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Ultrasonic Multiplexer OPMUX v12.0

Manual

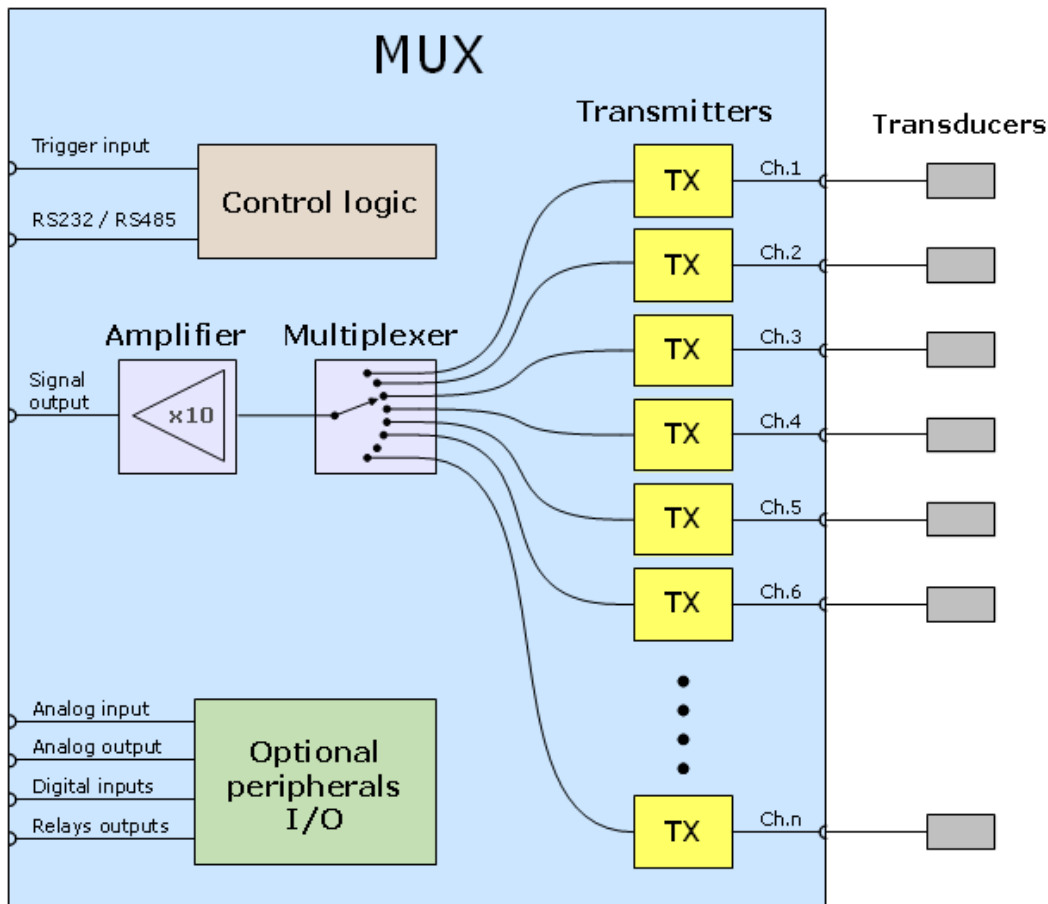
For OPMUX with firmware version 1.01

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1 Description

OPMUX is particularly well suited for ultrasonic measurements as well as other kinds of measurements that need many channels. Together with the measurement card OPCARD ([link](#)) and ultrasonic probes it could be used as complete ultrasonic testing device. Each channel has separate pulser & receiver.



Flow diagram of MUX

MUX can operate with transducers of the resonant frequency of 0.5MHz - 25MHz and any impedance.

Depending on the version MUX has from 4 to 35 channels. Each channel can operate as a transmitter and as a receiver. Only one transmitter can operate at the same time.

Transmission and reception can take place on different channels - for example, we transmit by the transducer connected to the first channel and we receive the signal from the second channel transducer.

MUX is equipped with a memory, which contains preset sequence of active channels (i.e. the sequence of addresses of transmitters and receivers for subsequent triggers).

MUX has got one output signal. Transmitter with which you want to record the signal is selected by the internal multiplexer. Then the signal is fed to an amplifier with filter.

The device is configured via the serial interface (RS232 standard).

The device is powered by a 12V DC. The device is equipped with a fuse, short circuit - and thermal protection in circuits of transmitters.

Input trigger reacts even on very short pulses (<400ns) as TTL - levels.

MUX can be equipped with additional input and output peripherals:

- Analog Input 0V-10V
- Analog Output 0V-10V
- Four relays to control an external load
- Two digital inputs for buttons connecting.

1.1 Technical data

Device parameters

Power supply:	12V DC; 2A
Channels (available types of MUX):	4; 8; 11; 16; 19; 32; 35 channels
PRF (pulse repetition frequency):	75kHz (<5kHz for one channel)
Max cable length between computer and the box:	30m

Box size (height / length / width)

MUX4	3,5cm / 17cm / 14cm
MUX8+3	8cm / 20cm / 15cm
MUX16+3	8cm / 30cm / 20cm
MUX32+3	8cm / 40cm / 20cm

Communication interface

Interface type:	RS232 (standard option); RS422 / RS485*
Baud rate:	115200
Connector:	DB9, female

*on request; not available in MUX4

Transmitters

Output impedance:	<1 Ω
Ultrasonic transducer frequency:	from 0.5MHz to 20MHz
Pulse amplitude range:	0 (off) – 400V*
Amplitude control:	serial interface or analog input 0-10V
Pulse length:	from 0.1us to 6.3us (resolution 0.1us)
Fall Time:	<=25ns

*maximum voltage depends on the load

Signal amplifier

Bandpass filter bandwidth (3dB):	1MHz – 15MHz*
Gain:	20dB
Maximum input signal amplitude:	\pm 200mV

Maximum output signal amplitude:	±2V
Input impedance:	50Ω @10MHz
Output impedance:	<1Ω

*parameter can be changed on request

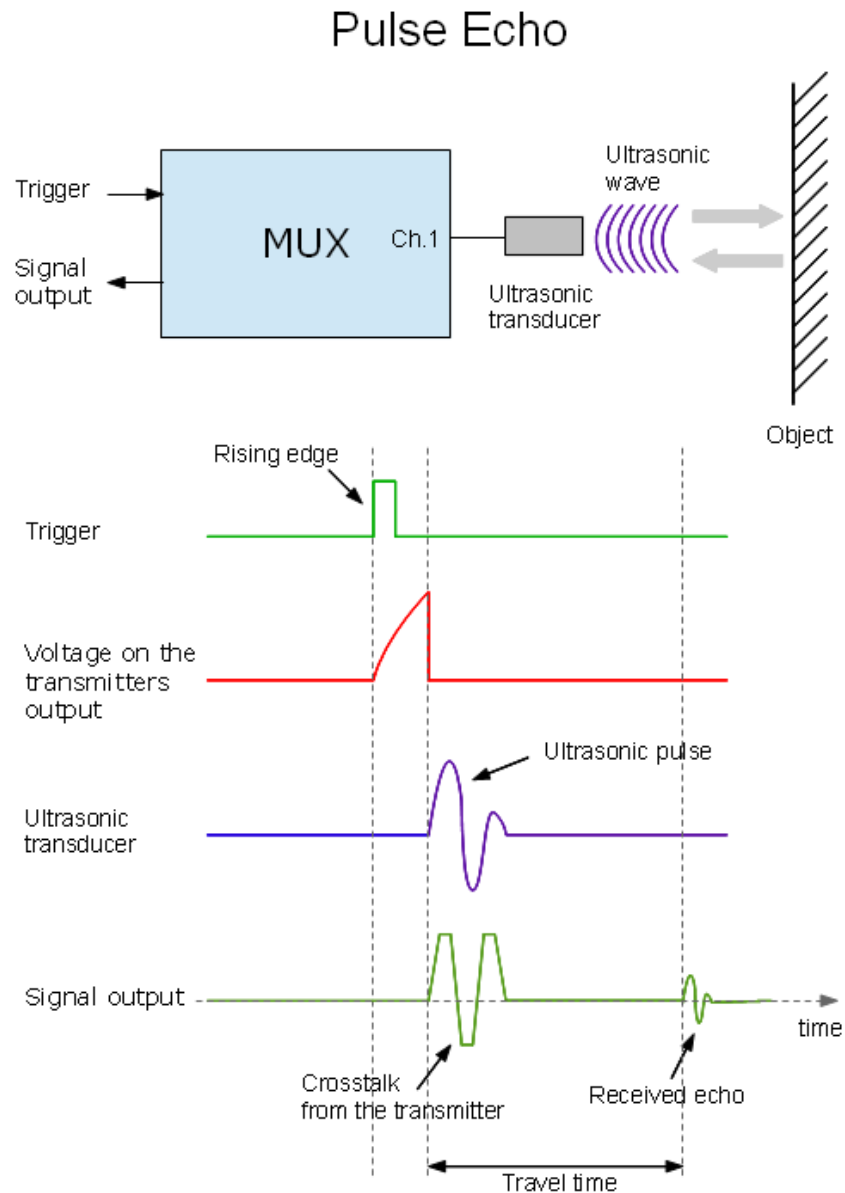
Optional peripherals I/O

Analog input:	Voltage input: ± 0V-10V Bandwidth: 360Hz Resolution 12bit
Analog output:	Voltage output: 0V-10V Bandwidth: 530Hz Resolution 12bit
Relays:	Up to 4 outputs; Nominal switching capacity: 2A 24VDC, 2A 125VAC
Digital input:	Up to 2 inputs; Inputs Accept Voltages to 5.5 V; Input includes pull-up resistor to 5V;

1.2 Measurement engineering

MUX allows to work using two measurement methods:

- Work by reflection (Pulse Echo)
- Work by transition (Through Transmission)



Pulse Echo (PE)

This method uses the same ultrasonic transducer to transmit and receive.

To work in this mode, is necessary to select the same channel of the Mux to transmit and receive (Ch.1 on figure above).

