APPLICATION NOTE
HOW TO USE IO'S OF CUA-XXX

NEWSON NV

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1 CONNECTION TO PERIPHERALS OVER RS485

The CUA-XXX control board is fitted with **7 IO channels** for connection with peripherals. Those peripherals include lasers, automation equipment, resolvers, other CUA-XXX devices...

Single bit connections between devices can only work when their signal references (zero volts) are the same. Adding a zero-volt-connection to equalize those references seems an easy way to guarantee this.
However, one should avoid making ground loops when setting up connections between devices in an industrial environment. Grounding the power supply of devices greatly improves their noise immunity and safety. Most peripherals will therefore have their power supply grounded. All devices with a grounded power supply have their signal references interconnected over the ground connection.
An additional reference connection between such devices will result in a ground loop. Difference in ground potentials and ambient magnetic fields will induce currents in this loop. In general the resistance of a ground loop is small (< 1Ohm). As a result, small differences in ground potentials lead to large currents.
As a general rule, ground loops should be avoided.

Galvanic isolation is a well known solution for countering ground loops. However increased overall system cost and limited data speeds are drawbacks.

To allow interconnection with peripherals without ground loops, the CUA-XXX IO channels use **RS-485 transceivers**.
A single bit RS-485 data connection between devices consists of 2 complementary signal lines, a positive and a negative signal line.

Transmission (Output)

- When the logic value to be transmitted is high, the RS-485 transmitter will set the positive signal line (IO+) high and the negative signal line (IO-) low.
- When said value is low, the RS-485 transmitter will set the positive signal line (IO+) low and the negative signal line (IO-) high.

Reading (Input)

- To read the signal value, an RS-485 receiver compares the potentials measured on both signal lines.
- When the voltage applied on the positive signal line is higher than that on the negative signal line, the signal is read as high.
- When the voltage applied on the positive signal line is lower than that on the negative signal line, the signal is read as low.

A small hysteresis further improves noise immunity and transition response.
A direct zero volt connection is not needed. As a result, there is no danger of creating a ground loop. However a potential limitation between the devices still exists. This limitation is in most cases guaranteed by the grounding of the power supplies.
If one or both devices are not grounded, a connection between their zero volts should be made.
In case of unclarity regarding grounding, the connection between the zero volts can be made using a current limiting resistor. Currents induced by difference of ground potentials will be limited by this resistor.
For this purpose the CUA-XXX control card has a build-in current limit resistor (pin X7).

All devices supporting an RS-485 data connection can directly be connected to the CUA-XXX control board.
Typical examples are: resolvers and third party XY2-100 steering cards.

2 SPECIFICATION OF THE CUA-XXX IO PINS (RS-485)

		minimum value	typical value	maximum value	units
IO+[1]	logic low	-	0.7	-	V
	logic high	-	4.3	-	V
IO-[1]	logic low	-	4.3	-	V
	logic high	-	0.7	-	V
R-load[2]		54	-	-	Ohm
IO1,IO2,IO3,IO4 R-termination[3]		-	120	-	Ohm
voltage applied on IO+/IO-[4]		-7	-	12	V
input current IO+,IO-[5]		-0.4	-	0.5	mA

[1] IO pin configured as output

[2] Load is total resulting resistor value between IO+ and IO- lines (including termination resistor)

[3] IO1, IO2, IO3 and IO4 are fitted with 120 Ohm termination resistors

[4] This voltage range limits the ground potentials between the connected devices

[5] IO pin configured as input

3 EXAMPLE CONNECTIONS

RS-485 compatible devices can be directly connected with the CUA-XXX control card.
Specification of the CUA-XXX IO pins should be used to setup connections with devices that do not support RS-485.

3.1 SETUP TTL CONNECTION WITH LASER

TTL (*T*ransistor *T*ransistor *L*ogic) is a typical board level interface between components on a printed circuit board.

