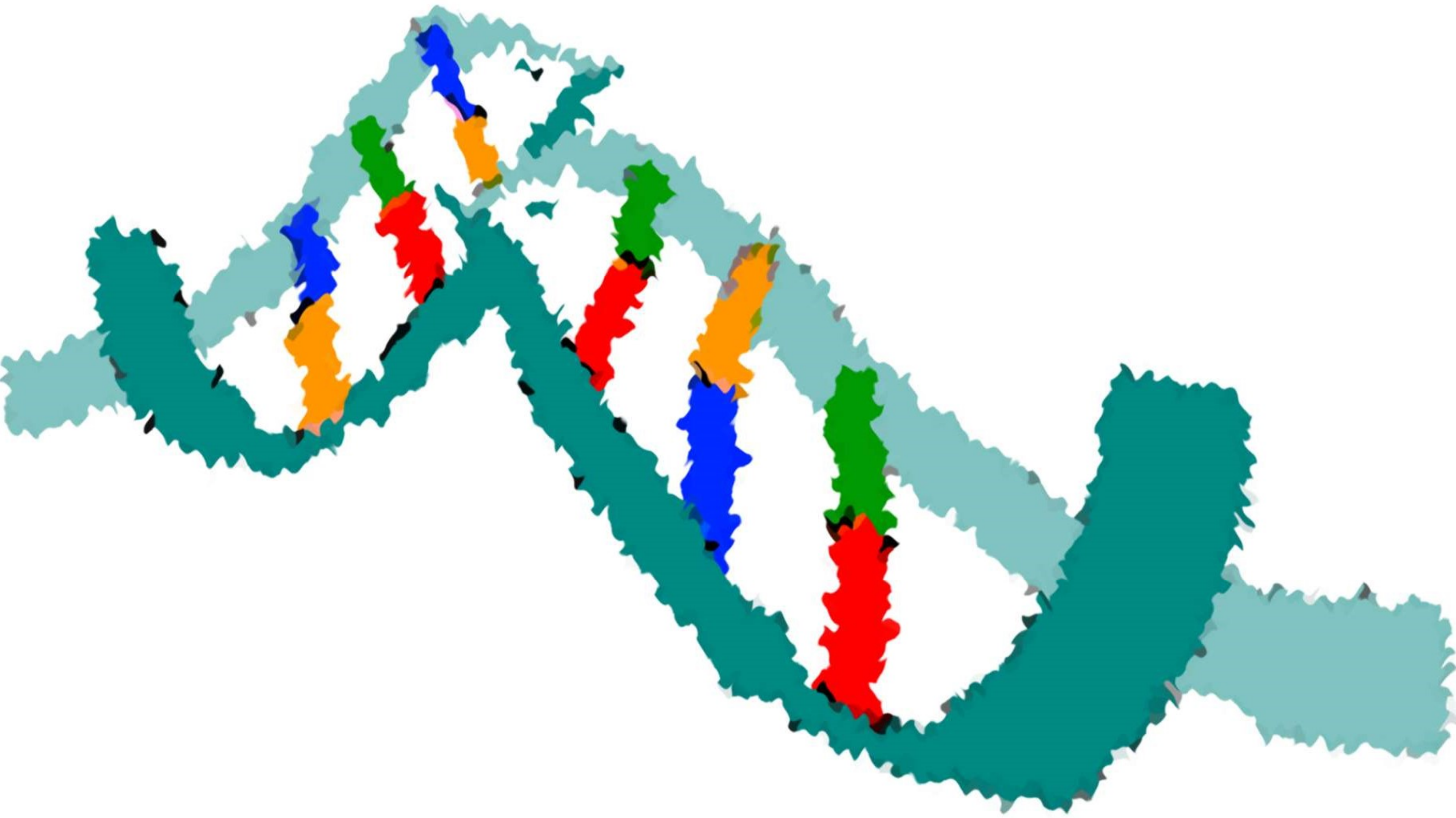
User Manual



Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO)

Smart Feeder Application

(Only for internal usage)

Created by Peter Loës
on 19.12.2017
In order of the
Max Planck Institute for Ornithology at Seewiesen (Germany)

Disclaimer

The Multifunctional Mainboard to Observe and Manipulate Organisms is to be used only as that described in this document. Any other method of usage is not permitted. If damage occurs due to incorrect usage, the manufacturer of the Multifunctional Mainboard to Observe and Manipulate Organisms is not liable.

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List of abbreviations

SF	Smart Feeder
LB	Light Barrier
RFID	radio-frequency identification
EFM	Energy Friendly Microcontroller
PCB	printed circuit board
DCF	D for Deutschland (Germany), C for long-wave transmitter, F due to the vicinity to the Town Frankfurt
ARM	Advanced RISC Machines
SD-CARD	Secure Digital Memory Card
PIT	Passive Integrated Transponder
LEUART	Low Energy Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
MOMO	Multifunctional Mainboard to Observe and Manipulate Organisms

1 System Overview

1.1 General Description of Functions

The Multifunctional Mainboard to Observe and Manipulate Organisms has been developed to record and manipulate animal behaviour. For this purpose, animals got equipped with transponders that can be activated and identified via reading devices. Every animal equipped with a transponder can thereby be identified individually. This technology can be used for every animal species on or in which it is possible to attach a RFID transponder of the size of a rice grain.

Within a population of several individuals carrying a RFID transponder, the Multifunctional Mainboard to Observe and Manipulate Organisms can save the presence and identity of the animals. Whenever an individual with transponder visits a feeder equipped with sensors, the sensor data, transponder code and the timestamp are saved on a SD-card.

Video recordings and visual observations have long been used by biologists to document behaviour of animals and to answer questions about territory, distribution and reproductive behaviour. However, these methods are time consuming, often inexact, and cannot be used when visibility is low (e.g. at night).

To achieve a flexible operation in the field, the Multifunctional Mainboard to Observe and Manipulate Organisms is supplied with electrical energy by a rechargeable accumulator.

The use of electronic devices in the field and nature requires special features in order to operate correctly. Special developments are needed in order to cope with changes in ambient temperature, humidity, pressure and when the electrical power grid is unavailable. However, such developments can be time-consuming and cost-intensive.

Many iterations in the development are needed in order to ensure a stable functioning of electronic products in the wild.

The Multifunctional Mainboard to Observe and Manipulate Organisms should be placed where the animals of interest often visit, such as feeders, nests, roosts, enclosures or bottlenecks.

One main usage for which the Multifunctional Mainboard to Observe and Manipulate Organisms was developed, is the feeder. Bird behaviour can be manipulated by rationing or even blocking their access to food. The so called ‘Smart Feeder’ records the bird’s presence and therefore provides information about their distribution and foraging behaviour.

A key strength of the Multifunctional Mainboard to Observe and Manipulate Organisms is that it runs autonomously. During the development, special attention was paid developing an energy saving operation, so that a battery pack would only have to be changed every two weeks up to several months, depending on the activity of the smart feeder. The SD cards used have enough memory space to save data for several months of data collection. These low operating expenses make the Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO) ideal for a use in isolated locations without grid connection. Furthermore, biological data is optimally collected when disturbance to the animal’s behaviour due to human presence is minimised. Compared with video recordings and observations, data generation is less error-prone and an increase of data volume is easily realizable. Nevertheless, MOMO also supports an activation and deactivation of video devices or cameras.

MOMO regularly surveys and documents the state of the smart feeder electronic system. A regular evaluation of these data can detect faulty systems and a necessary maintenance can be performed.

The Multifunctional Mainboard to Observe and Manipulate Organisms is currently used for animals with a diameter of less than 70mm, which is contingent upon the antenna of an animal transponder reader. Larger antennas with only marginal overhead are imaginable though, enabling a detection of larger animals as well.

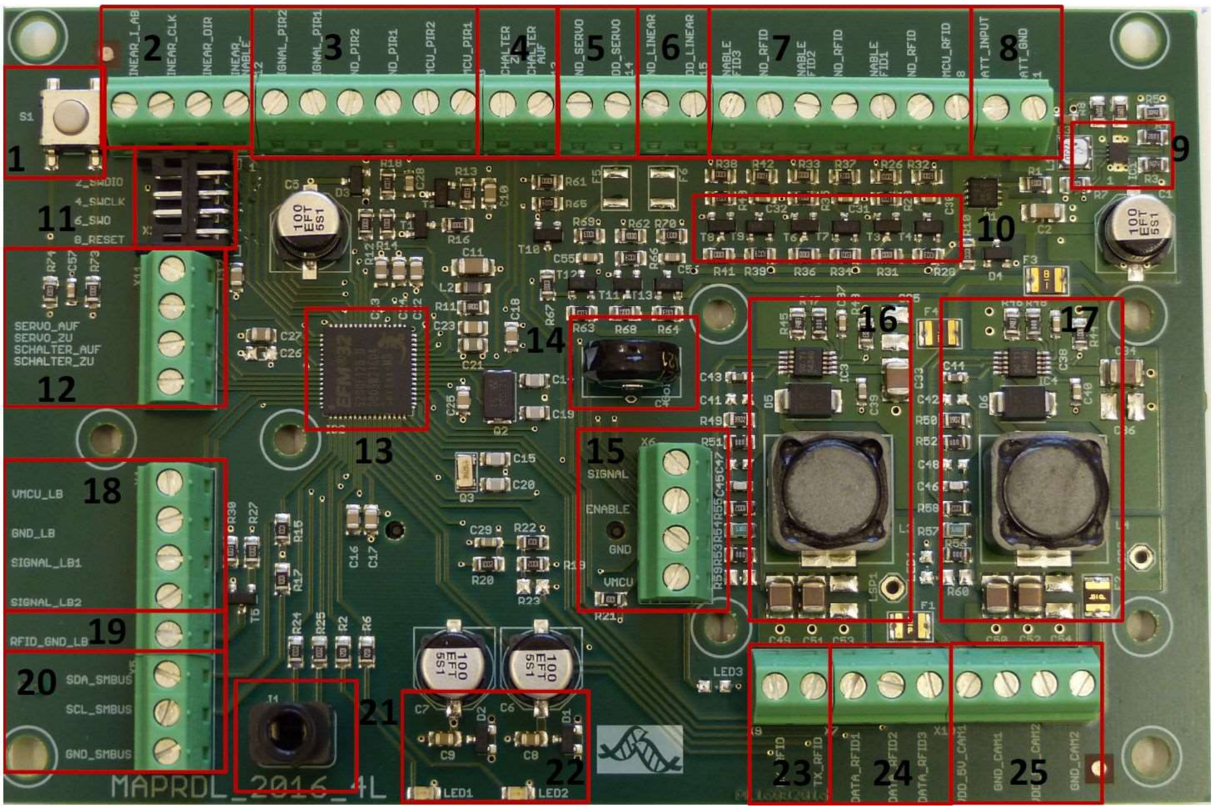
Some examples of potential uses are:

- nest boxes of birds
- roosting boxes of bats
- studying and monitoring mammals like rats, mice, hamsters, badgers, squirrels
- reptile research
- studying and monitoring fish
- studying breeding behaviour
- studying movement and dispersal of animals
- choice of nest boxes or roosts

1.2 System configuration main circuit board

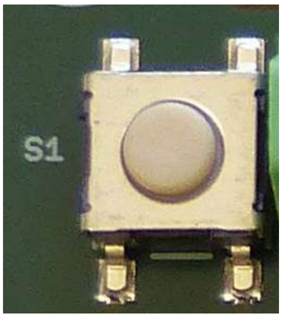
The smart feeder was developed over several years. After five years of development a reliable and efficient version was completed, which is described comprehensively in this manual. Additional detailed information, particularly concerning the electronic configuration, can be found in the datasheet.