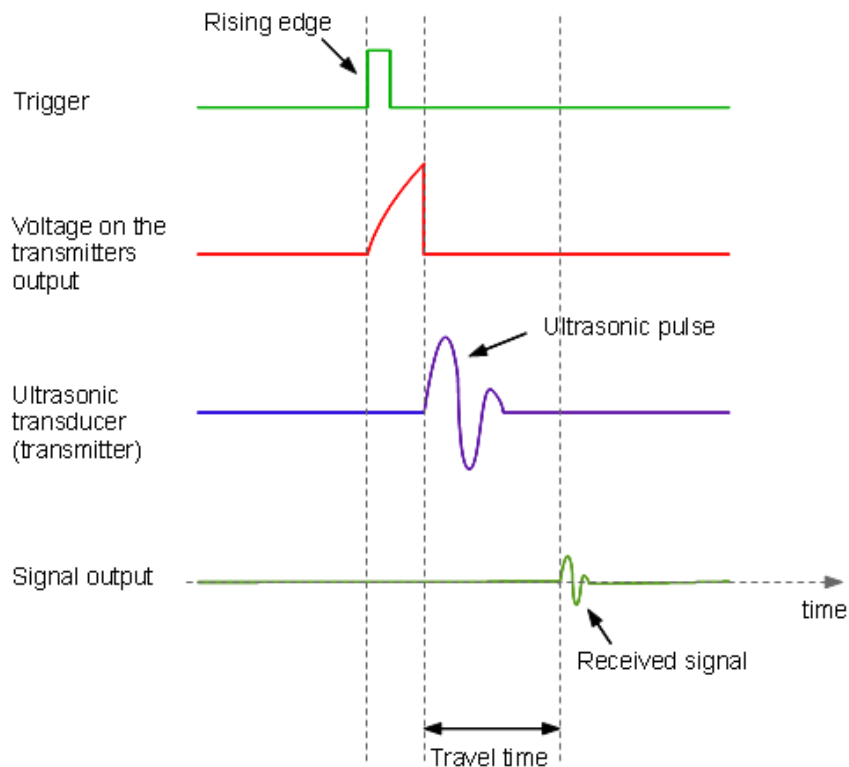
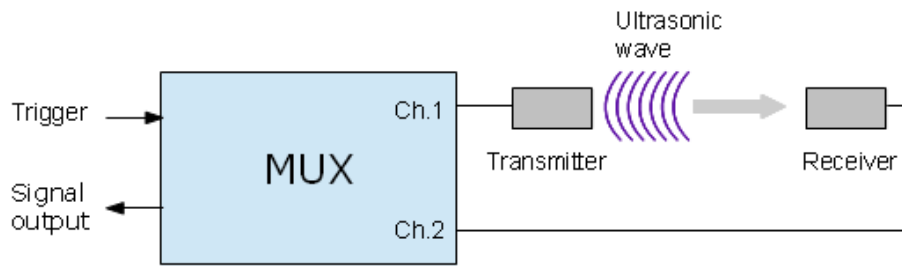
At the time of the coming of trigger signal, the transmitter will produce a pulse that actuates ultrasonic transducer. Transmitter generates ultrasonic waves that are reflected from the test object and received by the same transducer.

The signal registered at the MUX output (Output Signal output) will have small amplitude because of

attenuation of the ultrasound wave in the environment and of partially absorbing by the object. Therefore, you should set the appropriate gain at measurement card.

On the output signal will also appear crosstalk from the transmitter - this is universal effect.

Through Transmission



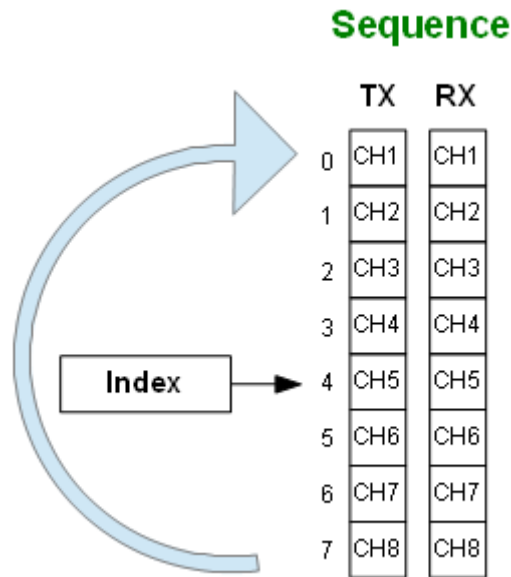
Through Transmission (TT)

This method uses two or more transducers. In this way, you can examine the attenuation of ultrasonic waves at the transition (as shown on the figure above) or register a wave reflected from the object (when transmitters are placed at different angles relative to the object).

In the example shown in the figure, connected to the first channel transducer is a sender of an ultrasonic wave, which is recorded by the transducer connected to the second channel.

1.3 The sequence of measurement

MUX is equipped with a memory, which contains preset sequence of active channels. An example of a sequence consisting of eight elements:



TX – transmitter address

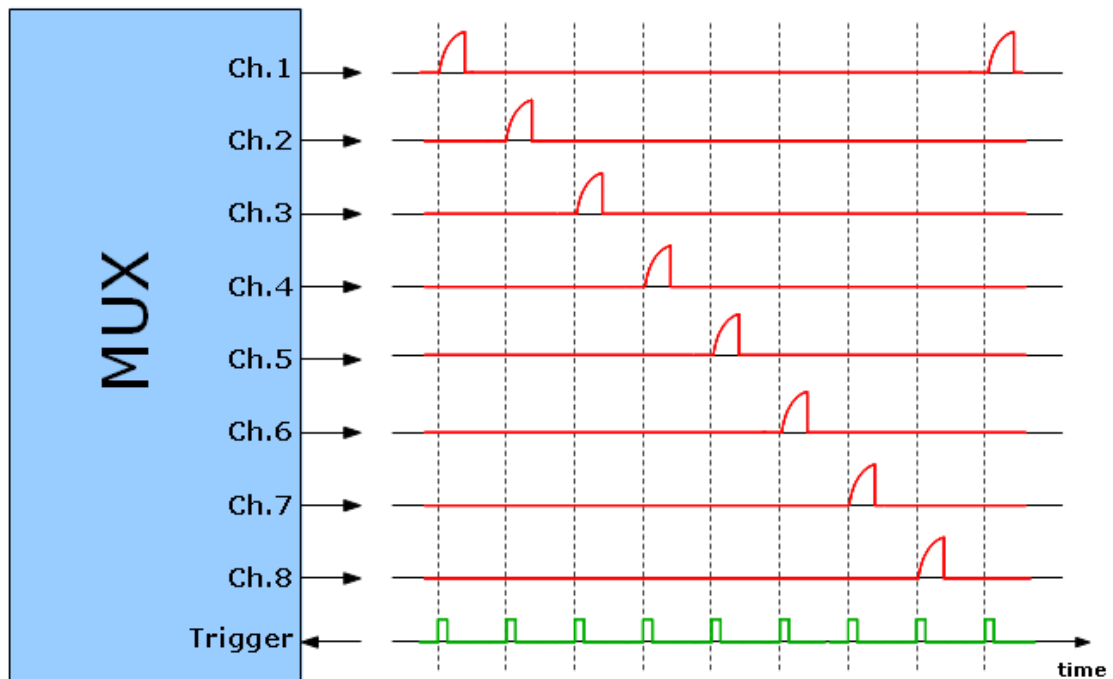
RX – receiver address

In this example, addresses of the transmitter and the receiver are identical. It means that according the first trigger sensor connected to the first channel (CH1) transmits and receives the signal at the same time (Pulse Echo).

According the second trigger, transducer connected to the second channel (CH2) transmits.

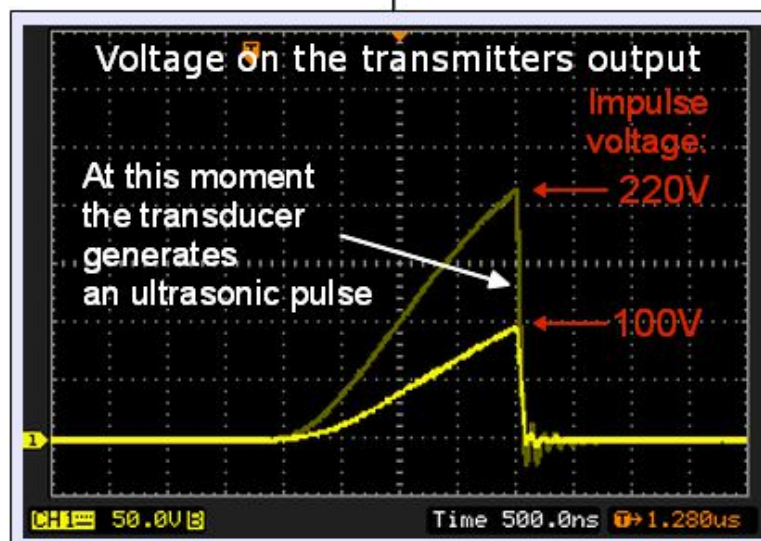
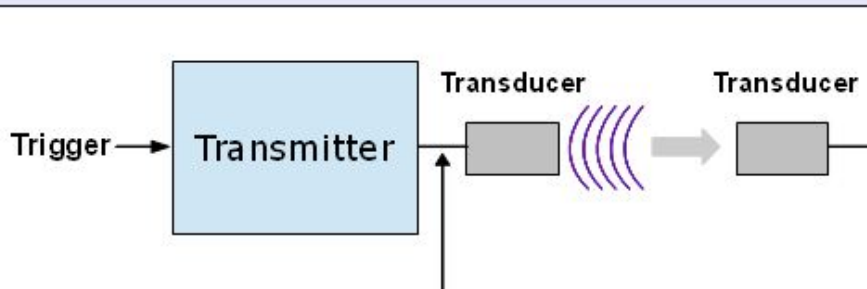
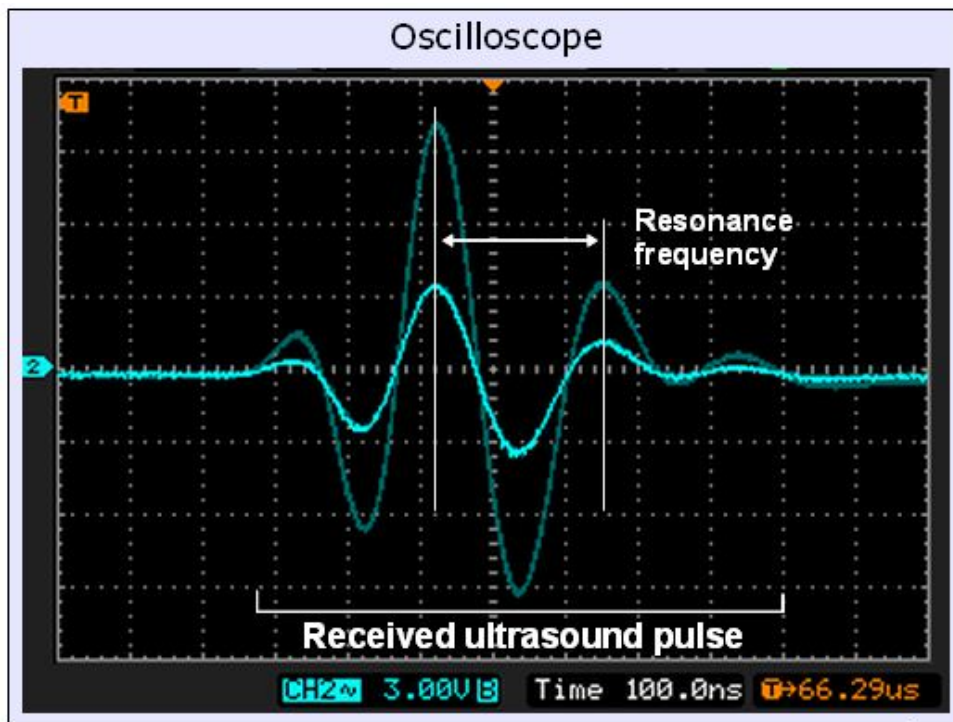
Ninth trigger will reset the index and starts playback of the sequence from the beginning

