ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA100

INTEGRATION OF PERSONAL PROTECTIVE EQUIPMENT CHECKS IN ACCESS CONTROL

P. Pok, F. Havart, T. Ladzinski, CERN, Geneva, Switzerland

Abstract

Access to the interlocked zones of the CERN accelerator complex is allowed only for personnel wearing standard personal protective equipment. This equipment is complemented by specialised personal protective devices in case of specific hazards related to the remnant radiation or the presence of cryogenic fluids. These complex devices monitor the environment in the vicinity of the user and warn the user of the presence of hazards such as radiation or oxygen deficiency. The use of the devices is mandatory, but currently only enforced by procedures. In order to improve the safety of the personnel it has been proposed to verify that users are carrying their devices switched on when entering. This paper describes the development of a specialised multi-protocol terminal, based on Texas Instruments digital signal processor and integrated in the personnel protection system. The device performs local checks of the presence and status of operational dosimeter prior to allowing access to the interlocked zones. The results of the first tests in the Proton Synchrotron accelerator complex are presented.

INTRODUCTION

Several layers of protection help ensure the safety of personnel working in beam facilities at CERN. A number of systems are deployed offering facility wide protection: the access control and safety system, the fire detection and extinguishing systems, the gas detection and evacuation systems. In case of localised hazards, this systematic approach is complemented with active personal protective equipment. It includes operational dosimeters and personal gas level detectors. Conventional protective equipment like self-rescue masks or safety helmets constitutes the last protection layer.

The devices providing active personal protection are very specialised and their use is not common outside CERN. Hands-on training is provided to the users and reminders posted on the obligation of wearing the equipment at the access points and in the elevators. However, a systematic check to ensure in an automatic way that everyone is in possession of the necessary active protective equipment when entering a beam facility has not been provided so far.

The proposed solution is a terminal unit capable of tracking the protective equipment and communicating with the access system. The terminal unit can be triggered by the programmable logic controller (PLC) of the access booth, once a person steps in. During the access control verification process, the terminal unit is commanded to execute reading cycles to check the presence and the status of the personal protective devices. If the equipment is not present or not correctly set, the access system notifies the person to wear it properly and refuses access into the given interlocked zone. In particular, the objective for the terminal unit is to the check for the presence of operational dosimeters and oxygen detectors.

Operational dosimeters are provided by the Dosimetry Service at CERN. They are mandatory for everyone working in Limited Stay, High Radiation and Controlled Radiation areas [1]. The dosimeter displays the amount of dose and it has alarm functions when thresholds for dose or dose rates are exceeded. Before entering a hazardous area, the person has to read out and reset the dosimeter via a contactless reader terminal.

Oxygen level detectors are used in cryogenic facilities to cover the risk of oxygen deficiency hazard (ODH). Their use is mandatory in the Large Hadron Collider (LHC) tunnel areas. The device displays oxygen levels and sounds an alarm when a threshold value is reached. There are no terminal readers provided and the device does not offer native contactless communication mechanism.

After initial research, our team decided to design a multiprotocol terminal capable of communicating with a large set of devices in a contactless manner. Two cases were taken into consideration: the devices that natively communicate with their terminal units wirelessly, and the devices that do not provide any wireless interface. In the first case, the objective was to use the existing communication mechanism and in the second case to add an RFID tag to the equipment. Furthermore, the multiprotocol terminal had to meet every criterion of the access system both mechanically and electronically, and not hinder the access process itself.

TRACKING EQUIPMENT WITH RFID

Low frequency (LF) systems are widely used in access control, logistics or in implants for animal tracking. In low frequency Radio Frequency IDentification (RFID) systems the physical layer of the communication is realised through magnetic coupling. It is more resistant to detuning in the presence of metal objects than higher frequency solutions. The antenna coils of the reader and the transponder act like the coils of an air core transformer. The typical low frequency RFID transponders are passive devices, meaning that the transponder is energised by the alternating magnetic field that the reader emits and communicates by modulating the magnetic field by changing the load on its antenna coil.

