

24/9/22

(w/ eccu binning (to 1) of spike train see if
different

Global error minimisation function (what is the cost function)

MHz sample test.

Spin test

More experimental results

>Error of quantification per cluster (convol-to steps) %
error.

Switching up generation

Clockwise deviation from ideal. Spacing error.

Ratio of Zc displacement / switching zone size

$$| \frac{^0}{e} = \frac{2}{\text{poles}} | \frac{^0}{m} * \text{Number of zones} = 3 \cdot \text{poles}$$

Full electrical cycles is 6 switching steps 360°_e is 6 steps

$$360^\circ_e / 6 = 60^\circ_e$$

$$* 60^\circ_e = \frac{2}{\text{poles}} 60^\circ_m = 1_e^{\text{step}} = \frac{120^\circ m}{\text{poles}}$$

$$\text{in steps } \cancel{\frac{2^{14}}{360^\circ} \times \frac{120^\circ}{\text{poles}}} = \frac{2^{14}}{3 \cdot \text{poles}} \text{ "Number of digital steps per electronic switching step"}$$

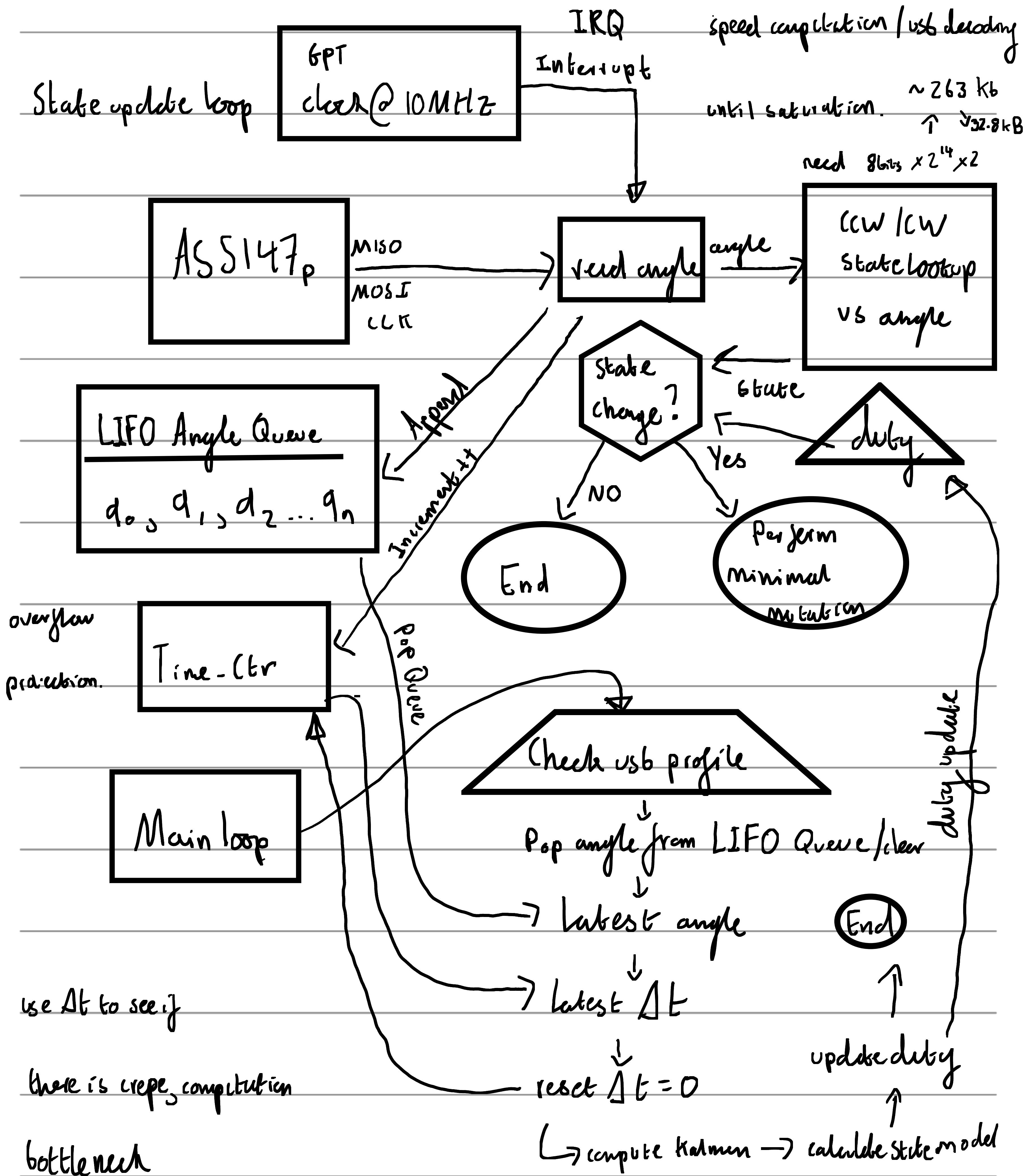
For poles = 14 we get $\frac{2^{14}}{3 \cdot 14} = \sim 390$ steps is the switching zone size.

$$\text{The Zc displacement is } 30^\circ_e \quad d_{Zc} = \frac{2^{14}}{6 \cdot \text{poles}}$$

Teensy 4.0 2Mbyte flash, 1Mbyte ram

Thinking about speed control loop

The IRQ can interrupt the



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Will attempt another cw/lcw run of about 10s with
node memory flag set.

Update combine report to deduce mean & error & relative error.

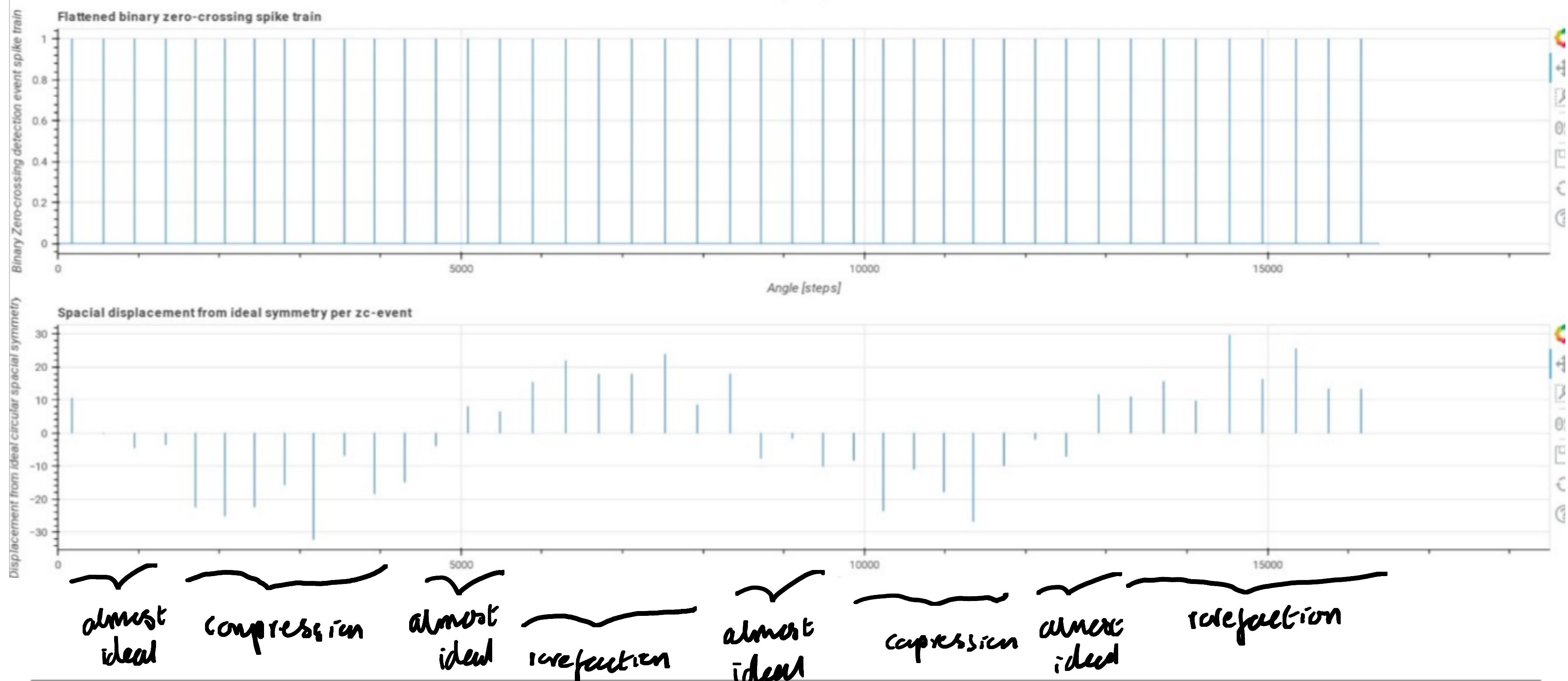
Displacements from ideal now that I have derived the formula, global ✓
error function.

→ displacements from ideal, new-mean: $\{ "z_{c-\text{chun}}": \{ 0: \text{up},$
per chunk get key, value tuple $\text{dist} \rightarrow \text{tuple} + \text{check}$ ✓
interesting oscillating pattern! 30 disp
max

→ cluster error

cluster me cluster 1 ... cluster N ✓
zcris... $10^{\pm 0.1}$... cluster min
✓ channel error avg. of errors max

Global errors based of displacement from ideal, do errors for abs as well as raw value analysis.