This example sequence in the timing diagram:



2 Transmitter

2.1 Function



Transmitter generates a high voltage pulse of a precise time when trigger signal comes. Falling edge of the pulse causes the excitation of the transducer and generation of the ultrasonic wave. This control causes that the transmitter is excited to its resonance frequency (for example, 5 MHz).

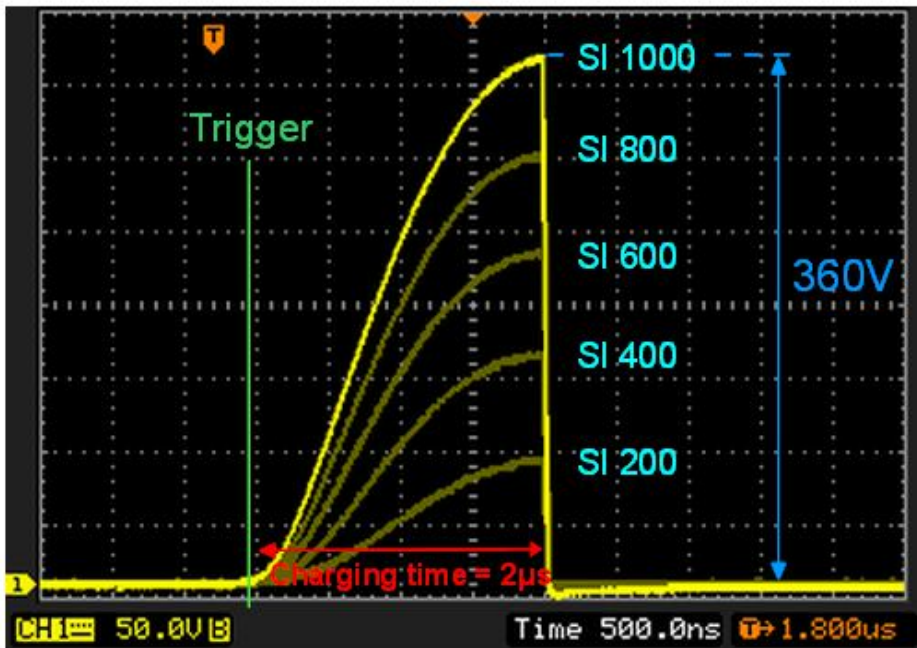
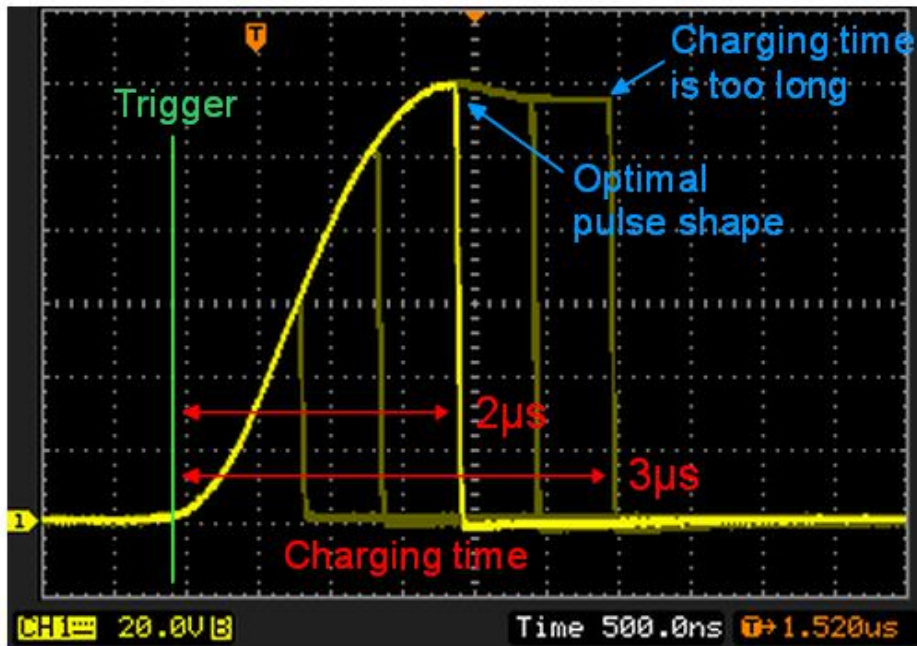
! The higher the voltage at the output of the transmitter, the higher the power of the generated ultrasonic.

2.2 Puls parameters

Pulse at the output of the transmitter can be controlled by two parameters:

- Charging time (SL command);
- Charging voltage (SI command).

The figures show the dependence of the pulse shape at the output of the transmitter according to the set parameters of the transmitting (SI and SL commands):



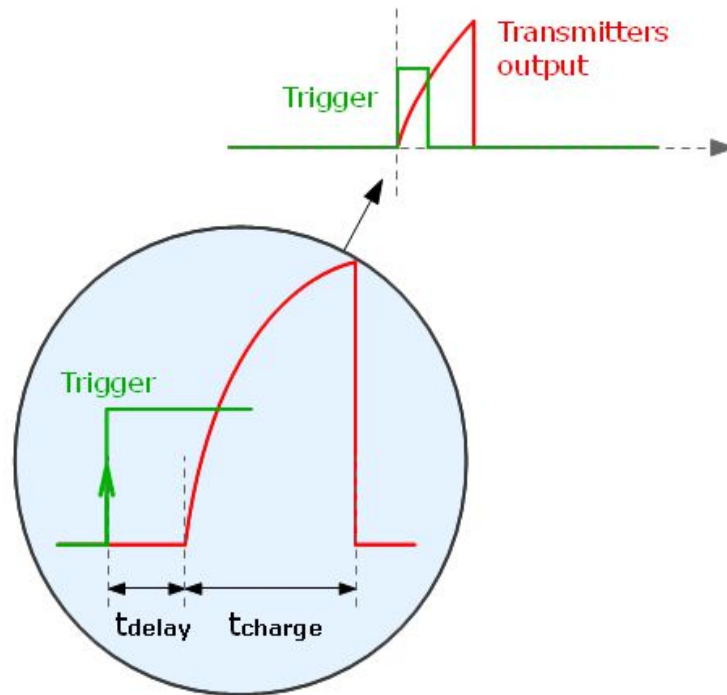
! The maximum pulse voltage depends on the type of sensor, and can be, for example 200V (unloaded transmitter has on output pins about 400V).

Optimal charging time depends on the type of used transmitter . Transmitters with a larger capacity, may require longer charging time.

! Extending charge time (after already reaching maximum voltage) nothing improves - it does not increase the ultrasonic pulse power . This causes unnecessary heating of transmitters.

2.3 Trigger delay

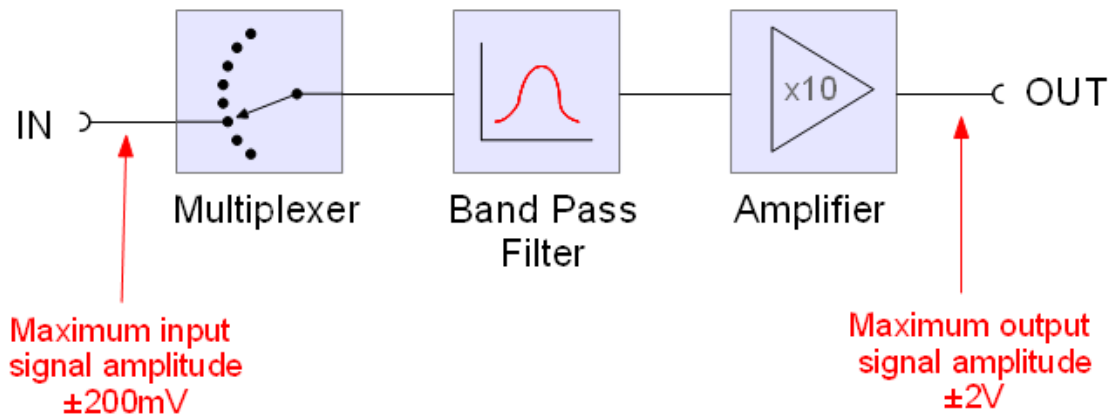
MUX reacts to the rising edge of trigger signal. But charging Pulse does not start at exactly the same time - the transmitter starts with some delay. This time marked as t_{delay} is about 200ns and is constant. This delay represents the time propagation of logic circuits.