1.2.1 Hardware Illustration (MOMO)



1	Reset push button	14	Gold Cap Capacitor
2	Connections for linear actuator control	15	Connecting terminal for the radio clock
3	Connections for two passive infrared detectors [3.5V@200mA]	16	Output voltage 3.5V-11V@ 2.5A for e.g. cameras
4	Connections for limit switch	17	Output voltage 3.5V-11V@ 2.5A for e.g. cameras
5	Power supply for servomotor [12V@1.5A]	18	Power supply light barrier
6	Power supply for linear actuator [12V@1.5A]	19	Connecting terminal for switchable RFID readers[12V@0.22A]
7	Connections for switchable power supplies for three RFID readers	20	Connections for the SMBus „System Management Bus“ of the battery pack
8	Power supply for MOMO	21	LEUART connector
9	Down converter	22	LED display devices
10	Switchable power supply for three RFID readers [3.5V@200mA]	23	Connections for RFID reader serial bus
11	Debug Interface	24	Connections for buses of the three RFID readers
12	Connections for buses of servomotor	25	Two connecting terminals for output of 3.5V-11V@ 2.5A for e.g. cameras
13	Microcontroller EFM32G230		

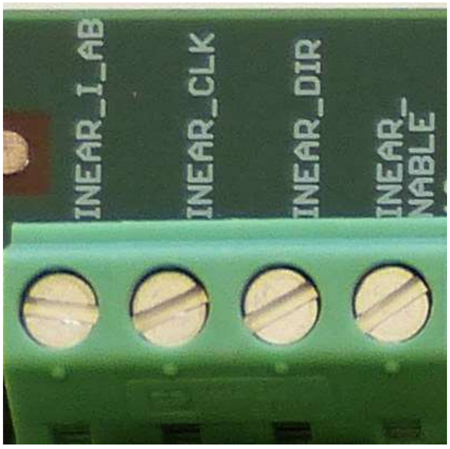
1.2.2 Buttons

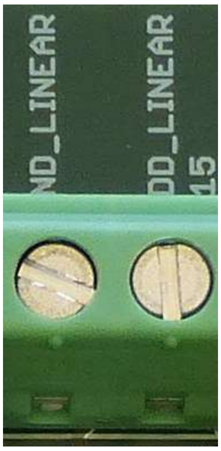


A ‘reset’ pushbutton is installed on the mainboard of the Multifunctional Mainboard to Observe and Manipulate Organisms, which restarts MOMO.

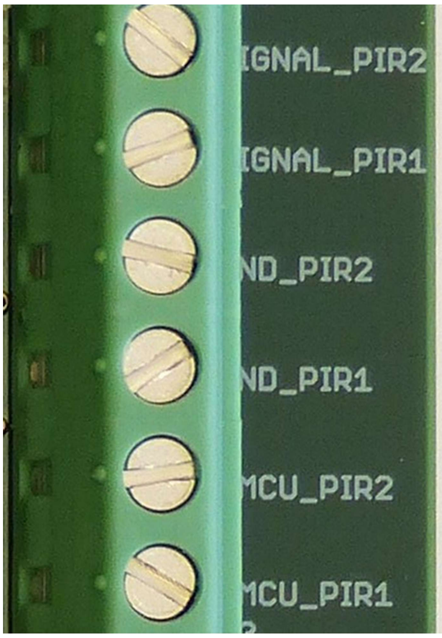
1.2.3 Connections for linear actuator control

A linear drive or linear drive system refers to all drive systems that lead to a translational movement. Linear drives enable the movement of machines (or elements of them) and facilities (or parts of them) on a straight line or on other default routes.





1.2.4 Connections for two passive infrared detectors

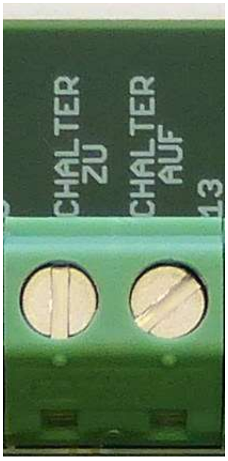


A motion sensor is an electronic sensor, which detects movements within its proximity, enabling it to function as an electrical switch. Its main usages are the activation of lighting or alarms.

A motion sensor can work actively using electromagnetic waves (HF or Doppler radar) and ultrasonic (ultrasonic motion sensor) or passively using the infrared radiation of the surroundings – combinations are possible.

The most commonly used type of motion sensors is the PIR-Sensor (*passive infrared*) is. It reacts ideally towards angular changes, e.g. when someone passes the sensor.

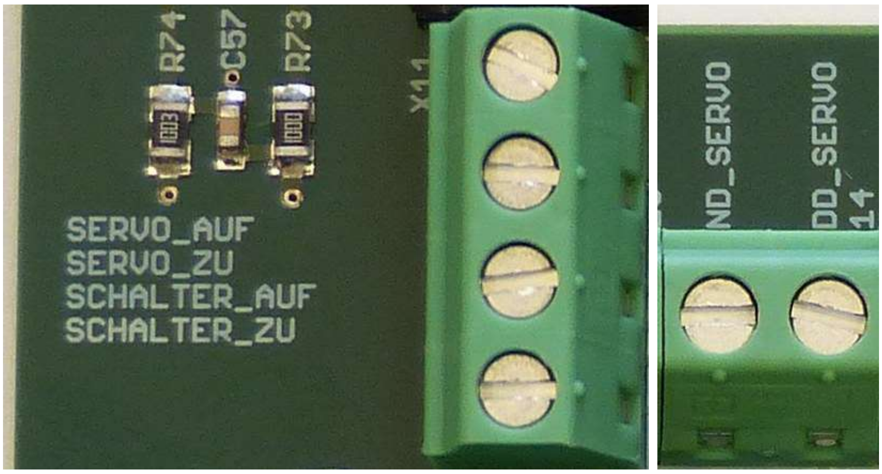
1.2.5 Connections for limit switch



Limit switches (also called *end switches* or *boundary sensors*) are sensors that detect when a moved item (e.g. a work piece or a machine component) reached a certain position. The produced signal can be transmitted electrically, pneumatically or mechanically. Within sequence control systems in engineering that consist of several working steps, limit switches detect the end of a movement and thereby induce the next step of the process. They are also used as safety switches (e.g. door closed) to prevent human and mechanical damages.

1.2.6 Power supply for servomotor

Special electro motors enabling a control of their angular position as well as of their motor shaft and their speed of rotation are termed servomotors. They consist of an electromotor that is additionally equipped with a location determination sensor. The angular position of the motor shaft, detected by the sensor, gets continuously forwarded to an electronic control system - the so called servo controller, which is usually fixed outside of the actual motor. The servo controller then regulates the movement of the motor via a control circuit, corresponding to one or more adjustable set values like a set angular position, the shaft or the set rotation speed.



1.2.7 Connections for three RFID reading devices

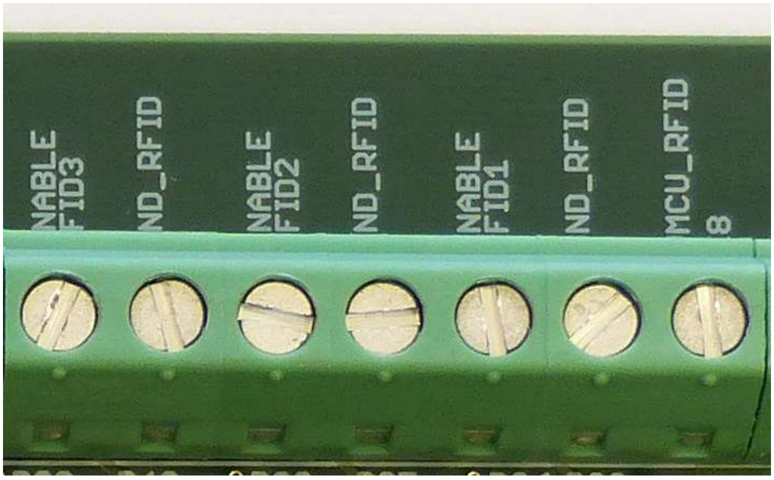
RFID (radio-frequency identification) describes a technology for transceiver systems that uses automatic and non-contact identification and localisation of objects and living organisms with radio waves.

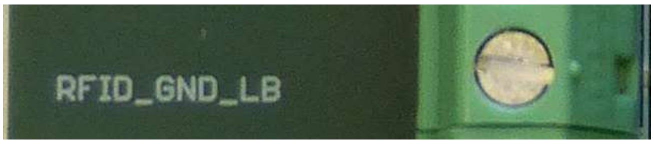
A RFID system consists of i) a transponder (sometimes referred to as radio tag) that is located on or within the object or living organism and contains an individual label and ii) a reading device for the readout of that label.

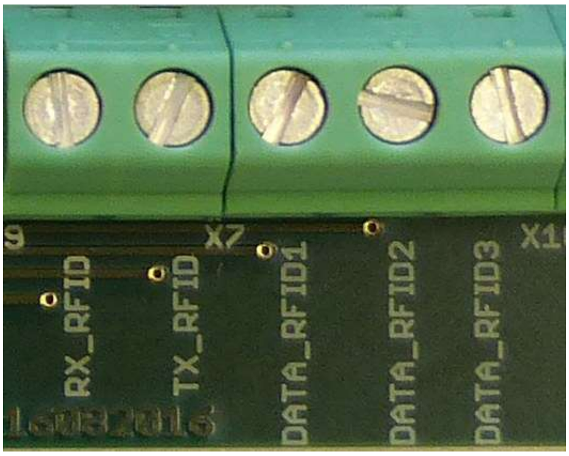
RFID transponders can be as small as a rice grain and implemented into e.g. pets or humans. Moreover, there is the possibility of producing the RFID transponders via a special printing technique of stable circuits made from polymers. The benefits of this technique emerge from the combination of a small size, an inconspicuous readout possibility (e.g. in the newly introduced ID card in Germany on the 1st of November 2010) and the low price of the transponder (sometimes even cents). This new technique could potentially replace the nowadays commonly used barcode.

The coupling takes place through an – by the reading device created – alternating magnetic field in short range or via high frequency radio waves. Thereby data gets transferred and the transponder is provided with energy. For an attainment of longer ranges, active transponders with an in-built power supply are used, that, on the downside, come along with higher costs.

The reading device contains a software (a microprogram) that controls the actual reading process and a RFID middleware with digital interfaces for further EDV systems and databases, see RFID buses of the MOMO circuit board.

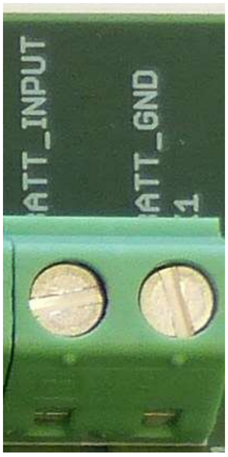


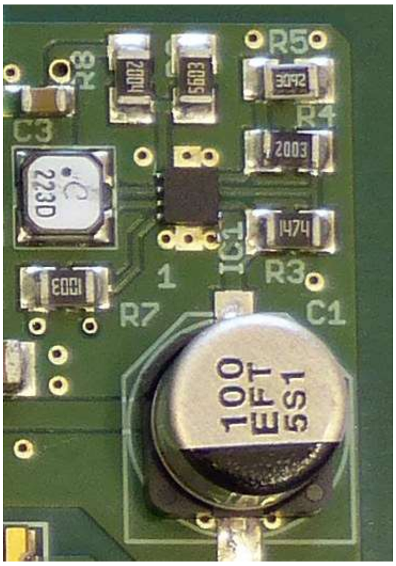




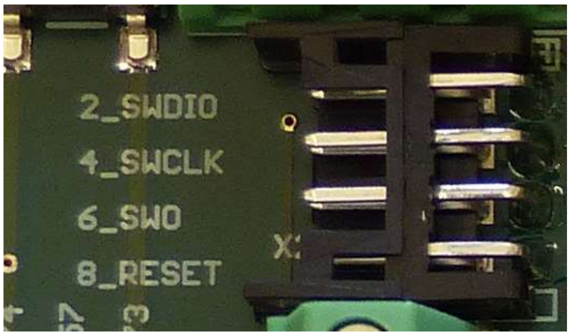
1.2.8 Power supply for MOMO

The Texas Instruments TPS62125 3-17V down converter is a highly efficient device, optimized for applications with low and very low power drain of up to 300mA output current. The large input voltage range of 3V to 17V supports four alkali-cells and one to four LiP battery-cells in serial configuration as well as applications powered with 9V and 15V. The down converter TPS62125 owns a precise low-consumption comparator, which is used for input voltage control to meet system specific requirements during power on and off.





1.2.9 Debug Interface (DBG)



The debug interface software is stored on the microcontroller flash memory. Only after the flash memory contains this information, the hardware can be operated. The connection is either realised directly with a USB cable to the debug interface or with a debugging probe. If the connection is realized directly through the USB cable only HEX files and BIN files can be transferred.

1.2.10 EFM32 Microcontroller

So called microcontroller (MCU) are flip chips that, at the same time, contain a processor and peripheral functions. In many MCUs, the internal and program memory are located partially or entirely on the same chip.

EFM32 is a family of microcontrollers offered by Silicon Laboratories. The EFM32 are 32-bit microcontrollers of different sub-families that use ARM cortex-M3 processors. The energy consumption received special focus during the development, which influenced naming: EFM stands for Energy Friendly Microcontrollers. The low power demand makes the EFM32 microcontroller especially suitable for applications with battery supply. EFM32 microcontroller contain several energy-saving modes that can be changed easily. Additionally, many peripheral devices can be plugged.

