

DATA SHEET
"CYA-A38, CYA-A38-AI1
CYCLOPS™" SINGLE MIRROR DEFLECTION SYSTEMS

NEWSON NV

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1 SAFETY WARNINGS

THE CYCLOPS ACTUATOR HAS A VERY STRONG OPEN MAGNETIC FIELD AT MIRROR SIDE.
KEEP MAGNETIC PARTS AWAY FROM THE DEFLECTORS MIRROR SIDE.
TAKE PROPER PRECAUTIONS WHEN HAVING BODY IMPLANTS (PACEMAKER, HEARING AIDS...)

WHEN A CATASTROFIC FAILURE OCCURS, INCIDENT LIGHT MAY LEAK THROUGH THE BACKSIDE OF THE DEFLECTOR. ADDITIONAL COVERING MAY BE NEEDED TO GUARANTEE LASER SAFETY WHEN USED TO DEFLECT HIGH ENERGY LASERBEAMS.

2 CYCLOPS™

While straight forward, using two mirrors for 2D positioning an optical beam has some drawbacks. Size of the mirrors is one of them. Real-estate needed to integrate the deflection system in a machine is another. Using a single mirror design, the CYCLOPS™ actuator family provides an efficient alternative for 2D optical beam positioning. When compared with a traditional 2 motor mirror solution, a single mirror solution brings some obvious advantages:

- Total system size is much smaller
- Optical losses are reduced by 50%
- Perfect tele centricity is achievable
- The size of the moving mirror is much smaller
- No torsional forces inside the mirror substrate

All members of the CYCLOPS™ actuator family are implemented as smart deflectors. Accuracy and speed are optimised by using actual mirror position tracking. All regulation electronics needed to drive and position the mirror are integrated within the body of the actuator.

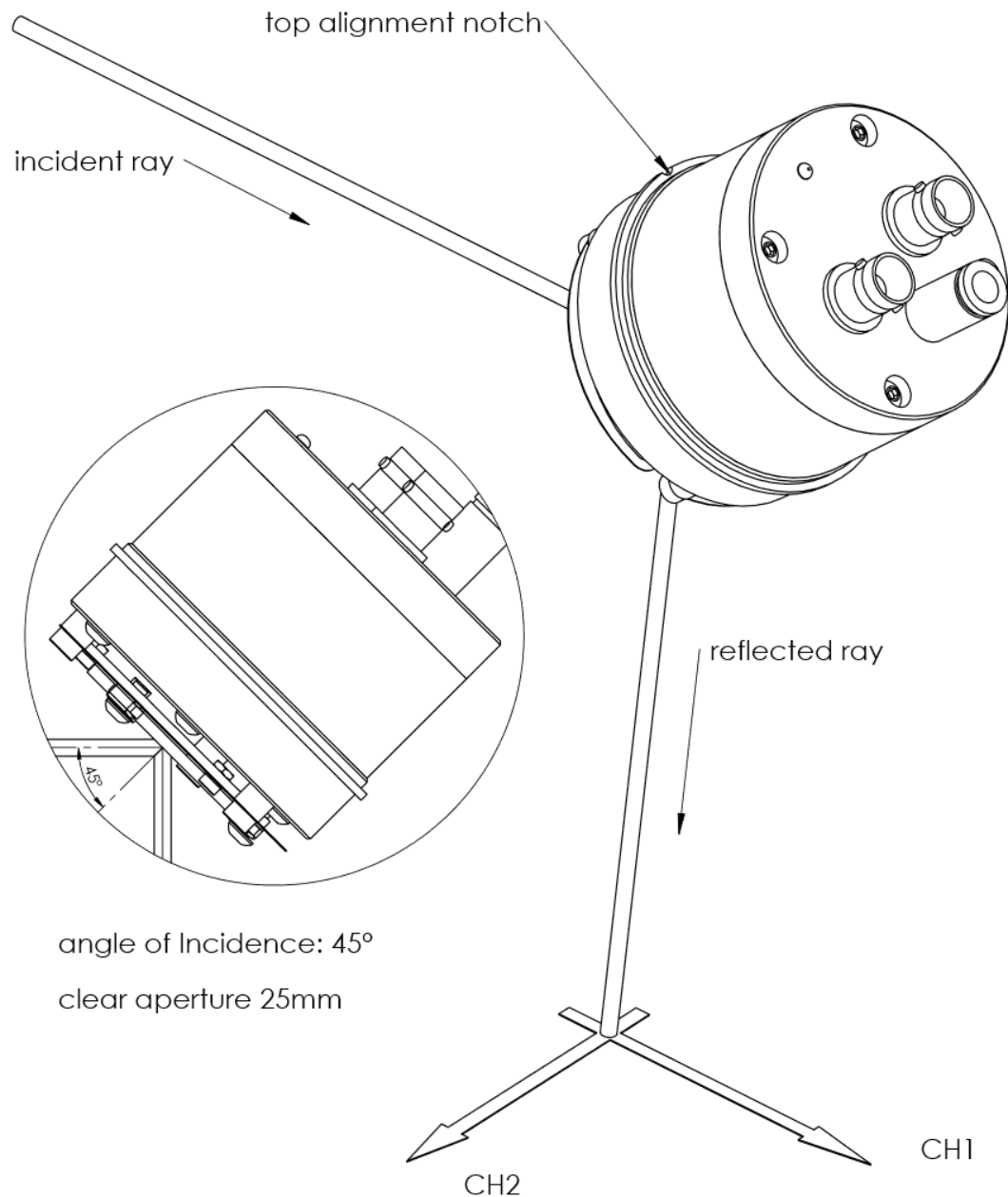
The CYA-A38 CYCLOPS™ deflector is a smart deflector comprising all electronics to control the mirror tilting. Two coaxial connectors, CH1 and CH2, are provided for power supply and exchanging setpoint and actual values for X- and Y-axis. The use of a dual coaxial connection between steering electronics and CYCLOPS deflector makes upgrading from a dual motor-mirror implementation straight forward. A 32-bit DSP controls the entire system. The CYCLOPS™ actuator can be directly connected with a regular CUA32™ control card. Several front ends are available for connection with third party control cards. (XY2-100, analog,...).

