The Z4D-C01 Micro-displacement Sensor

The Z4D detects the distance between its mounting reference plane (see figure x) to an object up to 6,5 mm (± 1mm) away by triangulation (see figure x).

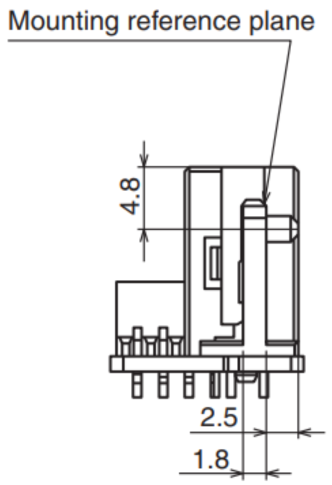

Figure x. Side view of the Z4D with an arrow pointing to its reference plane.

It has a max resolution of 10 microns, assuming a supply voltage ripple of 10 mV max. This also increases as the distance increases.

It gives the distance as an analog output between 0.2 - 4,7 V (Vcc = 5V).

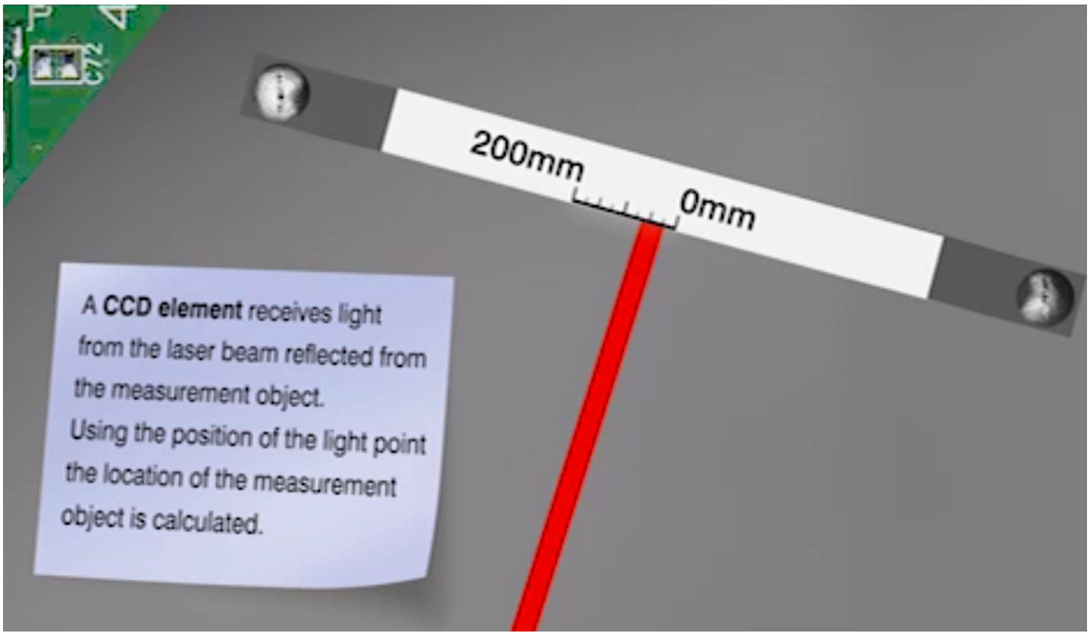

Figure x. A picture showing how laser triangulation works.

The Z4D needs a 3,5 - Vcc voltage pulse signal to control the LED used for triangulation.

The CNC Archimedean spiral (aka snail)

The Z4D is used in combination with the snail. This is due to the fact that each point on the circumference of the spiral gives a unique radius and thus unique angle.

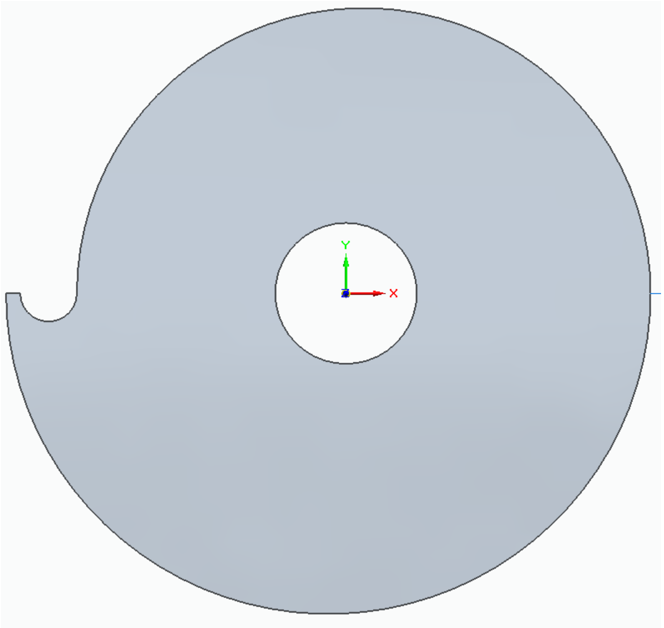

Figure x. The design of the snail.

