Technical Proposal

Charge measurements CAB300

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# History of Changes

The changes were inscribed from the first approved version (1.0.0). Before a change is inscribed, the version number of the document has to be inscribed.

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| Number | Page / Chapter | Description | Date | Name |
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# Introduction

This document describes the possibilities of BFH to measure the current sensors of LEM. The tests are performed in the Fuelcon Evaluator test bench.

## Terms, Definitions und Abbreviation

|  |  |
| --- | --- |
| Abbr. | Description |
| CAN | Controller area network |
| d | Day |
| DMM | Digital multimeter |
| HMI | Human-machine interface |
| NI | National instruments |
| NPLC | Number of power line cycles |
| PWM | Pulse width modulation |
| RMS | Root mean square |
|  |  |
|  |  |

## Related Documents

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| Ref. Nr. | Document | Description | Author |
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# Global project description

## Introduction

LEM is interested in performing high current, high accuracy tests for their current sensors. That can be done on the test bench located at ‘Bern University of Applied Sciences’ in Biel. This document describes the proposed way to perform these tests.

## System Overview

R

PCMCIA

Agilent 34972A multimeter

Ethernet

CAN output

PWM output

Ethernet

Evaluator B

Temperature chamber

NI Series 2

LeCroy oscilloscope

Analogue voltage output

Laptop

with MATLAB

HMI

DC

Analogue

current

output

## Supported sensors and suggested interfaces

### Analogue: Agilent multimeter

For analogue signals, an Agilent multimeter with Ethernet connection is being used.

### CAN: NI Series 2: CAN-PCMCIA-Adapter

The values of sensors with CAN output can be analysed within MATLAB by means of a CAN-PCMCIA-Adapter, for example a NI Series 2-Adapter.

### PWM: LeCroy 620Zi Oscillscope

To measure the duty cycle of the PWM signal, a digital oscilloscope is used, a Teledyne LeCroy 620Zi.

### LIN

As BFH does not have the necessary equipment to read from a LIN Bus, sensors with this interface are not supported at the moment.

## Precisions and resolutions

### Current to be measured

The resolution of the current of the Evaluator is 16 bit. The accuracy is 0.1% of the maximal value (600A), thus 600mA. As the transducers’ output values are compared to the values measured by the reference sensor, this low accuracy is not a problem.

The current will be proportional to the current signal specified in a .csv file. For post processing purpose, defined current pulses will be added before and after the measurement:

t

I

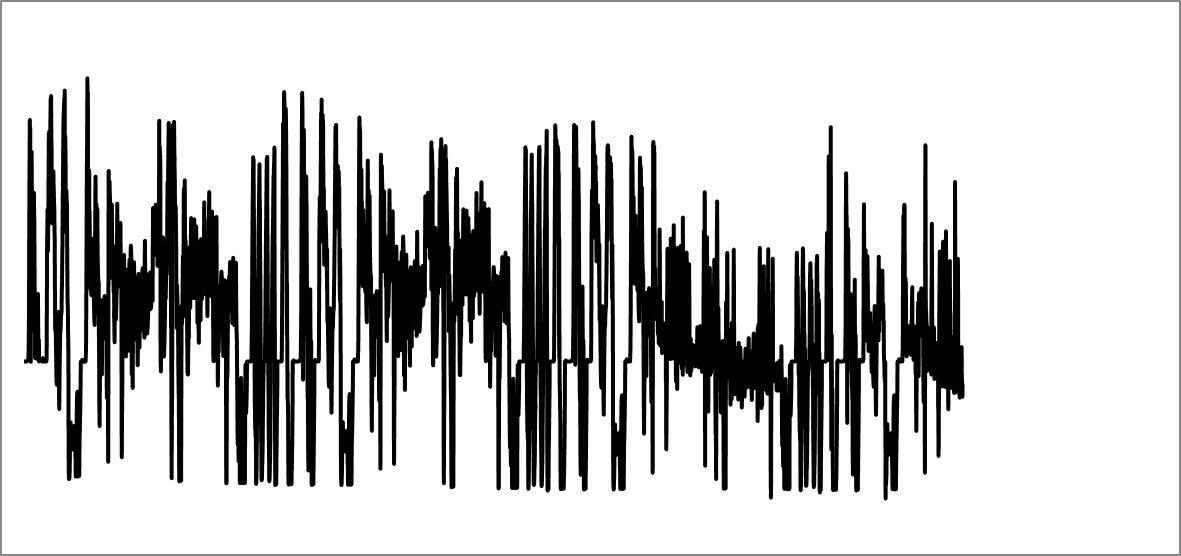


Figure 1: combined signal

With this method, MATLAB can recognise how long the entire measurement took. More details are to be found in section 3.11.

### Precision resistor

To use the reference current sensor ITL 900, the resistor on its output also has to be accurate enough. It is defined that the resistor should have a tolerance of 0.01%. Like this, measuring of 0.1% current sensors should be significant.

