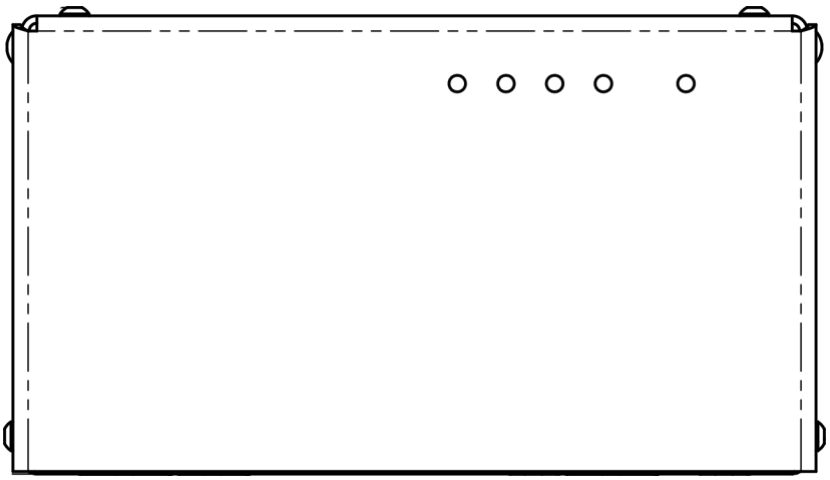
LSCB control board

User manual



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Description

LSCB is a control board, developed to simplify the design and use of flashlamp drivers based on power modules by OEM Tech. It provides a possibility for user to set and change an output voltage value for capacitor charger and Pockels cell driver, allows to form the output pulses for discharge circuit(s) and Pockels cell driver with user-defined delays and to vary other parameters. The output signals could be synchronized either internally or externally.

By default, LSCB controls single or dual-channel laser or IPL system with average power from 1 kW to 4 kW level and supports the next devices:

1) One capacitor charger of PCA-series
2) One or two NBU-1012 discharge circuits
3) One Pockels cell driver of QBU- or QBD-series
4) Full set of minor features like IDC, footswitch, synchro input and outputs

Besides, several customized modifications of LSCB are available on request (see also *How to order?* section):

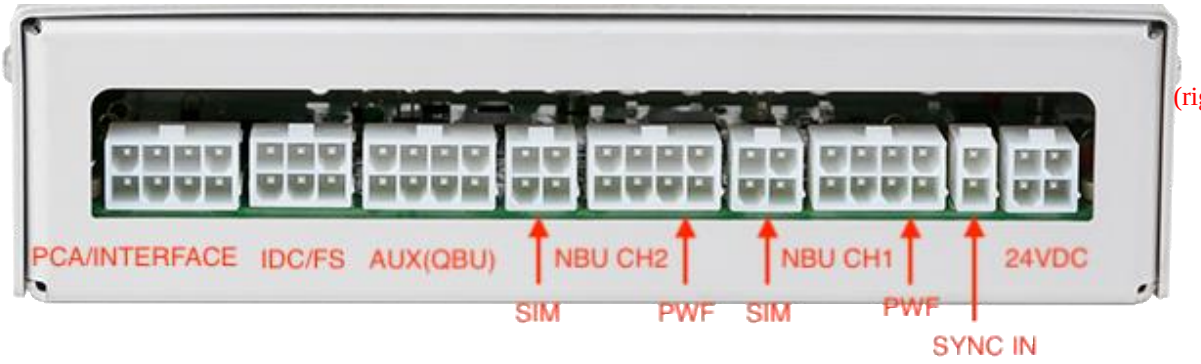
- "4 channel" version – for high power multi-channel Holmium lasers (it is able to control up to four flashlamps and synchronize their flashes with the rotating mirror)
- "PWM" version – for Nd:YAG, Alexandrite and IPL systems with long and truly rectangular pulses (it works with PWM-based discharge circuits of NBD-series)
- "Pico" version – for picosecond Nd:YAG lasers used in aesthetics (in addition to the standard equipment it is able to control a seed-oscillator driver)
- "RF" version – for aesthetic machines combining flashlamp (laser, IPL) and RF technologies (in addition to the standard equipment it is able to control a RF power module of RFPS-series)
- "Diode" version – for aesthetic machines combining flashlamp (laser, IPL) and diode technologies (in addition to the standard equipment it is able to control a diode driver of PDD-series)

Base interface to connect LSCB to PC or master control board is RS-232. RS-485 interface, as well as other variations, are available on request. Simple PC software is supplied together with the module.

Appearance

Connections, signals, signal descriptions

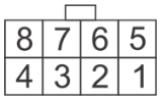
RS-232/485 (left side)



USB (right side)

PCA/INTERFACE: Molex 3930-1080

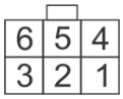
Capacitor charger of PCA-series is to be connected here.



PIN (color)	DESIGNATION	DESCRIPTION
1 (black)	Interface Return	See user manual of PCA-series capacitor charger for the detailed signal description
2 (white)	Fault	
3 (blue)	Inhibit	
4	N/C	
5 (red)	+15V DC	**Important note: signals on PCA/INTERFACE connector are galvanically isolated from other circuits of LSCB controller.**
6 (green)	Ready Indicator	
7 (yellow)	Voltage Program	
8 (violet)	Voltage Monitor	

IDC/FS: Molex 3930-1060

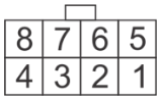
Door interlock connector and/or footswitch or fingerswitch are to be connected here.