The difference between the highest and lowest point is 2,5 mm. We got this number from testing the Z4D on a vice (see figure x), moving the Z4D closer/further away from an aluminium block and checking the output voltage on an oscilloscope and checking what distances the voltage peaked and dropped to 0.

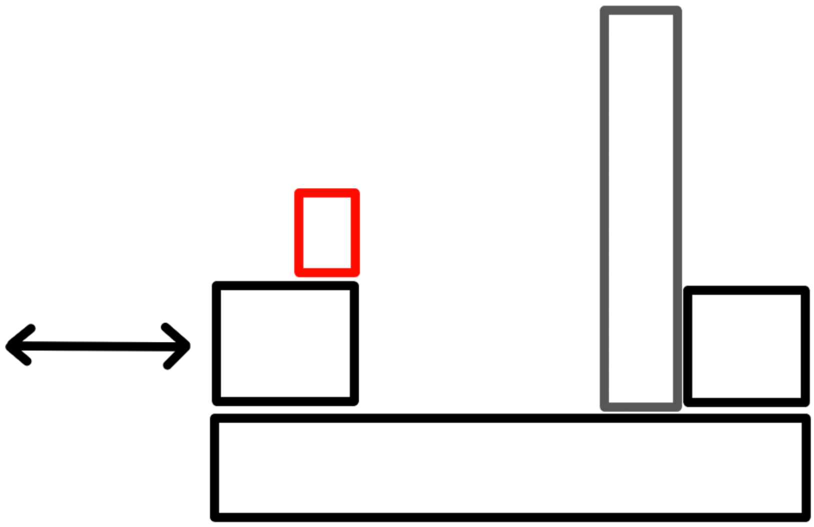

Figure x. The vice testing setup. Red = Z4D, Gray = aluminium block, Black = vice.

The HEDS-9040 optical encoder and codewheel

The HEDS has a resolution of up to 2000 counts per revolution.

It contains a single LED as its light source which is collimated into a parallel beam by means of a polycarbonate lens. Opposite the emitter is the detector circuit. This circuit consists of multiple sets of photodetectors and signal processing circuitry which produce the digital waveforms.

A codewheel rotates between the emitter and detector causing the light to be interrupted by the pattern of spaces and bars on the codewheel. The photodiodes are arranged in a pattern that corresponds to the radius and design of the codewheel.

The detectors are spaced such that a light period on one pair of detectors corresponds to a dark period on the adjacent pair of detectors which results in a three channel output.
(A, A’, B, B’, I, I’). Channel I is only used as an index pulse which is generated once for each full rotation of the codewheel. With this you can decode the position of the codewheel by observing the state of the A/B channels.

Power

The gimbal is powered with a power supply that is wired onto the metal parts of the gimbal (ball bearing and its holder) which in turn drive the current to the inner frames without the need to use slip rings or batteries.

The capacitors were added later due to the power delivery being unstable most likely due to the ball bearings rotating and/or wires not getting adequate contact with the metal parts. This helps reduce ripple and keep the current high enough so that the microcontrollers don’t power off during operation.

The capacitors are 2700uF, the supply voltage works fine at around 10V.

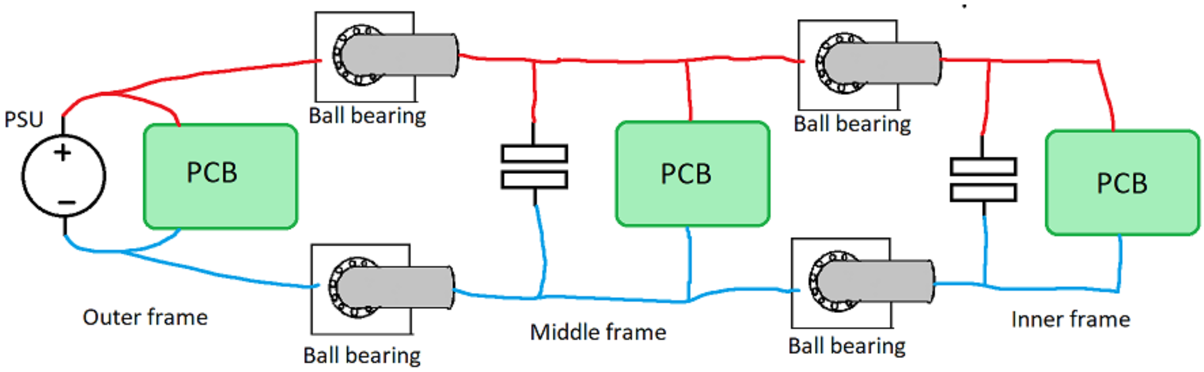

Figure x. The circuit diagram of the gimbal power supply.

PCB

The PCB is the part that links all the power and microcontroller dependent components together with their required infrastructure such as resistors and capacitors.