There are several public accessible communication protocols like the ISO11784/5, ISO14223 and ISO18000-2 standards [2-4]. Transponder chips in this RFID frequency range include EM41000/2 or HITAG with publicly accessible protocol [5-6]. RFID labels with these chips can be attached to the oxygen detectors in order to track their presence with the terminal unit.

Other devices like the Mirion Technologies DMC type operational dosimeters [7-8] use active communication,

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA100

meaning that the terminal unit does not have to emit a carrier signal when the other side responds.

We selected three target devices that our multi-protocol terminal should be compatible with, namely the EM41000/2, HITAG RFID passive transponders and the Mirion Technologies DMC 2000/3000 type dosimeters with an active transceiver.

DESIGN CONSIDERATIONS AND REALISATION

The terminal unit was designed to be installed inside the access booth known as Personnel Access Device (PAD). Thus, it is powered from a common 24V DC supply voltage rail of the PAD and connected to its controller via Profibus [9] as a Decentralised Peripheral (DP) slave device [10].

Another important restriction was the installation environment in the PAD, where the limited space is shared with other components. This resulted in using custom design antennas and frontend circuit to reach the required sensitivity. It was decided to use two antennas in a time division multiplexed way, i.e. only one reader antenna is active during the transmission process. Thus, the maximal supply current can be applied to one antenna, meaning greater transmitted power. In our first design, we calculated the peak current that goes through the antenna to be around 0.5A.

The functionalities of the device are based on a Texas Instruments TMS320F28062 C2000 core Digital Signal Controller (DSC) [11], which samples and processes the filtered antenna signals, drives the reader antenna driver circuit, and handles the Profibus interface chip. It communicates with the master PLC via the output and input bytes that are assigned to the device according to its General Station Description (GSD) file [12].

Figure 1 shows a simplified block diagram of the terminal.

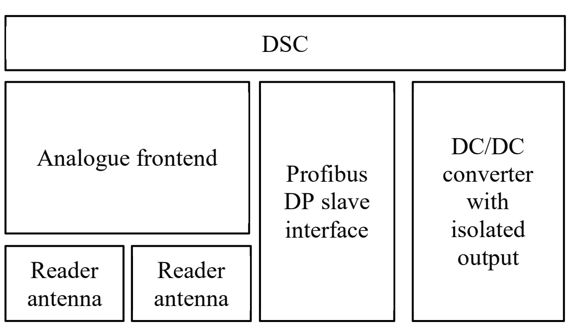

Figure 1: Architecture of the terminal device.

Powering Considerations

When designing the power converter of the device, the main goal was to find a cost-effective solution capable of providing sufficient current for the reader antennas during transmission, efficient enough in idle states and meeting the limitations provided by the given board space and the production technology. Galvanic isolation to improve noise immunity and safety was also an important criterion because of the application environment.

The calculated maximal supply current of the device was around 1A (during transmission). A flyback converter would have been a good choice for the given power range. However, there was a part of the circuit that could not be isolated, namely the inputs and outputs of the optocouplers and the transceiver chip that was connected to the Profibus. The required voltage output levels on the board were 3.3V and 5V on the isolated side and 3.3V on the non-isolated side.

These requirements led us to use a dual output power converter topology, which is a combination of a flyback and a buck converter, called *Fly-Buc*k topology at Texas Instruments. This power supply is regulated using the feedback of the non-isolated side; the isolation comes from using a coupled coil. In our application we used a coupled coil with 1:1 turn ratio, so the output voltages are almost the same on both sides (5.1V nominal), the isolated output being slightly lower due to the diode voltage drop.

The regulator and switching element of the circuit is a Texas Instruments LM5161 regulator that is set to operate at 750 kHz switching frequency.

Antenna and Frontend Design

We used a parallel plane antenna coil topology in the reader antennas, a one-turn loop for transmission and a several turn loop for reception. The antennas are realised on the same, four-layer Printed Circuit Board (PCB), with the perimeter size of 95mm by 265mm. The antenna can be placed on metal or plastic surfaces, which is an important aspect of its reading range.