PIN (color)	DESIGNATION	DESCRIPTION
1 (green)	IDC	Door interlock connection. The pin should be pulled to the ground to allow module operation.
2 (blue)	Footswitch (Fingerswitch)	Footswitch (fingerswitch) connection. Once output is enabled, the pin should be pulled to the ground to start flashes.
3 (white)	Synchro Output 1	Synchro output signal coincident with Pulse signal applied to the flashlamp (NBU PWF connector).
4 (black)	GND	Common ground of IDC, Footswitch, Synchro Output 1 signals
5 (white)	Synchro Output 2	Synchro output signal coincident with Pulse signal applied to AUX(QBU) connector.
6 (black)	GND 2	Ground of Synchro Output 2 signal

AUX (QBU): Molex 3930-1080

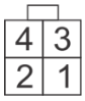
Auxiliary equipment, for example QBU-series Pockels cell driver is to be connected here.



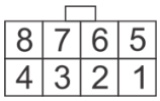
PIN (color)	DESIGNATION	DESCRIPTION
1 (white)	Pulse	See user manual of QBU-series Pockels cell drivers for the detailed signal description Another equipment with the compatible set of the controlling signals can be connected here instead of QBU. 15V DC is to be applied to pin 3 in this case to assure correct behavior of all signals.
2 (-)	N/C	
3 (red)	+15V DC	
4 (blue)	Enable	
5, 6 (black)	GND	
7 (yellow)	HV Monitor	
8 (green)	HV Program	

NBU/SIM CH1 and NBU/PWF CH1: Molex 3930-1040 and Molex 3930-1080

Discharge circuit of NBU-series is to be connected here.



PIN (color)	DESIGNATION	DESCRIPTION
1 (violet)	GND	See user manual of NBU-1012 discharge circuit for the detailed signal description
2 (yellow)	Simmer Sensor	
3 (red)	Simmer Enable	
4 (black)	GND	



PIN (color)	DESIGNATION	DESCRIPTION
1, 6 (black)	GND	See user manual of NBU-1012 discharge circuit for the detailed signal description
2, 4, 7, 8	N/C	
3 (orange)	Pulse	
5 (green)	Discharge	

NBU/SIM CH2 and NBU/PWF CH2: Molex 3930-1040 and Molex 3930-1080

The second discharge circuit of NBU-series is to be connected here (of course, it is possible to operate LSCB control board with only one NBU discharge circuit connected).

Pin layout and signal description are identical to NBU/SIM CH1 and NBU/PWF CH1 connectors.

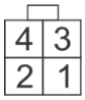
SYNC IN: Molex 3930-1020

Synchronization input for operations in regimes with external synchronization of flashes.

PIN (color)	DESIGNATION	DESCRIPTION
1 (white/blue)	Synchro Input	Incoming synchronization pulses should be applied to these pins if controller runs in external synchronization mode.
2 (black)	GND	

24V DC: Molex 3930-1040

The connector is used for powering LSCB controller.



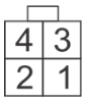
PIN (color)	DESIGNATION	DESCRIPTION
1, 2 (red)	24V DC	24V DC power is to be applied here.
3, 4 (black)	GND	

USB: Micro USB type

LSCB can be connected to PC using this connector via standard USB to micro USB cable.

RS-232: Molex 43045-0400

LSCB can be connected to the master control board using this connector. Connecting to PC is also possible, although an appropriate USB to RS-232 adapter is needed.



PIN (color)	DESIGNATION	DESCRIPTION
1 (orange)	RX	to be connected to TX of the host
2 (blue)	TX	to be connected to RX of the host
3, 4 (black)	GND	

LEDS:

There are several LEDs indicating state of LSCB controller

Power LED (blue):

- lights steadily while LSCB is powered

Simmer LED (yellow):

- blinks if at least one simmer supply is enabled (“s 1”), but the simmer monitor returns the absence of the simmer discharge (mS returns 0)
- lights steadily if all active flashlamps are simmered successfully

Charger LED (yellow):

- blinks if capacitor charger is enabled (“c 1”), but the capacitor bank isn’t charged yet (charger is not ready, i.e. mR returns 0)
- lights steadily if capacitor charger is enabled (“c 1”) and the capacitor bank is charged up to required value (charger is ready, i.e. mR returns 1)

Pulse LED (green):

- off when outputs are disabled
- in run mode lights steadily if output in two channels is set to synchronous («g 0») and blinks if output in two channels is set to counter-phasal («g 180»)

Error LED (red):

- lights steadily if one of connected devices reports about failure
- blinks if internal Fault of LSCB has occurred

Operations (first run procedure)

1. **If LSCB is controlled from PC via USB:**
   - Connect LSCB to PC using USB to micro USB cable
   - Drivers will be installed automatically on Windows 8 and higher
   - Run Windows software supplied together with LSCB

   If LSCB is controlled from another device via RS-232/RS-485 interface:
   - Apply 24V DC power to LSCB
   - Connect LSCB to the controlling device via RS-232/RS-485 interface
   - Get ready to send text commands to LSCB
2. Ensure that IDC and Footswitch circuits are connected properly and don't block the operations
3. Before starting the operations please check if the states of the following parameters (commands) match your application and re-set their values if necessary:

Parameter (If LSCB is controlled from PC via USB, see Appendix 1 for the details)	**Command (If LSCB is controlled from another device via RS-232/RS-485 interface, see Appendix 2 for the details)**
Active and non-active channels (**Active**)	a
Single pulse mode or pulse train mode (**Pulse mode**)	b
Whether channels are synphase or in counter-phase (**Phase**)	g
Whether the synchronization is internal or external (**Synchronization**)	x
External synchronization trigger edge (**Triggering edge**)	t
V_{MAX} of the capacitor charger (**Maximum voltage Vmax**)	vm
Impedance of your flashlamp (**Lamp impedance K0**)	!k0
Output power limitation (**Power limit**)	h