Within the Animal Presence RFID Data Logger the EFM32G230 microcontroller is used with 128 KB Flash Memory and 16 KB RAM Memory.

The EFM32 series is also known as “Gecko” by the developer, as these animals consume only 10% of the energy used by a mammal of similar size.

Energy Micro states that benchmark measurements with other leading energy saving MCU’s, found that the EFM32-MCU consumes only a quarter of the energy consumed by the other 8-, 16-, or 32-bit-MCU’s.

The EFM32 microcontroller based on the ARM Cortex processor is well suited for energy saving applications such as:

- electricity-, gas- and water-meters
- factory automation and building automation systems
- alarm and security technology as well as portable applications for medical engineering or within the fitness sector.

The ARM Cortex-M3 processor is developed by Energy Micro and has been bought by Silicon Labs. Since the used processor works with 32 bit, data processing is much faster than 8 and 16 bit CPUs. Therefore, tasks are completed with less clock cycles, which reduces the dwell time in an active mode substantially.

The EFM32G230 contains an UART-interface for communication with external systems, which is especially designed for energy saving. The interface is referred to as LEUART-interface. LEUART is a serial interface, a kind of bus system. Through the LEUART-interface, a jack connector and a USB cable can be used to establish a connection to a computer.

1.2.11 **Capacitor**

A capacitor (German “Kondensator”) is a passive electric component with the ability to store electrical charge and electrical energy of a continuous circuit statically in an electrical field.

When the electrical power supply through the battery is missing, the capacitor ensures an alternate power supply for the Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO). The capacitor is charged when the accumulator supplies energy to the system. This allows energy to be obtained for a certain time from the capacitor if it is required.

Especially the clock of the microcontroller continuous to be powered when there is no external electrical power supply.

Some applications only become possible through double layered capacitors. Despite its large capacity, it is very small in size. The dielectric strength is not exceptionally high however, with only a few volts. Through its large capacity, the Gold Cap is present to maintain the power supply when the main energy source fails. In devices in which data storage should remain in switched off status, the Gold Cap is particularly well suited.

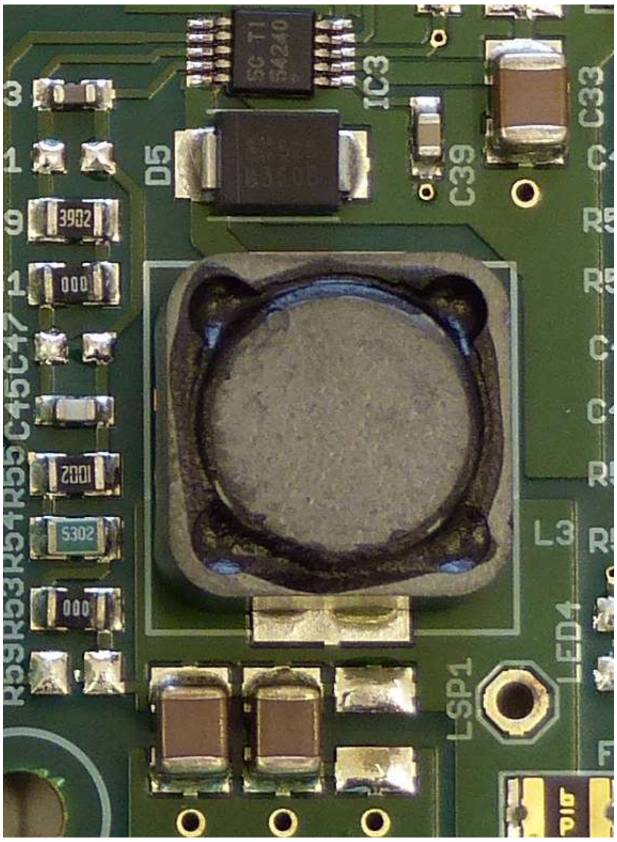
Life expectancy is limited from roughly 8 to 10 years. When the operating temperature is above optimal or the discharge current is high, the life expectancy and the capacity begin to decline over time. The Gold Cap most appropriate when it is rarely discharged and used with low currents.

1.2.12 Connecting terminal for the radio clock

See chapter 1.3

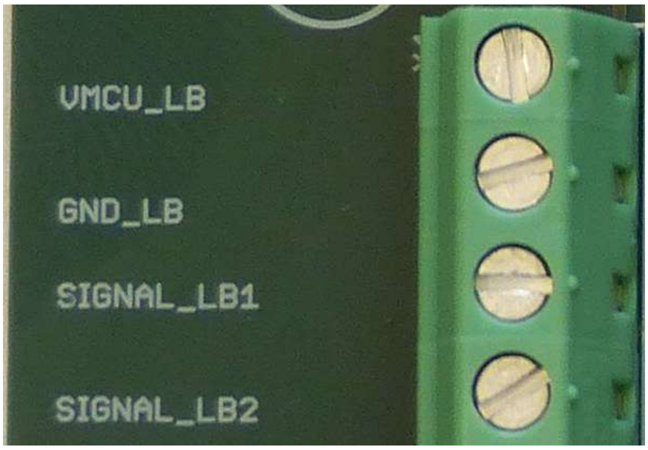
1.2.13 Output voltages (down converter)

The TPS62125 3.5V-42V down converter from Texas Instruments is a highly efficient converter, which is optimized for low and ultra-low power applications of up to 2.5 A output current. If no load is recognised by the controller, the standby current is 138 µA. The controller is run by MOMO in the Shutdown Mode. The Shutdown Current is 1.3 µA.



1.2.14 Power supply for light barrier

A light barrier is an optoelectronic system, which indicates an interruption in the beam of light and communicates this event via an electrical signal. This way, automatic devices can detect moving objects without contact. Examples are the detection of obstacles in autonomously closing doors or of invaders via alarm systems.

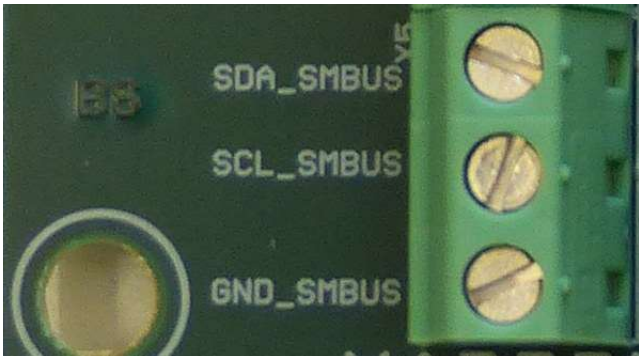


1.2.15 SMBus „System Management Bus“

MOMO supports following standard communication bus systems:

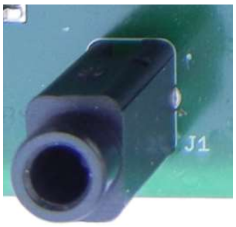
SMBus „System Management Bus“ (http://www.smbus.org/) as well as the **I²C „Inter-Integrated Circuit Interface**“ below a frequency of 100 kHz. https://en.wikipedia.org/wiki/I%C2%B2C

The System Management Bus (SMBus) is needed for the communication between MOMO and the microcontroller with ‘Battery management system’ (BMS).
For reading the single registers of the microcontroller with BMS via the SMBus, the software commands ‘SBS Commands’ were installed.



1.2.1 Jack connector as interface to a PC

For the development of the Multifunctional Mainboard to Observe and Manipulate Organisms an Interface for connection to a computer is intended. Through the data communication interface LEUART, which is provided by the microcontroller EFM32G230 out of chapter 1.2.10. The jack connector is used to connect the signal of the LEUART interface with a PC. For this, a jack connector with 3.5 mm, found in many audio applications, is applied. Please regard a power supply of 3.3 V when buying cables.



1.2.2 LEDs

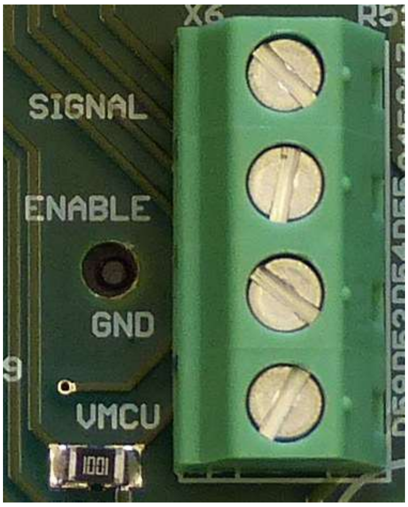
There are two built-in LED’s. The yellow LED (LED 2) indicates, that something is written on the SD card. If the red LED (LED 1) flashes, it indicates that the radio time gets received. If the LED 1 blinks longer than 5 minutes or flashes continuously, this indicates a malfunction.

1.2.3 SD Memory Card Connector

The data from the RAM memory is stored in form of *.txt files on the SD-card, this is located in the SD Memory Card Connector. The size of the memory influences the energy consumption; the smaller the memory size is, the smaller the energy consumption. Therefore, it is recommended for the Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO) to use a small SD memory size of 2 GB. Larger memory sizes increase MOMOs Energy consumption. Memory sizes are supported from 2 GB to 32 GB. Not every event is written onto the SD card immediately. It is first waited for the provided memory to be full. The writing on the SD card consumes quite some energy, which is why the access to the SD card should occur as rare as possible.

1.3 System configuration radio clock receiver

1.3.1 Connector



1.3.2 Hardware illustration

1.3.3 **Radio clock**

The current version of the Smart Feeder features a radio clock, which works in a similar way as a normal clock. In periodic intervals a signal to Europe from the long wave antenna in Mainflingen with a frequency of 77.5 kHz is received and synchronized. Long wave signals have been compared to short waves and medium waves, and have a relatively high range, making it is possible to receive the signal from Mainflingen with a range of up to 2000 km. On other continents, the time signals can be received as well, though with different frequencies.

countries	designation	frequency
Germany	DCF	77.5 kHz
France	TDF	162 kHz
China	BPC	68.5 kHz
Japan	JJY	40 and 60 kHz
USA	WWVB	60 kHz
Russia	Beta	25 kHz
Great Britain	MSF	60 kHz

The time of the radio clock is prompted every 24 hours by default and gets transferred to the clock of the MCU. A non-standard detection takes place during a reset of the system or after energy supply has been restored, after the capacitor was discharged for too long to bridge power supply and in case of the voltage to come below 1.8 V.

The power supply of the clock is driven by an accumulator, which is also used for the other electric consumers and is described in chapter 1.7.

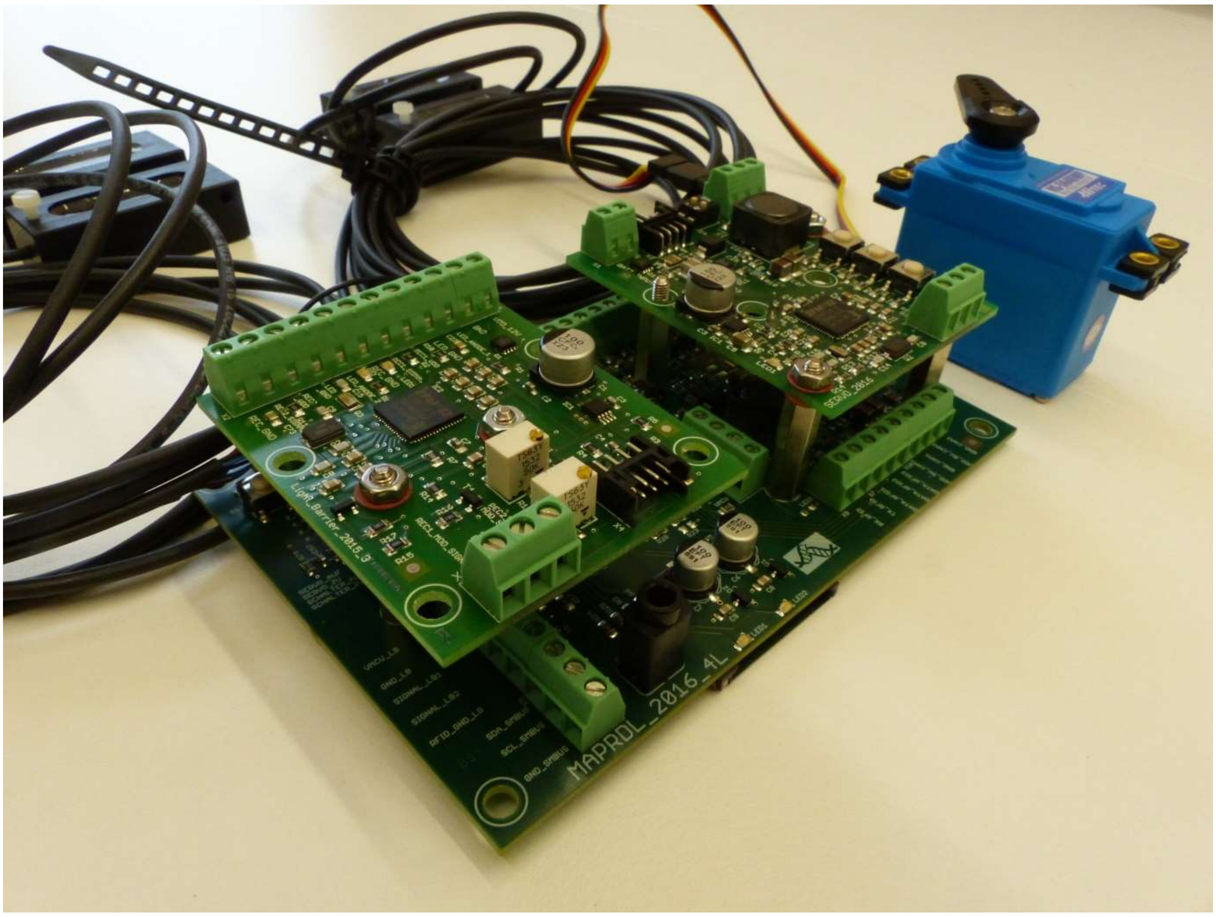
2 Smart Feeder (Hardware)