The one turn loop coil, that forms the transceiver antenna circuit with a series capacitor and a current limiter resistor is driven by an H-bridge MOSFET driver stage, switching the 4.5V supply voltage in both directions. This results in a 9V peak-to-peak voltage applied to the antenna circuit.

The receiver antenna is an 80-turn loop that is placed on three layers of the PCB, two layers with 40 turns and one for the connecting and pole wires. The receiver coil is connected to the frontend circuitry through capacitors in a balanced way. The parasitic capacitance of the antenna coil and the coil itself result in the resonant frequency of 107 kHz, below the desired value. This is because when the antenna is placed on the metal (steel) walls of the PAD, the eddy currents that appear in the steel plate decrease the inductance of the antenna coil, thus increasing the resonant frequency. With a spacing of 30-35mm between the antenna and the metal surface, the resonant frequency reaches the desired 125 kHz value. When placed on non-metallic surface, a tuning coil is connected in parallel to the antenna coil to get the desired resonant frequency.

The signal from the antenna is connected to the frontend in a differential way, and then split into two signal routes. One route for receiving the signals of active devices (the dosimeters) and another route for receiving the signals of load-modulation capable transponders, as shown in Fig. 2. The former route consists of an instrumentation amplifier with a gain of 20dB, a band-pass filter tuned to 125 kHz

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA100

and ends in the ADC input of the DSC. The other signal route is for decoupling the envelope of the amplitude-modulated signal of the load modulation. Thus, a simple full-wave rectifier, a capacitor tank and differential capacitive coupling is applied to the signal, before passing it through an instrumentation amplifier, a low-pass filter and ending up at an ADC pin of the DSC.

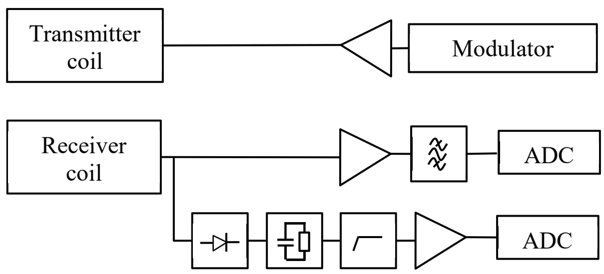

Figure 2: Block diagram of the antenna and the frontend.

Functionalities

The latest version of the terminal is operating with two antennas in a PAD and it is able to read the identifier and the state of the operational dosimeters worn by the people passing through the access booth.

A PLC controls the terminal via the Profibus DP-V1 protocol, with two output bytes that contain three individual bits and two groups of command bits. With the help of these command signals, the PLC can start and stop the reading process, can assign a time interval for the scanning process, reset the terminal, and index the table of the successfully read devices. Four input bytes serve for signalling to the PLC, two bit signals to indicate faults and the state of the reading process, three bits to indicate the number of successfully read devices and four bytes that contain the identifier digits and parameters of the read devices. The timing diagram of the signals described is shown in Fig. 3.

DSC Firmware

The firmware that is running on the controller of the board has been developed using the development toolchain provided by Texas Instruments.

The firmware was written with portability in mind. There is a thin hardware abstraction layer between the application layer and the programming layer of the processor (support libraries). The Texas Instruments SYS/BIOS operating system is used throughout the software layers to support real-time scheduling and communication between tasks.

The main tasks of the software are handling the data transfer and implementing the functionalities of the Profibus interface, realising the RF reader device, providing a basic user interface via serial communication line, indicator LEDs and push buttons.

The signal that drives the power stage of the transmitter antenna is generated by the Pulse Width Modulator (PWM) peripheral of the DSC. A simple driver module is used for setting up the peripheral (period time and pulse width) and enabling the signal generation in continuous or pulse packet mode. The former mode is used for generating a continuous carrier signal and the latter is used for generating precise amplitude modulated signals. A line encoder software module uses the interfaces of the PWM driver to generate the pulse position modulated signal that is used in communication with the DMC type dosimeters. The line encoder can take an array of bytes as an input and transmit each byte of the array with the least significant bit first.