4. Set main parameters:

Operating voltage (**Voltage**)	v
Pulse repetition rate (**Frequency**)	f
Pulse width (**Pulse length**)	p

5. Enable capacitor charger:

Charge	c

6. Trigger simmer discharge through flashlamp (flashlamps):

Simmer	s (s1, s2)

7. Enable flashes:

Start	r (r1, r2)

Specifications

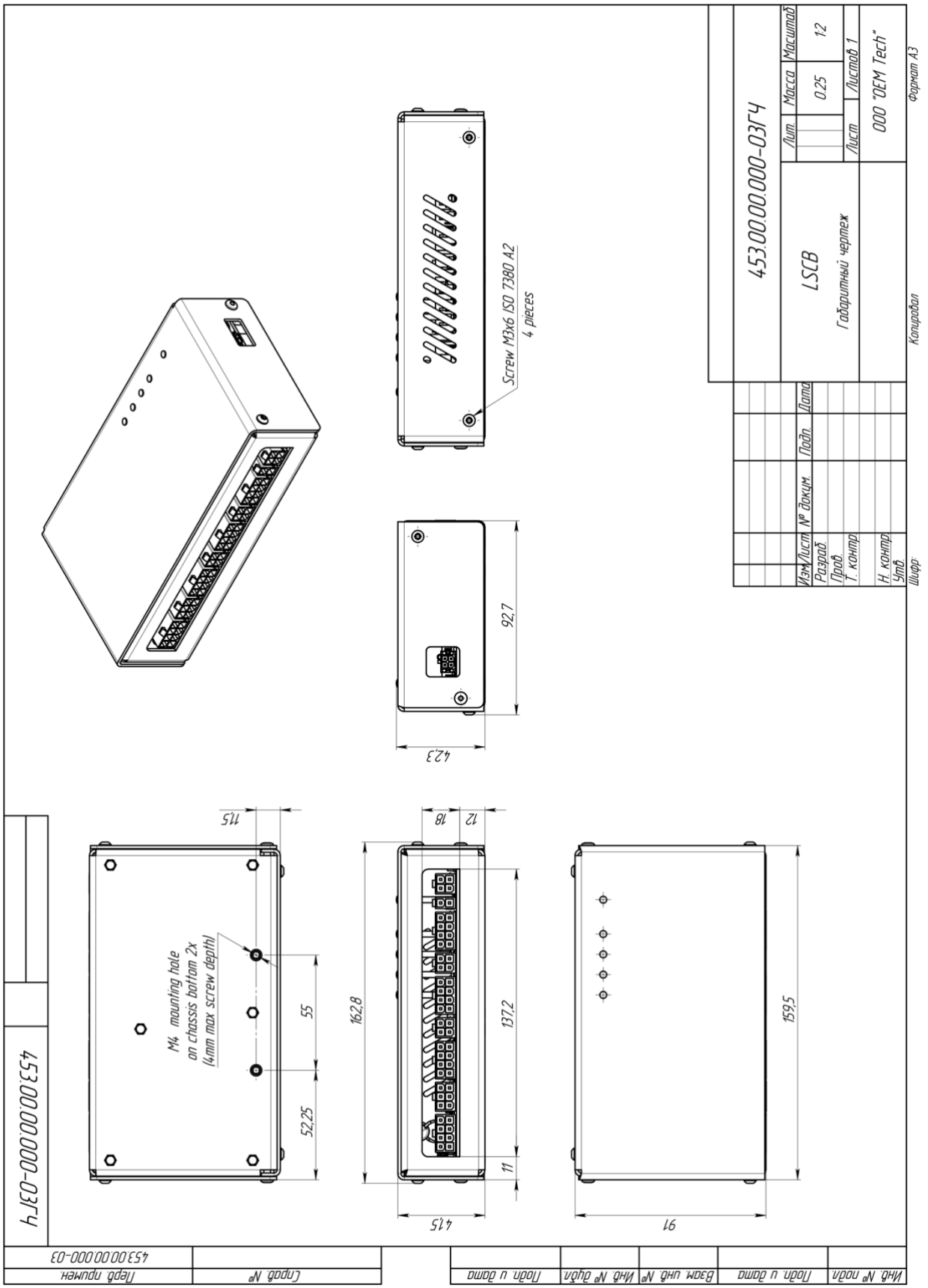
ELECTRICAL

Power:	
Input voltage	24V DC
Current consumption	1A max
Interfaces:	
Machine interfaces	USB RS-232 (by default), RS-485 (on request)
Synchronizations	1pc synchro input (more in some versions, see *How to order?* section for the details) 2pcs synchro outputs
Controlled power equipment	Modification dependent (see *How to order?* section for the details)
Other	IDC, footswitch, status LEDs
Cooling:	Passive
Environment:	
Operation temperature	+10… +40°C
Storage temperature	-20 … +60°C
Humidity	90%, non-condensing

MECHANICAL

Dimensions	See dimensional drawing below
Weight	Approx. 0.5 kg

DIMENSIONAL DRAWING



How to order?