Peripheral devices are essential for the regular operation of the Multifunctional Mainboard to Observe and Manipulate Organisms. Concerning the Smart Feeder application these include an accumulator, a radio clock receiver, a light barrier board with a light barrier, a RFID reader and a servomotor board with a servomotor.

2.1.1 Hardware illustration Smart Feeder

Required boards:

MAPRDL_2016_4L, light barrier actuator, servomotor actuator



2.1.2 **Light barriers**

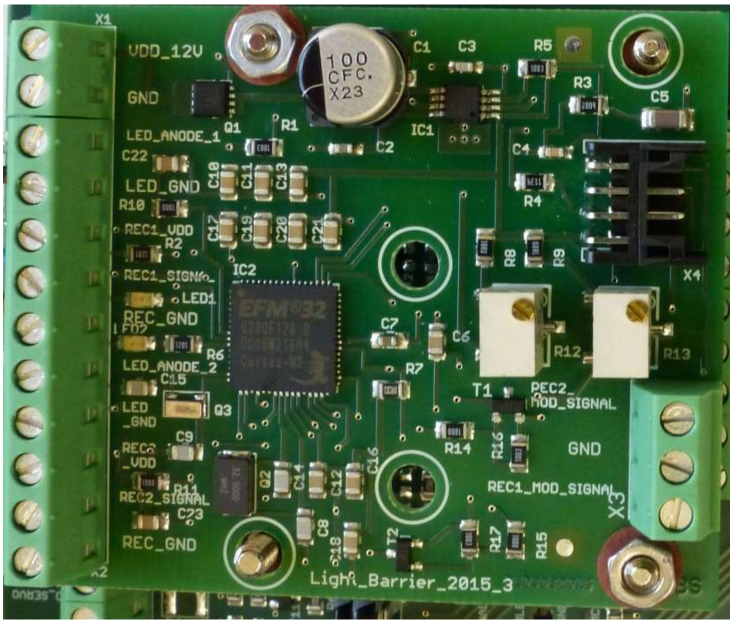
In optoelectronics, a light barrier is system, which indicates an interruption in the beam of light and communicates this event through an electrical signal. Light barriers are composed of a beam source (transmitter) and a photodiode (emitter) to receive the beam.

In the Smart Feeder application, the interruption of an animal is solely detected with light barriers. A maximum of two light barriers can be scanned with up to 100 Hz. The current drain is <120 µA (calculated amount) with a sampling of 10 Hz.

The detection of an object between the light barrier commands an activation of the RFID reader. This needs to occur in a relatively short time, as birds often move quickly. If signal transmission is slower, the RFID reader cannot receive the transponder signal from the bird, because the bird may already be out of range.

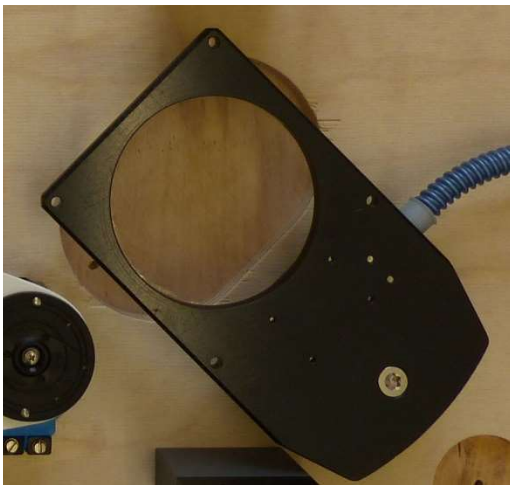
The light barriers work with adaptive selectivity, which means that pollution of the transmitter and emitter, aging or fluctuations due to temperature can be largely compensated for. This reduces the possibility of false detections for example through sunlight.

The required low-power light barrier actuator.



2.1.3 **RFID Reader for transponders**

RFID (radio-frequency identification) describes a technology for transceiver systems that uses automatic and non-contact identification and localisation of objects and living organisms with radio waves.



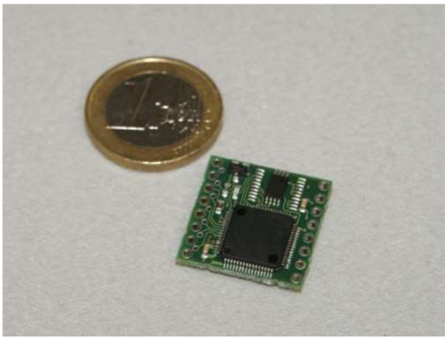
A RFID system consists of a transponder that is located on or within the object or living organism and contains an individual label and a reading device with an antenna for the readout of that label.

The coupling takes place via alternating magnetic fields produced by the reader within short range or via high frequency radio waves. Thereby, not only data is transmitted, but the transponder is also supplied with energy. Active transponders with a local power source are used to achieve longer ranges, but come along with higher expenses.

RFID's are also used in other areas such as electronic locks, ski passes, cashless payment transactions, electronic immobilizers and in libraries as theft protection.

The transponder frequency is not exactly the same as the RFID reader frequency. The RFID Reader works with a frequency of 125 kHz and the transponder with 134.2 kHz. However, both systems are compatible and function together.

2.1.3.1 RFID receiver module

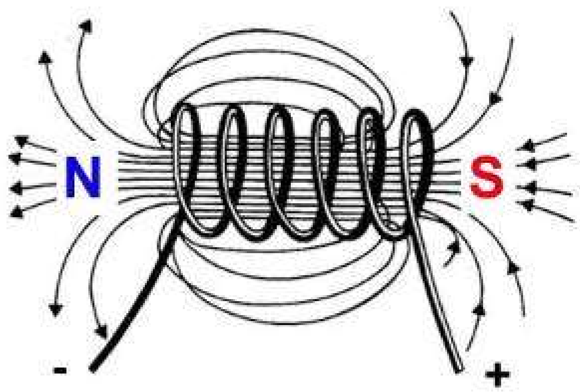


A RFID receiver module with a frequency of 125 kHz is used in the Smart Feeder application. The used receiver module from Elatec is designed with a small size, small price and versatile applications.

2.1.3.2 RFID antenna

The used RFID antenna has a diameter of 50 mm and is directly soldered on the RFID receiver module. If a voltage source is connected to the antenna, which is an air core coil with an inductivity of 490 µH and current begins to flow, an electric field is generated. The electric field is the energy source for the transponder.

If a transponder with its own antenna transmits a signal at a certain frequency, the RFID reader's antenna collects the signal and transmits it.

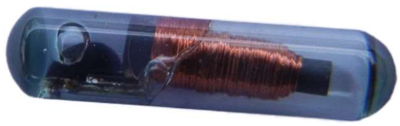


2.1.3.3 RFID Transponder

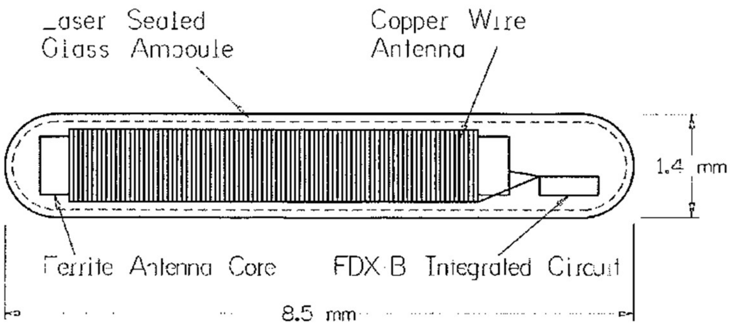
The used transponder is the highest performing passive transponder currently available on the market. These transponders are encapsulated in biocompatible glass and provide 100% unique identification. Because of the small size of 8 mm x 1.4 mm and a very low weight of only 30 mg the tagged animals are minimally affected. So it is possible to tag even very small animals such as red ants

The transponder contains a non-volatile flash memory. A combination of letters and numbers is stored on the flash memory during the production of the transponder.

The transponders are known as FDX-B MINIHPT8 and are made by the company Biomark. The FDX-B indicates that the full duplex technique is used.

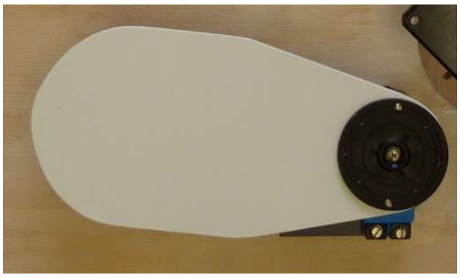


In duplex mode operating systems the electric field is always present and the transponder sends its signal as soon as it enters the reception area of the reader. The FDX transponder sends its ID continuously and can therefore be received relatively rapid.



2.2 **Servomotor**

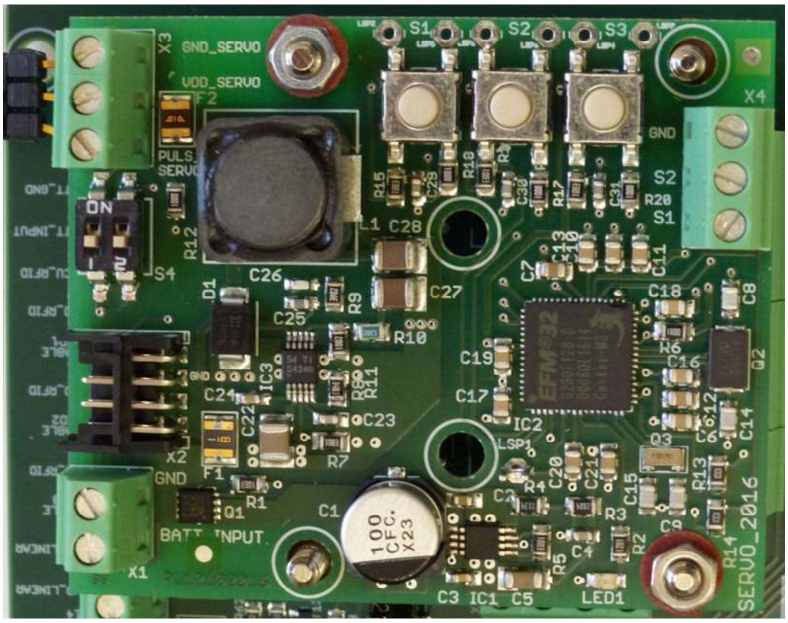
Food flap



Servomotor HITEC HS-5646WP

The low-power servomotor actuator can be programed manually via the 3 switches. The final positions ‘food flap open’ and ‘food flap closed’ can be set and the processing speed of the flap can be adjusted.

The required low-power servomotor actuator.