3 Measuring circuit

3.1 Description of signal circuit

Signal circuit consists of three main parts:

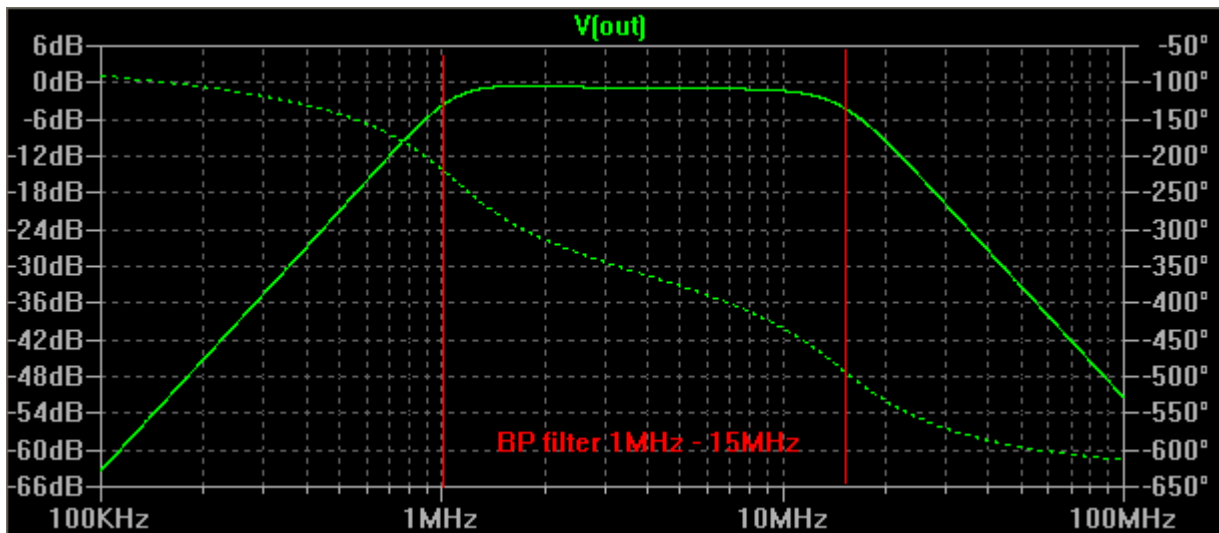


1. Multiplexer allows selecting the channel from which the signal is measured.
2. Bandpass filter cuts off noise apart from set measurement bandwidth.
3. Amplifier initially amplifies a weak signal received from the transducer, so that it can be sent to the measuring card even through the long cable.

The signal at the multiplexer input can have a maximum value of 400mVpp. With the amplifying x10 it makes the output signal amplitude 4Vpp.

MUX can operate with transducers of the resonant frequency of 0.5MHz - 25MHz.

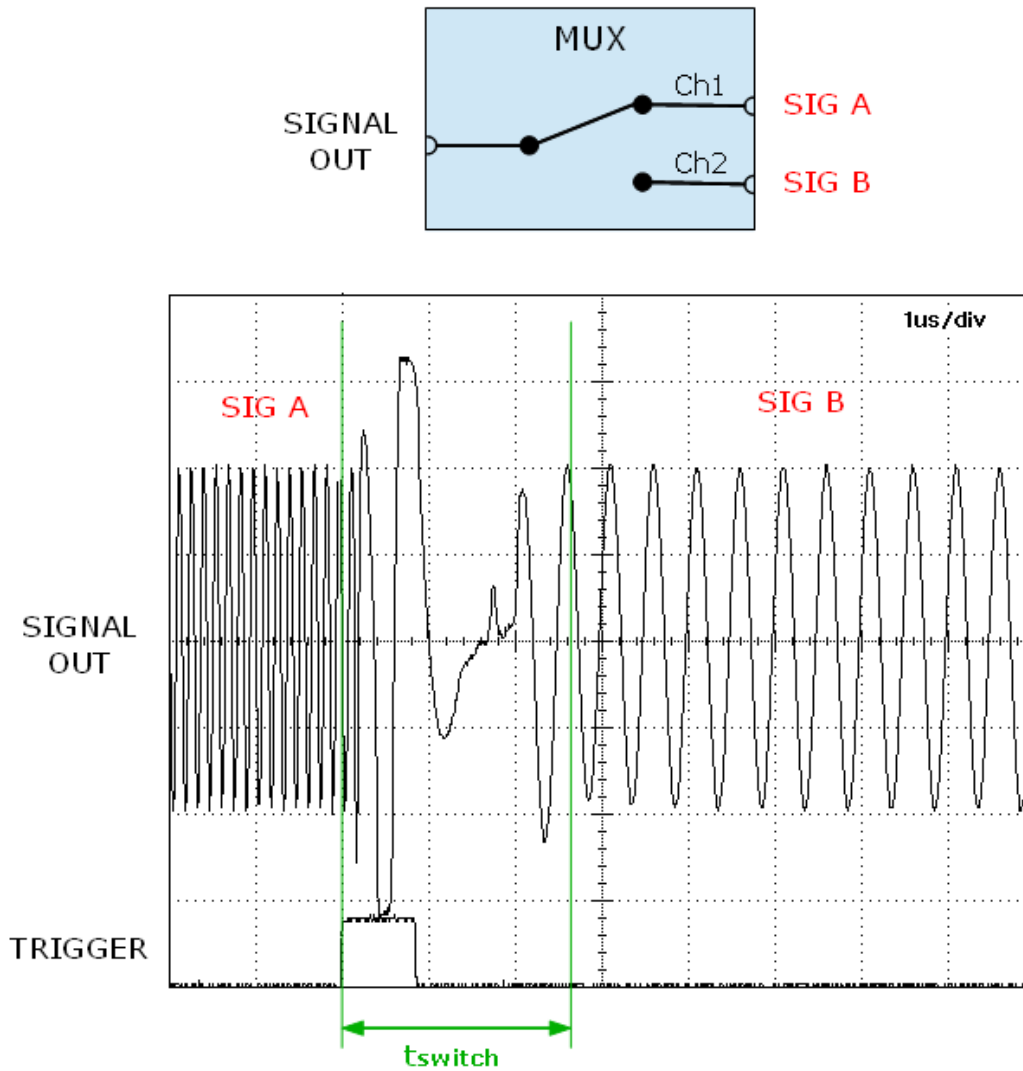
As standard in the MUX is used bandpass filter with a frequency response from 1MHz to 15MHz. At the customer's request, BP filter parameters can be matched to the transmitter.



Frequency response of standard filter

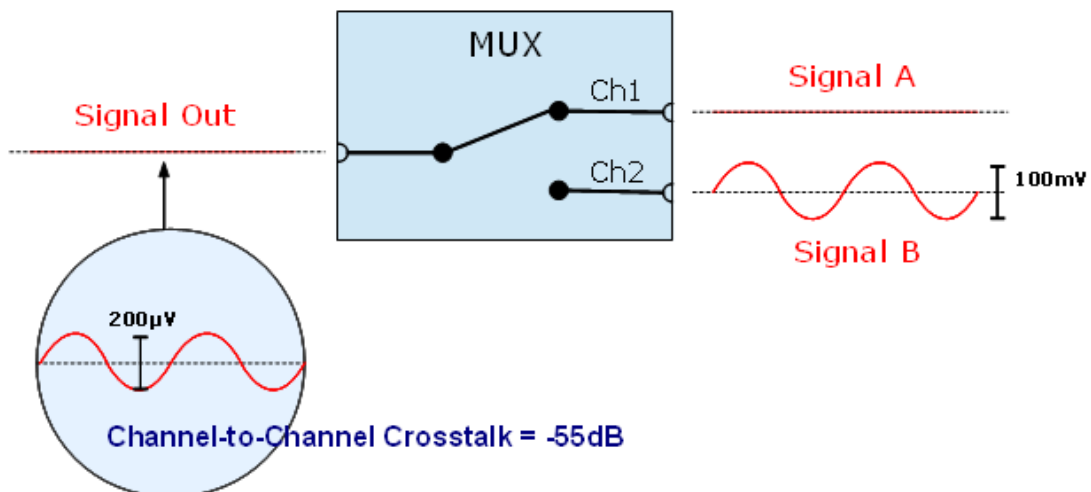
3.2 Channel switching time

Multiplexer channels are toggled when the trigger pulse appears. The signal from the selected channel is not immediately visible in the output. There is needed some time to stabilize the signal circuit. This time period marked as t_{switch} is about 3 μ s.