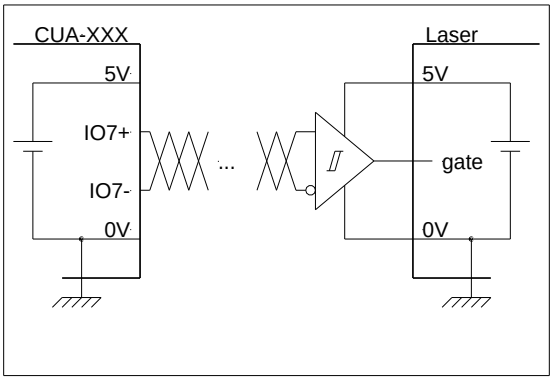
- TTL defines low as any value between 0 and < 0.8V.
- High is defined as any value between 2 and 5V.

When a laser has a TTL interface for its trigger, there are several solutions to connect it with the CUA-XXX control card.

3.1.1 Solution A

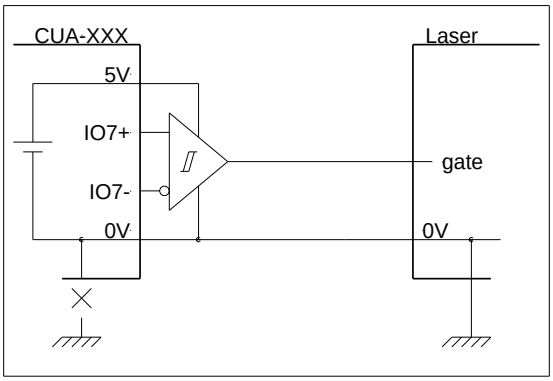
Converting the TTL compatible input of the laser to an RS-485 compatible one is an obvious solution. For this purpose, an RS-485 receiver should be mounted and powered at laser side.
This receiver will transform the RS-485 signal received from the CUA-XXX board into a TTL-signal suited for the laser.

1/ Some lasers provide a low current 5V output to power such interface electronics.
When the power supplies of laser and CUA-XXX board are grounded, there is no need to connect their zero voltages. They are already connected over ground. The maximal difference between the ground potentials is limited to -7V..+7V.



2/ When the laser doesn't provide a 5V output, one can consider mounting the RS-485 receiver at CUA-XXX side. The receiver can than be powered by the 5V output of the CUA. The result is a TTL connection between the devices.

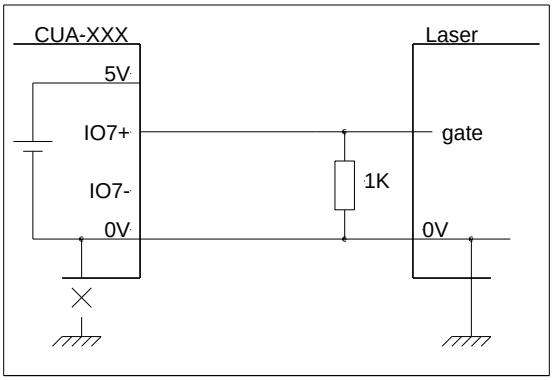
A zero volts connection between both systems is needed as a return path. The zero volts connection further guarantees that the references of laser and CUA-XXX control board are on the same potential.
When the power supplies of both system are grounded, this zero volt connection is redundant and will create a ground loop. Differences in ground potentials will lead to ground leveling currents through this loop.
Not grounding the CUA-XXX can be considered to safely connect the zero volt of laser with the zero volt of the CUA-XXX board. The ground loop is than completely removed and the CUA-XXX is grounded over the laser through the zero volt connection.



3.1.2 Solution B

TTL defines low as any value lower than 0.8V.
When the CUA-XXX sets an output low, the corresponding RS-485 compatible signal pin (IOx+) is pulled towards 0.7V.
In theory one could use this as a TTL signal. However it lays only 100mV below the low going TTL input threshold. So a direct connection between a CUA-XXX output and a TTL input will likely to be unstable.