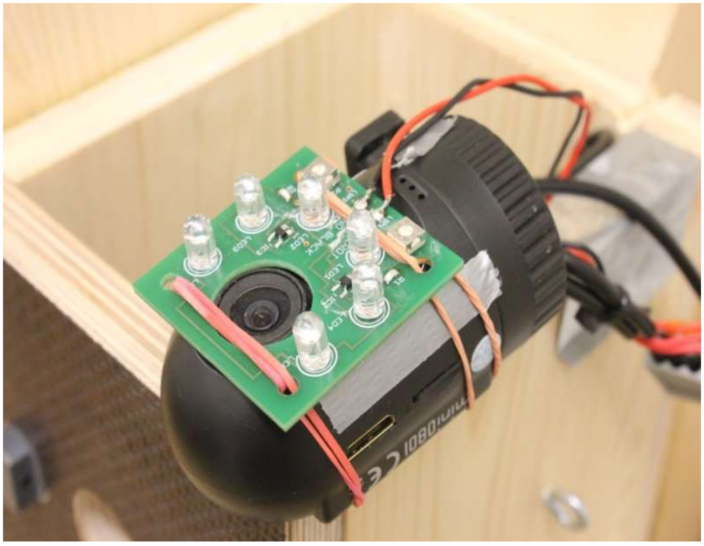


2.3 **Dashcam**

Video recording device with 12 V battery terminal.

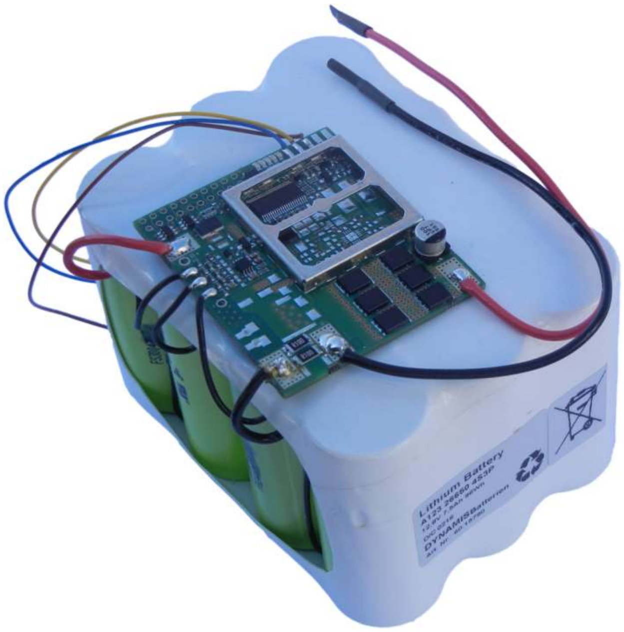
Housing for camera

Full HD Car DVR with GPS



2.4 **Accumulator**

The lithium-ion battery from the company Dynamis Batterien supplies Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO) with electrical energy. The capacity was chosen to ensure that there is enough energy to supply the Smart Feeder in a very active period for two weeks. Through the little specific energy of the lithium-ion battery of approximately 108 Wh/kg, the change of the accumulators is much less energy-sapping than with lead-acid batteries with a specific energy of 30 - 60 Wh/kg.



The three LED’s on the accumulator’s board indicates the state of charge. One lit LED indicates that the accumulator is fully charged. Two LED’s indicate the accumulator is halfway charged. Three LED’s indicate an almost empty state of charge

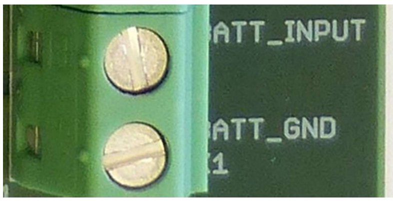
The lithium-ion battery has its own board, which can communicate with MOMO via a bus system. Currently, the temperature of the accumulator, the capacitance values and the latest current drain of the Smart Feeder are prompted from MOMO.

2.5 Pin assignment and connectors

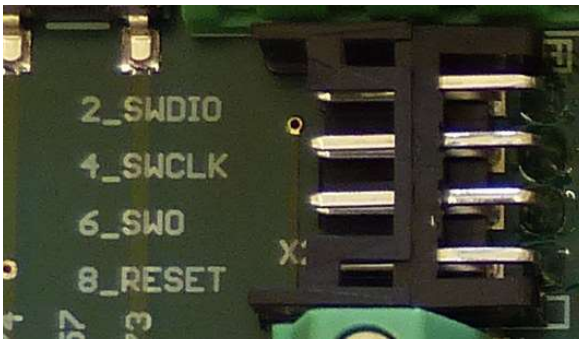
2.5.1 Pin allocation

2.5.1.1 Peripheral terminal

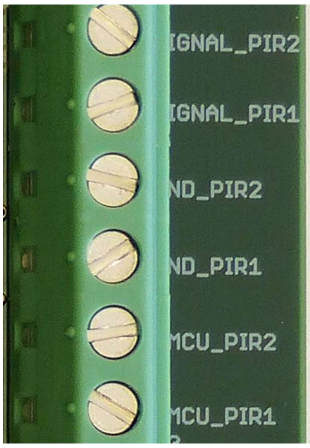
connection	designation	cable colour
X1-2	BATT_INPUT	red (battery pack)
X1-1	BATT_GND	brown (battery pack)



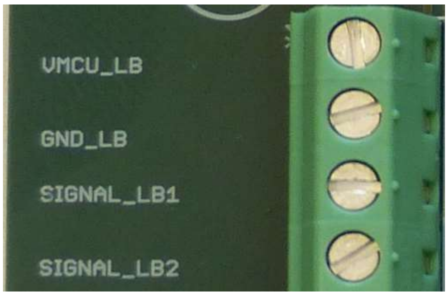
connection	designation
X2-1	VMCU
X2-2	SWDIO
X2-3:	GND
X2-4	SWCLK
X2-5	GND
X2-6:	SWO
X2-7	frei
X2-8	MCU_RESET

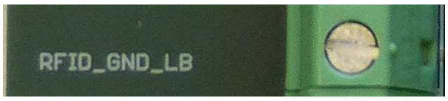


connection	designation	cable colour
X3-6	SIGNAL_PIR2	
X3-5	SIGNAL_PIR1	red/white LB
X3-4	GND_PIR2	
X3-3	GND_PIR1	
X3-2	VMCU_PIR2	
X3-1	VMCU_PIR1	

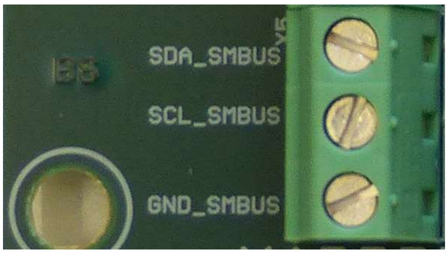


connection	designation	cable colour
X4-1	VMCU_LB	white (RFID)
X4-2	GND_LB	
X4-3	SIGNAL_LB1	
X4-4	SIGNAL_LB2	
X4-5	RFID_GND_LB	brown (RFID)

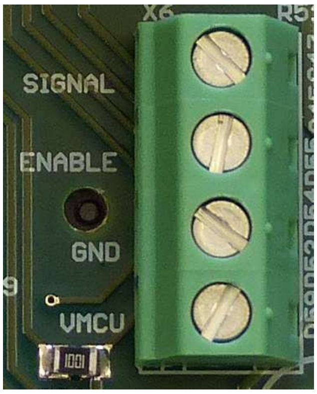




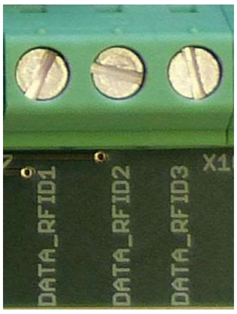
connection	designation	cable colour
X5-1	SDA_SMBUS	blue
X5-2	SCL_SMBUS	yellow
X5-3	GND_SMBUS	grey



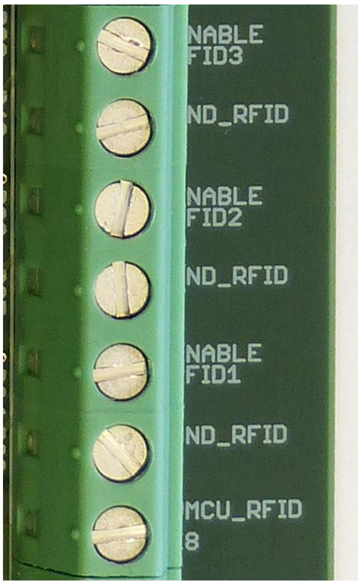
connection	designation	cable colour
X6-1	DCF_SIGNAL	green
X8-6	DCF_ENABLE	yellow
X8-5	DCF_GND	brown
X8-4	DCF_VMCU	white



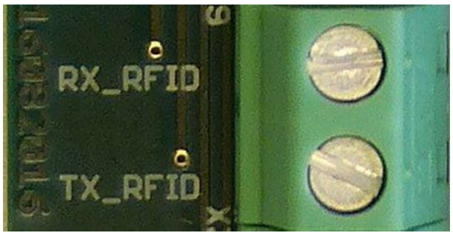
connection	designation
X7-1	DATA_RFID1
X7-2	DATA_RFID2
X7-3	DATA_RFID3



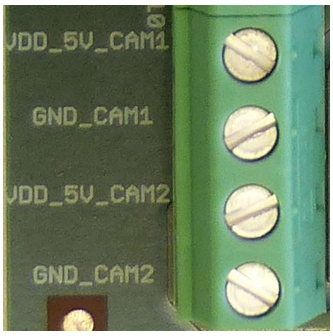
connection	designation	cable colour
X8-7	ENABLE_RFID3	
X8-6	GND_RFID	
X8-5	ENABLE_RFID2	
X8-4	GND_RFID	
X8-3	ENABLE_RFID1	
X8-2	GND_RFID	
X8-1	VMCU_RFID	



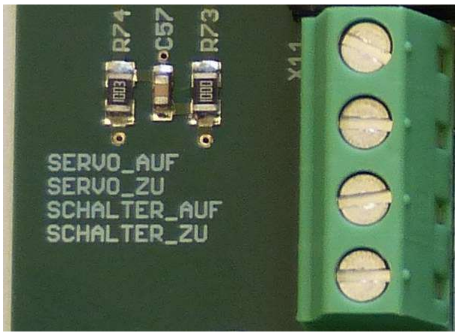
connection	designation	cable colour
X9-1	RX_RFID	grey
X9-2	TX_RFID	pink



connection	designation	cable colour
X10-1	VDD_5V_CAM1	red
X10-2	GND_CAM1	black
X10-3	VDD_5V_CAM2	
X10-4	GND_CAM2	



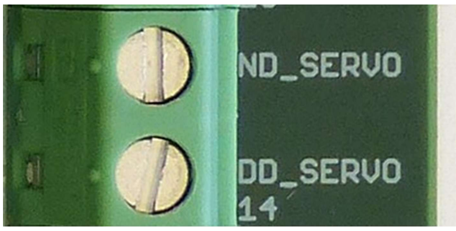
connection	designation	cable colour
X11-1	SERVO_AUF	red/white
X11-2	SERVO_ZU	red/white
X11-3	SCHALTER_AUF	
X11-4	SCHALTER_AUF	



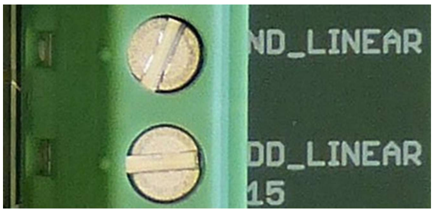
connection	designation	cable colour
X12-4	LINEAR_I_AB	
X12-3	LINEAR_CLK	
X12-2	LINEAR_DIR	
X12-1	LINEAR_ENABLE	

connection	designation	cable colour
X13-2	SCHALTER_ZU	
X13-1	SCHALTER_AUF	

connection	designation	cable colour
X14-2	GND_SERVO	
X14-1	VDD_SERVO	



connection	designation	cable colour
X15-2	GND_LINEAR	
X15-1	VDD_LINEAR	



2.5.1.2 Jack connectors for LEUART

connection	designation
J1	LEUART_RX
J1	LEUART_TX

2.5.2 Technical description of additional connectivity options for applications

PA3_CAM1_ENABLE; VDD_5V_CAM1:
Input Voltage Range: 3.5V-11V@2.5A

Applications: recorder, sound player, camera system, animal transponder reader, scale, heater element, cooling element, DC motors, light (infrared, LEDs), temperature sensor, humidity sensor, brightness sensor, motion sensor, light barriers, infrared sensor. Global System for Mobile Communications (GSM), Bluetooth

PA4_CAM2_ENABLE; VDD_5V_CAM2:
Input Voltage Range: 3.5V-11V@2.5A

Applications: recorder, sound player, camera system, animal transponder reader, scale, heater element, cooling element, DC motors, light (infrared, LEDs), temperature sensor, humidity sensor, brightness sensor, motion sensor, light barriers, infrared sensor. Global System for Mobile Communications (GSM), Bluetooth

PA6_RFID_POWER; RFID_GND_LB:
Electrically switchable mass: Input Voltage Range from Circuit: 3.3V@0.22A

Applications: animal transponder reader, heater element, cooling element, motors, light, temperature sensor, humidity sensor, brightness sensor, motion sensor, light barriers, infrared sensor.

