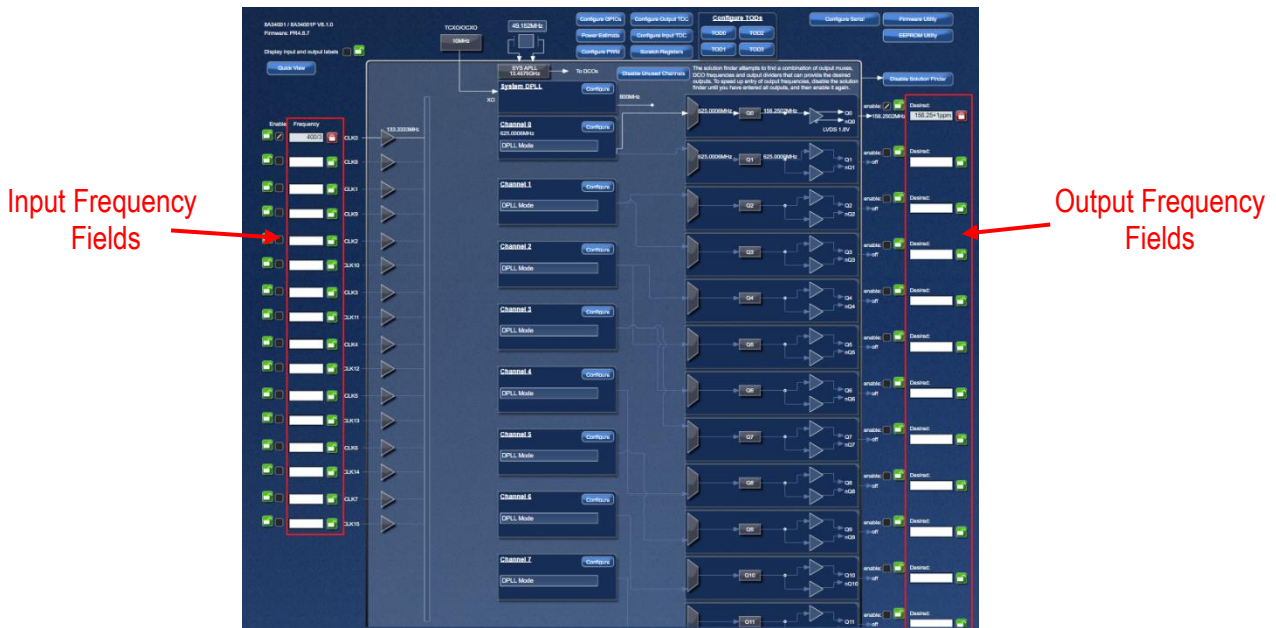


Figure 1. GU Input and Output Frequency Fields

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).

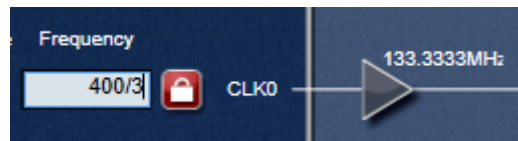


Figure 3. Arithmetic Expression as Frequency Input

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.

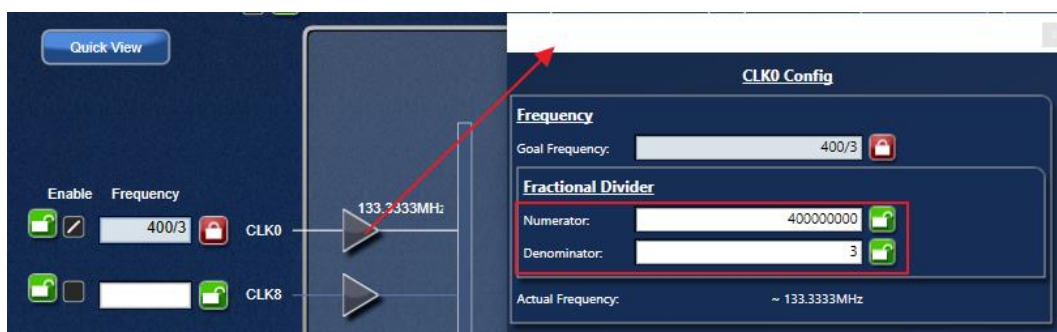


Figure 4. 133.333MHz Input Frequency Setting

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 2.6660571428571428571428571428571... (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.