Thinking about the above displacement away from $\frac{\pi}{3.14} \approx 390$ steps

Ideal spacing

chart above, interesting it seems to oscillate like a sinusoid with

a period of $2 \times$ the circular period. As the motor has circular symmetry

it make sense that the sum of displacements $\sum d_i = 0$, as

if not the pattern would shift specially on the next turn & it would not be periodically

stable over the circle, its not obvious to me why we get a 2 period sinusoidal like

pattern, perhaps this is evidence of some error based on angle, or

We have revealed some real manufacturing asymmetry for the A2212 motor.

Max displacements on the order of ~ 32.2106 angular steps
from ideal

$$\text{Conversion factor is } \frac{360^\circ}{2^{14} \text{ steps}} \quad [\text{degrees per step}] \quad \xrightarrow[2dp]{\text{up}} 0.71^\circ$$

$$\text{Average displacement from ideal spacing } \sim 16.1303 \xrightarrow[4dp]{\text{up}} \xrightarrow[2dp]{\text{up}} 0.35^\circ$$

$$\text{Smallest displacement from ideal } \sim 0.3578 \xrightarrow[4dp]{\text{up}} \xrightarrow[2dp]{\text{up}} 0.0079^\circ$$

$$\text{Best cluster error } 6.3774 \rightarrow 0.14^\circ$$

$$\text{Worse cluster error } 87.8996 \rightarrow 1.93^\circ$$

Would be nice to know how cluster error correlates to
error of the deviation from ideal symmetric spacing.

Thinking about ZC displacement, if it turns out the displacement from
ideal symmetry has a real physical pattern, then displacing the ZC by 30° en
would be a bad choice, instead take the middle point of adjacent ZC-events.

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Next step long duration cw/ccw run ~10s+, see what length
of time is stable.

iteration.

What naming convention for runs XX — Sept — A2Z12 — CW — X
date marsh meter direction

→ 29-sept-A2Z12-CW-1 99.95% match

rate

→ 29-sept-a2z12-ccw-1 99.96% match

rate

Combined reports for these two cluster error went up, deviation

from ideal went down. Interesting that the error (cluster) does
appear dependent on runtime! Big incentive to make sure cw/ccw
runs are of equal length!

How can we ensure run lengths are nearly the same?

Have host PC send the number of iterations required to
teasy (ADC), have that teasy only poll the slave n times,
have master teasy send termination serial print to host
so host can auto exit, giving the user some indication
of termination.

Then with source program for ADC teasy, have a flag for
run size, lots of short runs should minimize detector error, & lots
of these runs. \rightarrow Better capture \rightarrow Auto analyse command!

We probably can't prevent skew from misrabdes!

NuForce DDA 100

pink capacitive

Ohm meter
VU meter

Blue, detent mix

orange (drilled)

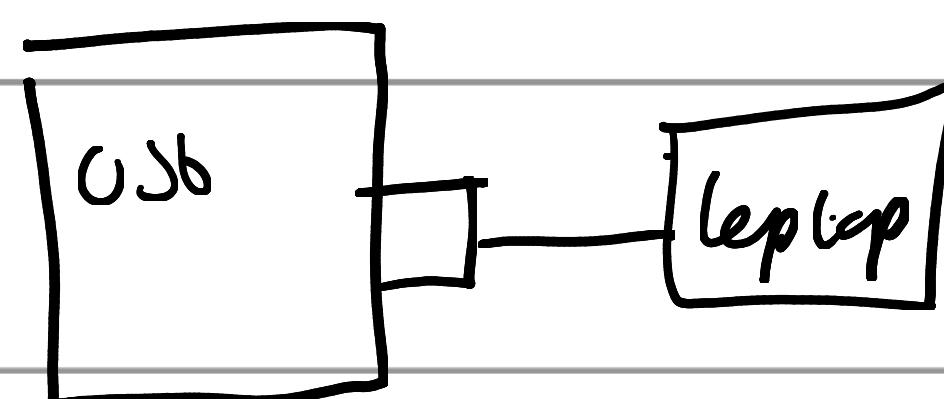
C1 30

chain 30

OLED

Inputs

Outputs



single button

Target Speed 33.3 rpm 33.0 X

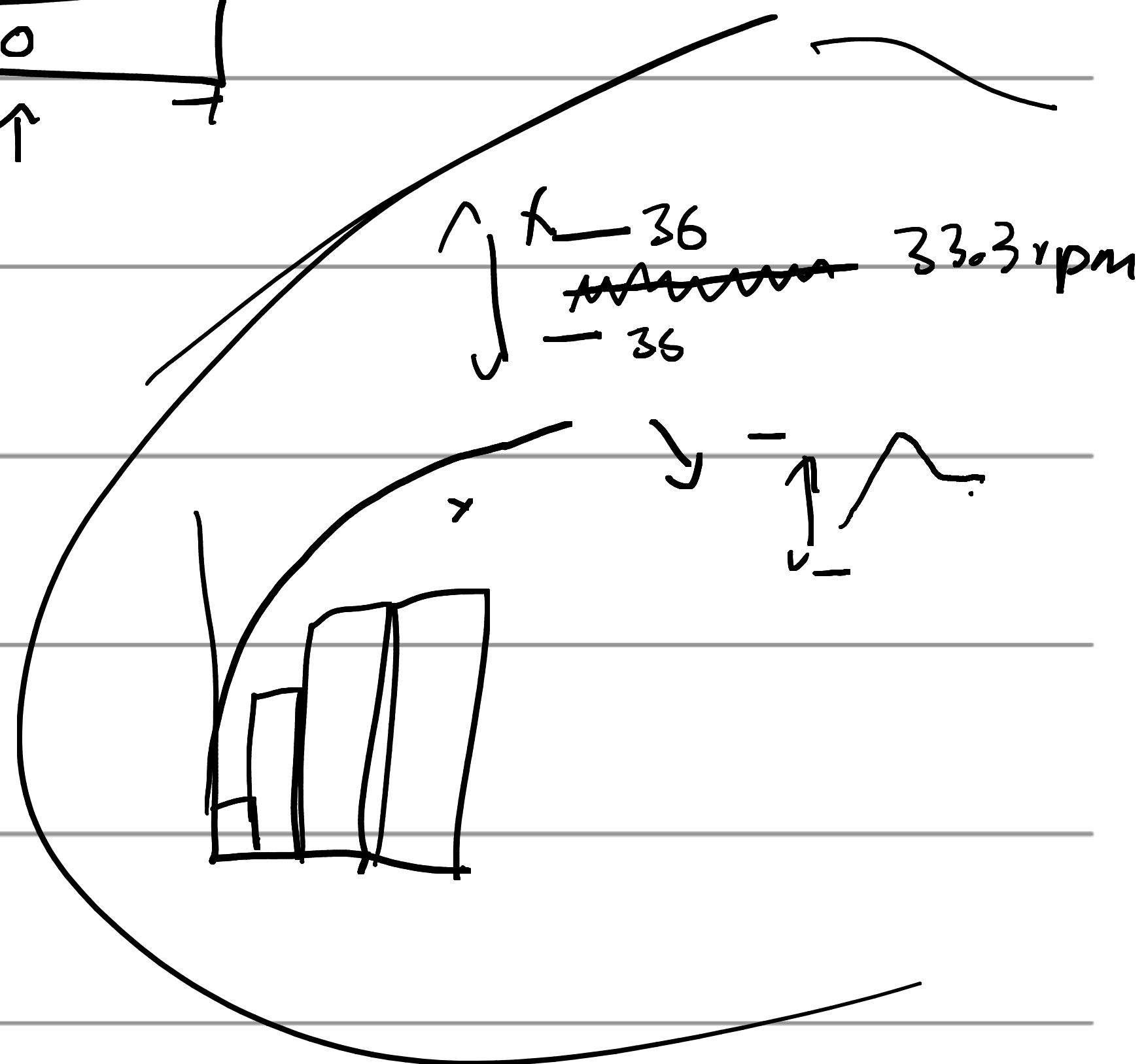
pitch (linear)

