Using a Fiber Optic CAN Bus for the Proton Source Control of the CERN PS-Linac

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Abstract

Following the recommendations for the use of field buses at CERN, the CAN (Controller Area Network) bus has been chosen to control and acquire the necessary parameters of the proton source of the LINAC II. This project represents two novel aspects, one on the hardware and one on the software side: since the source is on a high electrical potential (92 kV), a fiber-optic interface has been developed which permits communication between the VME CAN bus controller and the CAN equipment in the proton source over optic fibers. Concerning the software, the CAN protocol had to be integrated into the equipment access method used at the PS.

1 Introduction

Protons for the CERN accelerators are produced by a Duoplasmatron source [1]. The protons are injected into the LINAC2 where they are accelerated to 50 MeV. Fig. 1 shows the mechanical set-up of the proton source.

The task was to connect the proton source to the VME based control system of the PS [2]. In the previous system, the control electronics was housed in a CAMAC crate and the communication was done over an optical CAMAC Serial Highway. This worked fine, however, the CAMAC modules had become obsolete and one wanted to reduce the amount of space taken by the crate. So, in the frame of the renewal of the PS control system, Serial CAMAC had to be replaced by one of the 3 field buses recommended at CERN, Profibus, Worldfip or CAN bus. The CAN bus [3] was chosen because of its simplicity, robustness, cost-effectiveness, and because it seemed well adapted for this local and relatively simple control problem.

2 Stating the problem

Two 19 inch racks on isolating columns are provided to house the electronics. The racks are on a potential of 92 kV, the same voltage as the proton source. The electronics is powered by 220 V delivered by an isolating transformer (Fig. 1).

Five analog parameters have to be controlled:

- filament (cathode) heating current
- hydrogen gas flow
- main magnet current
- expansion cup magnet current
- voltage of pulse forming network (to create the discharge of the Duoplasmatron).

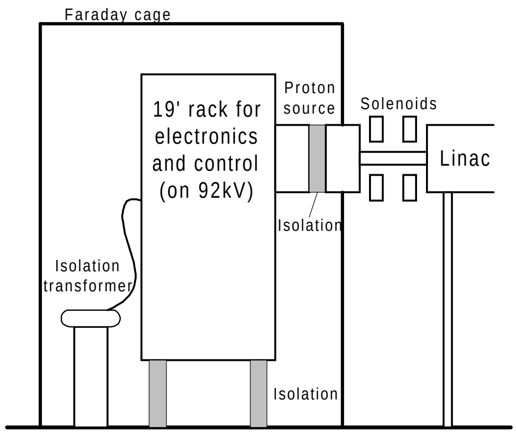

Fig. 1: Proton source for the PS

These five parameters are measured and have to be acquired by the control system. In addition, 2 more analog values (the polarisation cup voltage and a second measurement of the arc current), as well as 15 status bits have to be acquired.

Furthermore, 2 timing pulses are needed: one controls the pulsing of the source (the timing of the measurements is also derived from this pulse), the other one the length of the proton burst (“tail clipper”).

3 Hardware solution

Three pieces of equipment had to be selected:

- the CAN controller in the VME crate
- the CAN node with the necessary I/ O facilities for the proton source
- the fiber-optic interface to the CAN bus

3.1 CAN Controller

We did not find fiber-optic CAN buses commercially available, so the necessary interface had to be developed at CERN. This lead to the selection of VMOD-ICAN2 [4] as CAN controller because a MODULbus carrier board could be used to accommodate both the CAN controller and the conversion electronics.

3.2 CAN Node

A condition for the CAN node in the proton source was to be physically pluggable into a crate to be housed in the 19 inch rack provided for the control electronics. For ease of maintenance, the modules had to be exchangeable separately.

The input-output characteristics (control and acquisition of voltages, acquisition of status bits) are universal that virtually all CAN providers have these modules in their product range. However, most of the commercially available industrial I/O modules are clipped onto a TS35 mounting rail and thus less suited for our application. Finally, we selected the IND I/O S series from Weidmueller [5], which permits installation of the modules into an Euro-chassis, thus fulfilling the mechanical condition. This system uses a simple parallel bus on the backplane of the chassis to connect the I/O modules to a CAN CPU (Fig. 2). A drawback of the IND I/O S system is that it does not provide the possibility to synchronize acquisition to an externally given timing. This is essential for a pulsed device like the proton source. None of the two possibilities to relate a measurement to an external timing is provided, neither triggering a CAN message from the node nor accepting a Remote Transmission Request. Instead, an acquisition message is sent to the controller if, and only if, an input changes.