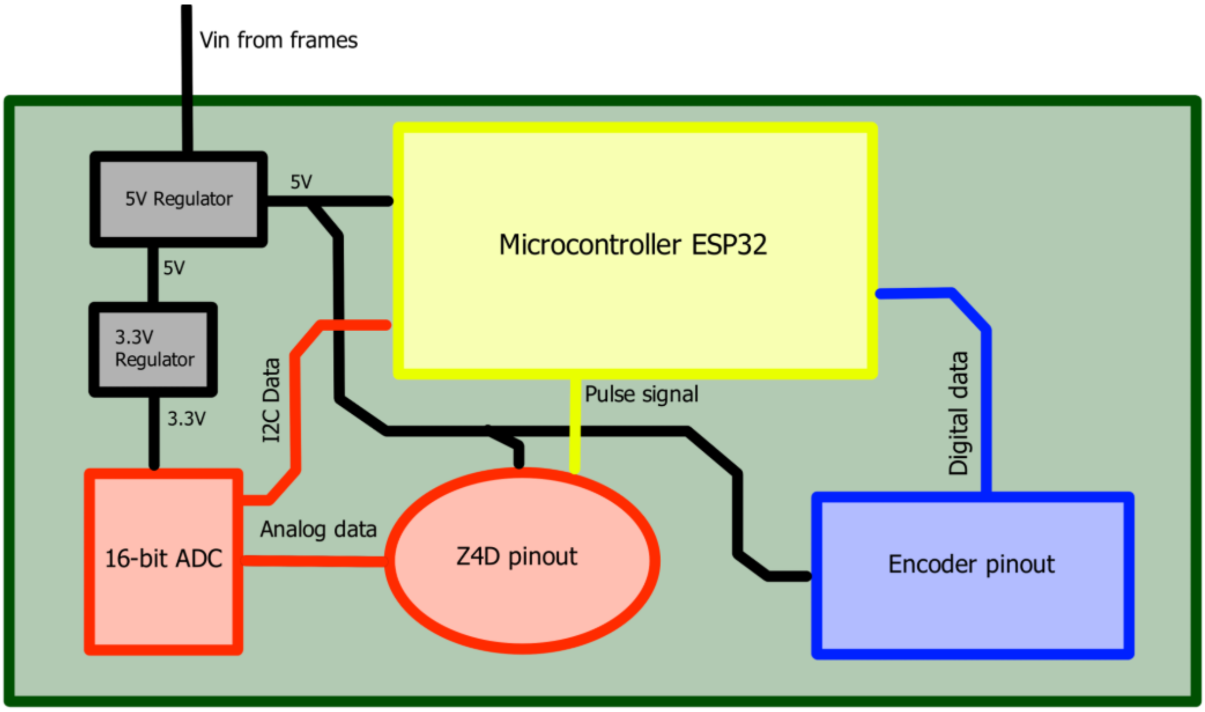

Figure x. Simplified PCB layout. Black = power, Red = Z4D, Blue = HEDS, Yellow = ESP32.

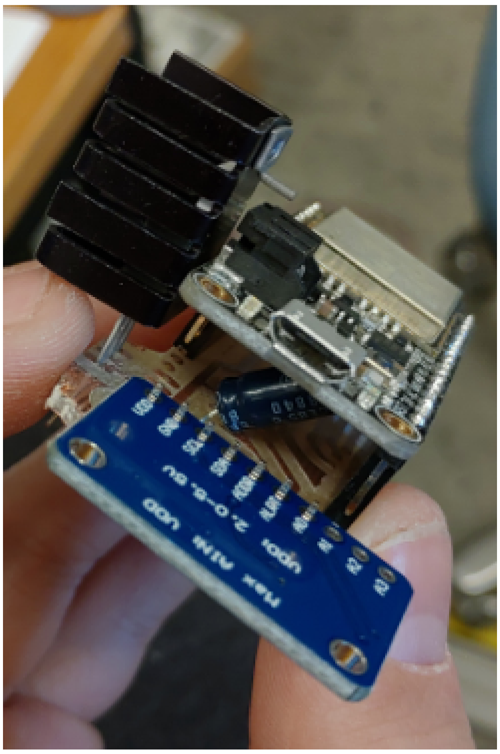

Figure x. How it looks in real life.

The cage

A 1.5U CubeSat must have its centre of gravity in a certain region surrounding its geometric centre. Adjustment along the CubeSat z axis could be solved by designing the cage in which it is confined to be at least 60 mm longer than the CubeSat and a mechanism was made to make up to 20 mm adjustments in the xy plane.

The cubesat is shifted in the xy plane by means of lead screws that are rotated to move it. One unavoidable issue with this design is that both sides of the cage must be screwed simultaneously.

The rails were deliberately made 60 mm longer than the CubeSat to account for the possible maximum CoM displacement in the z direction. Thus, the only mechanism needed was one that could lock the CubeSat in place and translate it along the rails. To accomplish this, two threaded M3 steel rods and three custom CNC parts were used.

Frames

The frames are made out of carbon fibre tubes, aluminium CNC parts and 3D printed parts stuck together with two part epoxy adhesive.

All of the frames are held up with an assortment of X-shaped aluminium rods that can stand on its own on a flat surface.