PA8_RFID1_DATA:
Device Pinout: TIM2_CC0 #0

The TIMER (Timer/Counter) keeps track of timing and counts events, generates output waveforms and triggers timed actions in other peripherals.

Applications: animal transponder reader, servomotor, counter.

PA9_RFID2_DATA:
Device Pinout: TIM2_CC1 #0

The TIMER (Timer/Counter) keeps track of timing and counts events, generates output waveforms and triggers timed actions in other peripherals.

Applications: animal transponder reader, servomotor, counter.

PA10_RFID3_DATA:
Device Pinout: TIM2_CC2 #0

The TIMER (Timer/Counter) keeps track of timing and counts events, generates output waveforms and triggers timed actions in other peripherals.

Applications: animal transponder reader, servomotor, counter.

PB12_N_SCHALTER_ZU:
Device Pinout: DAC0_OUT1 #0, LETIM0_OUT1 #1

The DAC is designed for low energy consumption, but can also provide very good performance. It can convert digital values to analog signals at up to 500 kilo samples/second and with 12-bit accuracy.

The LETIMER is a down-counter that can keep track of time and output configurable waveforms. Running on a 32.768 kHz clock the LETIMER is available even in EM2 with sub µA current consumption.

PC0_RFID_RX:
Device Pinout: ACMP0_CH0 #0, PCNT0_S0IN #2, US1_TX #0

The ACMP (Analog Comparator) compares two analog signals and returns a digital value telling which is greater.

The Pulse Counter (PCNT) decodes incoming pulses. The module has a quadrature mode which may be used to decode the speed and direction of a mechanical shaft. PCNT can operate in EM0-EM3.

The USART handles high-speed UART, SPIbus, SmartCards, and IrDA communication.

PC1_RFID_TX:
Device Pinout: ACMP0_CH1 #0, PCNT0_S1IN #2, US1_RX #0

The ACMP (Analog Comparator) compares two analog signals and returns a digital value telling which is greater.

The Pulse Counter (PCNT) decodes incoming pulses. The module has a quadrature mode which may be used to decode the speed and direction of a mechanical shaft. PCNT can operate in EM0-EM3.

The USART handles high-speed UART, SPIbus, SmartCards, and IrDA communication.

PC8_RFID1_MOSFET, VDD_RFID1:
Input Voltage Range from Circuit: 3.3V@0.2A

Applications: recorder, sound player, camera system, animal transponder reader, scale, heater element, cooling element, DC motors, light (infrared, LEDs), temperature sensor, humidity sensor, brightness sensor, motion sensor, light barriers, infrared sensor. Global System for Mobile Communications (GSM), Bluetooth

PC9_RFID2_MOSFET, VDD_RFID2:
Input Voltage Range from Circuit: 3.3V@0.2A

Applications: recorder, sound player, camera system, animal transponder reader, scale, heater element, cooling element, DC motors, light (infrared, LEDs), temperature sensor, humidity sensor, brightness sensor, motion sensor, light barriers, infrared sensor. Global System for Mobile Communications (GSM), Bluetooth

PC10_RFID3_MOSFET, VDD_RFID3:
Input Voltage Range from Circuit: 3.3V@0.2A

Applications: recorder, sound player, camera system, animal transponder reader, scale, heater element, cooling element, DC motors, light (infrared, LEDs), temperature sensor, humidity sensor, brightness sensor, motion sensor, light barriers, infrared sensor. Global System for Mobile Communications (GSM), Bluetooth

PC11_LINEAR_ENABLE:
Device Pinout: ACMP1_CH3 #0, US0_TX #2

The ACMP (Analog Comparator) compares two analog signals and returns a digital value telling which is greater.

The USART handles high-speed UART, SPIbus, SmartCards, and IrDA communication.

PC13_LINEAR_CLK:
Device Pinout: ACMP1_CH5 #0, TIM0_CDTI0 #1/3 TIM1_CC0 #0 PCNT0_S0IN #0

The ACMP (Analog Comparator) compares two analog signals and returns a digital value telling which is greater.

The TIMER (Timer/Counter) keeps track of timing and counts events, generates output waveforms and triggers timed actions in other peripherals.

The Pulse Counter (PCNT) decodes incoming pulses. The module has a quadrature mode which may be used to decode the speed and direction of a mechanical shaft. PCNT can operate in EM0- EM3.

2.6 Housing

2.6.1 Housing for the main board

The housing from the main board consists entirely of opaque polycarbonate. The lid is lockable with bayonet locks which are quick and easy to use. The screws are secured from falling out and prevents loss of any screws.

2.6.2 Housing for the accumulator

The housing from the accumulator consists entirely of polycarbonate, with the lid being made from transparent polycarbonate so the LED's inside may be seen without needing to open the lid. The lid is also lockable with bayonet locks. The same screws are used here and are also secured against falling out.

3 General working conditions

Component designation	Multifunctional Mainboard to Observe and Manipulate Organisms Smart Feeder Application
Manufacturer	MPIO http://www.orn.mpg.de/
Dimensions main board (L X B x H)	121 mm x 81 mm x 1,5 mm
Overall temperature range	-10°C to 70°C (DCF77)
Storage temperature range	-20°C to 60°C
Overall moisture	Relative moisture 35% to 85% (at 5 to 35°C)

Detailed information, in particular concerning the electrical properties of the Multifunctional Mainboard to Observe and Manipulate Organisms can be found in the datasheet.

The working conditions from single devices can be found in the datasheets in chapter 8.

4 Energy supply

The Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO) is especially designed to have low energy requirements. The electrical power requirements are explained more precisely in this chapter.

The EFM32G230 has five different economical energy modes, where only two of which are used for MOMO. These are the Deep Sleep Mode and the Sleep Mode whereby the Sleep Mode is the Active Mode and the Deep Sleep Mode is the Inactive Mode. In these energy modes different consumers are active. The Smart Feeder application of the Multifunctional Mainboard to Observe and Manipulate Organisms switches between the Active Mode and the Inactive Mode through light barrier activity. If the RFID reader and the light barrier detect no activity for 6 minutes, the Smart Feeder switches into the Inactive Mode again to save energy.

The energy-intensive consumers, like the RFID reader, are only supplied with electrical Energy when required. The RFID reader is the largest consumer of electrical energy in the Smart Feeder application, when no camera is connected.

Electrical properties and, to some extent, battery drain, can be drawn from the datasheets of the built-in components. The datasheets are linked in chapter 8.

In the following sections, the current supply and the voltage supply will be examined separately.

4.1 Current supply

4.1.1 ARM Cortex Processor

From the five available modes of operation only the Deep Sleep Mode and the Sleep Mode are used.

0.9 µA @ 3 V Deep Sleep Mode, including Real Time Clock with 32.768 kHz Oscillator, Power-on Reset, Brown-out Detector, RAM and CPU retention

45 µA/MHz @ 3 V Sleep Mode

4.1.2 RFID

RFID on measured: 35,4mA

RFID off measured: 1,36mA

(from schematics)

4.1.3 Light barriers

The light barriers are always supplied with electricity, independently from the two energy modes. To save energy, the status of the light barrier is not assessed continuously but 100 times per second, thus with a frequency of 100 Hz. Therefore, the light barrier has a very small electrical energy demand of roughly 120 µA.

4.1.4 Radio clock

The clock of the microcontroller is updated at a certain time every night through the time signal from Mainflingen. The radio time will be also updated when the system is reset.

Nominal current 100µA   Quiescent current 5 µA

4.1.5 LED

Each LED has an electric current demand of 2 m. There are two built-in LEDs.

4.1.6 **Accumulator LED’s and self-discharge**

LEDs	electric current demand
Without	271 µA
Only LED1	308 µA
LED1 + LED2	343 µA
LED1 + LED2 + LED3	384 µA

The self-discharge by lithium-ion-batteries at 20°C is less than 2% per month.

4.1.7 **Overview of the nominal currents**

This table contains the maximum current demands of the most important devices. If all are active at the same time, the current demand behind the down converter at 3,3 V is 51 mA and with that the maximum power input before the down converter is around 0,1683 W.

devices	currents
RFID	35.4 mA
2* LED	2 x 2 mA
ARM Cortex M3	45 µA/MHz (1.44 mA)
radio clock	0.1 mA
light barriers	2x 120 µA
Total current behind the down converter with 3.3V	42.2 mA (When all consumers are active at the same time without down converter losses)
Total input in front of the down converter with 12.8 V	155 mW (When all consumers are active at the same time with down converter losses)

4.1.8 Overview of the currents in the different operating modes

	Shutoff Mode	Stop Mode	Deep Sleep Mode	Sleep Mode	Run Mode
RFID	Not used	Not used	Off	Can be on	Not used
ARM Cortex M3	Not used	Not used	On	On	Not used
Radio clock	Not used	Not used	Can be on	Can be on	Not used
LED's	Not used	Not used	Can be on	Can be on	Not used
Light barrier	Not used	Not used	On	On	Not used
Down converter	Not used	Not used	On	On	Not used
Accumulator board	Not used	Not used	On	On	Not used

	Deep Sleep Mode (inactive mode)	Sleep Mode (active mode)
RFID (with 3.3 V)	0	On (35.4mA)
ARM Cortex M3 (with 3.3 V)	0,9 µA	45 µA/MHz (1.44 mA)
Radio clock (with 3.3 V)	0,1 mA (once a day for approx. 5 min; also at reset and start)	0,1 mA (once a day for approx. 5 min; also at reset and start)
LED (with 3.3 V)	2 mA (2 units if on)	2 mA (2 units if on)
Light barrier (with 3.3 V)	240 µA (2 units)	30 µA (2 units)
Down converter (3.3 V)	13 µA	13 µA
Total current behind the down converter (without down converter losses and 3.3 V)	0.0609 mA (2 x light barriers and und MCU	36.88 mA (RFID active, MCU active, light barriers, down converter)
Total input behind of the down converter (without down converter losses and 3.3 V)	0.0609 mA x 3.3 V = 0.000201 W = 201 x 10^-6 W	36.88 mA x 3.3 V = 0.122 W
Total input in front of the down converter (with down converter losses and 12.8 V)	(with η = 50%) 0.000201W/0.5 = **0.000402 W** = 402 x 10^6 W	(with η = 90%) 0.122 /0.9 = **0.136 W**
Total current in front of the down converter (with down converter losses 12.8 V) **(theoretical)**	(with η = 50%) **0.0314 mA**	(with η = 90%) **10.6 mA**
Measured **total current** in front of the down converter (with down converter losses 12.8 V) **(real)**	**0.22 mA = real measured inactive mode** (connected radio clock but inactive, controller in Deep Sleep Mode, Gold Cap, connected LED but off, buttons, down converter)	**11 mA = real measured active mode** (connected radio clock but inactive, controller, LED connected but off, gold cap, SD card, down converter, light barrier, RFID on)
Accumulator board with LED's current demand	(0.271 mA – 0.384 mA)	(0.271 mA – 0.384 mA)
Total current with accumulator board	0.3024 mA – 0.4154 mA	10.87 mA – 10.98 mA
Total Input ink. accumulator board with 12.8 V **(theoretical)**	**0.00387 W – 0.00532 W**	**0.139 W – 0.141 W**
Total Input with measured value + theoretically accumulator board demand with 12.8 V **(real)**	**0.028 W – 0.0158 W**	**0.141 W – 0.142 W**

4.2 Voltage supply

All consumers are supplied with 3.5 Volts, which are provided by the down converter from the 12.8 Volts from the lithium-ion-accumulator. An input voltage of 5 V for the down converter is sufficient.

4.3 Electrical energy storage

The main power supply is ensured by the lithium-ion-accumulator. If the accumulator is removed, a capacitor ensures the supply.

4.3.1 Accumulator

If the whole capacity of a lithium-ion-accumulator is completely used it can have negative effects on the lifetime of the accumulator. Therefore, a certain percentage of the total capacity is not used. The accumulator of the Animal Presence RFID Data Logger uses 83% of the total capacity.

