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CANopen powers subway auxiliary inverters

Leroy introduces how to implement some key features of auxiliary inverters' management onto commercial-off-the-shelf (COTS) technologies: the Brio hardware platform. In the context of the New York City Transit – R211 subway project, the platform acts as a remote input/output module based on CANopen.

Figure 1: The Brio R107 CANopen-based PLC (Source: Leroy)

The complete article is published in the September issue of the CAN Newsletter magazine 2022. This is just an excerpt.

Leroy Automation is manufacturer of automation systems for on-board train and rail signaling control-command systems. For several decades, they have been accompanying major rolling stock manufacturers, locomotive subsystem integrators, and original equipment suppliers for rolling stock vehicles as well as for many train fleet overhaul projects.

As part of on-board train architectures, energy management is an important topic where efficient power converters are key subsystems. Thanks to the auxiliary power converters or inverters, the current-voltage characteristics can be adjusted to match the requirements of subsystems installed into subway cars and railway vehicles. They also fulfil a significant role in safety by protecting the entire system, as they are resistant to over-voltages and short-circuits. The intelligence of the auxiliary inverters is implemented onto powerful embedded controllers, where high-speed digital signal processing tasks are common.

The hardware platform

Brio is an Ethernet-based decentralized-remote input/output module, designed to be embedded on-board in rolling stock vehicles. It is available as a product range offering different digital and analog inputs/outputs configurations, and several communication interfaces such as CAN, Ethernet, EIA-485, MVB, etc. In general, Brio finds its use cases in embedded railway systems like a programmable logic controller (PLC) or a remote input/output module (RIOM); where digital and analog I/Os are managed from one or several communication ports. Nevertheless, its internal hardware architecture is based on a powerful STM32 micro-controller and an FPGA device, which makes it suitable for various applications.

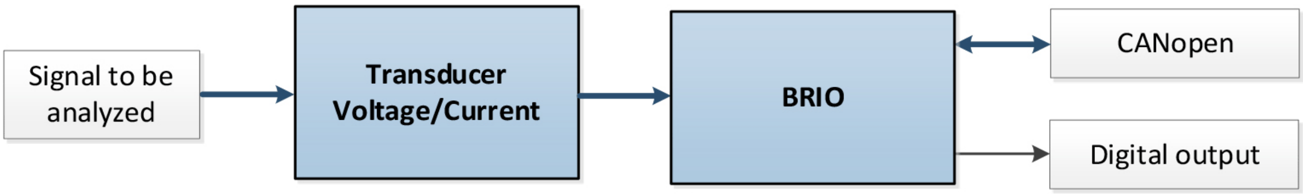

Figure 2: The final system solution could be presented as the following system-level block diagram (Source: Leroy)

In the context of the New York City Transit – R211 subway project, the platform acts as a remote input/output module based on CANopen. Fully compliant with the EN 50155 railway standard, it counts not less than 55 I/O signals on a thin size-6U board footprint. It is the ideal COTS solution to be integrated in train propulsion systems. In parallel, the company has been asked to think about an innovative solution for the Brio to be able to detect in real-time a ripple voltage on a high-voltage DC line around 900 V_{DC}. The technical specification was restrictive: the AC ripple signal can range from 0,35 V_{rms} to 70 V_{rms}, and can be on any two frequencies between 0 kHz and 1 kHz. In addition, the system had to be fully configurable and monitored from the CANopen interface (ripple frequencies to be detected, detection temporal window, V_{rms} threshold to declare the ripple present or not, measured energy for both frequencies), and had to activate specific digital outputs on frequency detection.

In digital signaling processing (DSP), the DFT (discrete fourier transform) is a tool to find a specific frequency in a signal. Simulations have shown that a DFT linked to Hann windows, gave good results with an acceptable accuracy on signals recorded on train. The DFT equation by itself is not so complex:

$$X(k) = \sum_{t=0}^{N-1} x(t)e^{-i\frac{2\pi k}{N}t}$$

It just says that "X(k)" is the level of the frequency "k" in the complete signal represented by a set of "N" samples "x(t)" of the analyzed signal. The Hann window consists in deforming the analyze signal before applying the DFT algorithm. Indeed, the DFT implies a temporal windowing of the signal over N samples, which affects the signal spectrum. Applying a pre-deformation such as Hann windows prior to the DFT improve the frequency response of the DFT. The Hann window is also not very complex in terms of digital signal processing function. For a set of N samples, it gives a coefficient to apply on the sample "t" by the following formula:

$$w(t) = 0.5 \times \left[1 - \cos\left(\frac{2\pi t}{N}\right)\right]$$

In order to illustrate the efficiency of the Hann window, let’s take a pure sinus signal.

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