Acquisition of distributed CAN traffic for centralized analysis of functional and electrical levels

Sebastian Mellström

Lund University

ael10sme@student.lu.se

Abstract

This article contains a very condensed summary of aspects to address when building a distributed measurement system. Topics as sampling frequency, filtration and converter range is covered. Hopefully this article can shed some light on measurement systems and raise the interest of technology in general.

I. Introduction

When specifying and building a distributed measurement system there are many, many, aspects to address. This article aims to summarise the variables that are of highest importance to the subject, without getting too far into the technical details of how this is done and how the physical models behind work.

With that being said, it's about time to get into details. A measurement system is a system that measures something, an *object*, and delivers quantified values from that said *object*. The problem is that as soon as something is measured, it will affect the system measured. Intentially or unintentionally. Therefore the method used when measuring must be with as little affection as possible, or atleast at an acceptible level. With that being said, how do we know that the measured values represent what we want them to represent? This in combination with a desired frequency of measurements and a resolution that provides enough information to be able to act upon are by far the biggest problems encountered when designing measurement systems.

II. Methods

Mainly there are two ways to approach this problem. The first is to use theory previously known or unknown, to reach a specification that is good enough. The second is to go directly to the source and start measuring with oscilloscopes and other tools to find out what the properties of the system to be measured are. In reality, the best approach is probably in-between. By measuring and using theory as support to decisions probably gives the best results for most people.

I. Qualified Analysis

By relying on theory one can specify a system that, according to specification, handles everything. Caveat *every* possiple input is handled appropiately. Without proper knowledge it can be very dangerous to draw conclusions. In the case of a electrical measurement system there will be noise on the bus, undesired EMI[1] and EMC-issues[2]. This can be hard to handle with only theory as a tool. However, the subjects to look into are with what frequency the system must be sampled, at what resolution and if there is a need of filtration before and/or after sampling.

[1] Electromagnetic Interference

[2] Electromagnetic Compability

II. Quantified Analysis

Here there are two paths to travel, either one can take an hands-on approach and do measurements, tests and experiments directly with the system, or one can study similiar appliances to find out how the persons involved specified that system. As noted before it is very wise to try to cover as many aspects as possible, as this will most surely result in a better result.

III. Theory

The most fundamental topic to adress is at what frequency shall we sample the system. According to the Nyquist-Shannon sampling theorem, to be able to detect a signal with frequency f, we need to sample with a frequency that is atleast twice, $f_s = 2 \cdot f$. If this requirement is not fulfilled, we won't be able to detect the signal in a satisfactory manner. But since most communication is done with rapid change between a high and low signal level, we need an even higher sampling frequency to be able to detect changes of signal level. Many protocols use the level transitions to provide synchronisation for the receiver, or even include the system clock for further synchronisation. Therefore we need to be able to detect edges. By knowing the rise- and falltime, and selecting the lower of the two, this is fulfilled. Using this time as a guideline for sampling frequency will undoubtly result in a much higher sampling frequency when only adressing the frequency of the main signal, but will enable conversion from electrical samples to logical data.

With this covered, it brings us to the next topic, filtration of incoming signals. As mentioned before the highest frequency we can detect depends on what sample rate we use. However, the signals with higher frequency don't dissapear, they're still there. In fact, the signals with a higher frequency will be aliased into our sampled signal in a manner that is not desireable.

$$|f - n \cdot f_s|, n \in N = f_{alias}(N) \tag{1}$$

To avoid this, filtering of the incoming signal is employed. Typically a low-pass filter is used in these situations, removing high-frequency components starting from a certain frequency.

The final thing to adress is resolution of the sampled data. By having the noise level at $\pm\frac{1}{2}LSB^3$ and let the absolut maximum amplitude be at the highest code of the signal, ultimate resolution is provided. However, it is wise to avoid saturating the converter. If the converter overflows information about the signal is lost since nothing can be told from that more than that the converter was saturated, and for how many samples it was so. Therefore it is recommended to not fully saturate the converter, but instead keep absolute signal level slightly lower than the highest available code from the converter.

IV. Result

By using and exploiting the theory and background described in this article, it was possible to build a distributed measurement system that samples an electrical bus used in vehicles in the common wealth, as well as in other appliances. In addition to the sampling, the node also performs an conversion to logical data and relays the information to a receiving server. This makes it possible to sample the bus and see how the signal propagates and what other signals that reside on the communication bus. The method used in the thesis was a combination of a qualified analysis and a quantified, just as described in this article. Slightly inclined to quantified though, as it gives results faster. More about the aforementioned subjects and much more is available in [1].

References

[1] S. Mellström, "Acquisition of distributed CAN traffic for central analysis of functional and electrical level", Dept. of Biom. Eng., Lund University, 2015

[3] Least Significant Bit