The CYA-A38 Ai1 CYCLOPS™ is a smart deflector that can be operated without any additional electronics. This actuator is able to generate setpoints, handle image calibration and gate a laser all by itself. An 8 pin M12 style connector provides connectivity with any host computer or PLC over an ethernet connector. The device is fully compatible with the 802.3af power over ethernet standard.

True to our company philosophy, low power supply needs and integration flexibility are additional advantages resulting from our approach to a single mirror 2D deflector design. In a typical 45° setup, a CYA-A38 actuator provides a 2D solution with a clear aperture of 25 mm while consuming only 2Watts of energy. Said low power needs are achieved by using moving coil technology in combination with high efficient class D amplifiers. A CYCLOPS™ actuator only has two basic parts. The stator comprises magnets and electronics while the mirror mount, a freely moveable printed circuit, holds the actuator coils and provides support for the mirror. The stator generates a magnetic field that extends outside the actuators body. The mirror and its mount freely float within this field and is kept in position by regulators and plate springs. The X and Y steering commands supplied to or by the deflector are translated into hover values to get the required mirror tilt angles. The tilting forces are generated by interaction between the magnetic field and electrical currents flowing through the mirror mount. The latter is kept above the stator by said springs. The springs also serve as electrical connections between amplifiers and actuation coils. Multi point height sensing (AIMS) achieved by means of transformer style couplings between mirror mount and stator completes the dual axis closed loop mirror tilting.

When used with high power lasers (>1KWatt), it is advisable to cool the mirror. For this purpose, the deflector has an air inlet connector. The coolant gas blows through the entire deflector to cool the back side of the mirror. The flow also helps to cool the deflector itself. Most optical mirrors have dielectric coatings guaranteeing reflection above 99%. Not reflected light however will be absorbed by the deflector. Assuming a 1KWatt beam and a mirror with 99.5% reflection results in 5Watt optical power that will leak into the deflector. This level is more than twice the power consumed by the device itself. Using mirrors with backside coating will help to reduce this thermal loading. The CYA-A38 Ai1 can also be fitted with a sensor to measure the mirror back temperature. The integrated steering electronics can then use the samples to abort operation when the mirror becomes too hot.

3 SETUP



When a ray is reflected on a rotating mirror, the angle between incident and reflected ray changes twice the mirrors rotation angle. This statement is true when the mirror rotating axis is perpendicular with the ray. In this setup the rotation axis in CH1 direction is perpendicular while the angle between ray and the rotation axis of CH2 is 45°. As a result, the optical deflection angles of CH2 are attenuated. The resulting marking field becomes rectangular. The deflector maps CH1 and CH2 setpoint data into mirror hover positions to achieve the desired tilt. A compensation strategy is used to counter said angle reductions and make the marking field more squarish. All CYCLOPS™ actuators have a mechanical mark in the shape of a notch or arrow. This mark should be oriented on the top side, pointing towards the laser source.

4 TYPICAL CHARACTERISTICS CYA-A38, CYA-A38-AI1

4.1 SPECIFICATIONS

General

Actuator principle	moving coil	
Coil inductance	4	μH
Coil resistance	250	mOhm
Regulator	digital 20 bit	
Amplifier	class D	
Mirror position sensor	AIMS (patented)	
Electrical connection CYA-A38	2x 50 Ohm BNC	
Electrical connection CYA-A38-AI1	M12 ethernet	

Mirror

diameter	38.1	mm
thickness (preferred)	2	mm
cooling air flow connector	6	mm

Positioning (optical angles)

Rated angular excursion CH1 (1)	240	mrad
Rated angular excursion CH2 (1)	240	mrad
Regulation jitter (peak to peak) at one sigma	15	μrad
Drift measured over 8 hours	10	μrad
Repeatability	10	μrad
Step response 24 mrad, settling to 200 μrad	10	msec
Step response 2.4 mrad settling to 200 μrad)	3	msec
Track delay	700	μsec
Bandwidth	500	Hz