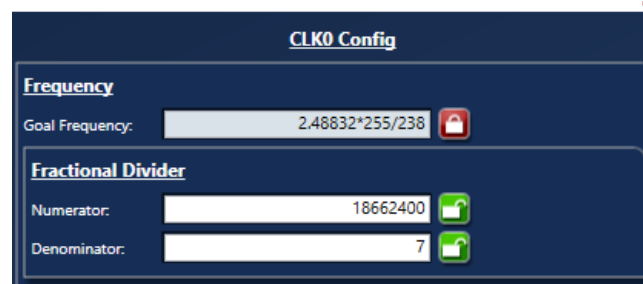


Figure 6. CLK0 M/N Calculations

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

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

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.

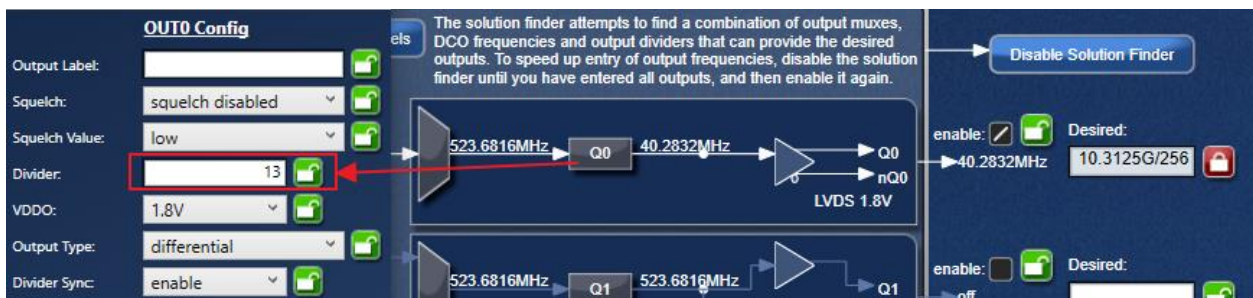


Figure 7. Q0 Output Divider

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

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

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, it shows the "Goal" and "Actual" DCO frequencies. They are rounded, and should only be used for approximations of the frequency.

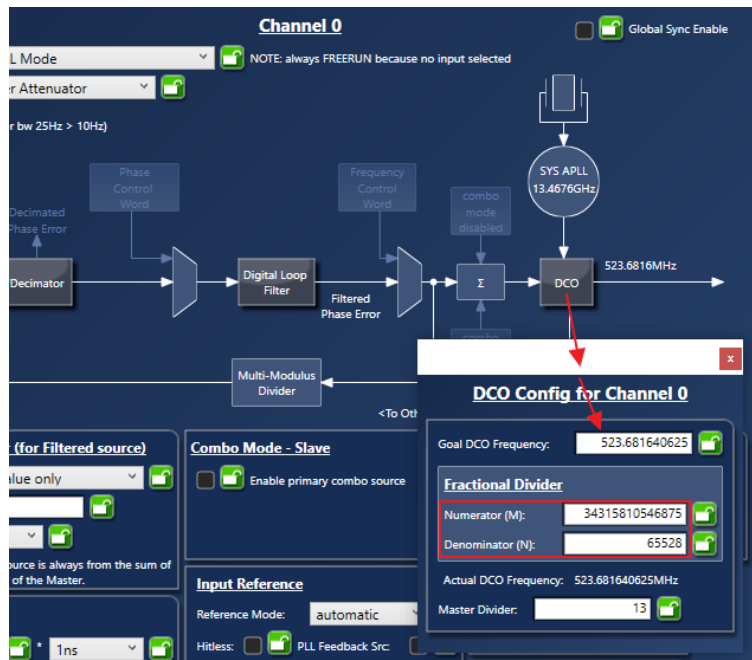


Figure 9. DCO M/N Configuration

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:

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

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.

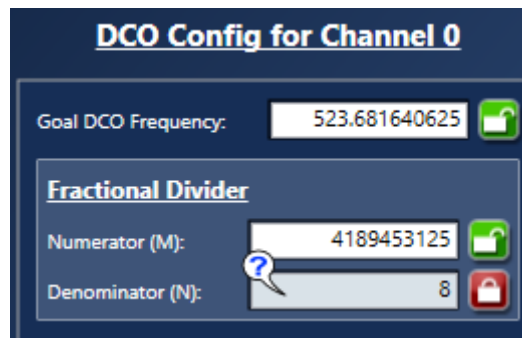


Figure 10. DCO Denominator Override

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 result 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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