Roughly 17 % of the capacity of the accumulator are not used.

voltage	12.8 V
Nominal capacity	7.5 Ah
Total capacity	8.97 Ah
stored energy	96 Wh

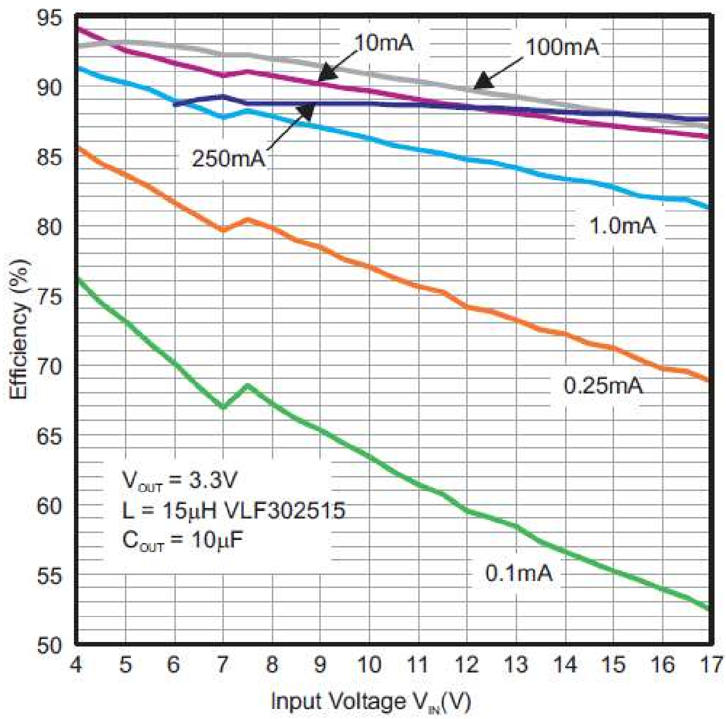
The lithium-ion-accumulator has its own board, which is able to communicate with the Animal Presence RFID Data Reader via a data bus.

4.3.2 Capacitor

If the energy supply from the accumulator is no longer available, a capacitor with 0.22 farad ensures the energy supply. The stored energy is enough to supply MOMO for around 30 seconds. During the discharge, the voltage of the capacitor declines from 3.6 Volts to 1.8 Volts.

4.3.3 **Conversion losses**

The accumulator provides electrical energy with a voltage of 12.8 Volts. The EFM32G230 and other consumers require a significantly smaller voltage of around 3.3 Volts. This reduction of voltage is achieved by a down converter which is described in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**. The down converter doesn’t work with transformers but with resistors.



4.3.4 **Range estimation of the accumulator**

Range at maximum power (If the Multifunctional Mainboard to Observe and Manipulate Organisms is always active and there is no maintenance, RFID)	96 Wh / 0.142 W = 676 hours = **28.16 days**
Range at minimum power (The Multifunctional Mainboard to Observe and Manipulate Organisms is in the Deep Sleep Mode and there is no maintenance; radio clock and RFID off, 1x light barrier)	96 Wh / 0.0058 W = 16552 hours = **690 days** = 1.889 years

The value for the range at minimum power can only theoretically be achieved. In reality the self-discharge causes the accumulator to be discharged earlier. Moreover, an inactivity of more than two years is not intended for the application.

5 Operation of the Smart Feeder

The operation of the Multifunctional Mainboard to Observe and Manipulate Organisms (MOMO) with the Smart Feeder application will be explained in this chapter. This includes the information detailing accumulator replacement, SD card change, software updates, the loading of the accumulator and troubleshooting.

5.1 Accumulator replacement

The accumulator has to be replaced in periodic intervals. The range of an accumulator depends on several factors, including ambient temperature, activity of the Smart Feeder and therefore energy demand of the Smart Feeder. The activity usually depends on the season of the year. As birds have a higher level of activity near the Smart Feeder (SF) during the winter time, the SF is often in the active mode and needs much more energy than during other seasons.

5.1.1 Reasons for accumulator replacement

The accumulators have boards with three LED's which indicate the state of charge. If three LED's are blinking this shows that the accumulator is almost empty and should be exchanged as soon as possible. When two LED's are blinking the accumulator is half full and one LED blinking indicates an almost full accumulator. If there are no LED's blinking the accumulator is completely empty and no longer able to supply energy.

When all LED's are lit permanently this indicates a defect at the accumulator or at the accumulator board. In this case the whole accumulator needs to be changed.

5.1.2 Placement of the accumulator

The wind and therefore also rain, snow and mist in Europe primarily come from the west. This can be seen visibly on trees where the western-facing sides are often moss-covered. Therefore, placement of the accumulator on the eastern side can minimize the possibility of damage due to oxidation.

Moreover, the accumulator can be placed in a way that water can drain away at an edge and does not accumulate at the connector or at the cable input.

If the accumulator becomes warm, it can age more rapidly or be damaged. The operating temperature range of the accumulator is between minus 30°C and 55°C according to manufacturer specifications. When the sun shines directly on the accumulator it is possible to exceed this range. Therefore, the accumulator should be protected against direct sunlight through e.g. placement on the north-facing side of a tree or by shading it in another way.

When placing the accumulator, one should be aware of these external environmental influences and place the accumulator appropriately, because of the high costs of the accumulators.

5.2 **SD card change**

The SD cards have a large memory size so that the memory may be filled only after several months or even years.

As continuous recording of data is desired and as unexpected malfunctions of the Smart Feeders are always a possibility, they should be visited and controlled regularly every couple of weeks. In doing so, SD cards can be exchanged and stored data can be checked. If there is unusual data on the SD cards, it could indicate a malfunction of the Smart Feeder. In this case, a maintenance should be arranged.

5.3 **Software update**

There are three possible methods to write software code on to the flash memory. The debug probe method from IAR systems and the debug interface method without debug probe are always possible. If software has already been written on the flash memory by either of these methods, an additional method using SD cards is also available.

The microcontroller EFM32G230 contains a flash memory with a memory size of 128 KB. This memory contains the software by which the microprocessor works. 128 KB of memory is a sufficient size for operation, even with very complicated applications of the Multifunctional Mainboard to Observe and Manipulate Organisms. Update possibilities are described in more detail in chapter 7.1.

5.4 **Loading the accumulator**

The accumulators should be changed and charged in regular intervals. The accumulator has to be visually checked for damage when it is changed.

5.4.1 **Recharger**

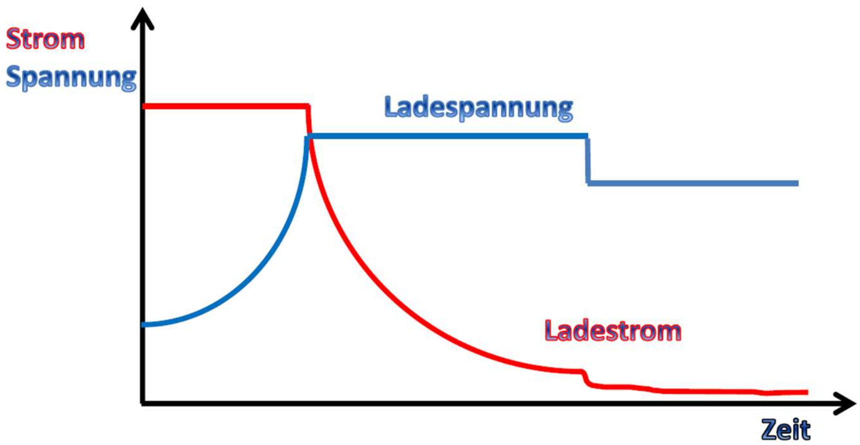
Device description	Mascot type 2541 Li, 4 cell, 2A, Lithium Ion Battery Charger, 35W
Manufacturer	Mascot http://www.mascot.no/home/
Nominal power	35 W
Battery voltage	12V
Charging current	Up to 2 A
Recommended battery capacity	1 – 10 Ah
Loadable cells	4
Charging characteristic	IUoU

The charge process is separated in to three sections.

1. Charging current is 2 A until the voltage reaches 14.7 V
2. Voltage will be held at 14.7 V; Current declines slowly
3. A yellow display shows that the charging current is declined under 1 A
4. If the charging current is below 250 mA the recharger switches off.
5. In the maintenance charging module the accumulator voltage will be kept at 13.7 V.

5.4.2 **Charging method IUoU**

UIoU means that the initial charging current is constant similar to the CCCV charging method until the final charging voltage is reached. Then the voltage is held at the charging end voltage. This constant high voltage can be harmful for the accumulator and reduce the capacity. Therefore, the voltage will be reduced after a certain amount of time; with that the maintenance charging is initiated. With the reduced voltage the accumulator can be charged permanently and the amount of current is roughly like the self-discharge. The “I” in IUoU stands for constant current, “Uo” stands for constant voltage with charging end voltage and “U” for reduced constant Voltage



5.4.3 Charge time

The accumulators can be charged in roughly one day to ensure that the accumulators are securely fully-loaded.

Theoretically, a charging time of roughly 3 hours in both rechargers is enough for a complete loading.

The charging time at the IUoU can be marginally less, because the Uo phase at constant voltage with end-of-charge voltage can be higher than the CV voltage at the CCCV method.

7.5 Ah / 2A = 3.75 h

A discharged accumulator with 7.5 Ah requires a charging current of 2A for more than 3.75 hours, because the loading does not take place with a maximal current of 2A the whole time.

5.5 Troubleshooting Smart Feeder

The current version of the Smart Feeder has taken three years of development. Some malfunctions could be encountered and thus lead to experience in troubleshooting and development of specific procedures for malfunctions which may be detected.

5.5.1 Troubleshooting in the field

The field troubleshooting takes place after a malfunction is detected through information from the data collected in the SD cards. Incorrect data indicates a malfunction at the Smart Feeder.

5.5.2 Troubleshooting in the laboratory

Via the LEUART-interface the Smart Feeder can be connected to a PC. This makes it possible to transfer information transmitted by the Microcontroller. This allows for a detailed view into the Smart Feeder.

If the failure cannot be detected via the LEUART-interface, the Smart Feeder has to be measured electronically for further troubleshooting.

6 Software

The Software on the flash memory in the Multifunctional Mainboard to Observe and Manipulate Organisms is programmed with the programming language C. This software is diverse for different applications and has to be regenerated for every application. It needs to be smaller than 128 KB for the flash memory. The software for the Smart Feeder application will be described in this chapter. It includes reset options, the reset process, how data is stored and what occurs when the SD card is changed. Also described is how regular queries are stored, what can be done with the built-in buttons on the board and the possibility of software updates.

6.1 Reset

The reset can be used to restart the system of the Multifunctional Mainboard to Observe and Manipulate Organisms when an unknown failure occurs. The procedure for a reset is always the same. The reset is a new start and can be compared with the start of a PC.

6.1.1 Possibilities to perform a manual reset

The Multifunctional Mainboard to Observe and Manipulate Organisms can be restarted manually in two ways:

- Via pushbutton
- Reset after electrical energy was not available for considerable time, so that the capacitor could not provide enough energy. The capacitor has enough energy to provide MOMO for approx. 3 min.

6.1.2 Procedure after reset

After a reset the following procedure takes place:

1. Both LED’s (red and orange) will be illuminated to show that the hardware or software is active and the LED’s are working.

Only visible in a terminal program on a PC.

2. In case a SD card is recognised, its data system is mounted and the free space on the memory is displayed. This takes place at every exchange of SD cards during operation.

3. Afterwards it will be searched for a log file with the name “BOX*nnnn*.TXT” (*nnnn* is a random decimal number). In the case that the file exists on the SD card the name will be displayed on the LC display otherwise the file “BOX0999.TXT” will be created.

Furthermore, the DCF77 module is switched on to receive date and time. The red LED now flashes to the rhythm of the radio clock signal.

4. After date and time got synchronized, the red LED switched off.

6.1.3 **Reset protocol**

If a start or a reset of the Multifunctional Mainboard to Observe and Manipulate Organisms is carried out some protocol lines are written on the SD card to comprehend the process of the maintenance.

