1.2 Implementation of the WR calculations

In practice, delayMS is obtained in the following steps:

1. fixed delays ($\Delta_{txm}$, $\Delta_{rxs}$, $\Delta_{txs}$, $\Delta_{rxm}$) and alpha parameter ($\alpha$) are provided as calibration parameters.

2. more tricky calculations, requiring floating point, are performed only once on the WR Switch (WRS) and are precomputed for the WR PTP Core (WRPC), resulting in fixed-point int32 alpha ($fix \alpha$).

3. easy in fixed-point math calculations, delayMS is calculated from delayMM using $fix \alpha$ and $\Delta_{txm}$, $\Delta_{rxs}$, $\Delta_{txs}$, $\Delta_{rxm}$, where $delayMM = (t_4 - t_1) - (t_3 - t_2)$

The implemented calculations are summarized in the table. Of course, bit-shifting is used for division and multiplication by 2 (e.g. $\cdot 2^{40}$).

<table>
<thead>
<tr>
<th>Num</th>
<th>Calculation</th>
<th>WRS</th>
<th>WRPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\alpha_{neg} = \frac{1}{2^{\alpha}} - 1$</td>
<td>$\alpha_{neg}$ (double) is computed in HAL from $\alpha$ (double)</td>
<td>$\alpha$ and $\alpha_{neg}$ are used in pre-computation of $fix \alpha$</td>
</tr>
<tr>
<td>2</td>
<td>$fix \alpha = (\frac{1+\alpha}{2} - \frac{1}{2}) \cdot 2^{40}$</td>
<td>$fix \alpha$ (int32) computed in HAL from $\alpha$ (double)</td>
<td>$fix \alpha$ (int32) precomputed by hand</td>
</tr>
<tr>
<td>3</td>
<td>$delayMS = [fix \alpha \cdot (delayMM - \Delta)] \cdot \frac{1}{2^{40}} + \frac{1}{2} \cdot (delayMM - \Delta) + \Delta_{txm} + \Delta_{rxs}$</td>
<td>$delayMS$ (int64) calculated in int64 fixed-math from int32 values</td>
<td></td>
</tr>
</tbody>
</table>

The second formula can be easily traced back to the original formula:

$$delayMS = [fix \alpha \cdot (delayMM - \Delta)] \cdot \frac{1}{2^{40}} + \frac{1}{2} \cdot (delayMM - \Delta) + \Delta_{txm} + \Delta_{rxs}$$  \hspace{1cm} (11)$$

$$delayMS = [2^{40} \cdot (\frac{1+\alpha}{2+\alpha} - \frac{1}{2}) \cdot (delayMM - \Delta) \cdot \frac{1}{2^{40}} + \frac{1}{2} \cdot (delayMM - \Delta) + \Delta_{txm} + \Delta_{rxs}$$ \hspace{1cm} (12)$$

so

$$delayMS = (delayMM - \Delta) \cdot (\frac{1+\alpha}{2+\alpha} - \frac{1}{2}) + \Delta_{txm} + \Delta_{rxs}$$ \hspace{1cm} (13)$$

so

$$delayMS = (delayMM - \Delta) \cdot \frac{1+\alpha}{2+\alpha} + \Delta_{txm} + \Delta_{rxs}$$ \hspace{1cm} (14)$$

(15)