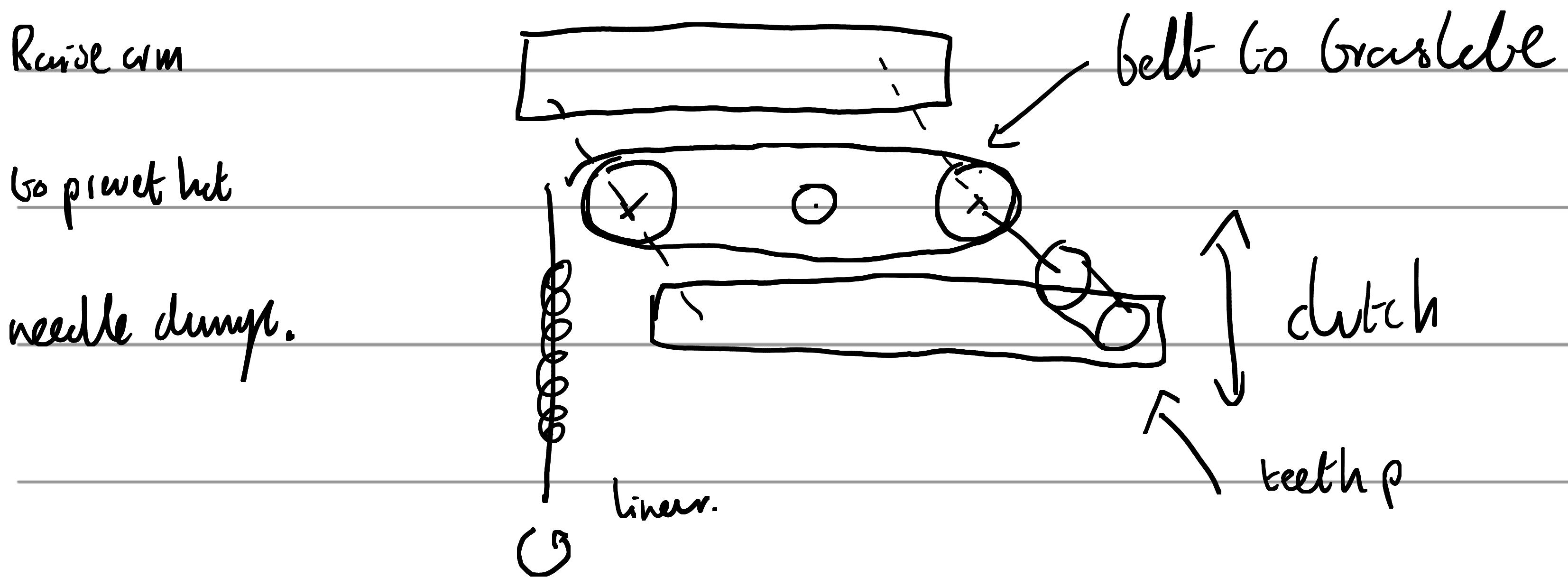
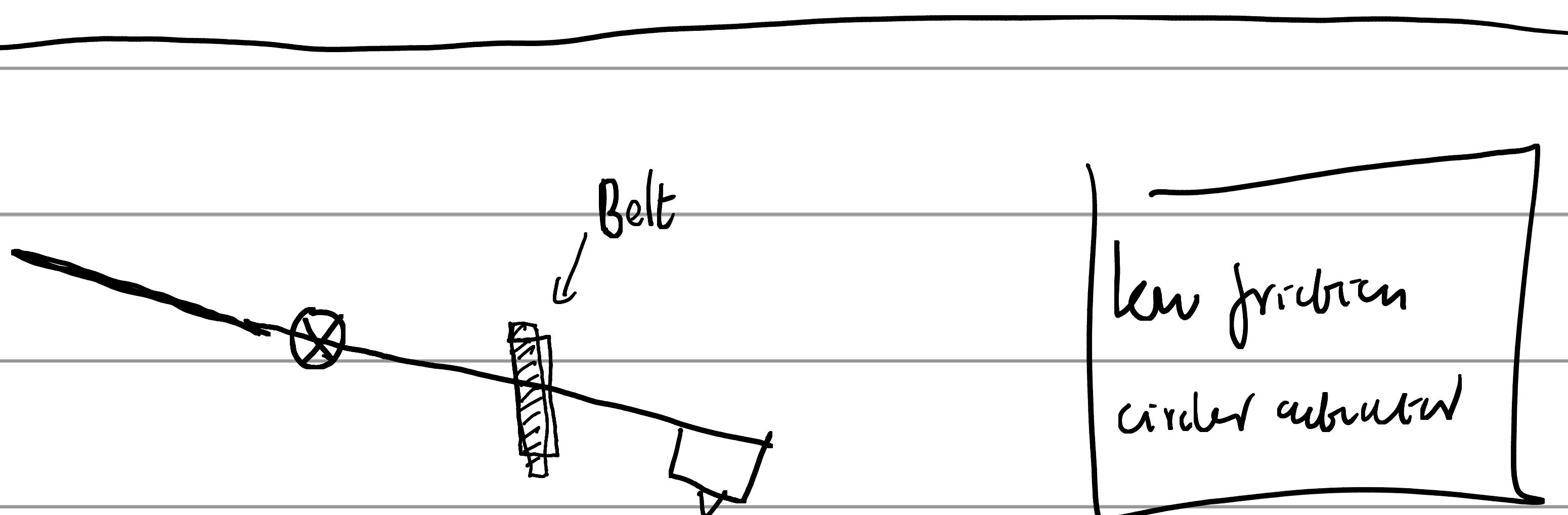
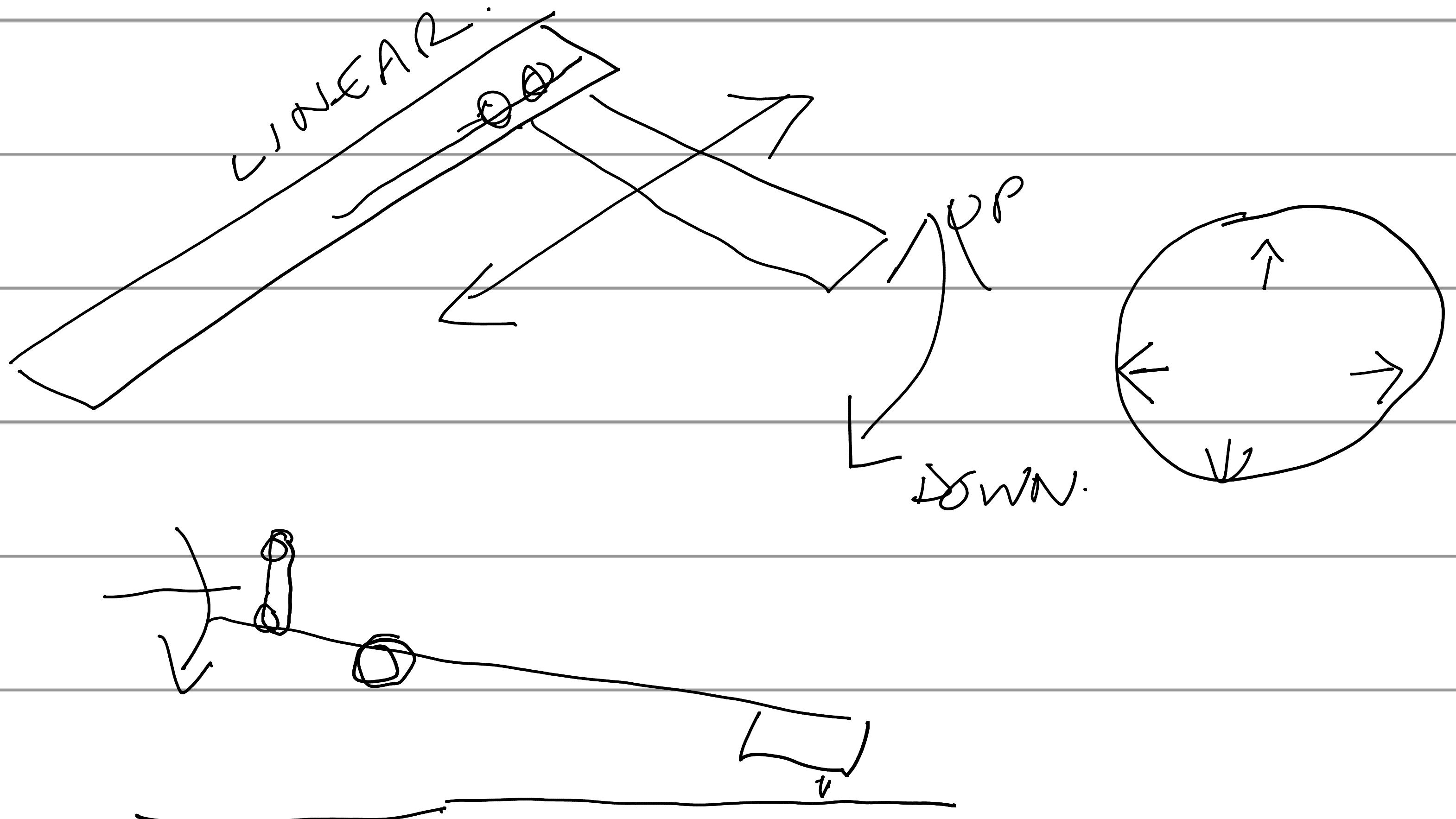
True Speed 33.2 (diagnostic usb)

