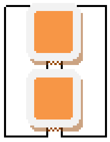
CRISP Error Calculation Algorithm

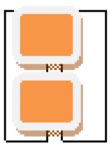
At focus ideally what we want:



\begin{multline} \\ PD_1 = 75 \\ PD_2 = 75 \\ SUM = \frac{ PD_1 + PD_2}{2} = 75\\ OFFSET = 0 \\ ERR = (PD_1-PD_2) - OFFSET = 0\\ \end{multline}

Returned light is distributed evenly between the two halves of the detector and is hitting the center of the detector pair. Small changes in intensity of the returned light will not affect the ERR. If PD1 and PD2 suddenly see only 70, still ERR = 0 so no ERR signal applied to servo loop.

More likely we have something like this:



\begin{multline} \\ PD_1 = 85 \\ PD_2 = 55 \\ SUM = \frac{PD1+PD2}{2} = 70\\ OFFSET = PD_1-PD_2 = 30 \\ ERR = (PD_1-PD_2)-OFFSET = (85-55)-30 = 0\\ \end{multline}

Now if we change slightly the received intensity, say \begin{equation}SUM = 65 \end{equation} That would be consistent with \begin{equation} PD_1 = \frac{65}{70}×85 = 78.9 \ \ \ and \\ PD_2 = 51.1\\ Now \ \ \ ERR = (78.9-51.1)-30 = -2.2 \end{equation}

So there is a residual error that will cause servo motion to try and move the focus just due to a change in light intensity.

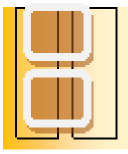
From arguments like this, you can see that it would be desirable to operate where the OFFSET is close to zero. You will discover that you can change the OFFSET at focus by moving the main CRISP adjustment screw and then re-doing the Step 3 `Set Gain` function. You will probably discover that the highest "dither" ERR numbers and low `OFFSET` numbers are not at the same place, as we might wish they were ideally. You may find that tuning the CRISP for low `OFFSET` numbers may be beneficial for stability, rather than tuning for maximum "dither" ERR.

Unfortunately, the situation is even more complicated than this. In addition to signal light returning from the focus interface, there is also background light that likely illuminates the detector non-uniformly.

A note on the Numbers

SUM is % of full scale. Full scale is for each detector is 8192 raw counts. In the examples above, PD1=85 is really 85% of 8192 = 6932; PD2 = 55 is 4505; OFFSET = 2427; etc. ERR displayed is in NOT raw counts but rather the correction applied to the motor in encoder counts. However, ERR of zero implies (PD1-PD2) = OFFSET.

Consider the case where there is a non-uniform background intensity on the detector:



\begin{equation} \\ PD_1 = BG_1 + S_1 \\ PD_2 = BG_2 + S_2 \end{equation}

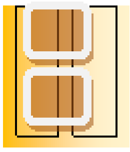
When the focus changes slightly, the returned spots move laterally but the background level on the detectors remains constant. In “Dither” mode, we expect the real signal to shift slightly back and forth between the two halves of the detector. For small changes in focus position, dF, we find changes in signal dS == ERR.

\begin{equation} PD_1 – PD_2 = BG_1 + S_1 – (BG_2 + S_2)\end{equation}

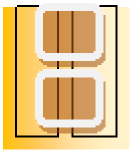
The “Dither” operation eliminates the non uniform “background” problem when doing the calibration…

\begin{equation} \\ (PD_1 – PD_2)|0 – (PD_1 – PD_2)|dF = BG_1 + S_1|0 – BG_2 – S_2|0 – BG_1 – S_1|dF + BG_2 + S_2|dF \\ ERR = (S_1-S_2)|0 – (S_1-S_2)|dF \\ \end{equation}

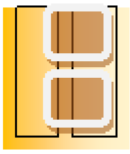
If all of the light from the reflected spot falls on the detector pair, and just moves from one side to the next, and the light in the returned spot is uniform, then ERR will be constant despite small lateral moves of the detector position:



Case 1

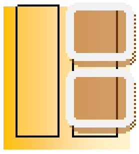


Case 2



Case 3

All of these cases would give about the same ERR number for small “Dither” focus changes because the uniform light spot is always on the sensor.



Here, the light is “falling off” the edge of the sensor, only just touching the PD1, so the ERR number for small dither will be small.

Now we can see the problem when we adjust the detector position for OFFSET of Zero when the returned intensity changes. Look at Case 2 and Case 3 above. In Case 2 the returned light is approximately centered on the detector. Any change in returned intensity will not generate a change in S1 – S2 because each detector half sees about the same level of “real” signal. In Case 3 a small change in returned intensity will generate result in a change in S1-S2 because most of the signal is striking the right –side detector. Note however, OFFSET for Case 3 is closer to zero than for Case 2 because non-uniform background light is hitting on the left-side detector more strongly.

Suggestion to adjust CRISP as follows based upon these considerations:

1. Find “best” detector position using maximum dither “ERR” numbers as usual. Note OFFSET, AGC, etc. Be sure ERR is zero before you go so step 2.
2. Remove the sample! Now no returned light is coming from the interface. You probably now have a non-zero ERR number.
3. Press “RESET OFFSET.” This will change the OFFSET such that the ERR is zero.
4. Now replace the sample – returning as close as possible to previous focus.
5. Now you should again have a non-zero ERR number. Adjust the main detector lateral adjustment knob so that ERR goes to zero.
6. Go to step 2) and repeat the process until you have roughly zero ERR with or without the sample installed. Maybe this process converges 🙂 !

crisp, tech note