Access control system

System Overview

General Description

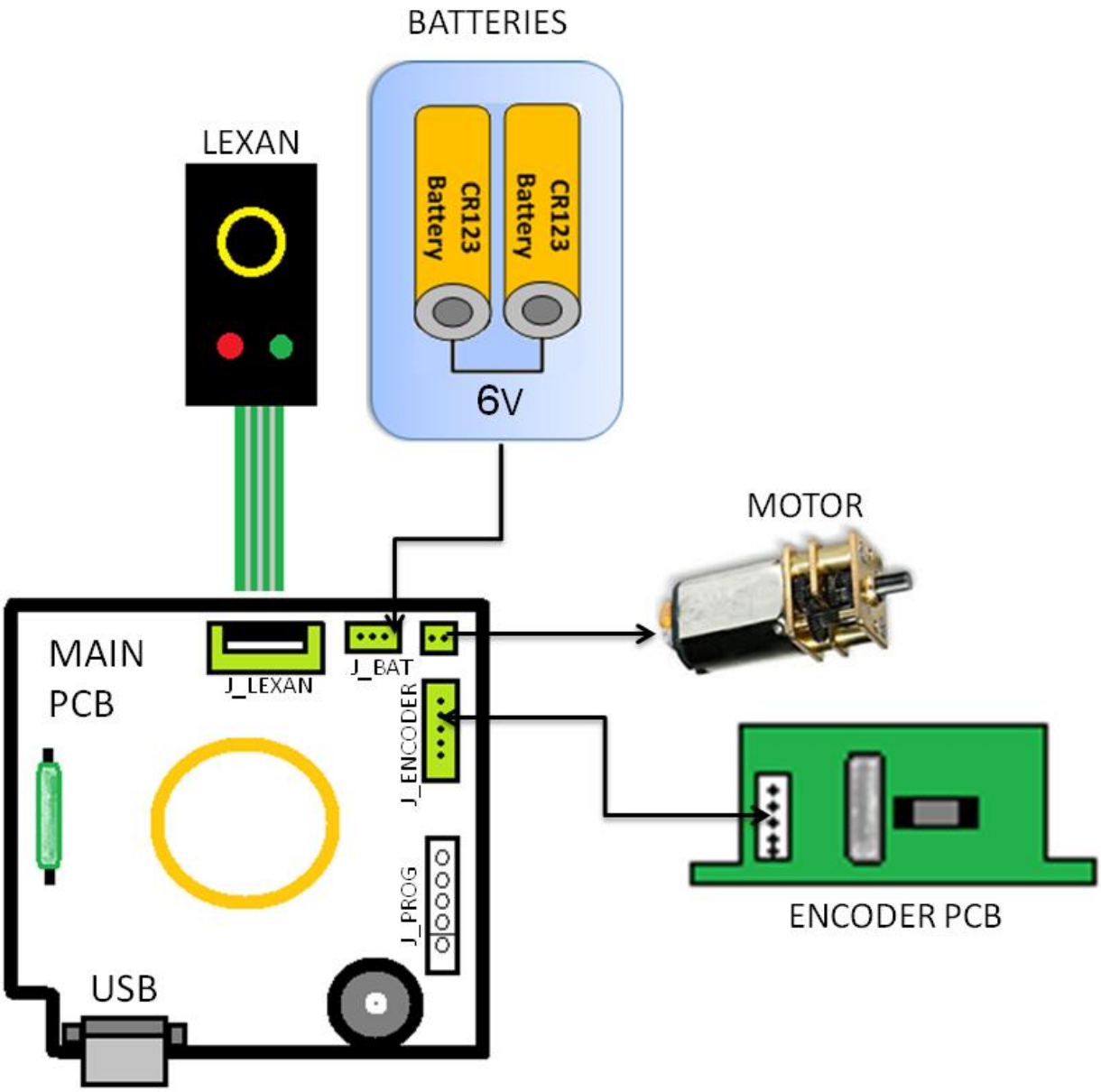
An access control system is a smart padlock for preventing unauthorized access of strangers and workers to storage facilities and containers at jobsites.
Access to the padlock is enabled using a mechanical key and user tags (LF 125 kHz RFID tags) for users identifications.
The system can be connected to PC using USB cable. The connection allows to manage the users database, control system settings and download log of events.
The device is powered using two CR123A (2 x 3V) non-rechargeable batteries.