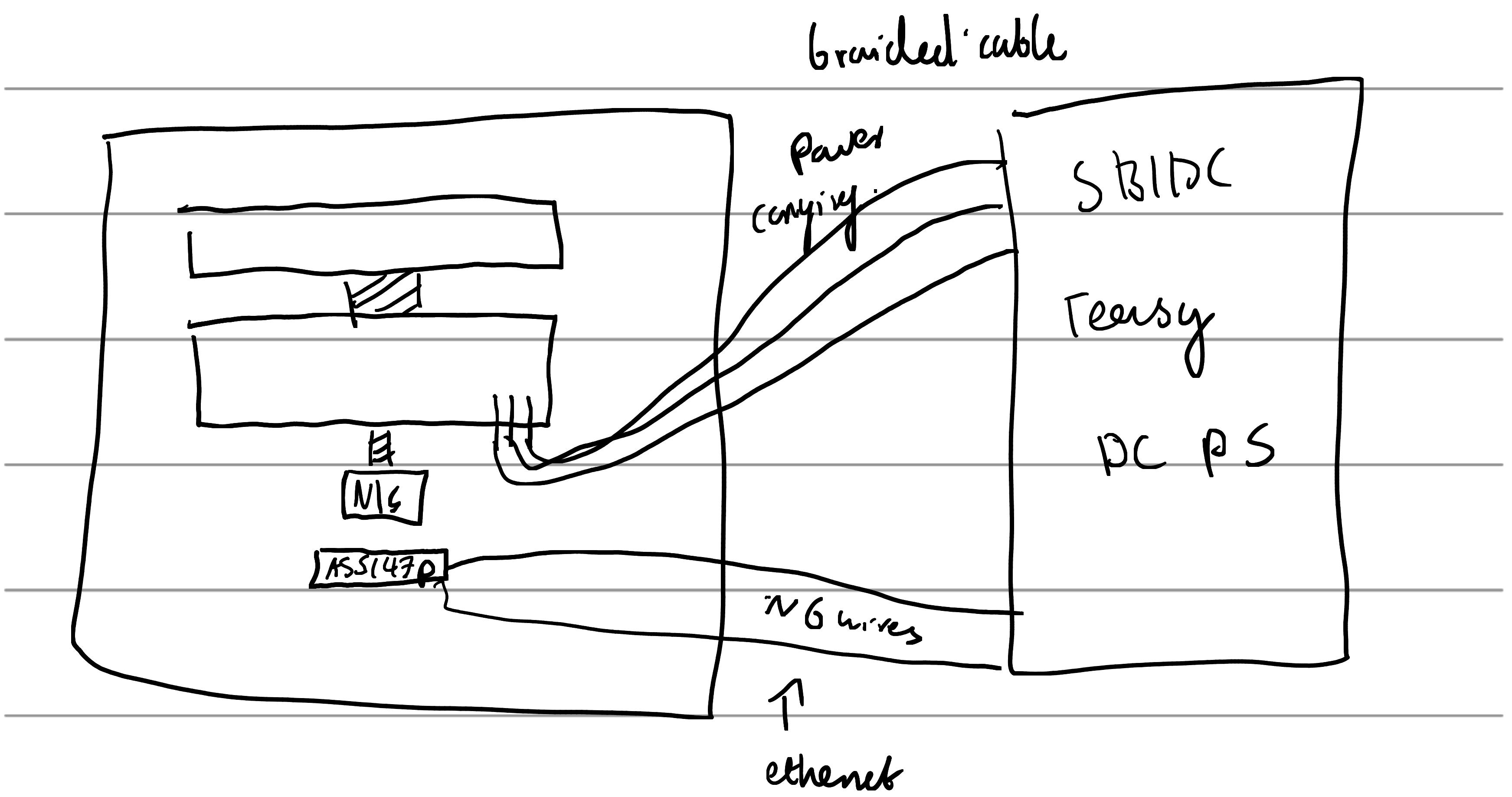
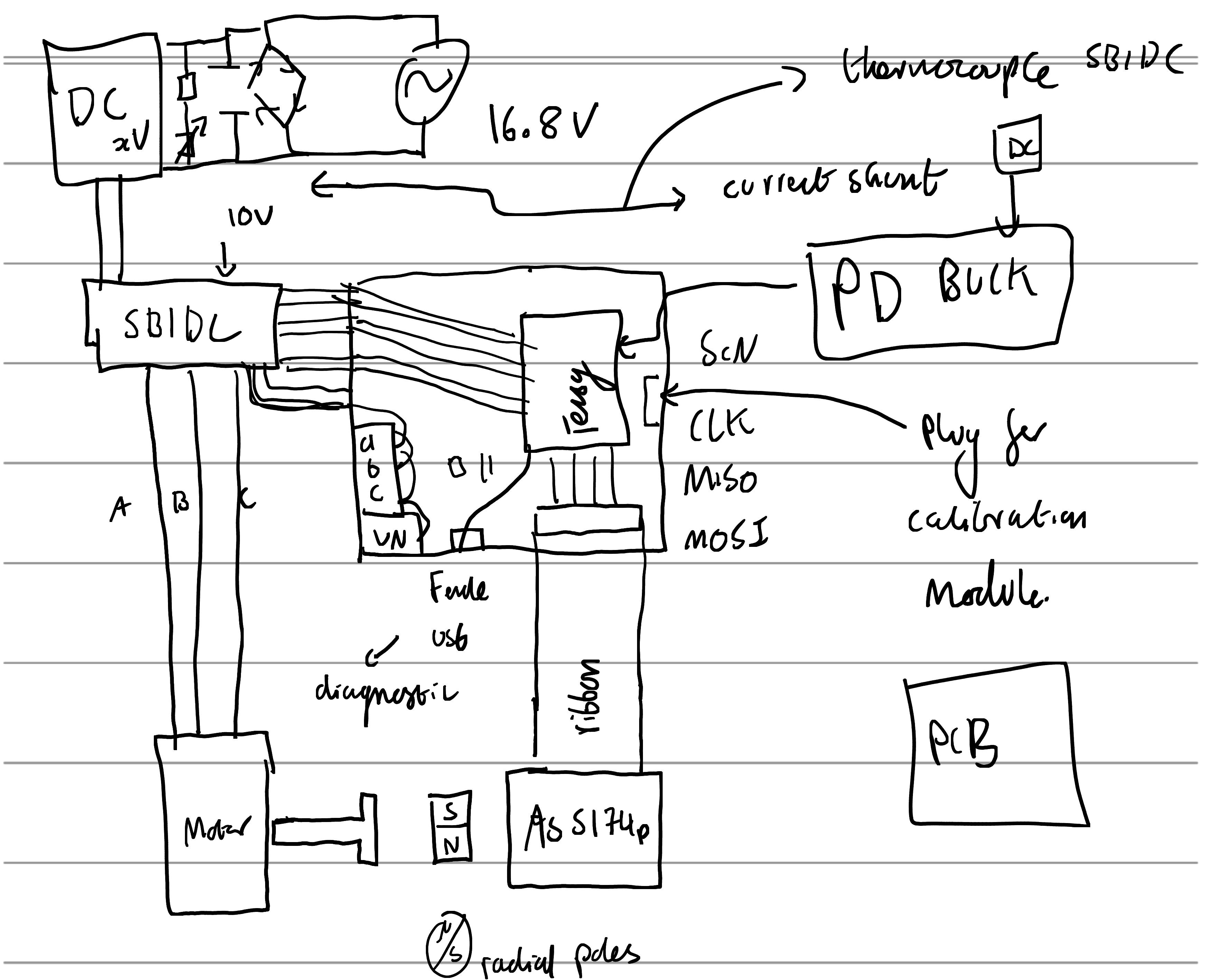
speed (button)
dial

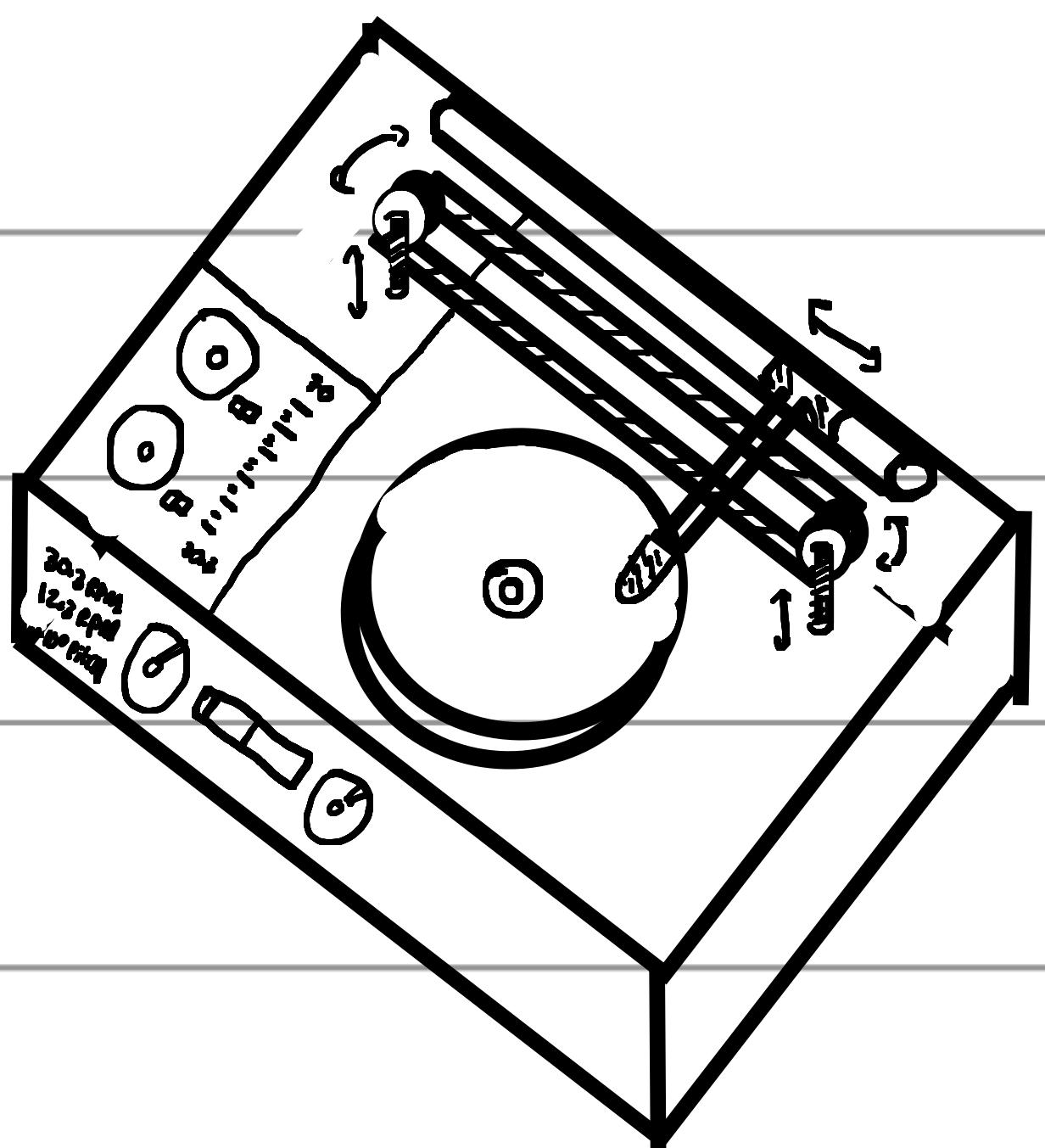
Pitch 0

↓
coarse grain
vs fine grain









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(created sample rate program, capturing cycles @

1,041,611 Hz ... need about $5 \times$! or at minimum 2.84 MHz

removing nano second delay (3ns) ... 1.515064 MHz
removing parity check 1.6744 MHz bad values

running at 816MHz 2,371,990 Hz bad values.