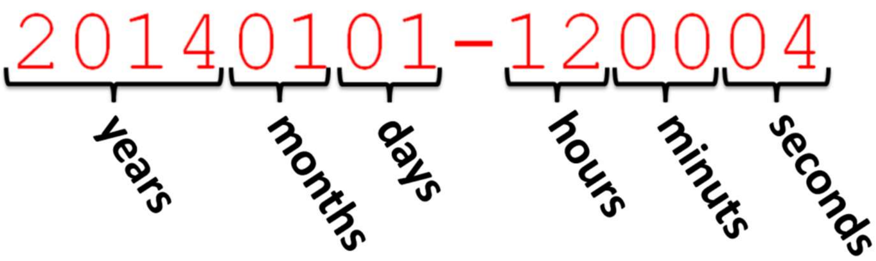
```
20140101-120000.000 DCF77: Enabled

20140101-120000.000 SD-Card Inserted

20140101-120000.054 SD-Card Initialized

20140101-120000.054 SD-Card File System mounted

20140101-120000.497 SD-Card 1938MB free

20140101-120000.499 Using Filename BOX0666.TXT

20140101-120000.517 MCU: EFM32G230F128 HW-ID: 0x245D670356B3C2C0

20140101-120000.550 Battery Manufacturer Name :  Dynamis

20140101-120000.576 Battery Manufacturer Data :  61.90002/15790

20140101-120000.602 Battery Device Name       :  BMS2-4_V0.3

20140101-120000.629 Battery Device Type       :  Lithium-Ion

20140101-120000.636 Battery Serial Number     : 00008

20140101-120000.643 Battery Design Voltage    : 3.300V per cell
```

```
20140101-120000.651 Battery Design Capacity   : 7500mAh
20140101-120000.658 Battery Full Charge Capac.: 8079mAh
20140101-120000.666 Battery Remaining Capacity: 7268mAh
20140101-120000.674 Battery Runtime to empty  : More than 6 weeks
20140101-120000.681 Battery Actual Voltage    : 13.3V
20140101-120000.689 Battery Actual Current    :    0mA
20140101-120000.690 Reading Configuration File CONFIG.TXT
```

6.2 Data storage

All important information from the RAM memory will be saved in a txt-file on the SD card. Every event or stored message begins with the date and time of the event.

Following the date and time there is a blank space. Then follows the actual status message.



Procedure after SD card change

After a new SD card is plugged in the following procedure starts.

1. It displays that a new SD card has been detected.

```
20140101-120004 SD-Card Inserted
20140101-120004 SD-Card Initialized
20140101-120004 SD-Card File System mounted
```

2. The following line shows how much free space remains on the SD card.

```
20140101-120011 SD-Card 1880MB free
```

3. Afterwards it will search for a log file with the name „BOX*nnnn*.TXT“ (*nnnn* is a random decimal number). In case that the file exists on the SD card the name will be displayed on the LC display otherwise the file „BOX0999.TXT“ will be created.

```
20140101-120011 Using Filename BOX0999.TXT

20140101-120011 Media Change: BOX0999.TXT -> BOX0020.TXT
```

4. The hardware ID will be displayed, which is a unique number allocated to each Multifunctional Mainboard to Observe and Manipulate Organisms

```
20140101-120011 MCU: EFM32G230F128 HW-ID: 0x24B4010253FD82EE
```

5. The status of the accumulator is then displayed, including the manufacturer name, manufacturer data, device name, device type, serial number, design voltage, design capacity, total capacity, remaining capacity, remaining time at actual current and at least the measured actual voltage.

```
20140101-120011 Battery Manufacturer Name :  Dynamis

20140101-120011 Battery Manufacturer Data :  61.90002/15790

20140101-120011 Battery Device Name       :  BMS2-4_V0.3

20140101-120011 Battery Device Type       :  Lithium-Ion

20140101-120011 Battery Serial Number     : 00008

20140101-120011 Battery Design Voltage    : 3.300V per cell

20140101-120012 Battery Design Capacity   : 7500mAh

20140101-120012 Battery Full Charge Capac.: 8968mAh

20140101-120012 Battery Remaining Capacity: 4122mAh

20140101-120012 Battery Runtime to empty  : More than 6 weeks

20140101-120012 Battery Actual Voltage    : 13.149V

20140101-120012 Battery Actual Current    :    3mA
```

6. The configuration file CONFIG.txt is read. This process enables the manipulation of the different identities. Up to 52 identities can be programed. A detailed description can be found in the CONFIG.txt file. Attention should be paid to further settings of energy-saving times, light barrier logic for known birds, animal transponder readers, switching off time and transponder identification for unknown identities (UNKNOWN). Standard stocks for flaps and cameras.

```
20140101-120000.690 Reading Configuration File CONFIG.TXT

ON_TIME                  : 03:35

OFF_TIME                 : 22:40

LB_FILTER_DURATION       : 10

RFID_PWR_OFF_TIMEOUT     : 360

RFID_DETECT_TIMEOUT      : 15

KEEP_OPEN                : 60

KEEP_CLOSED              : 120

CAM1_DURATION            : 15

                         : KEEP_OPEN : KEEP_CLOSED : CAM1_DURATION

108196A801AF0001         :       180 :     default :   default

9E1CE7D001AF0001         :    ALWAYS :     default :   default

ANY                      :       120 :         240 :       360

D5CD24B43A6F0001         :    ALWAYS :     default :   default
```

7. The time of the microcontroller is updated through the signals from the radio clock. This process usually only takes a few minutes.

```
20140101-120856 DCF77: Time Frame 1 is 20160315-143100

20140101-120956 DCF77: Time Frame 2 is 20160315-143200

20160315-143200 Initial Time Synchronisation

20160315-143200 DCF77: Time Synchronization 14:32:00

20160315-143200 DCF77: Disabled
```

6.3 Periodic routine queries

6.3.1 Time update

Every 24 hours, during the night the time from the microcontroller is updated by the signals from the radio clock.

```
20170304-015500.000 DCF77: Enabled

20170304-015659.279 DCF77: Time Frame 1 is 20170304-015700

20170304-015759.283 DCF77: Time Frame 2 is 20170304-015800

20170304-015800.284 DCF77: Time Synchronization 01:58:00 (MEZ)

20170304-015800.001 DCF77: Disabled
```

```
Further outputs:

Log ("DCF77: Changing time zone from MEZ to MESZ");

Log ("DCF77: Changing time zone from MESZ to MEZ”);
```

If the DCF77 is not connected, there is no sync signal and no synchronisation.

6.3.2 Battery status query

At 11 a.m. and 11 p.m. the battery status is written on the memory as well as on the SD card. In addition, the current power demand is calculated. The range of the accumulator is calculated from data taken from the accumulator board. The remaining capacity and the current power demand are used for the calculation of the remaining range.

```
20170303-230000.014 Battery Remaining Capacity: 7271mAh

20170303-230000.021 Battery Runtime to empty  : More than 6 weeks

20170303-230000.029 Battery Actual Voltage    : 13.3V

20170303-230000.036 Battery Actual Current    :    0mA
```

6.4 Recorded events

One task of the Multifunctional Mainboard to Observe and Manipulate Organisms is to record the behaviour of animals. In the Smart Feeder application this is achieved via recordings from the light barrier activity and transponder detections as well as via the closing of the shutter.

6.4.1 Light barrier activity

The light barriers are always active and are always supplied with electrical energy. They are the trigger for the RFID Reader which is by far the largest energy consumer.

```
20160323-112408 LBO:ON       # Light barrier outer on

20160323-112408 LBI:ON       # Light barrier inner on

20160323-112408 LBO:off      # Light barrier outer off

20160323-112408 LBI:off      # Light barrier inner off
```

6.4.2 Transponder activity

The RFID reader is switched on by light barrier activity. This needs to occur very quickly as the transponder may be rapidly moving through the barrier and its number needs to be read completely. The birds have a particularly high velocity when approaching, which is why the RFID Reader needs to be activated very quickly.

```
20150723-154010 RFID is powered ON

20150723-154010 Transponder: D5CD24B43A6F0001

20150723-154122 RFID is powered off
```

Because it is likely to detect further activity after a transponder is detected, the RFID remains on for an additional 6 minutes after the last transponder signal.

6.4.3 **Servomotor activity**

The servomotor is closed or opened after the query of the CONFIG.txt file.

.

```
20170317-114613.295 Shutter will be opened

20170317-114528.437 Shutter will be closed
```

6.4.4 **Connections for possible recording devices (camera)**

```
20170317-105658.000 CAM1 is powered on

20170317-105758.000 CAM1 is powered off

20170317-105658.000 CAM2 is powered on

20170317-105758.000 CAM2 is powered off
```

6.4.5 **Standard recording**

In the following there are typical status messages:

```
20170317-112428.223 LB1:ON

20170317-112428.223 CAM1 is powered ON

20170317-112428.224 RFID is powered ON

20170317-112428.584 Transponder: 0B6122B43A6F0001:0:A:15

20170317-112428.585 Shutter will be closed

20170317-112428.823 LB1:off

20170317-112428.823 LB1:off

20170317-112452.000 CAM1 is powered off

20170317-113038.000 RFID is powered off
```

6.4.6 **Power Good and Power Fail**

- Battery gets disconnected
- Power fail gets detected
- RFID Reader and CAM1 get switched off
- Battery gets reconnected
- normal function without reset, RFID Reader and CAM1 get reactivated on demand

```
4/18/2017 12:45:06.274 [RX] - 20170418-124506.221 Power-Fail: Received
interrupt (POWER FAIL)

4/18/2017 12:51:44.342 [RX] - 20170418-125144.296 LB1:ON

20170418-125144.402 LB2:ON

4/18/2017 12:51:45.030 [RX] - 20170418-125144.985 LB1:off

20170418-125144.986 LB2:off

4/18/2017 12:53:59.514 [RX] - 20170418-125359.436 Power-Fail: Received
interrupt (POWER GOOD)
```

6.5 Occurrences when it is not possible to write on the SD card

When the SD card is full or if there is no SD card is in SD card slot an error message is written on the LEUART-BUS. During a normal operation of the Smart Feeder application of the Multifunctional Mainboard to Observe and Manipulate Organisms, it is not common that data is lost due to an absent or malfunctioning SD card, because the internal memory for events provides 2 KB, which should be sufficient for many events to be stored.

`ERROR: Log Buffer Out of Memory - lost 1 Messages` (only appears on HyperTerminal screen of the PC)

More error messages:

```
ERROR Config File - Line 131, pos 26, ID: OUT OF MEMORY
SMB_Reset: Try to recover from invalid state
SMB_Reset: Recovery failed, giving up
CfgRead: FILE OPEN - Error Code
CfgRead: FILE READ - Error Code
CfgRead: Line %d too long
Config File - Line %d, pos %ld: Invalid Variable Name
Config File - Line %d, pos %ld: Unknown Variable
Config File - Line %d, pos %ld: Unknown Variable
Config File - Line %d, pos %ld: Value expected
Config File - Line %d, pos %ld, %s: Invalid time
Config File - Line %d, pos %ld, %s: OUT OF MEMORY
Config File - Line %d, pos %ld, %s: Unsupported data type
Config File - Line %d, pos %ld: Garbage at end of line
LogError ("LogFileOpen: Error Code %d", res);
See if Log File is open */
LogError ("LogFlush: Init Failed");
LogError ("LogFlush: Error Code %d", res);
LogError ("LogFlush: Disk Full");
```


7 Expiry after keystroke

The Multifunctional Mainboard to Observe and Manipulate Organisms contains a button for conducting a reset.

After pressing the S1 button, the whole system will be restarted. The procedure of the restart is described in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**.

7.1 Update options

There are three possibilities to write software code on the flash memory.
The method of the Debug Probe and the one via the Debug Interface always work. If software was written on the flash memory via either one of these the methods examining the content of a newly inserted SD card and searching for software updates, a third method can be implemented.

7.2 IAR Systems Debug Probe

Through the debug probe from IAR systems it is possible to load compiled software code on the flash memory. The software from IAR for the debug probe is necessary for this.

IAR Systems also distribute the software IAR Embedded Workbench to create and compile C code. The compiled C code can be loaded on the flash memory by the debug probe.

7.3 With USB on 10-pole Debug Interface Connector

This method only allows HEX and BIN files to be transferred to the flash memory and has the benefit of the original C code not being readable anymore.

7.4 Via SD card and boot loader

If software has already been written on the flash memory by either of the methods from chapter 7.2 or 7.3 a third method through a boot loader is available. If the software of the flash memory contains the command to search for new software when recognizing a new SD card, this new software can be installed.

8 Contact details

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8. Links to the datasheets

Datasheets need to be saved within the folder ‘datasheets’, which has to be in the same content as the documentation. For every link there is a document within this folder.

EFM32G230

IAR J Tag ARM

LC display

SD card reader

Button

Capacitor

Jack connector

USB cable

Down converter

LED’S

Radio clock

Light barrier

RFID reader

RFID transponder

Housing for the main board

Housing for the accumulator

Battery charger Fronius

Battery charger Mascot

Battery cell

Content