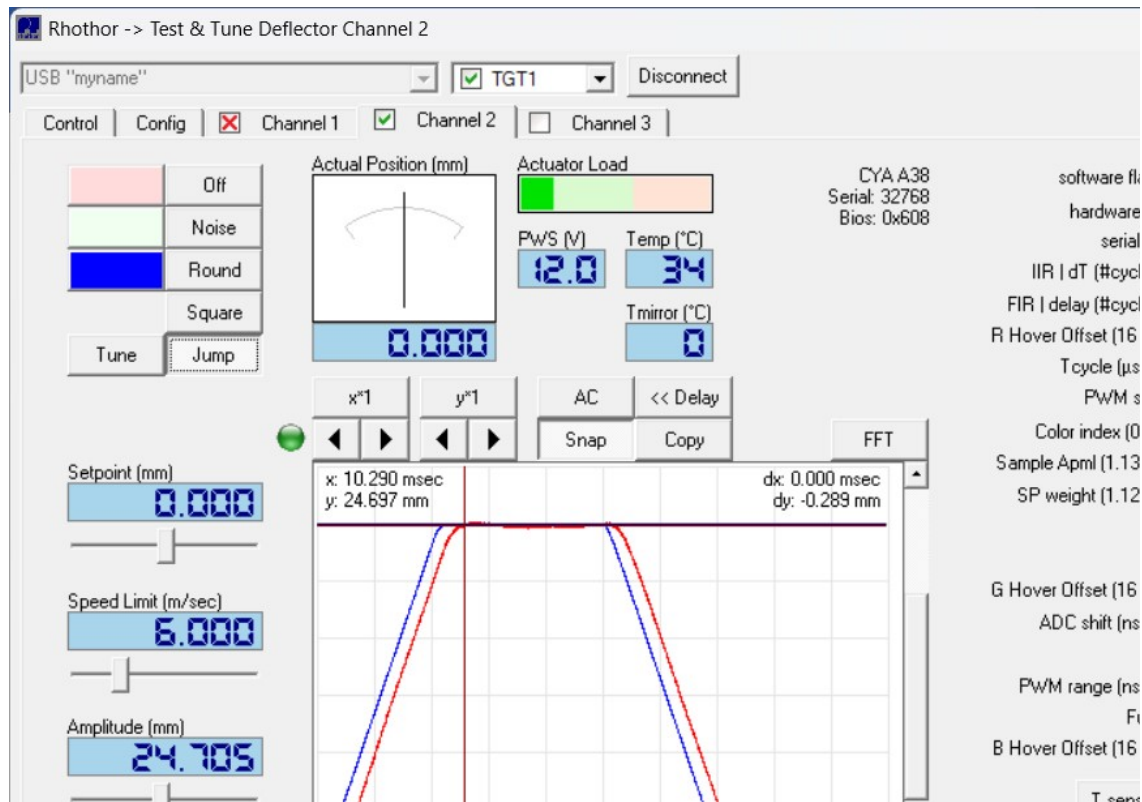
(1) angular ranges when deflector is mounted like described in chapter 3