Remove ns delay blocks reading cycle

try 2ns fail

try 3ns 814MHz fail

3ns 720MHz -71.412 MHz

2ns 720MHz → fail why rye missing 8000-16000

$$\text{Sample Rate} = S_R = \frac{2^{14}}{60} \cdot w[\text{rpm}] \quad \frac{60 \cdot S_R = w[\text{rpm}]}{2^{14}}$$

3ns 720MHz $S_R = 1,411,700$

$$w[\text{rpm}] = 1,169,8 \text{ Hz}$$

Code optimised for "fastest" 1,451 MHz

720MHz / Fastest | 3ns

goal 10,416 rpm

1,451,500

$S_{S3} | 5.55 \text{ Hz}$

→ 0.01 steps so

$$\text{best case sample every } \frac{2}{2^{14}} \times 360^\circ = 0.04^\circ$$

This is for target number

10,416 rpm.

For azz12:

target

16,800 Hz

$$\frac{60 \cdot S_R}{2^{14}} = w(\text{rpm})$$

$$w(\text{rpm}) = 5,169.8 \text{ Hz}$$

$$= 0.307$$

16,800



Sample every $\leftarrow \sqrt{0.307}$

0.671 $\leftarrow 3.2496 \text{ steps}$

Min cluster error is about 6.377 steps. X

Trying crasy loop optimisation

1,478379 MHz

1.8% improvement from JCSL

720 MHz, parity removed.

trying remove 3ns delay on last 2 bits.

7.8% improvement

1,565 MHz

~5731.73 rpm.

Remove all logic from last 2 bits, apart from
value shift.

13% improvement

1,651 MHz

5% improvement
from shifting delay

6047 rpm

Convert 16 \rightarrow 32 bits mask 14 1's

goal 2.084 MHz

2.3% input from 16 bits @ 1.69 MHz

alternate 3/2 ns @ 1.743 MHz

all 2ns @ 1.88 MHz

Try no op for wait @ 1.8996 MHz

6956.73 rpm

→ 800 sans
slowly unusable.

1.9 MHz With fewer first no-ops

goal was
2.084 MHz

from 0.2

1.935395

7687.3 rpm

$\sim 86\%$ improvement.

10,416 1.46 steps.

$$@ 16,800 \text{ rpm} \quad \frac{16.8 \text{ k}}{7087.32} \approx 2.37 \text{ steps.}$$

ie - reading the data sheet 2^{14} is not the accuracy of the encoder its 2^{12} , I can see ± 4 steps only so this makes sense.

$$\frac{60 \cdot S_R = w(\text{rpm})}{2^{12}} \quad S_R \text{ best } 1.935395 \text{ MHz}$$

$$w(\text{rpm}) = \frac{281350 \text{ rpm}}{4096}$$

1,935,395

looking at uncalibrated single direct dither errors they were on the order of 6 steps, as we are only getting ± 4 steps, the error is only slightly more than min step size. so worse

target
x

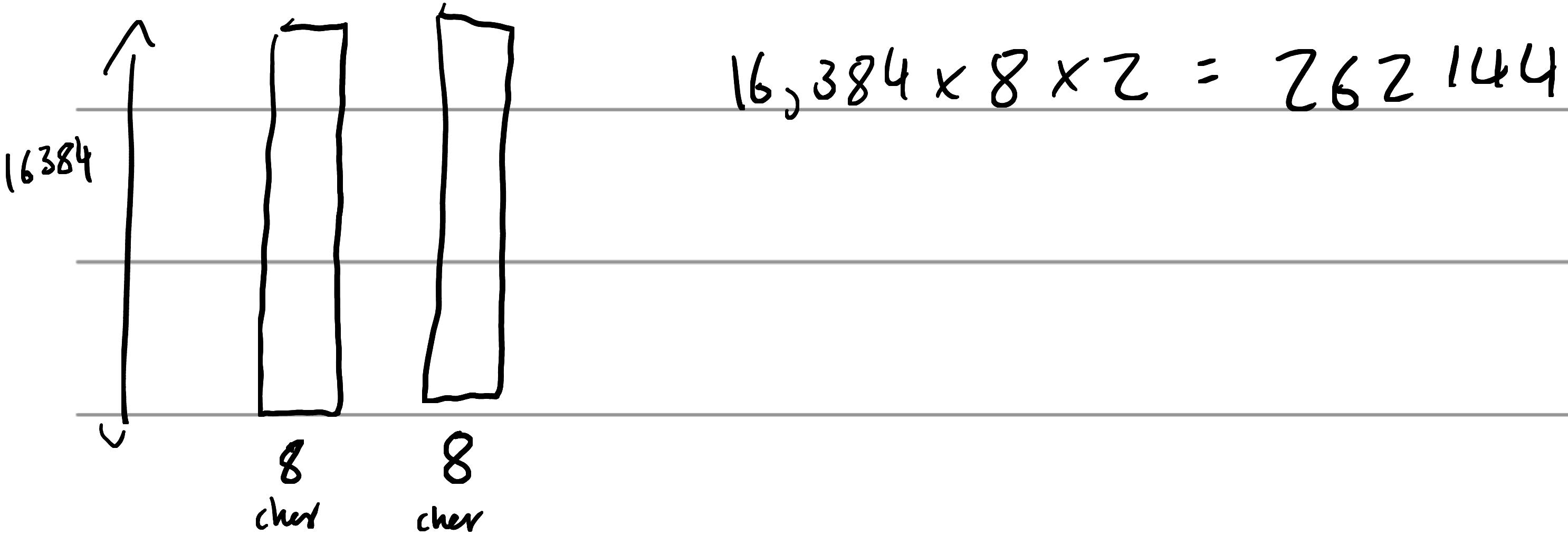
worse case 16

0 4 8 12 16 80 ± 8

| ~~xx~~ ~~xx~~ ~~xx~~ ~~xx~~ |

Another thing the config map was going to be

CW CCW



But in reality there are really only $4096 (2^{14})$

$$\text{so } 4096 \times 8 \times 2 = 65,536$$

would need to build a 2^{12} map &c for cw(ccw), should divide

we angle we get by $4_3 > 7^2$ bitshift. (CANNOT DO THIS) get odd angles at high speed

Should see how fast we can get with overclock using delay
nanoseconds. (try 1ns) interpolation
No NEED

(rate different versions based on different MHz (any clock))

NO NEED
stable @ 600 MHz

(rethink to combine cluster errors ignoring systematic error (multi-scale))

29/9/22

Re-testing fast angle encoder method.

	Smallest freq	Rpm Max	Round down
@ 720 MHz (max double)	1,924,956	28,197	
@ 600 MHz	1,604,086	23,497	
@ 528 MHz	1,411,581	20,677	

To be safe if we are going to do a loop for this we should back off the max speed by at least 10%. even @ 600MHz, with 10% reduction

we are over 21 k rpm.

10% reduction

Renewing clocks
after angle measure.

720	1732460	25377	304
600	1443677	21147	184
528	1270422	18609	112

Important observation, raw angle data does include odd numbers! So the T517up does interpolate at high speed!

Neat! Will have to keep ZC map as a 2^{14} bit number, as bit shifting odd numbers will loose precision. Fine.

So what is left to do:

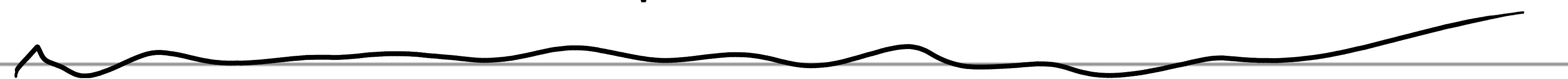
→ Combined cluster errors + burst after shifting clusters from different rows over the top of each other to reveal a cluster error divorced from the systematic displacement.

→ Programmable run-times & (easy ADC exit and to host).

→ Perhaps improvements to sync/sync so that multiple runs are easier to perform.

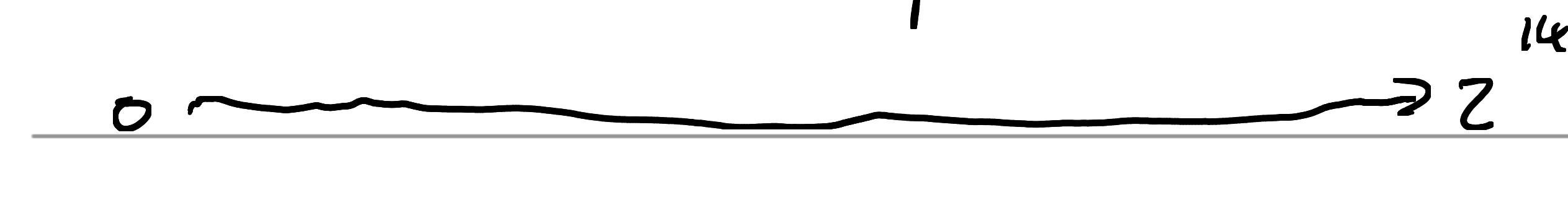
→ Final cw/cw displacement maps.

→ ESC high speed program



Thinking about how to get cluster errors without systematic errors.

We have the unbinned histograms & identifier



dataset 1 111 221 111



dataset 2 1211 111 111
identifier 00000000 1111111111 22222222

dataset
cluster counts
for normalization

↓
we have weighted
histos

don't need

Convert this to

dataset channel i } [angles,] → dataset channel cluster
cluster x }

$M_0 - \bar{c}_m < 0$ M_0 $\bar{c}_m - M_0$ \bar{c}_m M_1 $\bar{c}_m - \bar{M}_1 > 0$ Shift all dataset channel clusters
 $M_0 < \bar{c}_m$ 1111 \bar{c}_m 1111 $\bar{M}_1 < M_1$ to be centered on (\bar{c}_m) , move points by mean
difference of cluster mean center to dataset cluster center

Then recreate histogram (nearest int) with errors

→ merge datasets.

mostly done just need to plot values + best.