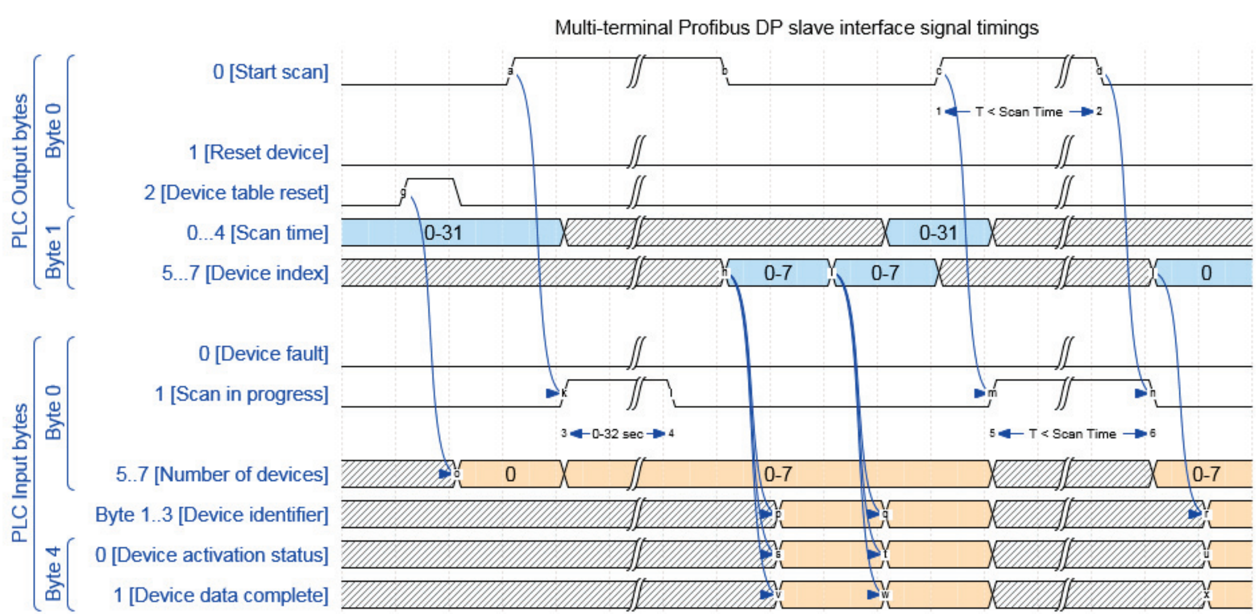

Figure 3: PLC output and input signal timing diagram.

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA100

The signal receiver and processor part of the firmware consists of several modules, starting from the driver that controls the ADC peripheral. As the reader antennas are designed to be used in a time-multiplexed way, the ADC driver can provide a single stream of a sampled signal from one of the four ADC input pins. The sample rate of the stream is configurable, as it is different for the signal routes of the active and passive devices. In case of receiving signals from the active devices, the bandpass-filtered signal on the ADC input pin is sampled at 500 kHz rate, then rectified and filtered digitally, and finally down sampled to 31.25 kHz. On the other signal route for the passive devices (LF RFID transponders), the ADC input is sampled at 31.25 kHz rate. These signal streams are fed into the line decoder module. As both the active and passive devices use Manchester encoding for line coding, the same decoder module is used to produce decoded bit stream from the input signal. The decoder module automatically adjusts the threshold levels according to the dynamics of the signal and the noise level.

The Profibus interface consists of an external chip to handle the data link (FDS) and application (DP-V1) layers of the protocol and software modules to configure the interface chip. The interface chip is connected to the DSC via Serial Peripheral Interface (SPI) bus that operates at 2Mbps rate. The Profibus slave address of the terminal is set with an eight channel DIP switch in binary format.