Temperature

Operating ambient temperature	-10 to +50	°C
Storage temperature	-10 to +60	°C

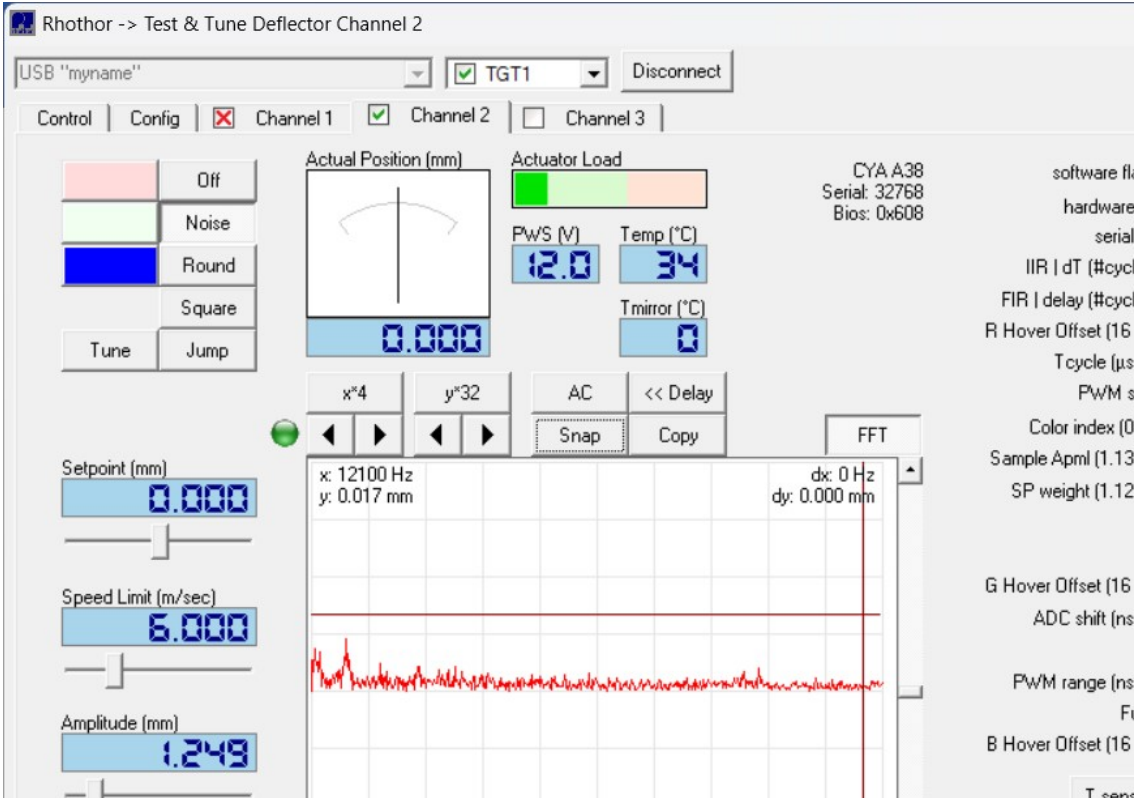
4.2 STEP RESPONSE

All tests were done using a CUA32 control card and rhothor software. The system was set up as drawn in chapter 3. Distance between mirror (fused silica 38.1x2mm) to surface was 1000 mm and the field was calibrated to 240*240 mm. Setpoint speed and bandwidth were software limited (6000 mm/sec and 700 μsec).



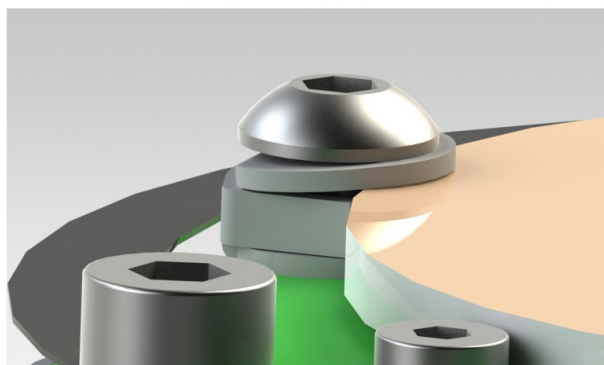
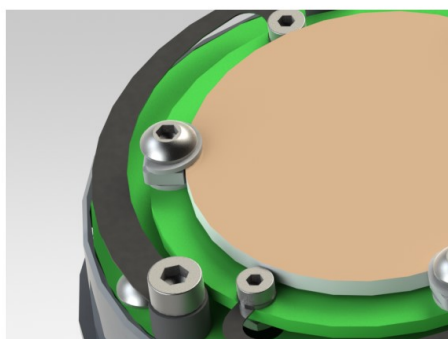
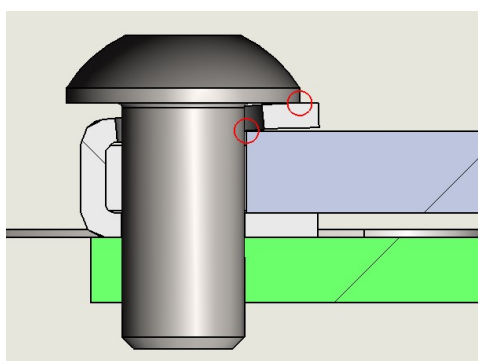
4.3 JITTER

Following FFT diagram showcases the regulation jitter of the system. The system was switched on, setpoint set stable at center position. The spectral content (up to 12KHz) of the noise shows some peaks all below 15 μm .



5 MIRROR MOUNTING

CYCLOPS™ actuators can be fitted with 1.5 inch round mirrors. Preferred thickness is 2 mm. Those mirrors are clamped using small aluminum brackets kept in place with M3x6 screws. Clamping presses the mirror onto the tilting part while providing lateral freedom to handle thermal expansion differences. When mounting the mirror, care should be taken when tightening the screw. The thread in the tilting part has a negative tolerance. This serves as a screw locking mechanism but implies that some torque is needed to turn the screw. In order to have a good fixture, the screw needs to be turned until it contacts the bracket, and the bracket contacts the mirror (red circles on drawing). Note that the bracket only touches the mirror at its outside border. On the other side the bracket touches the head of the screws. This method slightly bends the bracket. This bending provides a spring-loaded fixture of the mirror. When overtightened the bracket will be fully pressed against the mirror. The mirror could chip off due to resulting pressure forces. When too loose, the system becomes mechanically unstable.