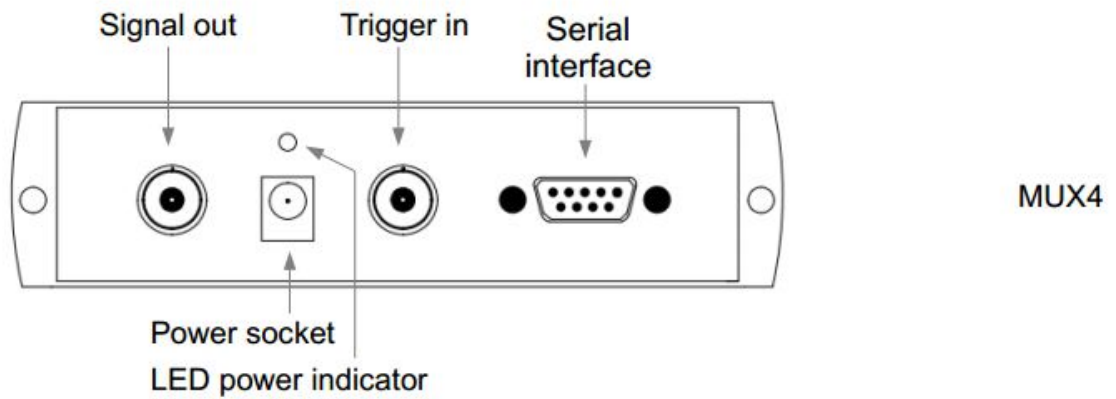
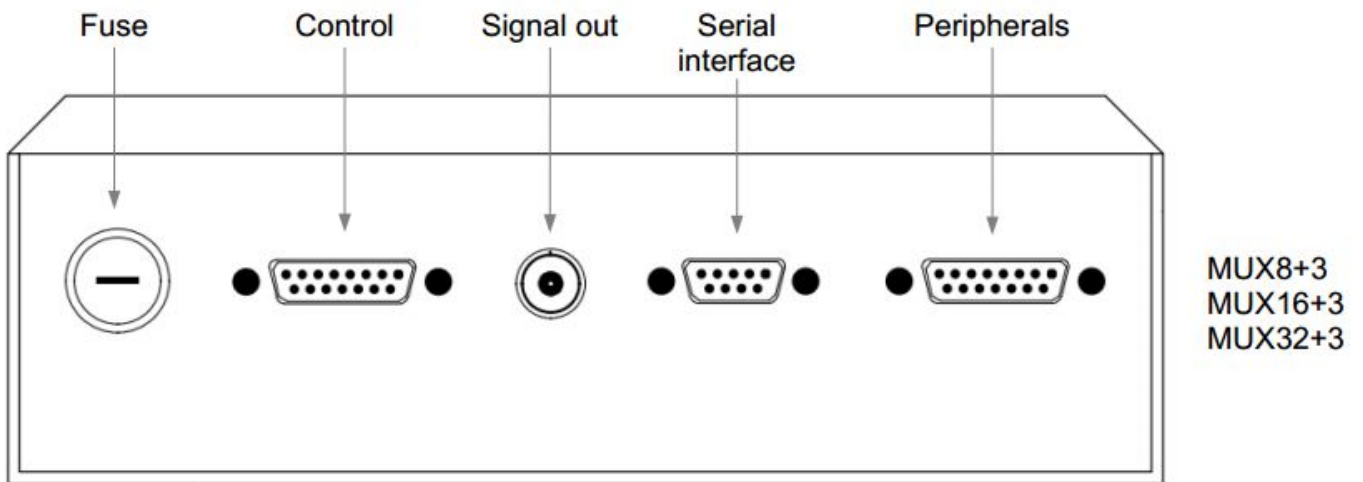
3.3 Crosstalk between channels

Crosstalk between channels is inevitable. However, it has very little value - unselected channel signal achieves the output but is attenuated about 550 times.



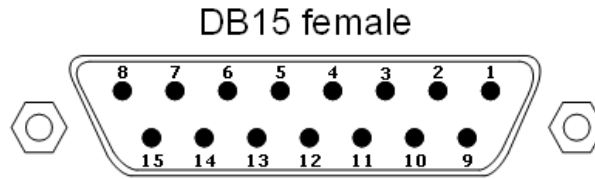
4 Sockets

4.1 Arrangement of the sockets on the housing of the MUX



4.1.1 Control

Female DB15 type socket. The connector is used to connect power and control signals from the measurement card.



PIN	Description	PIN	Description
1	Trigger input (TTL)	9	General Input 1 (TTL)
2	General Input 2 (TTL)	10	General Input 3 (TTL)
3	GND	11	n.c.
4	Switch Output 1 (TTL)	12	Switch Output 2 (TTL)
5	MUX ok (TTL)	13	General Input 4 (TTL)
6	n.c.	14	GND
7	Vreg input (0-10V)	15	n.c.
8	+12V DC (power supply)		

! MUX requires power (pin 3 and pin 8) and the trigger signal (pin 1) – the using of other lines is optional.

„MUX ok” pin:

After power of the device is on the state of this pin became to be high. This means that the device is properly initiated and is ready for use.

It goes down when thermal protection is activated. (see chapter **Thermal protection**).

4.1.2 Power socket

This is power DC socket with pin of 2,1mm.

It is to connect to Wall Socket Adapter, +12VDC 2A.

! MUX4: fuse is located on the printed board. To replace it, you have to open the case (for this purpose, unscrew the two screws on the front panel).

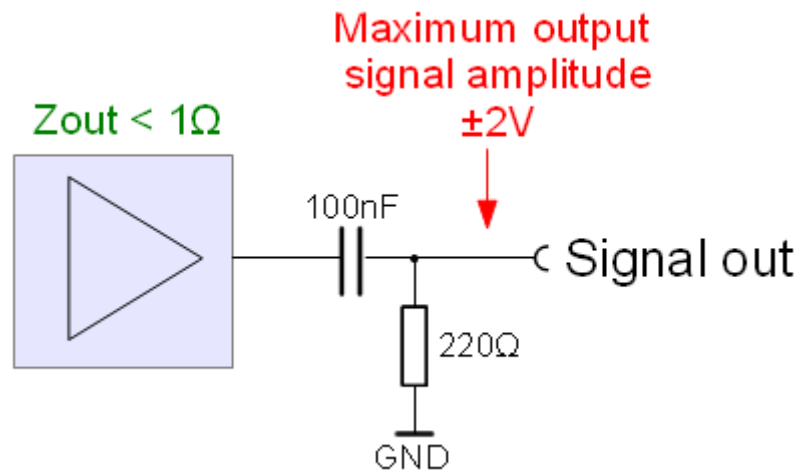
4.1.3 Trigger in

BNC type connector. It is to connect trigger signal (TTL) from measuring card.

4.1.4 Signal out

The analog signal from the selected channel is led to BNC connector.

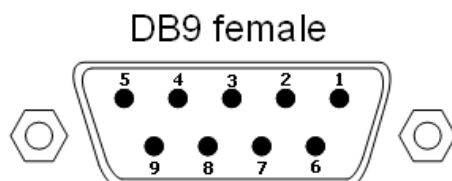
The figure shows a simplified diagram of the output stage:



The signal is AC coupled. The amplitude of the signal output can have a maximum value of 4V_{pp} . In most cases, the measuring card is placed at a long distance from MUX, what requires the use of long cables. Working with large signal amplitudes increases immunity to external interference.

4.1.5 Serial interface

Female DB15 type socket. Serial interface (RS232 or RS485/422) deserves to configuration of the MUX.



RS-232 mode

PIN	Description	PIN	Description
1	n.c.	6	n.c.
2	TXD	7	n.c.
3	RXD	8	n.c.
4	n.c.	9	VOLTAGE
5	GND		

RS-485 half duplex mode (optional)

PIN	Description	PIN	Description
1	RTX-	6	n.c.
2	RTX+	7	n.c.
3	n.c.	8	n.c.
4	n.c.	9	VOLTAGE
5	GND		

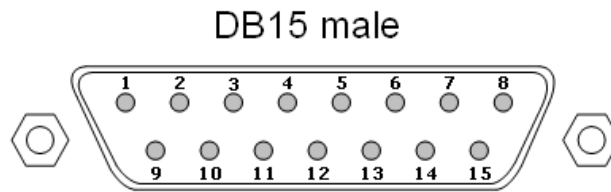
RS-422 / RS-485 full duplex mode (optional)

PIN	Description	PIN	Description
1	RX-	6	TX-
2	RX+	7	TX+
3	n.c.	8	n.c.
4	n.c.	9	VOLTAGE
5	GND		

VOLTAGE – optional +12V (normal not connected)

4.1.6 Peripherals

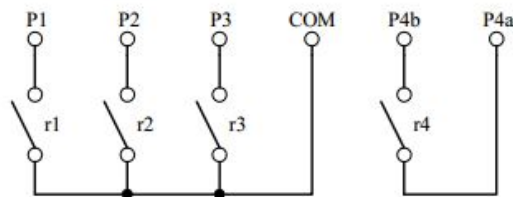
Male DB15 type socket. There are additional Input-Output pins.



PIN	Description	PIN	Description
1	Relay 1		
2	Relay 2	9	Relay 4a
3	Relay 3	10	Relay 4b
4	COM	11	+12V out (optional)
5	Digital input 1	12	GND
6	Digital input 2	13	GND
7	Analog out +	14	Analog out -
8	Analog in +	15	Analog in -

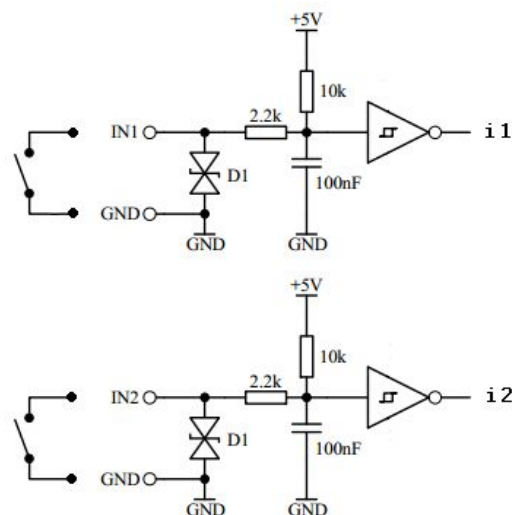
There are simplified diagrams of I/O.