A solution is to change the data artificially for all input modules at the moment of the measurement, without affecting the real data. For the digital input this is simple: one spare bit is toggled at every acquisition timing pulse. For the analog input modules, the digital output (after the ADC) is held at a fixed value except for a window of a few ms which allows the ADC output to settle for the correct value which in turn causes the sending of the data (of course, the real data must always be different from that fixed value!). A small timing module (Fig.2) generates the window and delivers the necessary signals to the input modules.

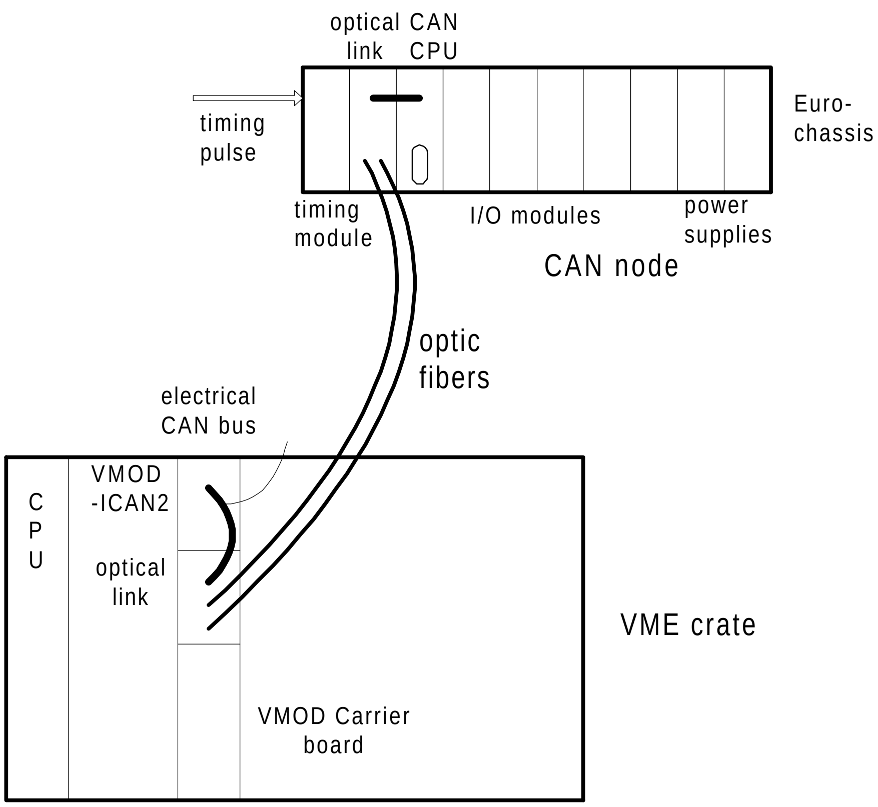

Fig. 2: CAN Net for PS proton source

3.3 Fiber-optic CAN Interface

The CAN node being on 92 kV, a transmission of the CAN messages via optic fibers is mandatory. Two fiber-optic interfaces are necessary: electrically they are the same, but mechanically they are in the form of a MODULbus mezzanine board for the VME CAN controller, and in the form of an Euro-module for the CAN node. The circuit schematics is shown in Fig. 3.

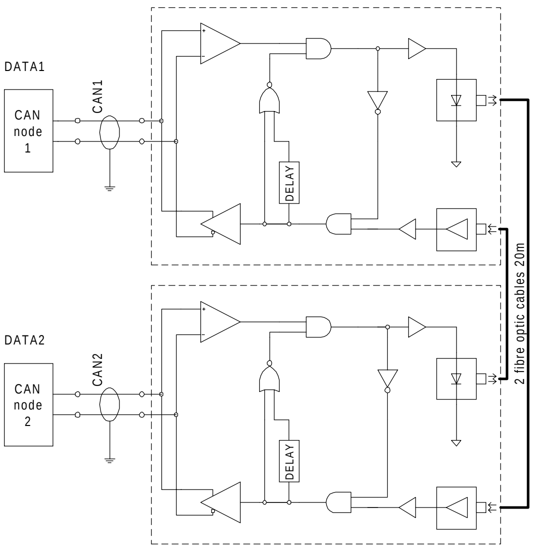

Fig. 3: Fiber-optic CAN interface

Whereas one copper cable can transmit signals in both directions, one needs two optic fibers, one for each direction. These paths have to be mutually exclusive which is achieved by interlocking them: if one path is activated (dominant level), the other one is automatically blocked. Without this, the bus would latch-up at the first dominant level because it would be transmitted back within two propagation times and hold the bus indefinitely at dominant level.