Modification / description	Part number	Controlled equipment
Standard – suitable for the vast majority of applications including IPL, long pulse lasers and Q-switched laser systems (Nd:YAG, Ruby, Alexandrite, Holmium, Erbium etc)	LSCB	1pc PCA-series capacitor charger (*) 1-2pcs NBU-1012 discharge circuits 1pc Pockels cell driver of QBU-series or QBD-series
4-channel – for high power multi-channel Holmium lasers (it is able to control up to four flashlamps and synchronize their flashes with the rotating mirror)	LSCB-4	1pc PCA-series capacitor charger (*) 1-4pcs NBU-1012 discharge circuits
PWM – for Nd:YAG, Alexandrite and IPL systems with long and truly rectangular pulses (it works with PWM-based discharge circuits of NBD-series)	LSCB-PWM	1pc PCA-series capacitor charger (*) 1-3pcs discharge circuits of NBD-series (with PWM) or NBU-series (free discharge)
Pico – for picosecond Nd:YAG lasers used in aesthetics (in addition to the standard equipment it is able to control a seed-oscillator driver)	LSCB-Pico	1pc PCA-series capacitor charger (*) 1-2pcs NBU-1012 discharge circuits 1pc SDC-series seed-oscillator driver
RF – for aesthetic machines combining flashlamp (laser, IPL) and RF technologies (in addition to the standard equipment it is able to control a RF power module of RFPS-series)	LSCB-RF	1pc PCA-series capacitor charger (*) 1-2pcs NBU-1012 discharge circuits 1pc RFPS-series RF power supply
Diode – for aesthetic machines combining flashlamp (laser, IPL) and diode technologies (in addition to the standard equipment it is able to control a diode driver of PDD-series)	LSCB-PDD	1pc PCA-series capacitor charger (*) 1-2pcs NBU-1012 discharge circuits 1pc PDD-series pulsed diode driver

(*) multiple capacitor chargers can be connected in parallel in master-slave configuration and controlled from a single LSCB

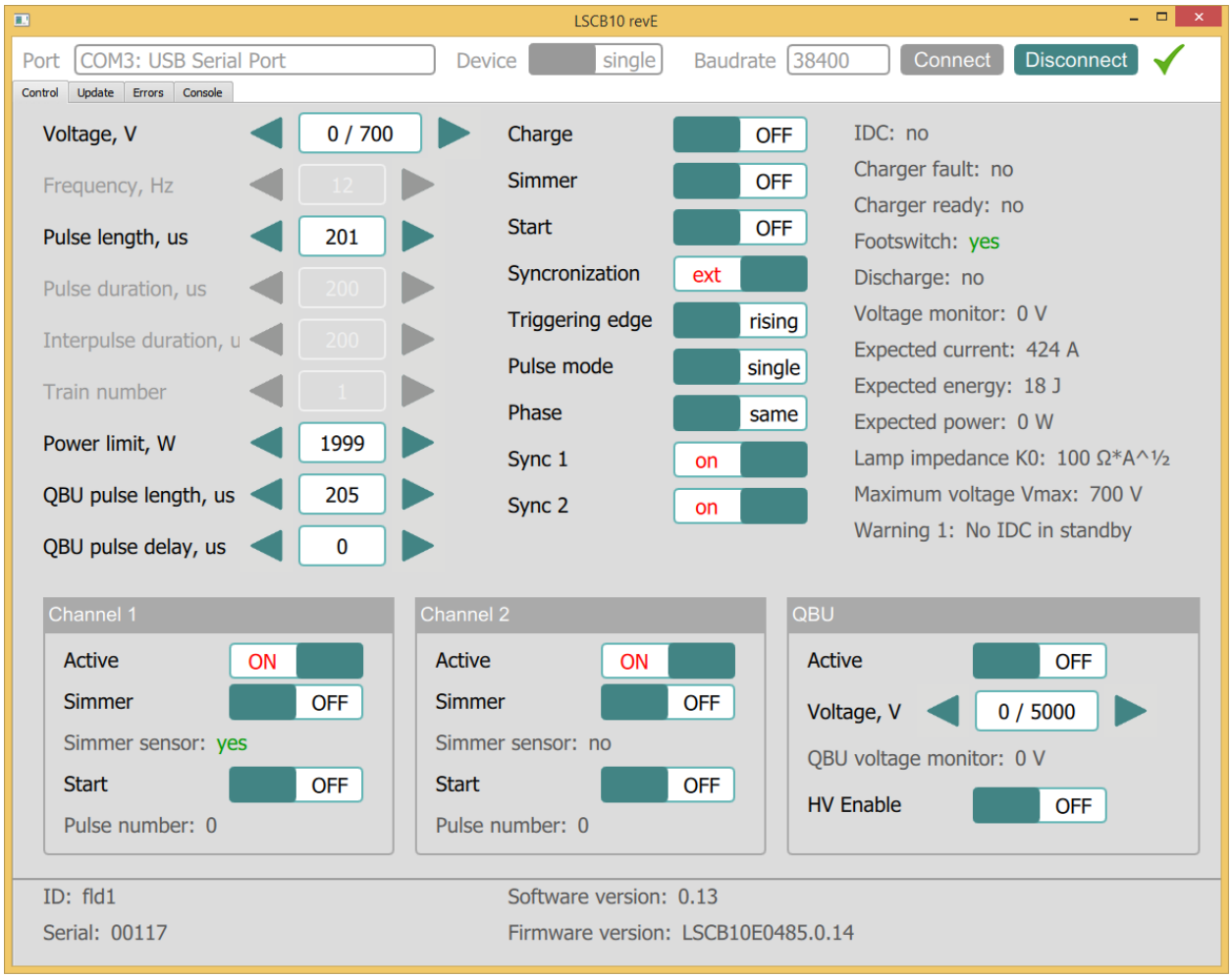
LSCB has an additional hardware protection from too long flashes caused by MCU failure. In other words, the maximal allowed pulse width may depend on hardware configuration. Please let us know the desired protection level at the moment of order by adding the corresponding suffix to LSCB's part number:

- -1ms – hardware protection limits maximal pulse width at 1ms level
- -10ms – hardware protection limits maximal pulse width at 10ms level
- -100ms – hardware protection limits maximal pulse width at 100ms level
- -XXms – other level (XX milliseconds)

Examples:

- LSCB-1ms – standard LSCB, 1ms maximal pulse width
- LSCB-PWM-20ms – PWM version of LSCB, 20ms maximal pulse width

Appendix 1. Software description



Voltage – sets the desired output voltage (V)

Frequency – sets the desired repetition rate of flashes (Hz)

Pulse length – in **Single pulse mode** – sets the desired pulse width (us)

Pulse duration – in **Pulse train mode** – sets the duration of individual pulselets (us)

Interpulse duration – in **Pulse train mode** – sets the interval between the individual pulselets (us)

Train number – in **Pulse train mode** – sets the number of pulselets in each train

Power limit – sets the average power limit (W)

QBU pulse length – sets the pulse width which is sent in form of TTL “1” to Pulse pin of AUX(QBU) connector

QBU pulse delay – defines delay between pulses applied to NBU and QBU; can be positive and negative

Charge – turns capacitor charging module on and off

Simmer – turns simmer supplies of all **active** NBU-1012 on and off

Start – enables and disables flashes in all **active** channels

Synchronization – select synchronization mode – **Internal synchronization** / **External synchronization**

In **Internal synchronization mode** flashes are defined by LSCB

In **External synchronization mode** flashes are defined by external signal applied to SYNC IN connector of LSCB

Triggering edge – in **External synchronization mode** defines the triggering edge of synchronization signal – either rising edge or falling edge

Pulse mode – switches LSCB between **Single pulse mode** and **Pulse train mode**

Phase – switches LSCB between synphase and counterphase operations of Channel 1 and Channel 2 (if both are active)

Sync 1 and **Sync 2** – defines if the first and the second synchro outputs are active or not

Channel 1 Active and **Channel 2 Active** – makes the corresponding channel active or inactive

Channel 1 Simmer and **Channel 2 Simmer** – starts/stops simmer supply in Channel 1 and Channel 2 respectively

Channel 1 Start and **Channel 2 Start** – starts/stops flashes in Channel 1 and Channel 2 correspondingly

QBU Active – makes QBU channel (i.e. AUX(QBU) connector) active or inactive

QBU HV Enable – enables/disables high voltage output of QBU

QBU Voltage – defines the output voltage of QBU

IDC – status of Door Interlock (IDC signal of IDC/FS connector) – flashes are prohibited if IDC loop is open

Charger fault – internal fault status of the capacitor charging power supply (Fault signal of PCA)

Charger ready – Ready signal of PCA

Footswitch – footswitch status (FS signal of IDC/FS connector)

Discharge – status of discharge resistors (Discharge signal of NBU-1012)

Voltage monitor – the actual voltage on the capacitor bank (Voltage monitor of PCA)

Expected current – the calculated current through the flashlamp (calculations are based on Voltage and Flashlamp impedance K0 values)

Expected energy – the calculated flash energy (calculations are based on Voltage, Flashlamp impedance K0 and Pulse length values)

Expected power – the calculated power through flashlamp (calculations are based on Voltage, Flashlamp impedance K0, Pulse length and Frequency values)

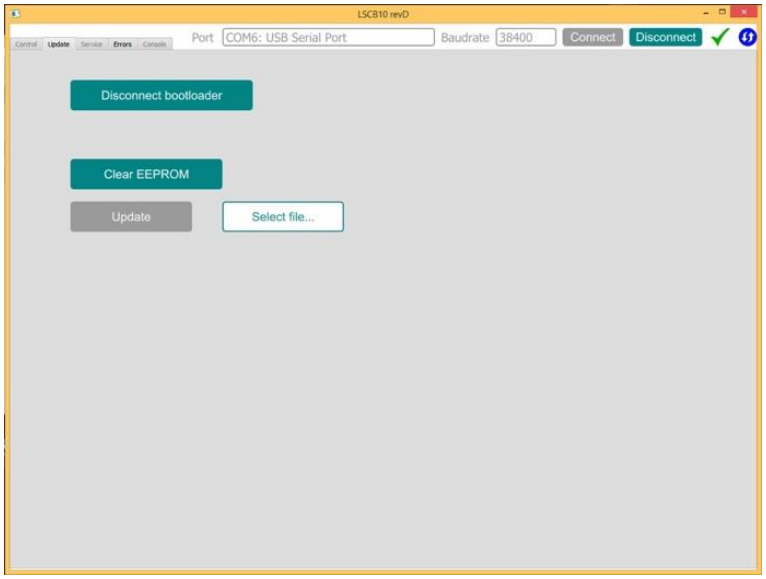
Lamp impedance K0 – should be set in accordance flashlamp datasheet

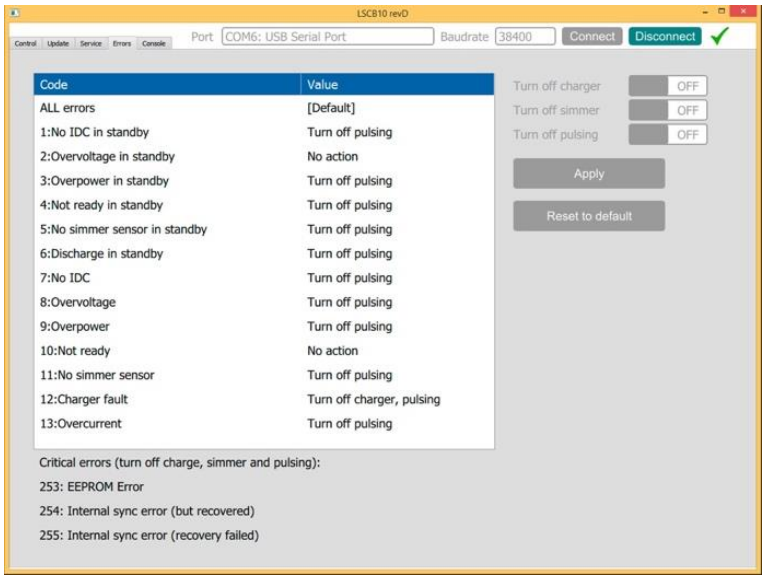
Maximal voltage Vmax – maximal voltage of the particular capacitor charger (should be set in accordance with PCA part number)