Diagram 1: System components overview

System functionality

- Enables locking and unlocking the padlock using mechanical key and RFID user tags.
- Preventing access from unauthorized people.
- Hold log records of last operations that was performed.
- Enables USB communication for management and control.

Hardware Block Diagram



Hardware modules:

- ***MCU (STM32L151RBT6)*** - An ARM Cortex M3 MCU is connected to 2 crystal oscillators. The core is driven by 16 MHz osc which is multiplied by internal PLL to yield frequency of 24 MHz. The USB core frequency is multiplied by the PLL to achieve 48 MHz.
  The second crystal oscillator provides frequency of 32.768 kHz to feed the RTC core.
- ***Motor Driver*** **(DRV8832DGQ)** - An IC dedicated for driving the motor, changing rotation direction and motor stall sensing.
- ***Motor*** **(12GF-1215)** - An electromechanical device which converts electrical energy to rotational energy (torque). The electrical motor will open/ close the electromechanical latch upon command from the MCU.
- ***Buzzer*** **(GT-0905A)**- Magnetic transducer, An audio signaling device, used as part of the UI.
- ***125 kHz LF RFID reader(MLX90109)*** - A module that reads the RFID tag (EM4100 protocol). The reader generates frequency of approx. 125 kHz to energize the passive RFID tag.
- ***EEPROM memory (24AA256)*** - External memory IC that contains locks DB, configurations and LOG.
- ***Push Button*** - Mechanical switch for lock control.
- ***LEDs*** - A semi conductor light sources, part of the user interface.
- ***Encoder (EC10E1220501)*** - An electromechanical device to determine the scroll position.
- ***IR LED + Photo transistor (GP1S094HCZ0F)*** - Used to reset scroll position (find the zero point).
- ***USB*** - USB connector for serial USB communication.
- ***Power Management*** - Module that supplies power to all hardware modules and performs battery voltage measurements. Contains MCP1702T LDO.

The MCU - STM32L151R8T6 is an ultra low power ARM based 32-bit MCU that controls all system functionality. The MCU is powered using LDO which feeds it with regulated 3.3V. When there is no user interaction with the system the MCU enters sleep mode in which it draws current of 50uA and all other peripheral modules are turned off.
The MCU wakes upon external interrupts from the Push Button and the Encoder and also upon internal timer. When the MCU is in active mode it draws current of 10mA @ 24MHz.
The MCU core is fed with 16MHz crystal oscillator (Y2) which is multiplied using internal PLL to obtain frequency of 24MHz.
The MCU also has a USB peripheral which feeds from 48MHz clock, this clock frequency is obtained by multiplying the 16MHz with internal PLL.
The 32.768KHz crystal (Y1) is active at all time (when power is applied) and drives the internal RTC core.
The firmware of the MCU is programmed using the JTAG connector.
There is also a UART port for DEBUG (P4).
The system contains an 256 Kbit EEPROM IC for storing users' database and log records.
The EEPROM is powered from 3.3V LDO and can be switched off when not in use using Q10.
The EEPROM communicates with the MCU using I2C interface.
The DRV8832 provides an integrated motor driver solution for battery-powered toys, printers, and other low-voltage or battery-powered motion control applications. The device has one H-bridge driver, and can drive one DC motor or one winding of a stepper motor, as well as other loads like solenoids.
The output driver block consists of N-channel and P-channel power MOSFET's configured as an H-bridge to drive the motor winding.
The motor driver is used to drive a small DC motor that opens and closes the electromechanical latch. The motor is connected to JMOT connector.
The motor driver is controlled by the MCU using two digital pins IN1 and IN2, and its power is fed directly from the battery or the USB port.
It is configured in hardware to regulate the motor voltage using internal PWM to 5.1V or less (depends on power source USB or battery).
The RFID module was designed to read passive RFID tags - EM4100 protocol.
This module generates carrier with frequency of 125 kHz to power the passive tag using an analog front end IC - MLX90109 which also decodes the received signal from the tag.
The transferred data rate is 2 Kbps with Manchester ASK modulation.
The RFID module is active only when an RFID tag with a magnet is inserted to ACS dedicated slot. The magnet inside the tag triggers the reed switch which cause the MCU to activate the MLX90109 to produce 125 kHz frequency. MLX90109 is switched using the MOSFET transistor Q6.
125 kHz frequency is obtained using a parallel LC antenna which yields resonant frequency of 125 kHz.