If one node starts to transmit, the signal is transmitted into one direction and arrives at the receiver after the propagation delay. The other path is interlocked by the NOR gate (Fig. 3) which assures that the data is correctly received.

If two nodes start to transmit at the same time or within a time interval of less than the propagation delay, the direction of the signal flow (corresponding to which node has higher priority) may change within one bit time. This causes variations in the pulse length and glitches. The worst case is shown in Fig. 4: both nodes transmit the same data bits. The signal from node 2 arrives at node 1 slightly before node 1 starts to transmit, but just too late for node 1 to detect that the bus is already busy. In the measurement shown in Fig. 4, DATA1 and DATA2 correspond to the signals the nodes want to transmit, and CAN1 and CAN2 are the signals measured after the electrical transceivers of the nodes (Fig. 3). Positive signals correspond to dominant bus levels. The measurement was done at a bit rate of 1Mbit/s with an optic fiber length of 20m.

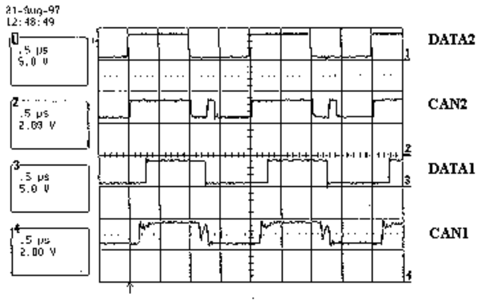

Fig. 4: CAN signals using fiber-optic transmission

The pulses and glitches which appear at the nodes do not cause any harm if

- the data is correct around the internal bit sampling point,
- edges do not cause a faulty resynchronization of the bit sampling.

Both conditions are fulfilled: the sampling point is around the last third of the bit time where the signals are clean, and the edges of the pulses of CAN2 do not cause a resynchronization because the value after the edge is not different from the value at the previous sampling point.

4 Software

For the proton source control, there are only 2 different kind of messages:

- the control messages, generated cyclically by the VME CAN controller, which in turn is controlled by the VME CPU,
- the acquisition messages, triggered by an acquisition timing pulse and generated in the CAN node (there can be more than one message per cycle for the same data).

These messages have to be treated by our general control system which works as follows: at every machine cycle, a real-time program in the VME CPU reads all acquisition messages from the CAN link and puts them into predefined data columns. For acquisition, a real-time program has to select the correct messages (it has to sort out the messages with fixed values generated at the end of an acquisition window). Then it writes the control values via the CAN link into the CAN node. The control values have before been put into corresponding control data columns by an Equipment Module (EM) call [6]. The EM asynchronously writes control data into data columns and reads acquisition data from data columns. It thus represents the link to standard application programs which do the man-machine interface.

The application programs correspond to level 7 of the ISO communication model. The consequence is that there is no advantage in using higher level CAN protocols, e.g. DeviceNet (Allen Bradley), SDS (Honeywell) or CAL (CIA), because they do not adhere to the standards in our application programs. The CAL (CAN Application Layer) was considered but would have introduced another software layer without giving much benefit, also because all functions serving to reconfigure CAN nets are completely unnecessary in our case.

5 Conclusions

CAN permits data control and acquisition at moderate cost: it is the least expensive of the three field buses recommended at CERN. The proton source control costs about a quarter of the equivalent solution with CAMAC. However, the commercially available CAN nodes (CAN processors and I/O modules) are not well suited for processes needing synchronization with external events. It is expected that this situation will improve with the arrival of new products, because CAN naturally offers the possibility to synchronize processes. The fiber-optic CAN interface developed at CERN permits us to extend the range of applications into areas which are electrically heavily disturbed or whose nodes are on different electrical potentials like in our case.

6 References

[1] M. Hone, “The Duoplasmatron ion source for the new CERN Linac preinjector”, CERN int. note PS/LR/Note 79-37 (1979).

[2] F. Perriollat, C. Serre, “The new CERN PS control system overview and status”, Proceedings of ICALEPCS, Berlin, Germany, Oct. 18-23, 1993, p.86-90.

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