Relays:



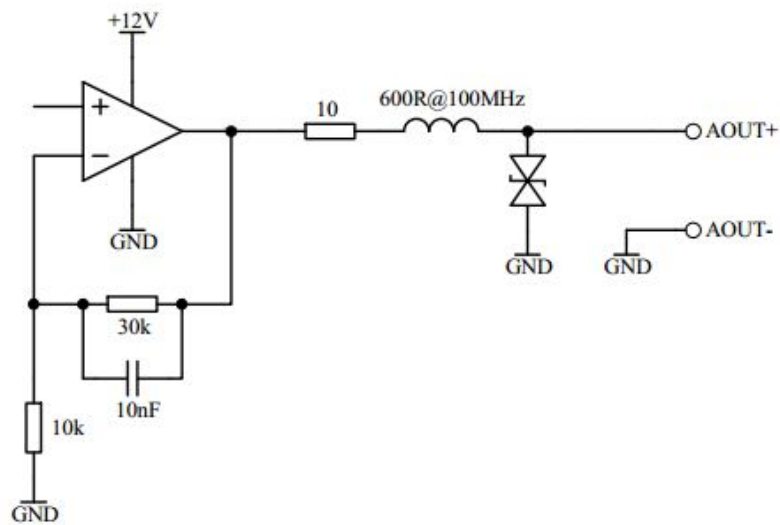
- rated current: 2A/120VAC; 2A/24VDC
- max rated power 240VA (AC)
- operate / release time: 5ms / 5ms

Digital Inputs:



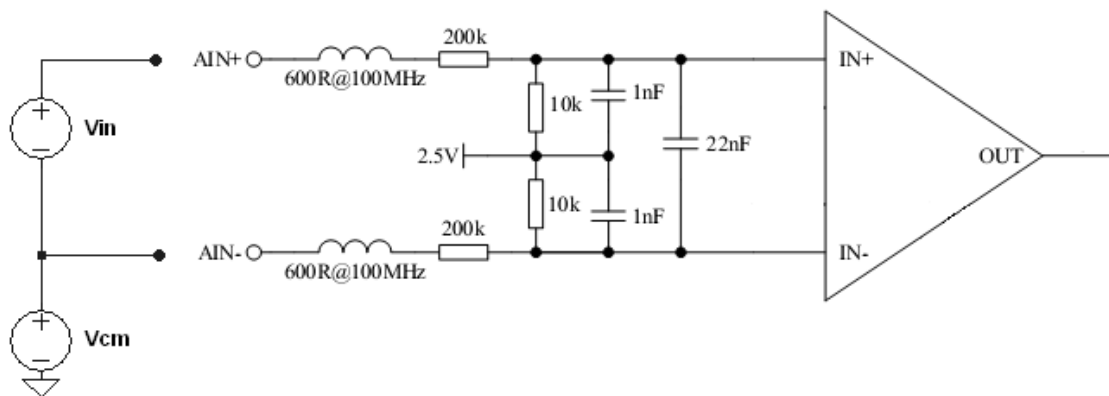
- input pulse must be at least 50 ms

Analog output:



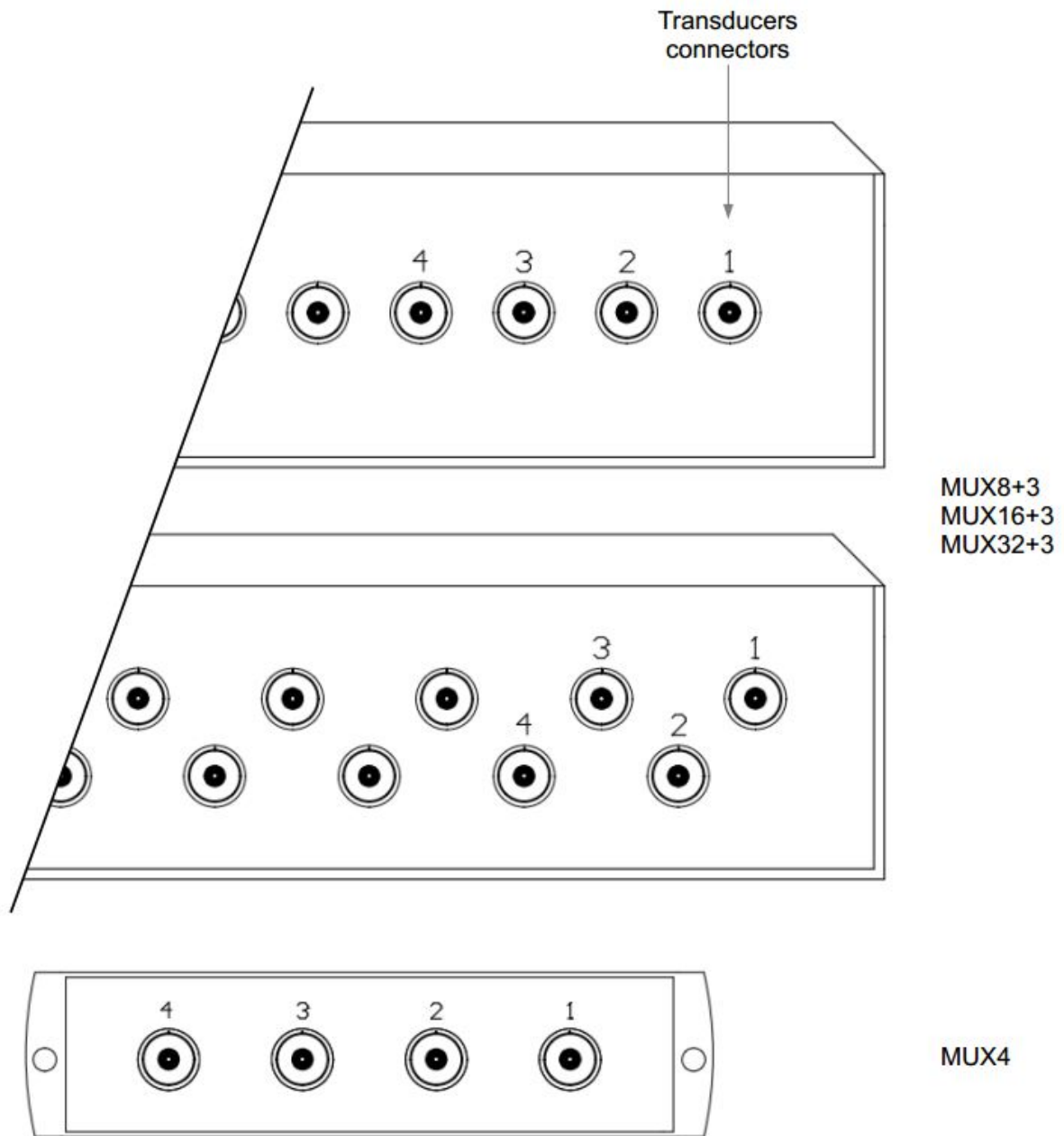
- Bandwidth: 530Hz
- Output Voltage: 0...10V
- Resolution: 12bit

Analog Input:



- Bandwidth: 360Hz
- measuring range: $\pm 10,5V$
- Vcm max: $\pm 10V$
- Resolution: 12bit

4.2 Connectors on the rear side of MUX housing



These are transducers connectors. BNC connectors are typically mounted in the MUX.

At the customer's request, can be mounted sockets of another type (i.e. Lemo type).

Depending on the number of channels, sockets are arranged in one row or in two rows. Regardless of the distribution of slots, the socket on the extreme right side is always the number 1 channel.

5 Control commands

- Each command must be terminated by the end of the line: **/n** (LF – „Line feed“ . The ASCII code is a sign of the value of 10 (dec)).
- Parameters can be separated by a space, comma or semicolon.
- A "?" sign for asking orders must be separated from the command by a space.
- **RS232** settings: **115200, 8bit, parity: even, 1bit stop**
- MUX acknowledges the command by sending feedback in the form of:
<order mnemonic> OK /n
- If the order contains an error MUX sends a feedback in the form of:
< order mnemonic > ERR <error code> < optional text message > /n
- If the MUX does not recognize the command, sends the information in the form of:
ERR < error code > < optional text message > /n

5.1 Getting started

command	Mnemonic	description
Ready	RDY	Receiving the command "RDY" is confirmed by feedback "R" Any other command will return an error message in the form of an "E"

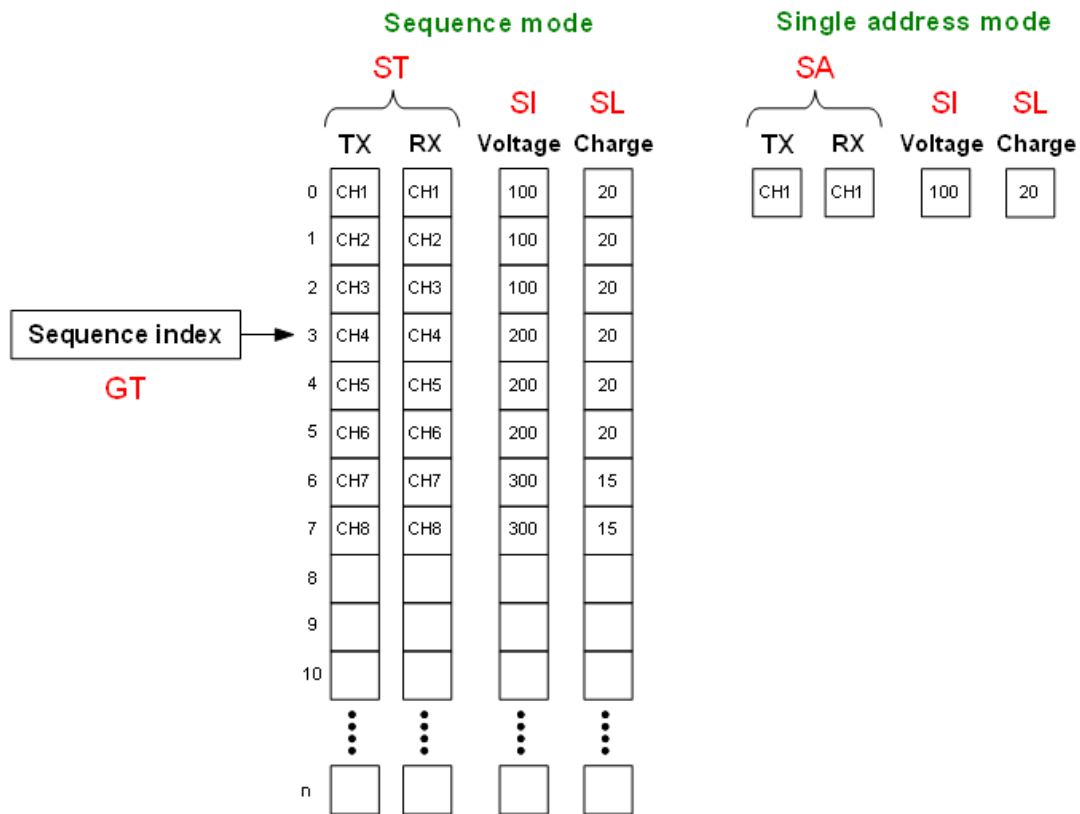
5.2 Measuring sequence

MUX has two modes of operation:

- Work with the sequence (ST)
- Work with a single address (SA)

 **These two modes are independent of each other. For each of them you should set separately the transmit / receive address, charging voltage (SI) and charging time (SL).**

You can switch between modes at any time by typing ST or SA



Trigger control

Control Trigger	CT x	x – trigger status: 0 – trigger off (turning off of the trigger does not affect the array index.) 1 – trigger on (turning on of the trigger resets array index)
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! Before each changing of parameters (new sequence, transmission parameters), we recommend to block the trigger (command CT 0).