ERROR (or **WARNING)** – the last error occurred

Important note. By default LSCB is supposed to be the only controller in the system. However, for complex systems several LSCBs can share the same RS-485 bus and work together. Please contact the manufacturer for the details.

Other tabs of the software allow to customize LSCB's parameters and its behavior in the case of faults (errors) as well as to update firmware.





Appendix 2. RS-232 protocol description

RS-232 connection parameters: 38400 bps, 8 data bit, 1 stop bit, no parity

Command format is: {command} {data (optionally)} {end-of-line}

- Command is 1 to 5 character long (see list below)
- Data is ASCII-string, command and data must be separated with space (space symbol)
- End-of-line symbols are \n or \r\n
- Lowercase commands set values (no return from the controller), uppercase commands return values. For example, if "v 300" sets voltage to be 300, "V" returns 300. So, *set* and *get* command of the certain value have the same letter, but *set* command is lowercase, and *get* is uppercase.
- Monitor commands (uppercase, but with preceding 'm' letter) only return values.
- Every command (except monitors, that begin with letter *m*) has limits (lower and upper) that can be established by *_cmd* and *^cmd* commands, where *cmd* is certain command. For example, *_p* and *^p* establish lower and upper bounds of available pulse length. Note: you may narrow allowed range of the command with respect to default range, but widening may lead to abnormal functioning. **We strongly recommend to contact the manufacturer before extending the operating limits.** Maximum range of *_cmd* and *^cmd* commands: -214748364.8 ... 214748364.6 for commands *f, !k0, !s, !r* and -2147483648 ... 2147483646 for other commands. *_CMD* and *^CMD* return lower and upper bounds of command cmd.

List of available commands:

- v – sets the desired output voltage (in volts)
  - example «v 300»
  - min 100, max 700, increment 1, default 200
- p – sets the desired pulse width (in microseconds)
  - example «p 250»
  - works in single pulse mode of operations only
  - min 50, max 1000, increment 1, default 200
- f – sets the desired pulse repetition rate (in hertz)
  - example «f 0.5»
  - «f 0» means single shot
  - min 0, max 50, increment 0.1, default 1
- V, P, F – return the corresponding set points

- b – sets "single pulse" or "train of pulses" mode of operations
  - «b 0» – single pulse, «b 1» – train of pulses
  - in train of pulses mode parameter p is ignored, and parameter f defines the repetition rate of pulse trains
  - allowed values 0, 1, default value 0
- n – sets number of pulses in pulse train mode
  - example «n 3»
  - min 1, max 100, increment 1, default 1
- on – sets pulse duration in pulse train mode (in us)
  - example «on 1000»
  - min 50, max 2000, increment 1, default 200
- off – sets interpulse interval in pulse train mode (in us)
  - example «off 1000»
  - min 50, max 2000, increment 1, default 200
- B, N, ON, OFF – return the corresponding set points

- x – sets the synchronization mode (internal synchronization or external synchronization)
  - «x 0» – internal, «x 1» – external
  - allowed values 0, 1, default value 0

- t – sets triggering edge in external synchronization mode
  - «t 0» – rising, «t 1» – falling
  - allowed values 0, 1, default value 0
- X, T – return the corresponding set points
- sd – in external synchronization mode sets additional sync delay between synchro input and outputs (IGBT pulse or QBU pulse, whatever comes first) (in microseconds)
  - example «sd 300»
  - min 15, max 400, step 0.1, default 15
- SD – return the corresponding set point
- a1, a2 – enable the first and the second synchro outputs respectively
  - «a1 1», «a2 1» – enable, «a1 0», «a2 0» – disable
  - allowed values 0, 1, default value 1

- a – sets the mask of active channels
  - «a 0» – neither channel 1 nor channel 2 is active; «a 1» – only channel 1 is active; «a 2» – only channel 2 is active; «a 3» – both channels 1 and 2 are active
  - any use of the command forcedly sets "s", "s1", "s2", "r", "r1", "r2" to 0
  - allowed values 0, 1, 2, 3, default value 0
- A – returns the mask of active channels

- s1 – turns the simmer supply in channel 1 on and off
  - «s1 1» – on, «s1 0» – off
  - the command is ignored if channel isn't set active with "a" command
  - allowed values 0, 1, default value 0
- s2 – turns the simmer supply in channel 2 on and off
  - «s2 1» – on, «s2 0» – off
  - the command is ignored if channel isn't set active with "a" command
  - allowed values 0, 1, default value 0
- s – turns the simmer supply in all active channels on and off
  - «s 1» – on, «s 0» – off
  - "s1" and "s2" follow "s" automatically (once the corresponding channels are set active with "a" command
  - allowed values 0, 1, default value 0
- c – turns the capacitor charging module on and off
  - «c 1» – on, «c 0» – off
  - allowed values 0, 1, default value 0
- r1 – enables / disables the output in channel 1
  - «r1 1» – enables, «r1 0» – disables
  - the command is ignored if channel isn't set active with "a" command
  - allowed values 0, 1, default value 0
- r2 – enables / disables the output in channel 2
  - «r2 1» – enables, «r2 0» – disables
  - the command is ignored if channel isn't set active with "a" command
  - allowed values 0, 1, default value 0
- r – enables / disables the output in all active channels
  - «r 1» – enables, «r 0» – disables
  - "r1" and "r2" follow "r" automatically (once the corresponding channels are set active with "a" command
  - allowed values 0, 1, default value 0
- S1, S2, S, C, R1, R2, R – return corresponding set points