6 CONNECTING CYA-A38 CYCLOPS™

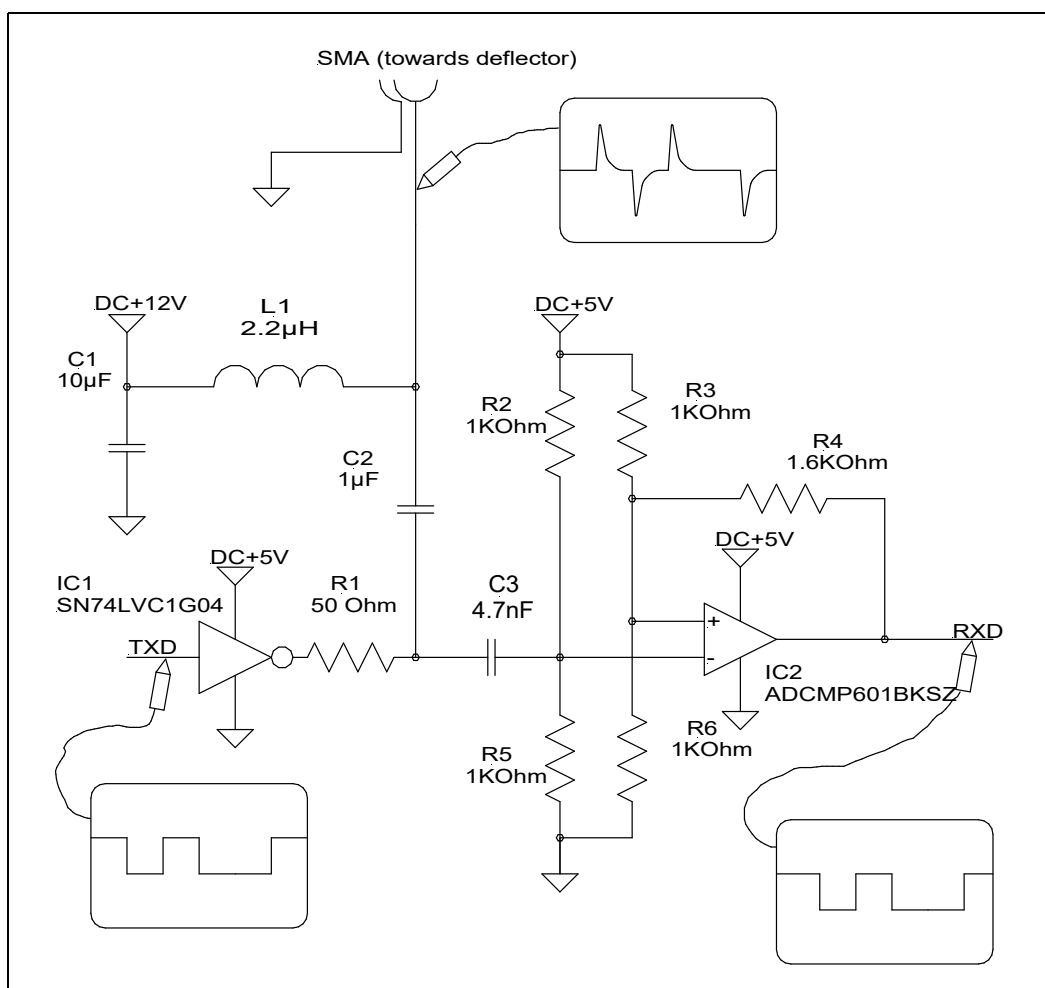
6.1 ELECTRICAL SPECIFICATION

Connector Type (1)	BNC	
Power supply (2)	12	V
Minimal power supply	9	V
Maximal power supply	13	V
Average PWS current (3)	300	mA
PWS peak current (3,4)	2	A
Serial modulation type	AC-UART	
Serial baud rate	10	Mbit/sec
Serial number of data bits	8 + 1	Bit
Serial number of stop bits	1.5	Bit
SMA inner contact to SMA shield AC resistance	50	Ohm
SMA inner contact to SMA shield AC reactance	2.2	μH
SMA shield to enclosure voltage	-5...+5	V
SMA shield to enclosure resistance	220	Ohm
SMA shield to enclosure reactance	1	μF

- (1) other types (SMA,SMB) on request
- (2) The deflector has limited protection (Zener diode) against reverse polarity and over voltage
- (3) Current level is the sum of currents floating into the system through CH1 and CH2
- (4) Peak current levels and duration depend on deflector excitation.

6.2 MODULATION ELECTRONICS

For compatibility with single axis smart deflectors, the CYCLOPS™ actuator is fitted with two coaxial connectors, CH1 and CH2. In general, CH1 is used for exchanging X axis data while Y data is transferred over CH2. Both connections are also used to provide power to the device. Following schematic shows the modulation electronics for one channel needed to exchange setpoint and actual positions with the deflector.



The data towards the deflector (TXD) is high pass filtered while the power supply (DC+12V) is low pass filtered. The high pass filtering is achieved through inductor L1 and resistor R1. Capacitor C2 only serves as a DC level shifter between output amplifier (IC1) and the deflector's power supply. The time constant of the high pass filter equals 44 nsec ($2.2\mu\text{H}/50\text{Ohm}$). The saturation current of inductor L1 should be high enough to handle the deflector's peak currents.