Reading the index of array sequence

Get Table Index	GT	Returns the current position in the sequence array (position is counted from zero)
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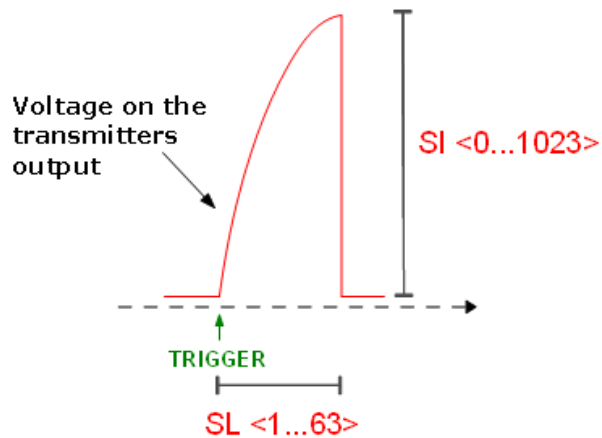
Setting a single address :

Set Single Address	SA T R	T – transmitting channel R – receiving channel (Addresses can be separated by commas or spaces) (Command disables the trigger) (Command switches to a single address mode)
	SA T	T – transmitting channel In this case, the address of the receiving channel is the same as the address of the transmission channel. (command disables the trigger)
	SA	switches to a single address mode (command does not affect the trigger and index of sequence address but stops trigger for 2us)
	SA ?	Feedback will be sent in the following form : SA T R

Setting of sequence array :

Set Table	ST T ₀ R ₀ T ₁ R ₁ ... T _n R _n	T _n – transmitting channel R _n – receiving channel, (addresses can be separated by commas or spaces, number of arguments in the list must be even) (command disables the trigger) (command switches to a sequence mode)
	ST	switches to a sequence mode (command does not affect the trigger and index of sequence address but stops trigger for 2us)
	ST ?	Feedback will be sent in the following form: ST T T ₀ ,T ₁ ,T ₂ ,T ₃ ,T ₄ ,T ₅ ,T ₆ ,T ₇ ,T ₈ ,T ₉ ,T ₁₀ ,T ₁₁ R R ₀ ,R ₁ ,R ₂ ,R ₃ ,R ₄ ,R ₅ ,R ₆ ,R ₇ ,R ₈ ,R ₉ ,R ₁₀ ,R ₁₁

5.3 Puls parameters



Charging voltage settings:

Set Impulse Voltage	SI V	V – puls voltage. Value from range of 0 ..1023 (it adjusts the charging voltage in the range of 0...100%)
	SI V ₀ I ₁ V ₁ I ₂ V ₂ ...	Charging voltage depends on the position in the sequence table. V ₀ – initial charging voltage (set just after the command). I ₁ V ₁ – if the sequence is in a position I ₁ , charging voltage V ₁ will be set. I ₂ V ₂ – if the sequence is in a position I ₂ , charging voltage V ₂ will be set (Command stops trigger for 30us)

	SI ?	
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Charging time settings:

Set Impulse Length	SL x	x – charging pulse duration. It is a value in the range of 1 to 63, expressed in units of [0.1us]. For example, the command "SL 20" will set the duration of the charging pulse 2us
	SL C ₀ I ₁ C ₁ I ₂ C ₂ ...	Charging voltage depends on the position in the sequence table. C ₀ – initial charging time (set just after the command). I ₁ C ₁ – if the sequence is in a position I ₁ charging time C ₁ will be set I ₂ C ₂ – if the sequence is in a position I ₂ charging time C ₂ will be set (Command stops trigger for 30us)
	SL ?	

Selecting of voltage charging control source

Config Impulse Voltage	CI x	x – specifies the source of the value of the charging voltage control: R – charging voltage is set through RS232 (SI command) A – charging voltage is controlled by analogue input (Control connector) (Voltage range is 0...10V, (it adjusts the charging voltage in the range of: 0...100%) (When power is on default enabled is RS232)
	CI ?	

5.4 I/O Peripherals

Relays

Set Relays	SR x	The command controls the relays: x: 0 – turning off all of the relays, 1 – turning on all of the relays. T – changes state of relays to the opposite. C – enables control from the measurement card
	SR r ₁ r ₂ r ₃ r ₄	command individually identifies the status of each relay r ₁ r ₂ r ₃ r ₄ : 0 – turn off 1 – turn on T – changes state to the opposite. X – don't change state.

Digital Inputs

Enable Input	EI ei ₁ ei ₂	This command sets the type of edge (falling / rising), which responds the input (IN1 / IN2) to. ei ₁ ei ₂ : 0 – the input is not checked. 1 – input reacts on the rising edge 2 – the input reacts on the falling edge The function returns the current state of the inputs simultaneously in the form of: EI i ₁ i ₂
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		<p>0 – input is low</p> <p>1 – input is high</p>
		<p>If MUX detects a change of the inputs, sends information in the form of:</p> <p>IN1 – there was a change in the input IN1</p> <p>IN2 – there was a change in the input IN2</p>

Analog output 0-10V

Set Voltage	SV x	Set voltage on analog output. x –DAC's word (12 bits, value from the range of 0..4095)
	SV ?	Returns voltage value on analog output (in the form of DAC's word)
	SV x mV	Set voltage on analog output. x – voltage in [mV] in the range of 0 .. 9999mV
	SV ? mV	Returns voltage value on analog output (mV)

Analog Input 0-10V

Get Voltage	GV	Returns voltage value on analog input. Voltage in [mV]
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5.5 Diagnostics

Version information	# ?	Information about firmware version
Software Trigger	TRG	MUX's trigger is generated by software
Reset	RST	Device Reset

Get Temperature Measurement	GTM	Returns temperature value of radiator in Vreg circuit (Temperature in Celsius degrees with resolution 5°.)
Get Voltage Measurement	GVM	Returns voltage value of Vreg and one of Vreg_in. In form of: GVM <Vreg> <Vreg_in> (Voltage in [mV])

5.6 Error Messages

- MUX acknowledges the command by sending feedback in the form of:

<order mnemonic> OK /n

- If the order contains an error MUX sends a feedback in the form of:

< order mnemonic > ERR <error code> /n

Some errors are not related to a specific command (i.e. "Uart frame error"). In this case MUX sends the information in the form of:

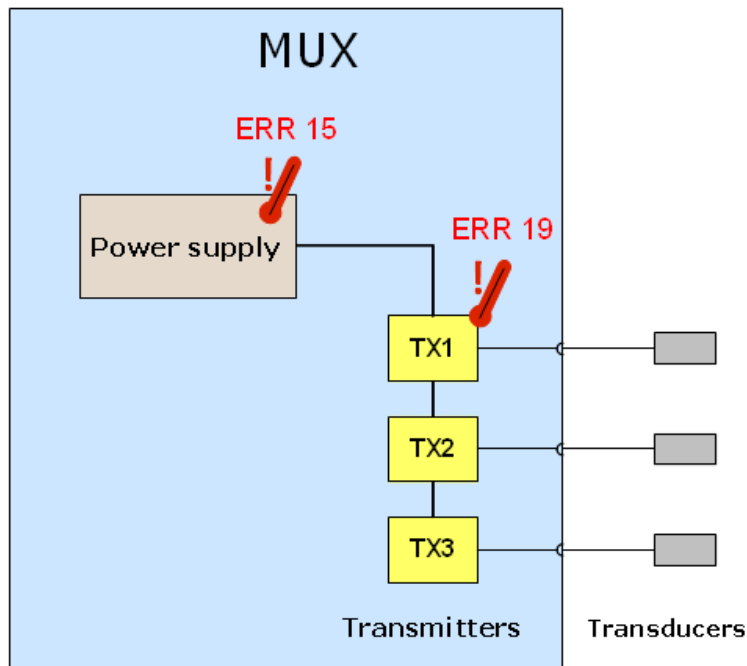
ERR < error code > /n.

Error code	Error message
2	"RS232 frame error"
3	"Watchdog Reset"
4	"Wrong command"
5	"Too few parameters"
6	"Too many parameters"
7	"Too many items in the command"
8	"Odd number of parameters"
9	"Wrong parameter"
10	"Wrong address"
11	"Address out of range"
12	"Wrong voltage"
13	"Analog input source is selected"
14	"Wrong impulse length"
15	"Power transmitters temperature is too high"
17	"Even number of parameters"
18	"Lost trigger"
19	"Transmitters is overheating"
20	"UART receive buffer overflow"
21	"Device is busy"

5.7 Thermal protection

MUX has a double thermal protection:

1. The temperature of the power module of transmitters is monitored (the temperature can be read by GTM command)
2. Each of transmitters has got a thermal protection. The user, however, does not have an access to information which of the transmitters is too hot.



When a thermal protection is activated, the device


- sends a message about the activation of the protection ("ERR 15" or "ERR 19")
- deactivates trigger
- deactivates power supply
- changes the state of "MUX ok" pin to „0" (see chapter **Control**).