- g – sets phase shift between channel 1 and channel 2
  - «g 0» – phase shift is 0 degrees i.e. both channels are run simultaneously; «g 180» – phase shift is 180 degrees i.e. channels are run in counter-phase
  *- if phase shift is set to 180 degrees, this means the pulses in channel 2 are delayed relatively to the pulses in channel 1 for 1/(2*f) second*

- *allowed values 0, 180, default value 0*

- G – returns the corresponding set point

- h – sets maximal power limit (in watts)
  - *example «h 1000»*
  - *«h 0» disables the protection*
  - *min 0, max 2000, increment 1, default 2000*
- !k0 – sets flashlamp impedance used for calculations (in $VA^{-1/2}$)
  - *example «!k0 28»*
  - *min 5, max 50, increment 0.1, default 10*
- !i – sets maximal current limit (in amps)
  - *example «!i 1000»*
  - *the value mustn't exceed IGBT current rating; to high value might result in IGBT blow up*
  - *min 1, max 3000, increment 1, default 1100*
- !t – defines if simmer sensor is mandatory to permit pulses
  - *«!t 0» – mandatory, «!t 1» – isn't mandatory*
  - *«!t 1» might be used in systems where the load is different from flashlamp*
  - *allowed values 0, 1, default value 0*
- !p – defines if capacitor charger is mandatory to permit pulses
  - *«!p 0» – mandatory, «!p 1» – isn't mandatory*
  - *«!p 1» might be used for quick discharge of the capacitor bank*
  - *allowed values 0, 1, default value 0*
- H, !K0, !I, !T, !P – return corresponding set points

- hv – sets the desired QBU voltage (in volts)
  - *example «hv 3000»*
  - *min 2000, max 5000, increment 1, default 2000*
- l – sets pulse width of QBU pulse (in us)
  - *synchro output #2 will have the same pulse width*
  - *min 0, max 1000, increment 1, default 200*
- d – sets delay of QBU pulse with respect to IGBT pulse (in us)
  - *synchro output #2 will have the same delay relatively to synchro output #1*
  - *min -1000, max 1000, increment 1, default 0*
- qa – sets QBU channel active or inactive
  - *«qa 1» – activates, «qa 0» – deactivates*
  - *activation of the QBU channel allows enabling it and pulsing*
  - *allowed values 0, 1, default value 0*
- q – enables / disables the output of QBU
  - *«q 1» – enables, «q 0» – disables*
  - *allowed values 0, 1, default value 0*
- HV, L, D, QA, Q – return corresponding set points

- vm – sets maximal voltage of the capacitor charger (V_{MAX})
  - *correct setting of V_{MAX} is necessary to match the output signal of LSCB programming the voltage with the corresponding input signal of the capacitor charger unit; set vm accordingly to the p/n of the capacitor charger used*
  - *once vm command is sent to LSCB, it also automatically changes the maximal voltage (^v) and recalibrates the voltage*
  - *example «vm 300»*
  - *min 100, max 1500, increment 1, default 700*
- hvm – sets maximal voltage of the QBU
  - *set hvm accordingly to the p/n of the Pockels cell driver used*
  - *the behavior of hvm command is similar to one of hv command*
  - *example «hvm 5000»*
  - *min 1000, max 6000, increment 1, default 5000*
- VM, HVM – return corresponding set points

- !j1 – sets pulse counter for channel 1
  - example «!j1 0»
  - min 0, max 2147483646, increment 1, default 0
- !j2 – sets pulse counter for channel 2
  - example «!j2 0»
  - min 0, max 2147483646, increment 1, default 0
- !J1, !J2 – return pulse counters for channel 1 and channel 2 respectively

Monitor and error commands:

- mV – voltage monitor (capacitor charger, volts)
- mHV – voltage monitor (QBU, volts)
- mF – returns capacitor charger fault state
  - 0 – no fault, 1 – fault
- mR – returns ready state (status of the capacitor charging module)
  - 0 – not ready, 1 – ready
- mI – returns IDC state
  - 0 – open, 1 – closed
- mW – returns footswitch state
  - 0 – footswitch is released, 1 – footswitch is stepped
- mS1 – returns simmer sensor state in channel 1
  - 0 – off, 1 – on
- mS2 – returns simmer sensor state in channel 2
  - 0 – off, 1 – on
- mS – command returns the mask of simmer sensors
  - 0 – both simmers are off; 1 – only simmer in channel 1 is on; 2 – only simmer in channel 2 is on; 3 – both simmers are on
  - generally the return of "S", "R", "mS" commands coincides with mask while "s1", "s2", "r1", "r2" commands aren't used and no fault occurs
- mD – returns state of embedded discharging resistors
  - 0 – no discharge, 1 – discharging
- mP – returns expected power (in watts)
- mC – returns expected current (in amperes)
- mE – returns expected pulse or pulse train energy (in joules)
- mJ – returns error code:
  0 – No error (in all modes)
  1 – No IDC in standby – no IDC (on start)
  2 – Overvoltage in standby – voltage exceeds maximum voltage for charger (on start)
  3 – Overpower in standby – expected power exceeds the limit (on start)
  4 – Not ready in standby – charger hasn't got ready within certain time (on start)
  5 – No simmer sensor in standby – simmer arc hasn't been established within certain time (on start)
  6 – Discharge in standby – attempt of pulsing while capacitor bank is forcibly discharged through embedded discharge resistors of NBU (during discharge only)
  7 – No IDC – no IDC (in run mode)
  8 – Overvoltage – voltage exceeded maximum voltage for charger (in run mode)
  9 – Overpower – expected power exceeded the limit (in run mode)
  10 – Not ready – charger is not ready during some time (in run mode)
  11 – No simmer sensor – simmer arc has been lost for some time (in run mode)
  12 – Charger fault – internal failure of the capacitor charger (in all modes)
  13 – Overcurrent – expected current exceeds the limit (in all modes)
  253 – EEPROM error – due to EEPROM error some parameters have been reset to default values; try turning power off and on again; if error persists, contact the manufacturer
  254, 255 – Internal sync errors – try turning power off and on again; if error persists, contact the manufacturer; in this case further operations might be impossible