The (DC) potential between inner wire and shield of the coaxial connection equals 12V. When the control card sends a data, every TXD bit transition will induce a glitch. Due to inversion by IC1, low going flanks induce positive glitches while high going flanks induce negative glitches. The height of the glitches is about 2.5 V (IC1 powered by 5V) . This is the result of the divide by 2 network constituted by the deflector's input impedance and the modulation electronics output impedance (R1). The glitch duration is set by the time constant of the high pass filter.

The returned data is obtained by demodulation using a Schmitt trigger. A positive glitch will reset while a negative glitch will set the Schmitt trigger's output (RXD). The hysteresis is set by the resistor values R3, R4 and R6. When RXD is high, the voltage on the non-inverting input equals 3.1V (IC2 powered by 5V). The voltage on the inverting input is set by the resistors R2 and R5 to 2.5V. A hereon applied positive glitch with amplitude larger than 0.6V will bring the potential above the non-inverting one. The comparator's output becomes low setting the voltage on the non-inverting input to 1.9V. A low going glitch is now needed to set the output back to high.

When 5V power lines are not available, the modulation circuit can also be powered by a 3.3V power supply. The resistor value R4 should be decreased to 1 KOhm in order to have a similar hysteresis voltage.

6.3 INSTRUCTION SET

For both X and Y axis, the CYCLOPS™ deflector uses a 20-bit two's complement presentation for set point and actual position. During operation the set point needs to be controlled by the application. Some applications also need to verify actual deflector positions. For ease of use the deflectors have both a 20 bit and a 16-bit interface to exchange these values. The latter disregards the 4 least significant bits and only accesses the 16 most significant bits.

The instructions and their replies are exchanged with deflector through a half-duplex UART connection. Transmitting a single byte takes 1.1 µsec. Depending on the instruction type the control card sends one or three bytes to the deflector. After reception the deflector will process it and start his reply within 1.5 µsec. The time between different instructions must be at least 10 µsec.

Instruction overview

Control	Resolution	Size instruction	Size reply	Execution time
20-bit absolute set point	1048576 bits	3 bytes	none	10 µsec
16-bit relative set point	65536 bits	1 byte	1 byte	10 µsec

UART byte format:

Serial data	START, B0, B1, B2, B3, B4, B5, B6, B7, LATCH, STOP
START	Start bit, low
B0..B7	data byte (B0 least significant bit, B7 most significant bit)
LATCH	instruction latch (1)
STOP	Stop bit, high

(1) The instruction set of a deflector comprises single and multiple byte instructions. When the LATCH bit is true, the received instruction is interpreted. Single byte instructions must have their LATCH bit set. On multiple byte instructions, only the last byte must have the LATCH bit set. All other bytes must be sent with LATCH bit cleared. All replies from the deflector are done with LATCH bit cleared.

6.3.1 20-bit absolute set point control

With a three-byte instruction, a 20-bit target position can be sent to the deflector. The deflector has internal speed and current limiters to guarantee save operation at all times. When the distance between target and set point is too far, the target position is clipped following a maximum speed principle. The maximum speed whereby the set point is allowed to change, is set at 105 Mbit/sec.

Serial bit sequence (1):

Instruction Byte 1	START,0,0,0,0,S0,S1,S2,S3,0,STOP
Instruction Byte 2	START,S4,S5,S6,S7,S8,S9,S10,S11,0,STOP
Instruction Byte 3	START,S12,S13,S14,S15,S16,S17,S18,S19,1,STOP

(1) S0..S19: new set point (20-bit two's complement, S0 least significant bit, S19 most significant bit)

6.3.2 16-bit relative set point control

A complete instruction set is available to control and query the 16 most significant bits of both set point and actual position using byte sized instructions. This control mode makes the deflector's full angular range accessible using 16-bit values. As a result, the physical angle change per bit is 16 times larger when compared with 20-bit control.

Controlling the set point is achieved by using μ step move instructions. When the deflector receives such an instruction, its value is added to the set point (16-bit presentation). The valid instruction range is limited from -111 to 111. All values outside this range are interpreted by the deflector as a system instruction, not as a μ step move instruction. Based on a selectable reply mode, a μ step move instruction will be replied with delta actual (mode 1) or echoing (mode 2).

The system instruction set comprises instructions to select reply mode and to query positions. At power up, the deflector switches to reply mode 1. In this mode any μ step move instruction will be replied with delta actual. When echoing is desired, the system instruction 126 must be used to change the reply mode to 2. In reply mode 1 it is possible to keep track of the actual position while reply mode 2 allows error control on the communication link.

The maximal speed whereby the set point can be changed using relative control, equals:

$$\text{max speed} = \text{max } \mu\text{step} * \text{max instruction frequency} = 111 * 200 \text{ KHz} = 22 \text{ Mbit/sec}$$

The deflector's maximal angular speed is more than three times faster than the speed achievable using 20-bit absolute set point control because (angular wise) every bit is 16 times larger.