To unlock the device, it is necessary to send the command: "CT 1", what causes:

- the activation of the trigger
- the changing of the state of the "MUX ok" pin to 1.

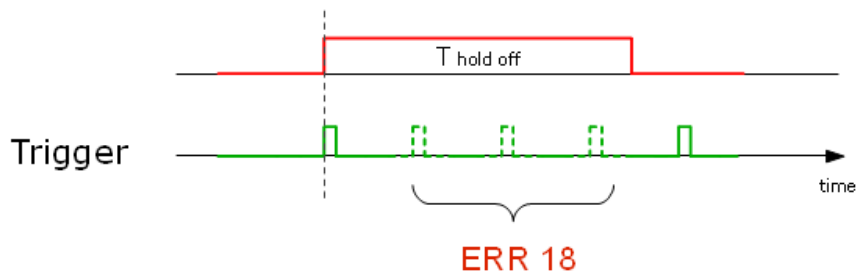
If after the command "CT 1", the device temperature does not fall down to a safe level, the thermal protection will work again.

If during the MUX operation thermal protection activates, you can try:

-  reduce the length and / or pulse transmission voltage (see chapter **Puls parameters**).
- reduce the PRF (pulse frequency of the trigger).

5.8 Exceeding of the maximum frequency of the input signal trigger

When MUX detects the input trigger pulse, starts to generating of high voltage pulse at the output of the selected transmitter (see chapter **Transmitter**). During this time ($T_{\text{hold off}}$), the device will not accept the next trigger pulses.

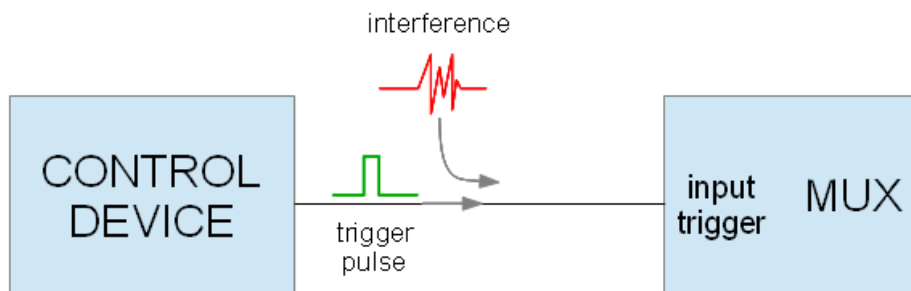


If during this time the input trigger pulses were detected, the device reports an error "ERR 18". This error means that the trigger pulse was omitted (the message does not specify how many pulses were omitted, at least one).

! The maximum frequency of the pulses at trigger input is 75kHz. Single multiplexer channel is not able to work by such frequency (depending on the load, the transmitter can work with PRF to 5 kHz).

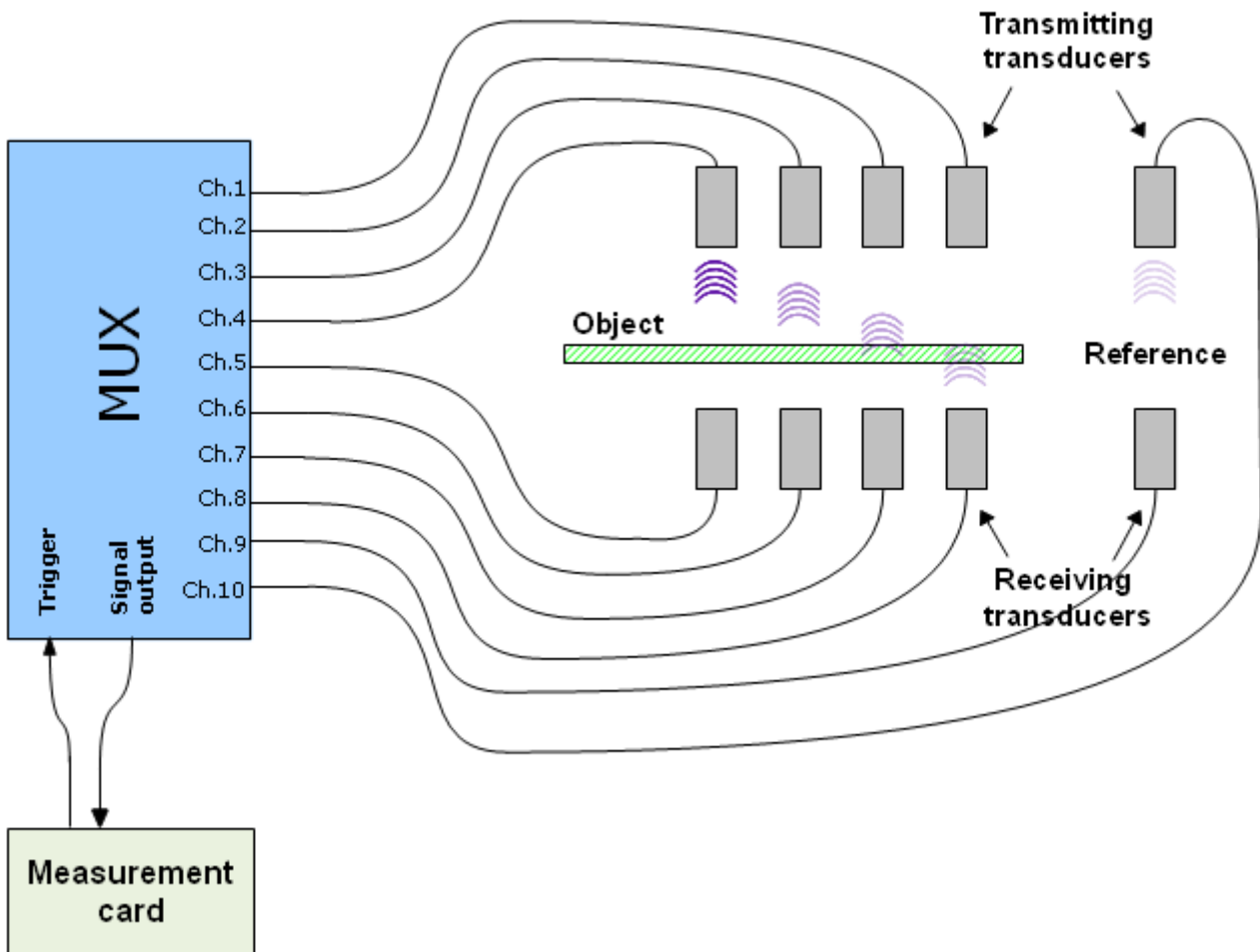
If during the operation, the MUX brings up an error "ERR 18", two things can cause it:

1. Your controller operates with too high PRF. Try to reduce the frequency of the trigger pulses.
2. External noises getting into the cable connecting the control device with MUX, causing false trigger pulses. In this case, check the cable and its arrangement.



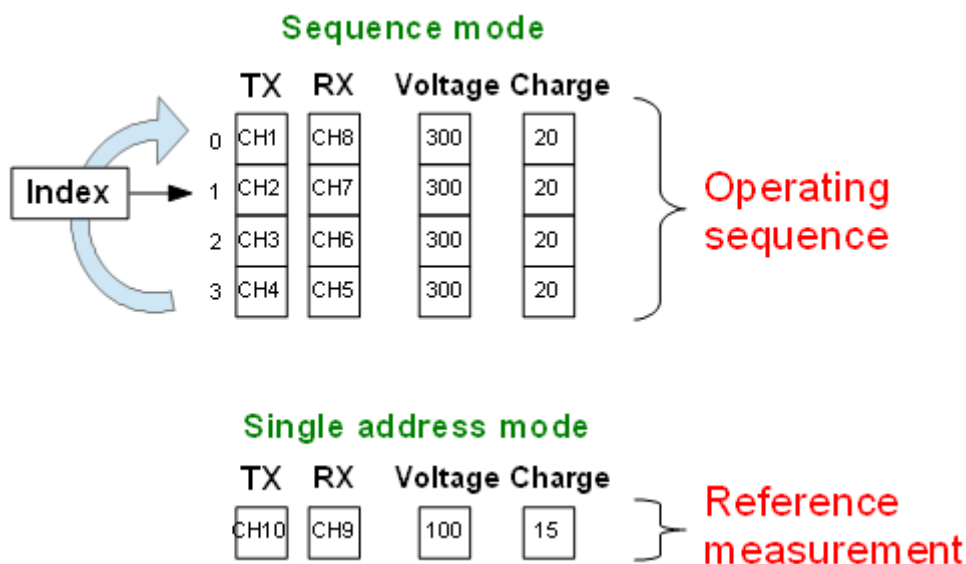
5.9 Sample application

Consider the example application. We examine the object at 4 points by measuring the attenuation of ultrasonic waves using Through Transmission method. An additional pair of sensors makes the reference measurement (temperature). In this purpose it is necessary to connect 10 transducers as shown on following figure:



Half of the transducers only transmit and the other half just receives. Measuring sequence consists of 4 steps. Reference transducers are used only for calibration and there is not need to use its during normal operation.

According to this description, MUX is programmed to operate following:



Following commands are sent via serial interface:

RDY when power is on, MUX requires this command to operate normally

First, the reference measurement is programmed:

SA 10 9 Single address mode, channel no 10 is chosen to transmit signal, channel 9 – to receive

SI 100 Single address mode, charging voltage is set as 100

SL 15 Charging time is 1.5us

Then measurement sequence is programmed:

ST 1 8, 2 7, 3 6, 4 5 Simple measurement sequence – transmission and receiving one after one channel

SI 300 Charging voltage for whole sequence is 300

SL 20 Charging time for sequence is 2us

MUX has been configured. Measurement starts.

CT 1 trigger is enabled

From this moment each triggering pulse causes exciting of transmitter no 1, then no 2, 3, 4 and then measurement sequence repeats.

If you need make measurement with reference channel you send following command:

SA

From this moment, triggering pulse causes exciting of transmitter no 10

After reference measuring there is possibility to be back to sequence by:

ST

(These two commands do not stop trigger)