For one of

16 Sept - ccw

24 - Sept - arviz - (W -)

Error looks somewhat high, need to check the histogram to check.

2/10/22

Plan for tomorrow:

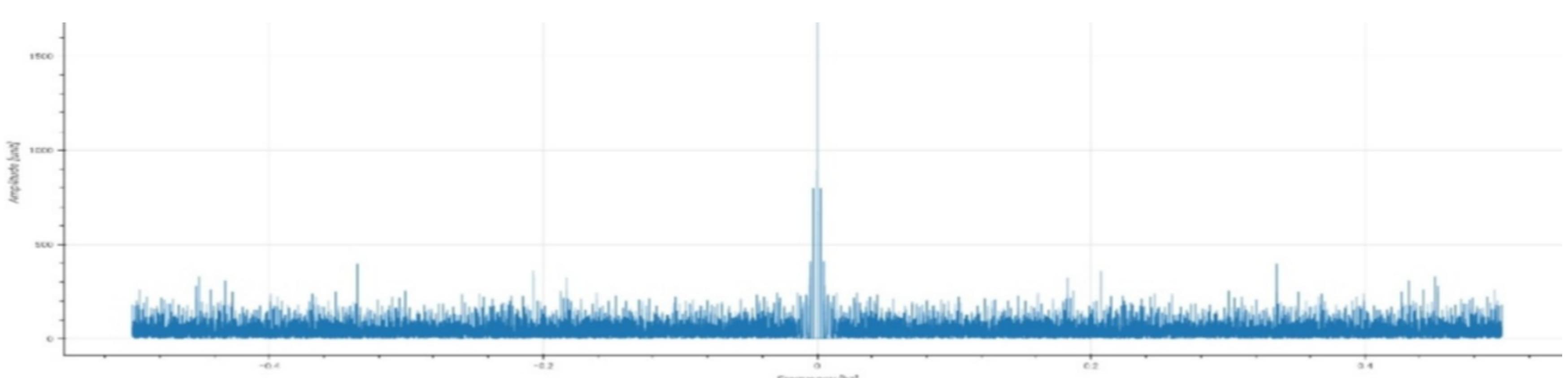
- Plot histogram + errors for merged translated database ✓
- Fix bugs ✓
- Create routine for running ADC collection for a fixed number of ticks. Host program modification, send the number of ticks via arguments. □

→ Finish routine which creates like ESC state up

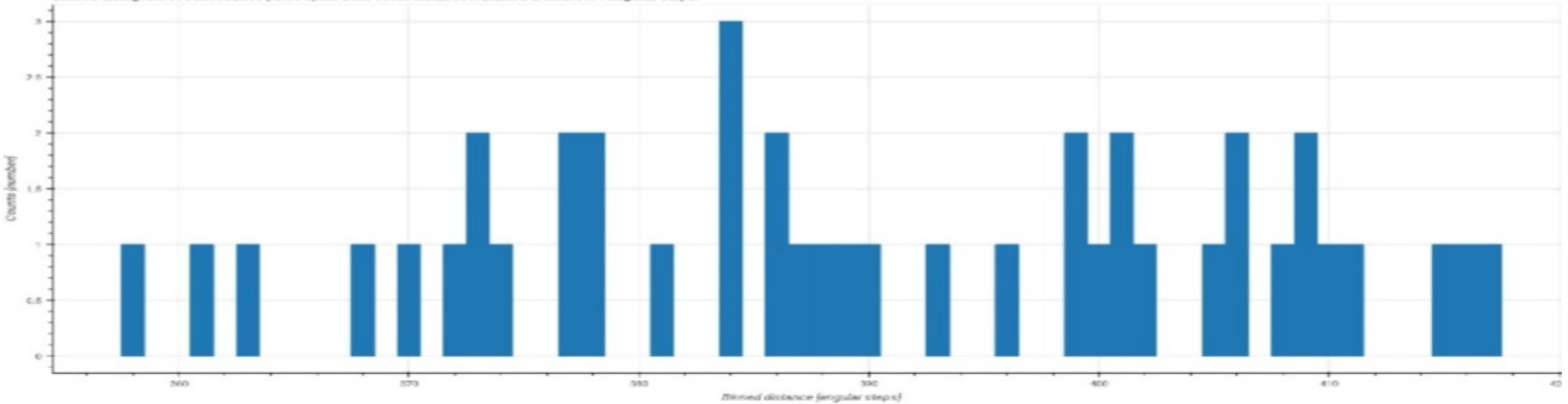
using circular mean of adjacent ZC events.

3/10/22

Finished translated histogram, need to negate brushbars
rather than adding it.



Binned histogram of consecutive pulse spike train event distances. Binned to nearest 1 angular steps.



Quantitative error analysis:

Cluster circular means and error

Mean cluster values and error indicates how well we know the location of the zero-crossing events, measured in [Angular steps]

Channel name	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Min error	Max error	Avg±std error	Min error % of ideal	Max error % of ideal	Avg±std error % of ideal
zc_channel_ar_data	14112.6170±124.0370	7121.9251±119.2398	2444.4419±109.8574	9494.9233±109.1508	179.2747±115.4289	4690.4734±121.2828	11734.8838±113.1370	109.1508	124.0370	116.0191±5.2937	27.9805	31.7966	29.7412±1.3570
zc_channel_af_data	15345.7793±187.3166	5883.7740±182.8516	10612.4580±173.4280	1334.7423±177.1812	8333.1955±184.0374	3549.4929±175.1113	12896.4734±178.1880	173.4280	187.3166	179.7306±4.7174	44.4579	48.0182	46.0735±1.2093
zc_channel_br_data	3172.1043±5.5437	10240.3975±5.5178	14936.5873±4.9961	7933.1039±5.9645	5484.5342±7.2939	12502.8851±5.7892	954.3577±5.2396	4.9961	7.2939	5.7350±0.7048	1.2807	1.8698	1.4701±0.1807
zc_channel_bf_data	6707.1475±41.8562	13707.0745±37.5573	2071.0931±34.6641	9109.3889±38.0131	4300.5924±32.8782	16158.1768±35.4017	11350.5429±39.2377	32.8782	41.8562	37.0869±2.7999	8.4282	10.7297	9.5071±0.7177
zc_channel_cr_data	10989.9241±5.7299	1708.2128±3.8161	6300.5940±5.7999	15756.7832±5.1319	13304.6125±5.4324	8722.7535±5.5221	3926.7893±4.5237	3.8161	5.7999	5.1366±0.6705	0.9783	1.4868	1.3168±0.1719
zc_channel_cf_data	566.9576±37.0307	9871.7574±35.2125	5085.7268±38.5561	14528.6790±38.7479	7531.6080±40.5783	12119.4142±37.7958	2813.8005±33.0995	33.0995	40.5783	37.2888±2.2909	8.4850	10.4021	9.5589±0.5873

Global error:

Global error from ideal symmetry indicates how consecutive zc-event distances deviate from ideal symmetry

- Ideal distance and average displacement from ideal value error: **390.0952±16.0629** [Angular steps]
- Relative error of zc-events from ideal: **4.1177** [relative error percentage]
- Actual measured mean and std dev of displacements: **390.0952±16.0629** | **100.0000±4.1177** [percentage of ideal]

Absolute displacement from ideal symmetry

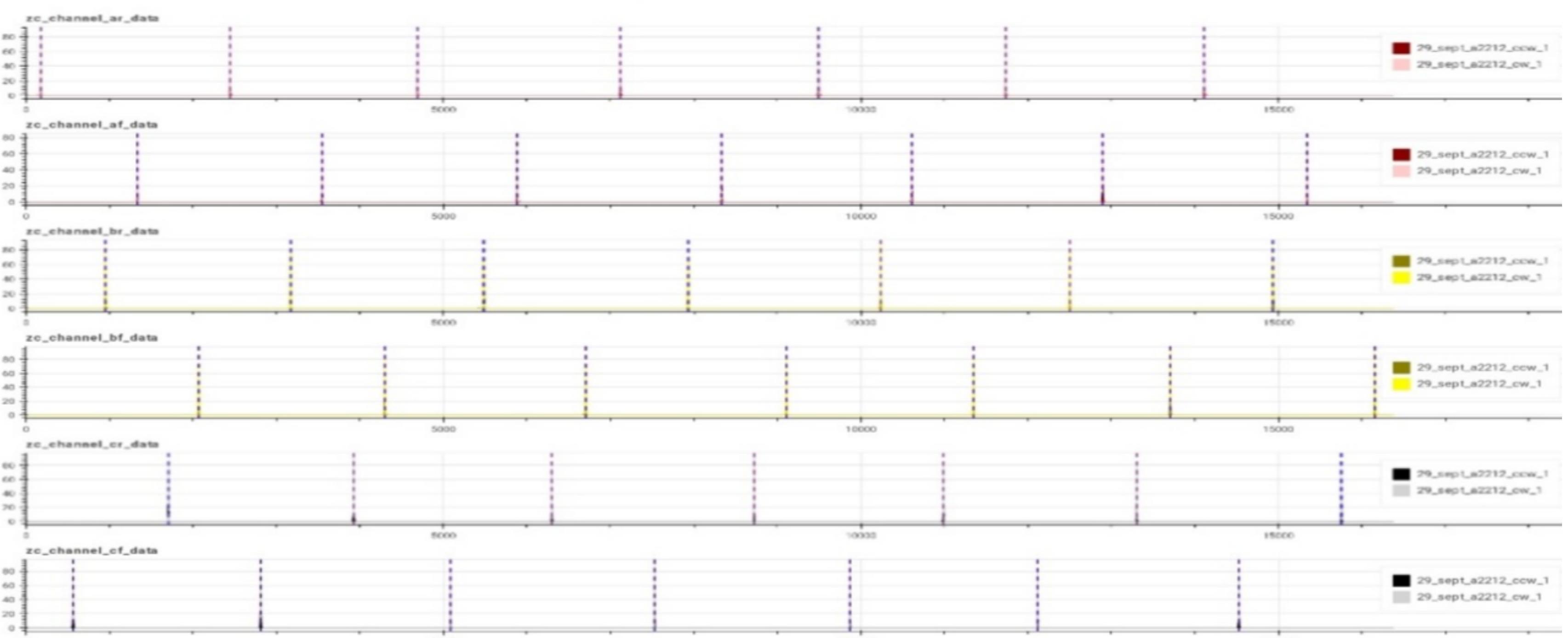
- Min value: 0.2142 [Angular steps] | **0.0549** [percentage of ideal]
- Max value: 31.7914 [Angular steps] | **8.1497** [percentage of ideal]
- Average value: 13.8715±8.0991 [Angular steps] | **3.5559±2.0762** [percentage of ideal]