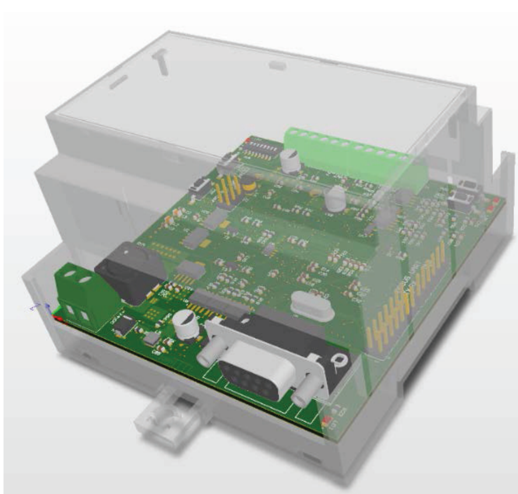

Figure 4: The multi-protocol terminal in a DIN-rail compatible enclosure.

Integration Inside the PAD

The printed circuit board of the terminal is housed in a DIN rail compatible enclosure and placed in the control rack of the PAD as shown in Fig. 4. As for the reader antennas, the objective is to place them in such a way that their effective field covers the chest part of a person standing inside the PAD and facing the biometry scanner unit as shown in Fig. 5. This way the terminal-device communication can take place during the biometric identification process.

Two types of PADs are in use at CERN; they differ in shape, size and material of the inner wall supporting the biometric scanner. Due to size restrictions, in the smaller PAD model, the antennas have to be hidden behind the sidewall, which requires small cut-out modifications, but the antenna efficiency is very high. In bigger models, the mechanical installation is easier, but due to steel surrounding, the efficiency of the antenna is slightly decreased.

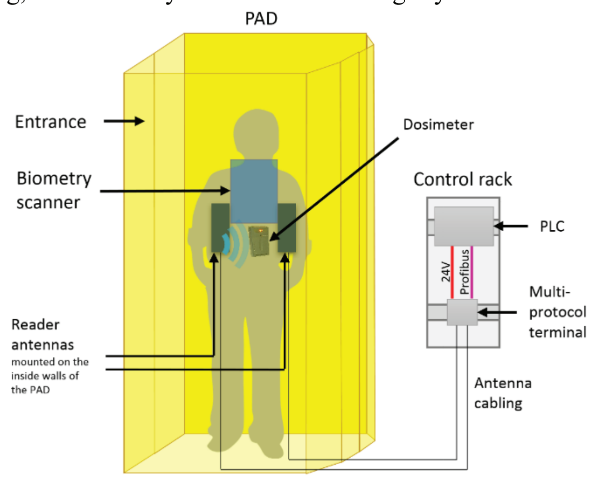

Figure 5: Integration of the terminal unit inside a PAD.

CONCLUSION

A multiprotocol terminal device capable of detecting the presence of personal protective equipment was designed and developed. It was installed in the LHC and PS type of PADs in a laboratory setup and successfully tested with the operational dosimeters in use at CERN. On-site installation in one of the PS accelerator access points is pending conclusive tests at the beginning of the next shutdown period, where a large number of accesses will take place.

REFERENCES

[1] E. Sanchez-Corral *et al.*, “Data management and tools for the access to the radiological areas at CERN”, in *Proc. ICALEPCS’13*, San Francisco, USA, Oct 2013, pp. 226-229
[2] https://www.iso.org/standard/53531.html
[3] https://www.iso.org/standard/50979.html
[4] https://www.iso.org/standard/46146.html
[5] http://www.smartstripe.com/wp-content/uploads/2012/10/EM4100.pdf
[6] https://www.nxp.com/docs/en/data-sheet/H184430_HITAGu_ISO_18000_2.pdf
[7] https://www.mirion.com/products/dmc-3000-electronic-radiation-dosimeter/
[8] https://www.mirion.com/products/dmc-2000-electronic-radiation-dosimeter/
[9] http://www.profibus.com/technology/profibus/
[10] http://www.profibus.com/nc/download/specifications-standards/downloads/profibus-standard-dp-specification/display/
[11] http://www.ti.com/product/TMS320F28062
[12] https://procentec.com/service-support/gsd-files/