MOLLER Helicity Board Settings

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MOLLER is expecting to use the following settings: Free Clock Mode at 1920 Hz, 10 µs T_Settle, 510.85 µs T_Stable, 64-window pattern, and 128-window delay. These choices were selected for the following:

1. The T_Settle time was chosen to be 10 µs because this is the shortest time it takes the RTP cell to change HV and settle down. The smaller the better since this is a deadtime for the experiment and with this selection the deadtime is 1.92%.
2. In Free Clock mode, once the frequency and T_Settle are determined, T_Stable is calculated as:
$$T\_Stable = \frac{1}{f} - T\_Settle.$$
3. MOLLER needs to run at high reversal frequency to suppress rate noise due to the density fluctuation of the liquid hydrogen target [1] and all kinds of mechanical noises that peak at low frequency.
4. 1920 Hz was selected since it's sufficiently high frequency and the 32nd harmonic of 60 Hz. The power line frequency and its harmonics are another major noise source that we are trying to suppress in the parity data.
5. The pattern was selected to achieve the following [2, 3]:
   a. Extends over 33334.4 µs spanning two 60 Hz cycles.
   b. Cancels 60 Hz and its harmonics with a few Hz around it to allow for any jitter in the line noise. The 60 Hz power line frequency is known to be relatively stable to about 59.70±0.05 Hz.
   c. The use of "multiplet" switching patterns helps to further suppress the effect of low frequencies which dominate the density fluctuation noise from the target [1].
   d. Repetition of the pattern with a pseudorandomized polarity selection provides cancellation of any residual average contribution of noise pickup to the mean helicity asymmetry.
6. The delay is normally selected to be two full patterns, in order to fully decorrelate any measurements with the real helicity.

Below are the selections that will be available in the new firmware update of the Helicity Generator Board.

Helicity Board Modes
1. Line Sync Mode: There are three line synced fixed-frequencies of 30 Hz, 120 Hz, and 240 Hz triggered by "Line Sync". The phase locking is forced during the last T_Stable period. The T_Settle time period may be chosen from the T_Settle Register. You cannot choose T_Stable in this mode only T_Settle. In this mode, Toggle, Pair, and Quartet are the only patterns available.
2. Free Clock Mode: This mode of operation allows the board to operate in free-running mode, where the T_Settle and T_Stable values are selected from the tables below. In this mode, you can select any T_Settle and any T_Stable.

Helicity Board Registers

1. T_Settle Register: There is a five-bit R/W register that determines the "T_Settle" portion of the helicity period with these selections: 5 µs, 10 µs, 15 µs, 20 µs, 25 µs, 30 µs, 35 µs, 40 µs, 45 µs, 50 µs, 60 µs, 70 µs, 80 µs, 90 µs, 100 µs, 110 µs, 120 µs, 130 µs, 140 µs, 150 µs, 160 µs, 170 µs, 180 µs, 190 µs, 200 µs, 250 µs, 300 µs, 350 µs, 400 µs, 450 µs, 500 µs, 1000 µs.

2. T_Stable Register: There is a five-bit R/W register that determines the "T_Stable" portion of the helicity period with these selections: 240.40 µs, 245.40 µs, 250.40 µs, 255.40 µs, 470.85 µs, 475.85 µs, 480.85 µs, 485.85 µs, 490.85 µs, 495.85 µs, 500.85 µs, 505.85 µs, 510.85 µs, 515.85 µs, 900 µs, 971.65 µs, 1000 µs, 1001.65 µs, 1318.90 µs, 1348.90 µs, 2000 µs, 3000 µs, 4066.65 µs, 5000 µs, 6000 µs, 7000 µs, 8233.35 µs, 8243.35 µs, 16567 µs, 16667 µs, 33230 µs, 33330 µs.

3. Helicity Pattern Register: There is a three-bit R/W register that determines the Helicity Pattern. The pattern selections are as follow:
   a. Toggle (+-+-+-+-…)
   b. Pair (+- or -+)
   c. Quartet (-++- or +--+)
   d. 8-window: Octet (+--+-++- or -++-+--+)
   e. 24-window: Hexo-Quad (+--+ +--+ +--+ -++- -++- -++- or -++- -++- -++- +--+ +--+ +--+)
   f. 32-window: Octo-Quad (+--+ +--+ +--+ +--+ -++- -++- -++- -++- or -++- -++- -++- -++- +--+ +--+ +--+ +--+)
   g. 64-window – type1: Thue-Morse-64 (+--+ -++- -++- +--+ -++- +--+ +--+ -++- -++- +--+ +--+ -++- +--+ -++- -++- +--+ or the complement)
   h. 64-window – type2: 16-Quad (+--+ +--+ -++- -++- +--+ +--+ -++- -++- +--+ +--+ -++- -++- +--+ +--+ -++- -++- or the complement).
   i. 64-window – type3: 32-Pair (+-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- +-+- or the complement)

4. Reporting Delay Register: There is a three-bit R/W register that determines the delay of the Delayed Helicity signal relative to the real time Helicity Flip signal. The delay time in units of helicity windows is selected as follows: No Delay, 1, 2, 4, 8, 16, 24, 32, 40, 48, 64, 72, 96, 112, 128 and 256 windows.

References

1. Target Boiling, Target Density Fluctuations and Bulk Boiling in Hall A Cryotarget. D. S. Armstrong, B. Moffit, and R. Suleiman, Jefferson Lab Technical Note: JLAB-TN-03-017, May (2003).
2. Helicity Pattern Evaluation, P. Nepal and P. King, Ohio University, 03 June 2022.
3. False Asymmetry from Fixed-Frequency Noise in the QWeak DAQ, Des Ramsay, Qweak DocDB-732, -888, and -906, 20 February 2009.