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{22nF \cdot 73.6uH}} = 125.074\,KHz$$

MLX90109 is powered from 3.3V driven from LDO.

The voltage on MODU pin controls the amplitude of the antenna as follows:

$$V_{ANT} = V_{DD} - V_{MODU} + V_{OS}$$

VMODU is set to a constant value by the resistors R31 and R26.

$$V_{MODU} = V_{DD} \cdot \frac{R_{31}}{R_{31} + R_{26}} = 3.3 \cdot \frac{19k}{19k + 100k} = 0.526V$$

$$\Downarrow$$

$$V_{ANT} = 3.3 - 0.526 + 0 = 2.774V$$

$$\Downarrow$$

$$P_{ANT} = \frac{V_{ANT}^2}{2\pi f_0 \cdot L_{ANT}} = \frac{2.774^2}{2\pi \cdot 125K \cdot 73.6\mu} = 133mW$$

Communication between MCU and MLX90109 obtained using two wire open drain serial communication.

Coil Antenna Specifications

Parameter	Symbol	Min	Typ	Max	Units
Coil Inductance	L	70	73.7	77	uH
Coil Resitance	RL	1.58	1.67	1.75	Ohm
Coil Heigh	H	-	2.86	3	mm
Outside diameter	OD	-	-	18.9	mm
Inside diameter	ID	16.9	17	17.5	mm
Lead Length	LL		20		mm
Tin Plated Lead end	LE		5		mm
Number of turns	LE		52		
Wire Diameter	-	-	0.2	-	mm

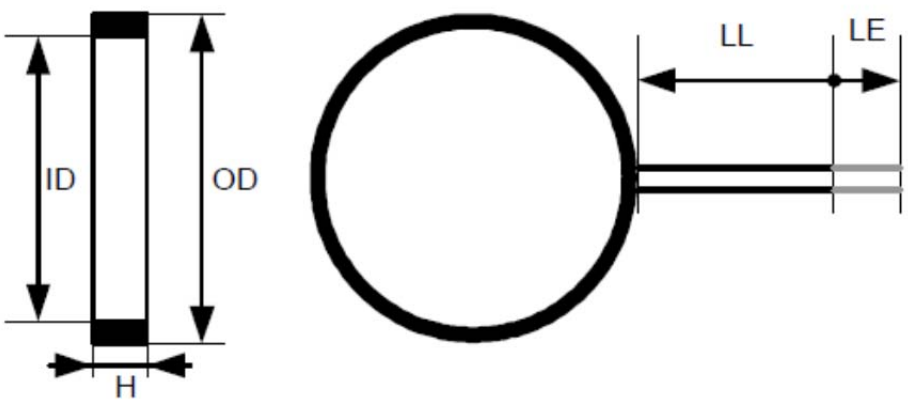


Fig. 1

User interface contains the following parts:
Buzzer (GT-0905A) - The buzzer produces sounds and melodies for various user notifications. It is driven using a MOSFET transistor (Q8) that is controlled by MCU PWM output pin.
Push button - located on the LEXAN PCB for setting different modes. It is connected to a MCU pin (connected via JLEX).
LEDs - located on LEXAN PCB (connected via JLEX connector) for status notifications, the LEDs are driven by 2 MCU pins.
ENCODER - (connected via P2 connector) determines key position for entering different system modes (the ENCODER itself with IR optical switch are located in ENCODER PCB).

ACS is powered using 2 CR123A, 3V, 1700mAH, Li-Ion batteries which are connected in series to obtain 6V.
ACS may be also powered from the USB port.
The LDO MCP1702T supplies all system modules with stabilized 3.3V.
The battery voltage is measured from the voltage divider (R9, R10) which connects to ADC pin in the MCU, this voltage divider is turned off by the MCU when not used by transistors Q4 and Q5.
Q7 is an open drain input to the MCU to determine when a USB cable is connected in order to establish USB communication.
The USB connector J1 has an ESD protection using the IC5 - IP4220CZ6.
IC2 is not connected.

The function of the Encoder PCB is to determine the position of the mechanical key.
Using different key positions the user can perform different operations with ACS.
SW2 is a simple mechanical rotary encoder which produces pulses when the key is turning on its axis.
The optical switch GP1S094HCZ0F contains a photo transistor and IR LED and it used to determine the zero point of the key position.