Adding a pull down resistor will lower the low output value and increase noise immunity of the connection.



This is a low cost solution for extracting a TTL compatible signal out of RS-485 signal.

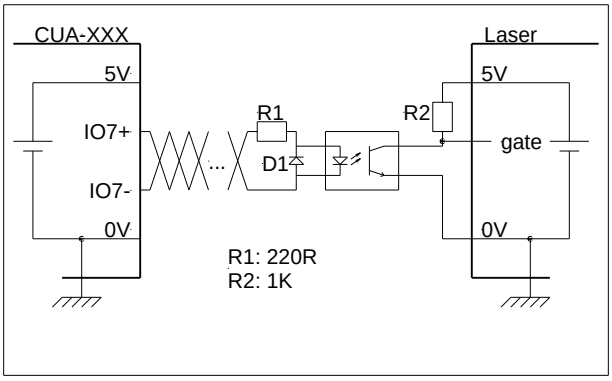
Its major draw back is the requirement that the zero (ground) potentials of both laser and CUA-XXX need to be the same.
R1 (1KOhm) is used as a pull down resistor. This resistor pulls the RS-485 signal (IO7+) down to zero volts when the signal is low.
Without the pull down, the low value of IO7+ pin will be 0.7V. Only 100mV above TTL threshold.
It is likely that both power supplies (laser and CUA-XXX control card) are grounded. So in theory the interfacing could be done over a single wire, using the ground as a return path. Legislation often forbids the use of ground as a current conductor so a zero to zero volt connection between CUA-XXX and laser is needed. This zero to zero volt connection will serve as a potential levelling connection for ground potentials between CUA-XXX and laser.
Not grounding the CUA-XXX can be considered to avoid the ground loop.

3.1.3 Solution C

When the ground potentials between laser and CUA-XXX board differ more than 7V, opto couplers should be used for interfacing. Depending on type of opt coupler, the voltage between the zero planes may exceed several hundred volt.

The emitter of the opto coupler should be connected over the RS-485 signal lines (IO7+/IO7-).
So the current that leaves the positive RS-485 signal line returns through the negative signal line.
A diode (D1) can be added to protect the emitter against inverse polarity. Polarity inversion happens whenever the logic signal is low. In this case, the RS 485 driver will drive the positive signal line to 0.7V and the negative signal line to 4.3V. The resulting voltage seen by the emitter of the opto coupler will be -3.6V.
A current limiting resistor (R1) can be added to limit the current.
Most opto couplers have a transistor (NPN type) as output. TTL level signals towards the laser are achieved by using this transistor in an open collector configuration with an added pull up resistor (R2).

When the laser doesn't provide a useable pull up voltage, an additional power supply is needed.
Some lasers have built in opto couplers that can be directly connected with the IO's of the CUA-XXX board.



3.2 CONNECTION WITH 24V SIGNAL LINES

Automation equipment often use 24V digital input/output pins.

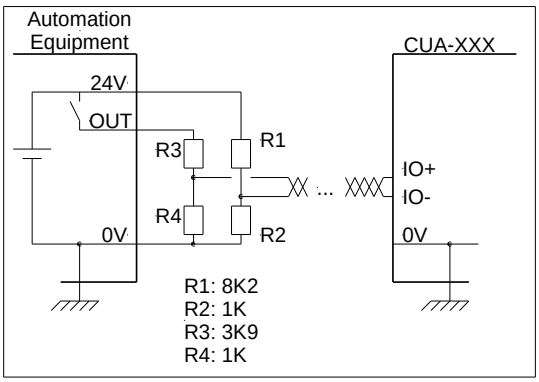
- When such an input pin is left open or connected to 0V, it will be interpreted as low.
- When connected with 24V the pin will be read as high.

Opto couplers or resistor networks can be used to connect such signals with the RS-485 lines of the CUA-XXX control card.