Single byte instructions

Instruction (1)	Description	Reply
-111... 111	μ step move instruction (8-bit two's complement)	Delta actual (when in reply mode 1) Echo μ step (when in reply mode 2)
112	fetch actual position	most significant byte actual position
115	fetch set point position	most significant byte set point
113	fetch least significant byte	least significant byte previous fetch
117	switch off deflector	0
125	switch on deflector, set reply mode 1	125
126	switch on deflector, set reply mode 2	126

(1) Undeclared instruction values are used by the rhothor™ tuning and configuration software. Do not use these values.

Serial bit sequence (1):

Instruction Byte 1	START,C0,C1,C2,C3,C4,C5,C6,C7,1,STOP
Reply Byte 1	START,R0,R1,R2,R3,R4,R5,R6,R7,0,STOP

(1)

C0...C7: 8-bit instruction (C0 least significant bit, C7 most significant bit)

R0...R7: 8-bit reply (R0 least significant bit, R7 most significant bit)

The relative targeting reduces the communication bandwidth. Only variations of the set point are communicated. A new target can't be sent directly to the deflector but needs to be translated and communicated as a chain of μ steps. This chain has to be compiled based on target position, deflector's set point and desired speed. To avoid querying the deflector's set point before every move, the control card should keep a local copy of it. After power up, this copy should be initialised by fetching the deflector's set point (boot cycle reply mode 1 and 2).

Example :

Assume that the deflector is at position 1000 and that ramping towards position 2200 at a speed of 1.2 Mbit/sec is needed.

<i>position (local copy of deflector's set point)</i>	<i>1000 bit</i>
<i>target (new position)</i>	<i>2200 bit</i>
<i>Speed</i>	<i>1200000 bit/sec</i>
<i>Distance</i>	<i>target-set point = 2200-1000 = 1200 bit</i>
<i>Duration</i>	<i>distance/speed = 1200/1200000 = 1 msec.</i>
<i>#μsteps (number of μsteps when sending at 5μsec interval)</i>	<i>duration/0.005 = 200</i>
<i>μstep</i>	<i>distance/#μsteps = 1200/200 = 6</i>

After sending 200 times the value 6, the deflector's set point will be increased with 1200. Sending those values at 5 μsec interval will result in a 1 msec. execution time for the ramp.

The deflector has a build in security against thermal overloading. When over steered above twice the thermal rating, it stops tracking. The amplifier and regulator are switched off and the deflector stops replying μstep move instructions. The control card can respond by sending command 125 (reply mode 1) or 126 (reply mode 2) to restart the deflector. Without response within 4 seconds the deflector will reset and a full boot cycle will be needed to restore operation.

6.3.2.1 Boot cycle reply mode 1 (actual position tracking)

step 1	send instruction 125	setup to reply μstep move commands with delta actual
step 2	send instruction 115	the deflector replies with most significant byte set point
step 3	send instruction 113	the deflector replies with least significant byte set point
step 4	send instruction 112	the deflector replies with most significant byte actual position
step 5	send instruction 113	the deflector replies with least significant byte actual position

After executing step 5, the control card has a 16-bit copy of the deflector's set point and the actual position. Changing the set point is done by sending μstep move instructions. The deflector will reply them with delta actual values. By integrating these replies, a live copy of the deflector's actual position can be obtained.

6.3.2.2 Boot cycle reply mode 2 (error control on data link)

step 1	send instruction 126	setup to echo received μstep move commands
step 2	send instruction 115	the deflector replies with most significant byte set point
step 3	send instruction 113	the deflector replies with least significant byte set point
step 4	send instruction 115	the deflector replies with most significant byte set point
step 5	send instruction 113	the deflector replies with least significant byte set point

Step 4 and 5 are optional. However, they give the advantage of a double read of the set point. The reply of step 2/3 and step 4/5 should be the same. If not you should fetch the set point again. Changing the set point is done by sending μstep move instructions. By verifying the replied echo's, the integrity of the instruction flow can be verified. If an echo is different from its instruction, the set point should be fetched again (restart at step 2).

6.4 POWER UP SEQUENCE

During normal operation the deflector only replies on received instructions. All communication needs to be initiated by the control card. The only exception is at power up. 100 msec after power up the deflector sends character 204. This is done to set the Schmitt triggers in the modulation electronics. After receiving the power up byte (204) from the deflector, the control card may send instructions. When the absolute set point control will be used, the control card can start sending the 3-byte sized instructions. When relative set point control will be used, the control card needs to set reply mode and fetch the current position(s) of the deflector prior to sending μ step move instructions.