- !er1, !er2 .. !er19 – a group of commands to define error behavior. Command numbers coincide with the error codes above, some are reserved for the future use. Parameter is string, which may contain following symbols: n – no action, c – charger, s – simmer, r – pulsing, d – set default value. Order of symbols doesn't matter. If string contains other symbols, they will be ignored.
  - for !er1 .. !er5 parameter defines when the check for error is performed (c – on charger start, s – on simmer start, r – on pulsing start)
  - example: "!er1 n" – check for IDC is never performed
  - example: "!er5 sr" – check for simmer sensor is performed on simmer start and on pulsing start, but not performed on charger start
  - for !er6 .. !er13 parameter defines actions performed when error occurs (c – turns charger off, s – turns simmer off, r – turns pulses off)
  - example: "!er7 csr" – turn off pulses, charger and simmer when IDC is 'open' in run mode
  - example: "!er12 d" – sets LSCB's behavior in the case of charger's Fault to default
- !er – sets the same mask for all errors
- !ER, !ER1 .. !ER19 – return the corresponding set points

Service commands:

- !s – time during which system waits for simmer sensor after turning on simmer (in seconds)
  - "!s 0" means infinite waiting time
  - min 0, max 100, increment 0.1, default 2
- !r – time during which system waits for ready sensor after turning on charger (in seconds)
  - "!r 0" means infinite waiting time
  - min 0, max 100, increment 0.1, default 2
- !b – sets RS-232/485 baud rate (Molex connector)
  - allowed values 4800, 9600, 19200, 38400, 57600, 115200, default value 38400
- !b1 – sets RS-232 baud rate (USB connector)
  - allowed values 4800, 9600, 19200, 38400, 57600, 115200, default value 38400
- !d – debug mode
  - 1 – debug mode, 0 – normal mode, default value 0
- !wd – exchange watchdog (in seconds)
  - watchdog turns off everything (i.e. pulsing, charger, simmers) when there is no communication with control board during certain amount of time
  - 0 – turns watchdog off
  - min 0, max 100, increment 1, default 0
- * – returns firmware version
- # or !SN – returns serial number of the device
  - format: any alphanumeric characters (except space and tab symbols) up to 20 characters long
  - to set serial, use !# or !sn commands
- !id – sets ID string of the device
- !ID – returns ID string of the device

- ^y – calibrates charger voltage (top point)
  - set some voltage close to top point, measure PCA's output, enter real voltage on capacitors as data for this command
- _y – calibrates charger voltage (bottom point)
  - set some voltage close to bottom point, measure PCA's output, enter real voltage on capacitors as data for this command
- -y – resets charger voltage calibration
- ^z – calibrates QBU voltage (top point)
  - set some voltage close to top point, measure QBU's output, enter real QBU voltage as data for this command
- _z – calibrates QBU voltage (bottom point)
  - set some voltage close to bottom point, measure QBU's output, enter real QBU voltage as data for this command
- -z – resets QBU voltage calibration

- **@** – ‘poll all’ command – returns values of all parameters in certain order
  - *order can be read by use of ‘=’ command*
- **=** – returns order in which ‘poll all’ command returns values
- **%** – ‘poll limits’ command – returns all limits of all parameters which have limits
  - *limits are returned in order “min max step”*
- There is a possibility to create user-defined poll list using @a, @b, @c, @d and @e commands
  - *@a V HV F P – creates a user-defined poll list of V HV F P parameters*
  - *@A – returns list of V HV F P parameters (e.g. 247 2000 9.5 273)*
  - *=A – returns list order (V HV F P)*
  - *%A – returns all limits of all parameters in list in “min max step” order (e.g. 100 700 1 2000 5000 1 0 50.0 0.1 50 100000 1)*

- .v – resets all values stored to EEPROM to default
- !fb – forbids EEPROM from writing
- .u – runs the bootloaders
  - *a complete set of bootloader commands is available on request*

Appendix 3. Parameter presets

Parameter	Minimum	Maximum	Increment	Default value
Output voltage, V	100	V_{MAX}	1	200
Pulse width, us	50	1000	1	200
Rep. rate, Hz	0 (single shot)	50	0.1	1
QBU pulse length, us	0 (disabled)	1000	1	200
QBU pulse delay, us	-1000	1000	1	0

All parameters are adjustable and can be re-set by the customer via software or RS-232 commands

Parameter	Default value	Parameter	Default value	Parameter	Default value
V_{MAX}, V	700	K0, $VA^{-1/2}$	10	Power limit, W	2000

All parameters are adjustable and can be re-set by the customer via software or RS-232 commands