3.2.1 CUA-XXX Input from a 24V Automation Equipment

The RS-485 receiver sees a signal as high when its non-inverting (positive) input has a higher potential than its inverting (negative) input.

- Resistor network R1/R2 is used to generate a constant 2.5V. This voltage is connected to the negative RS-485 signal line.
- Resistor network R3/R4 is used to reduce the signal amplitude of the 24V output to 5V. This reduced signal, at center tab, is connected with the positive RS-485 signal line.



When the output on the automation equipment is 24V, the resistor network will reduce this voltage to 5V.
This value is higher than the 2.5V of the inverting input, so the RS-485 receiver sees this signal as high.
When the signal of the automation equipment is open or zero, the resistor network will pull this voltage to 0V.
This value is lower than the 2.5V of the inverting input, so the RS-485 receiver sees this signal as low.

When both systems are grounded, there is no need for a zero connection.
In case of doubt about grounding, a zero to zero volt connection over a 100 ohm resistor can be used.
This resistor will reduce the ground leveling currents through the ground loop.

Anyway, the maximal difference between the ground potentials between CUA-XXX and the automation equipment is limited to about -7V..+7V.

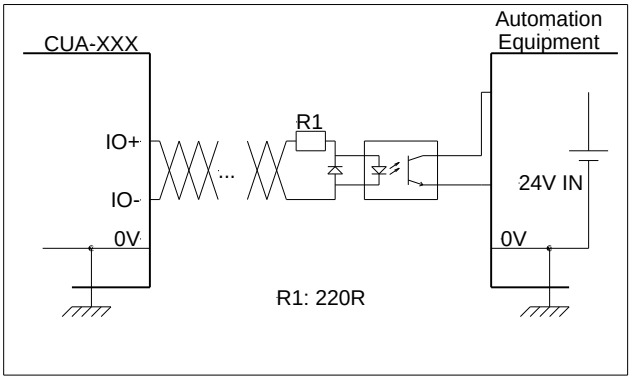
3.2.2 CUA-XXX Output to a 24V Automation Equipment

A pin of an automation equipment that is left open, is interpreted as low because there is no current flowing into it.
Using the transistor of an opto coupler in an open-emitter configuration is an easy way to connect an RS-485 signal with such a pin.

When the RS-485 signal is low (IO+<IO-), there is no current flowing through the emitter of the opto coupler making its output transistor non-conducting.
The automation equipment sees a floating input and interprets it low.

When the RS-485 signal is high (IO+>IO-), current flows through the opto couplers emitter. The output transistor conducts and the automation equipment sees a 24V on its input which he interprets as high.

The use of an opto coupler also allows for larger ground potential differences between CUA-XXX and automation equipment.



3.3 TIPS

CUA-XXX control board interfaces with other devices over RS-485 compatible lines. Such lines are differential lines.
Each IO port value is represented by 2 complementary signal lines. When one goes low the other goes high and vice versa.
Never shorten or connect signal lines to power supply rails.

The use of RS-485 connections allows limited ground potential differences between devices. In most cases this range (-7V to +7V) will be enough.
When the difference is higher, try a different grounding scheme to reduce it.
Use galvanic isolation techniques when the latter is not possible.

When powered down or during configuration all outputs on the CUA-XXX board become floating.
Add 1K pull up and pull down resistors to force an output to a know state when needed.
Pull up resistors should be connected to +5V while the pull down resistors should be connected to 0V.
Depending on the targeted state of the signal both signal lines of an IO can be either be pulled up or pulled down.

Single wire signals between devices need a zero volt connection as a return path.
When the power supply of those devices is grounded, this ground connection can be used as return path.
When the grounding scheme is unclear, an additional zero volt connection comprising a 10Ohm resistor could be considered.
When the devices are grounded, the formed ground loop will have a relative high resistance (>10Ohm). So the leveling currents in the loop will likely be small.
When the devices are not grounded, the 10Ohm zero volt connection provide a return path for the signal and guarantees that the references of the devices are the same.