Displacement from ideal symmetry

- Min value: -31.7914 [Angular steps] | **-8.1497** [percentage of ideal]
- Max value: 26.7248 [Angular steps] | **6.8508** [percentage of ideal]
- Average value: 0.0000±16.0629 [Angular steps] | **0.0000±4.1177** [percentage of ideal]

Translated histograms

By calculating the distance from the mean centers of each datasets channel cluster to the mean center of the merged datasets channel cluster. The histogram values are translated and error recalculated, thus eliminating the systemic error.

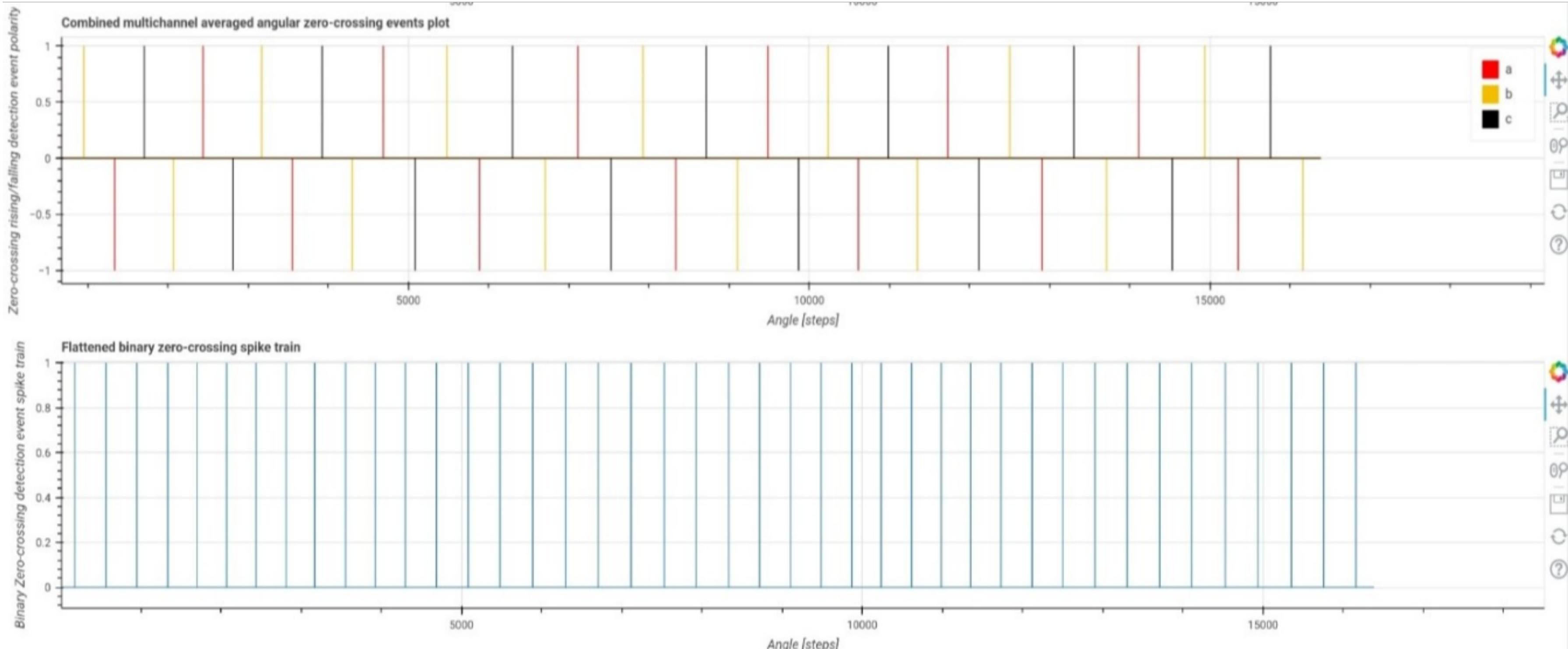


After brushing the cw/cw runs
the max error is dramatically reduced

Quantitative error analysis of translated histograms

Errors calculated by translating each cluster

Channel name	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Min error	Max error	Avg±std error	Min error % of ideal	Max error % of ideal	Avg±std error % of ideal
zc_channel_ar_data	14112.6170±5.6622	7121.9251±5.4831	2444.4419±4.9791	9494.9233±5.3468	179.2747±5.0677	4690.4734±5.1063	11734.8838±4.9239	4.9239	5.6622	5.2241±0.2570	1.2622	1.4515	1.3392±0.0659
zc_channel_af_data	15345.7793±5.5577	5883.7740±5.4595	10612.4580±5.3530	1334.7423±4.9853	8333.1955±5.2960	3549.4929±4.7732	12896.4734±4.7588	4.7588	5.5577	5.1691±0.3033	1.2199	1.4247	1.3251±0.0778
zc_channel_br_data	3172.1043±4.4547	10240.3975±4.4723	14936.5873±4.4923	7933.1039±4.8778	5484.5342±5.6964	12502.8851±4.5472	954.3577±4.7070	4.4547	5.6964	4.7497±0.4116	1.1420	1.4603	1.2176±0.1055
zc_channel_bf_data	6707.1475±5.4183	13707.0745±4.2709	2071.0931±5.0494	9109.3889±4.8261	4300.5924±4.9341	16158.1768±5.2075	11350.5429±4.6332	4.2709	5.4183	4.9056±0.3503	1.0948	1.3890	1.2575±0.0898
zc_channel_cr_data	10989.9241±5.7299	1708.2128±3.5279	6300.5940±4.9521	15756.7832±5.0658	13304.6125±4.6338	8722.7535±4.8334	3926.7893±4.4001	3.5278	5.0658	4.6055±0.4836	0.9043	1.2986	1.1806±0.1240
zc_channel_cf_data	566.9576±4.3949	9871.7574±4.7888	5085.7268±4.6613	14528.6790±4.5797	7531.6080±5.0920	12119.4142±5.0504	2813.8005±4.0328	4.0328	5.0926	4.6572±0.3436	1.0338	1.3055	1.1939±0.0881



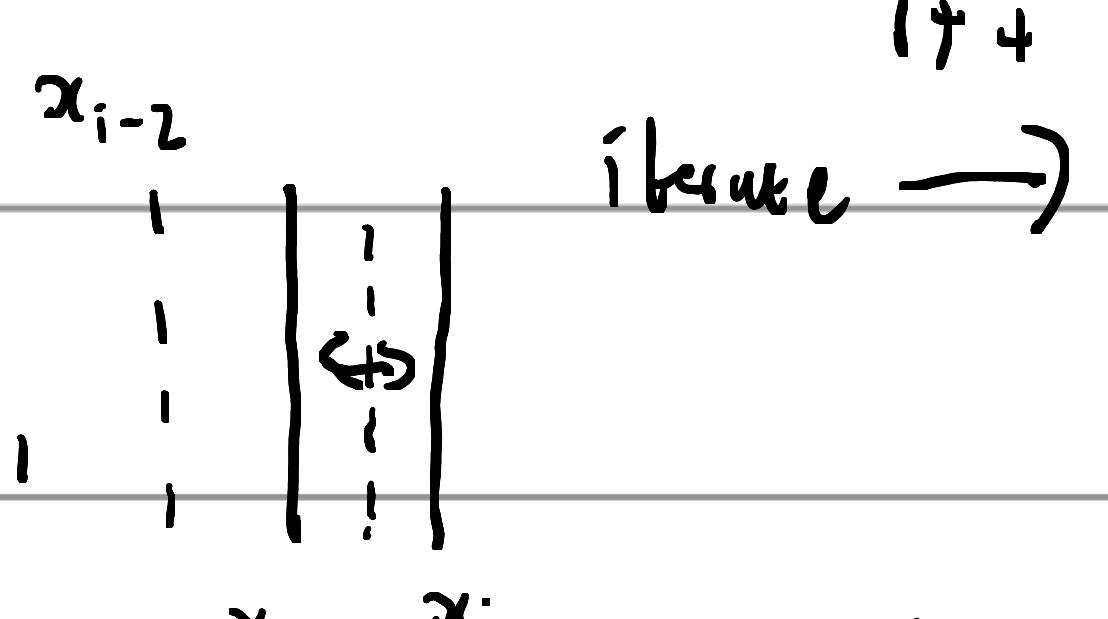
Thinking about final ZC map (state map).