7 CONNECTING CYA-A38-Ai1 CYCLOPS™

7.1 M12 PIN ASSIGNMENT

1	TXD+/return	RJ45-pin 1 (1)	IEEE802.3at
2	TXD-/return	RJ45-pin 2 (1)	
3	RXD+/power	RJ45-pin 3 (1)	IEEE802.3at, Vpower=56V, 30Watt
4	RXD-/power	RJ45-pin 6 (1)	
5	O14 collector	RJ45-pin 7 (1)	Galvanically isolated, Vce<80V, Ic< 50mA
6	O14 emitter	RJ45-pin 8 (1)	
7	O16 collector	RJ45-pin 5 (1)	Galvanically isolated, Vce<80V, Ic< 50mA
8	O16 emitter	RJ45-pin 4 (1)	

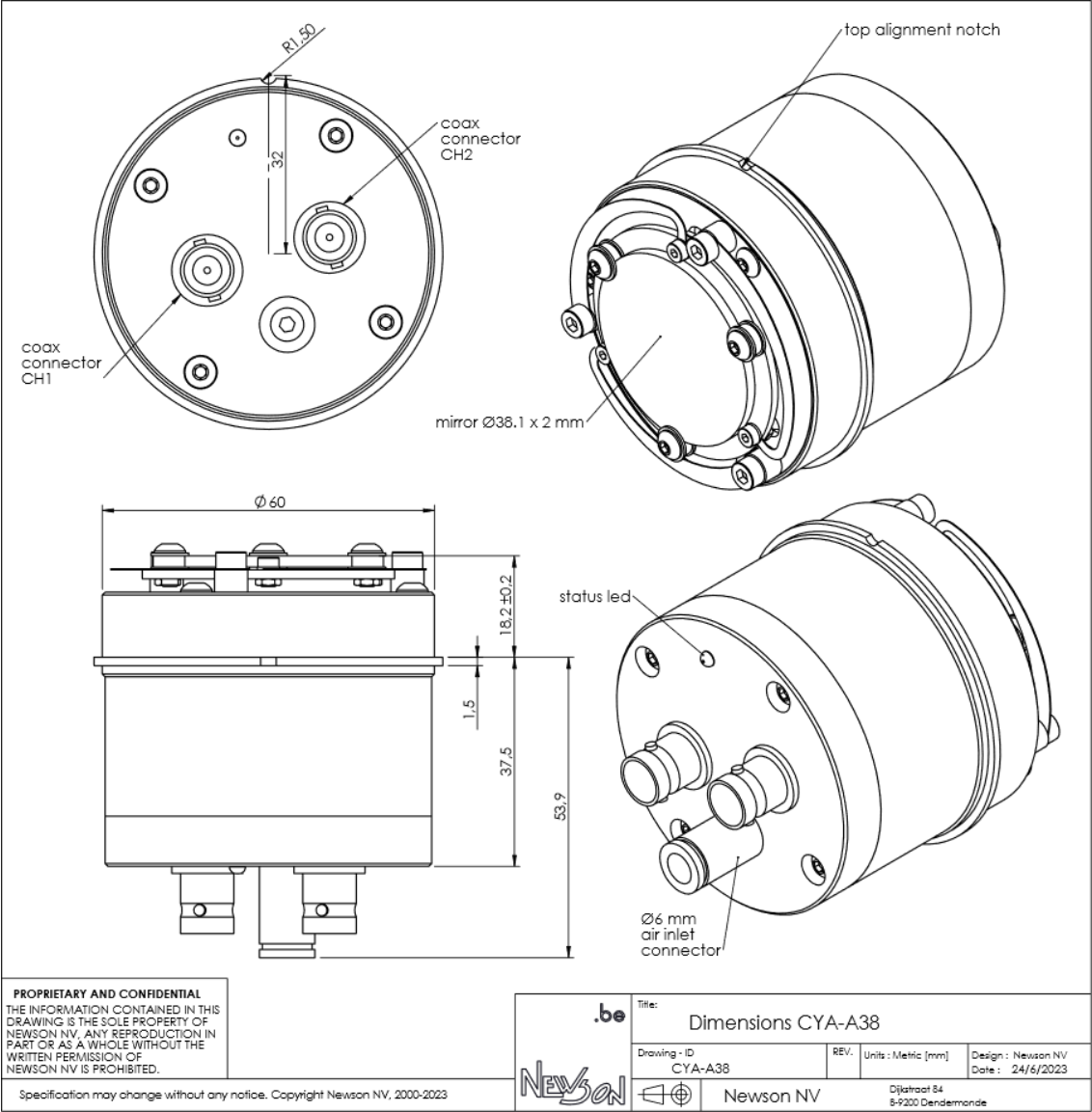
(1) connection map for bridging M12 with RJ45 style ethernet connector.

7.2 POWER OVER ETHERNET

The M12 connector is fully compatible with power over ethernet IEEE802.3at specification. Connect the actuator with the host or PLC through an ethernet IEEE802.3at compliant power supply. Power supply should be merged with data pairs 1,2 and 3,4 (M12 connector) This leaves pair 5,6 to be used as output 14 and pair 7,8 as output 16. Those outputs provide hard wired connection for an interlock and a gate signal. The interlock may be used as a system status indicator. It may NOT BE USED as a safety system. For more information regarding output signals 14 and 16 refer to datasheet and manuals covering CUA32 systems.

8 DIMENSIONS

8.1 CYA-A38



8.2 CYA-A38-AI1