Need function to identify the state state (channel, rising/falling direction)

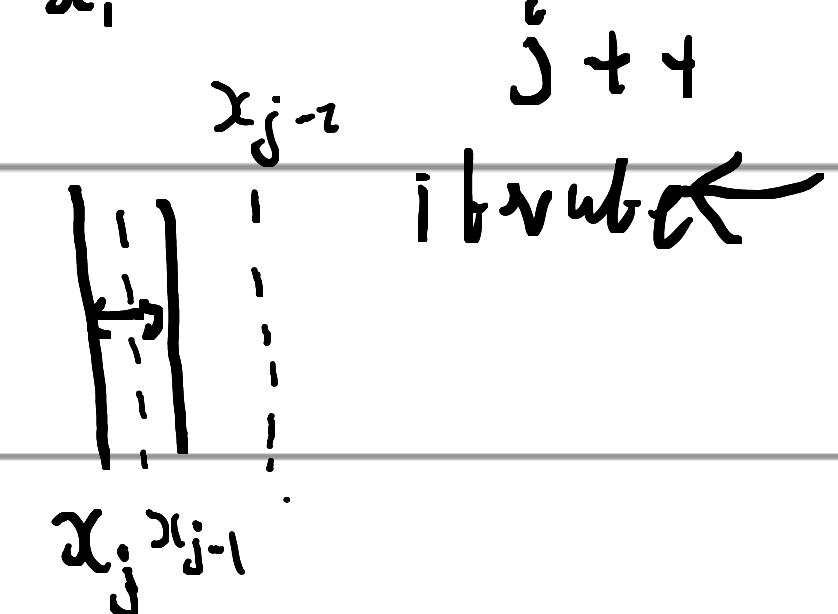
If going cw then circular step ++, ccw -- mean.

Midpoint is circular

If cw
midpoint $(x[i], x[i:\text{len}-1]) + x_{i-1}$



If ccw
- midpoint $(x[j], x[i=0]) + x_{j-1}$



5/10/22

Working on converting mean map into ZL LwLw map.

→ typing mean $\{ \text{"cloud"} : \{ 0 : 179.0 \} \}$
} ordered ZKV

$[(\text{"cloud"}, 0, 179.0), \dots]$

Take reverse for other direction.

Take midpoints of consecutive pairs, don't forget about $\text{idx}=0$ get last for the pair from end of sequence.

For range (distance) careful of -ve bracket

Mark angles displayed from c-valve (angle) away I saw

Start

plot binary state map for CCW ✓

Think I've made a mistake with the state-map. I think each needs to be shifted by 1 step (respecting cw+ve ccw-ve)

Counter-clockwise rotation (-ve)						clockwise rotation (+ve)						(W correct ✓)								
ESC	5	4	3	2	1	0	ESC	0	1	2	3	4	5	ESC	0	1	2	3	4	5
IN	C	C	B	B	A	A	IN	A	A	B	B	C	C	IN	A	A	B	B	C	C
SD	B	A	A	C	C	B	SD	B	C	C	A	A	B	SD	B	C	C	A	A	B
RISING	A	X	C	X	B	X	RISING	C	X	A	X	B	X	RISING	C	X	A	X	B	X
FALLING	X	B	X	A	X	C	FALLING	X	B	X	C	X	A	FALLING	X	B	X	C	X	A

This is expected to trigger this state

This is expected to trigger this state

S 4 3 2 1 0

0 1 2 3 4 5

Rising / Falling indicates the NEXT expected edge. (Check code!)

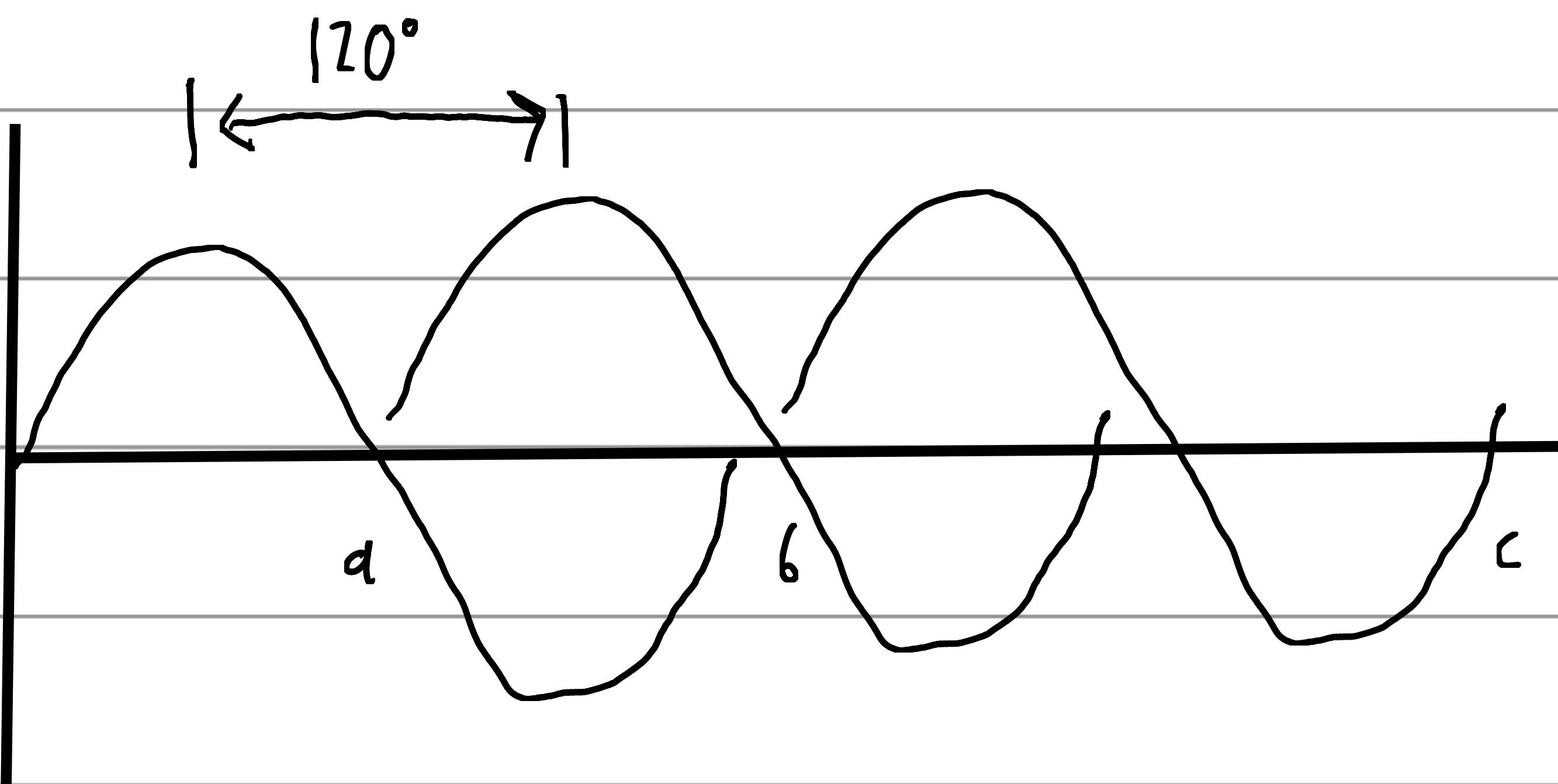
CCW						CW							
state	5	4	3	2	1	0	state	0	1	2	3	4	5
rise/fall	↓	↑	↓	↑	↓	↑	rise/fall	↓	↑	↓	↑	↓	↑
phase detect	C	A	B	C	A	B	phase detect	A	C	B	A	C	B

I think current version is correct.

Next steps:

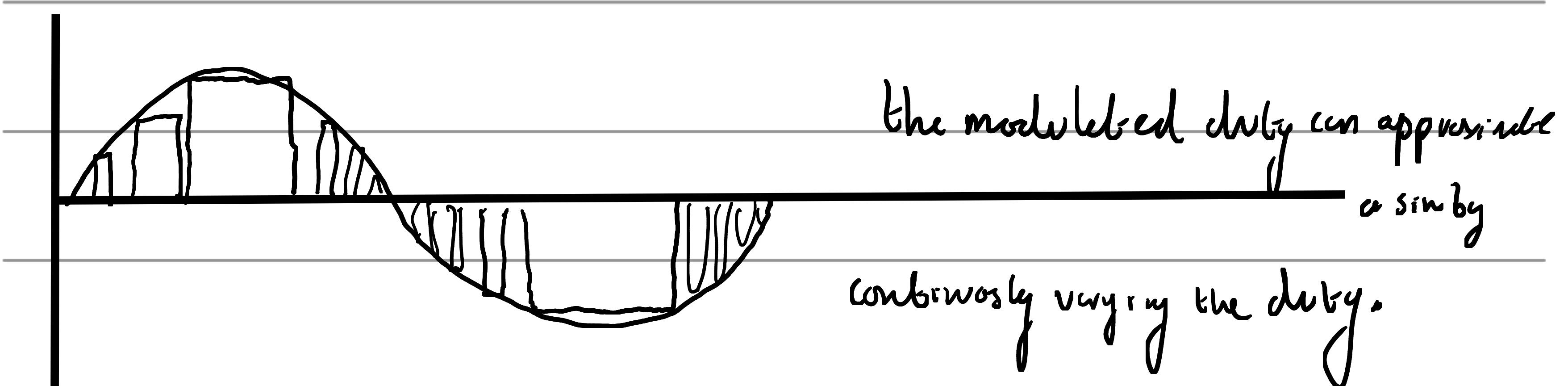
- Validate state map
- Create cpp file with statemaps for ESC
- Fix measurement in ticks 32 bits? (msg), end signal sym escape.
- ESC program
 - New even numbers concern
 - ESCusb decode logic (interrupts!) carefully, perhaps fix max duty electronically.

Alternatives simple sinusoidal commutation



change position of phase A, keep phases A, B, C 120° separation.
to change position *

(constructing a sinusoid via duty cycle.)



Where does the negative polarity come from?