The sensor’s power dissipation has to be high enough.

The reference sensor will measure RMS currents up to 400A, its output current will be up to 267mA.

The maximal current supplied by the Evaluator-B will be 600A. The reference sensor’s datasheet tells that the resistor at the output has to be smaller than about 14Ω. A common value is 10Ω. With this value, the power becomes

The maximal voltage over the resistor will be

The precision resistor has yet to be chosen.

### Multimeter specifications

The analogue voltages are measured by the Agilent 34972A device. It has following characteristics:

* Maximally 6½ digits (22 bits) of resolution. [datasheet, page 9] This is valid at the slowest speed.

At maximal speed, the resolution drops to 4½ digits (15 bits).

* 0.004% basic 1-year dcV accuracy [datasheet, page 9]. Again, this is valid at 6½ digits (at the slowest scan speed). Agilent doesn’t give values for the faster scan speeds.
* Offset not mentioned, autozero-function available to cancel offset. This reduces the sampling rate by approximately two. [<http://www.home.agilent.com/agilent/editorial.jspx?cc=CH&lc=ger&ckey=698734-1-eng&nid=-33257.922596.00&id=698734-1-eng>]

### Requirements for sensors with voltage output

To define the requirements to measure sensors with voltage outputs, we take a look at LEM current sensors for Automotive. We choose a sensor with an output voltage range of 2V. The typical accuracy is 1%. Our measuring accuracy should be 10 times finer, so 0.1% of 2V: 2mV.

In the measuring range of 10V, this would require an maximal error of

This is larger than the 0.004% basic 1-year dcV accuracy of the Agilent DMM, so this device can be used.

### Requirements for reference sensor measuring

The requirements to measure the reference sensor are tighter. There are several error sources when measuring the current with the reference sensor and the multimeter:

Precision transducer

error < ~50ppm

real current

Precision resistor

error < 0.01%

DMM resolution error <

DMM accuracy error

< ?%

Sampling error (see section 3.5.2)

measured current

Figure 2: error sources when using the reference sensor

In the worst case, all these errors can sum up. To get a reliable measurement of sensors with 0.1% error, the total error has to be small enough. It is that defined that the sum of the errors should not be larger than 0.05%.

The individual errors can be influenced by changing the scan rate of the DMM. With increasing scan rate, the resolution error and accuracy error will increase, but the sampling error (see section 3.5.2) will decrease.



Table 1: different considered errors

Table 1 shows a possible configuration. The resolution was chosen to be 21 bits. Like this, the sampling rate is limited to 50Hz / 2 = 25Hz (see section 3.5.4). If a sampling rate of 20Hz is chosen, the sampling error will be maximally 0.017% (see section 3.5.2). The resolution error is not relevant compared to the accuracy error. The accuracy error was calculated according to section “Example 1: Basic dcV accuracy” on page 15 of the DMM datasheet. The voltage range is 10V and the maximally measured voltage is 4V.

This results in a total error of 0.041%. Like this, a 0.1% sensor can be measured.

## Data rates

### Current update rate

The current can only be updated as fast as the Evaluator supports it. A research showed that the update rate of the set current is 500ms, so the update frequency is 2Hz. The data from the supplied csv-files will be adapted to this frequency, that means, if the frequency is higher than 2Hz, an averaging is performed, and if it is lower, the same values are used several times.

### sampling error

It is calculated how large the theoretical error gets because of the not synchronized clocks of current update rate and sampling rate. The sampling rate should be high enough, otherwise the sensors will generate an unnecessary error.

A MATLAB script was written. It visualizes the error due to this effect:



Figure 3: sampling error(oversampling rate)

The x-axis is the ratio of the sampling frequency to the current update frequency of the Evaluator.

The y-axis represents the resulting error due to this effect.

The analysed data was from LEMs Excel-file ‘XLS\_batt\_curr\_vs\_time\_20110606\_1502\_X10\_us06.xlsx’.

The graph shows that if the sampling frequency is an integer multiple of the current update frequency, the error is 0%. This makes sense, in this ideal case, the current updating frequency and the sampling rate would be synchronized. If the two frequencies are independent, the oversampling rate has to be high enough to minimize the error. At an oversampling rate of 9.9, the error is smaller than 0.02%, so the minimum oversampling rate is defined as 10. As the current update rate is 2Hz, the sampling frequency is 20Hz.

### CAN acquisition rate

The CAB300 Sensor submits a CAN message every 10ms. So the oversampling rate is 50, which is higher than requested. Figure 1 shows that the sampling error gets smaller than 0.004%.

### Analogue acquisition rate

As mentioned in section 3.4.5, one can change the acquisition rate of the multimeter.

This is done by changing the NPLC (number of power line cycles) value. This value determines over how many periods of the power line (20ms) the voltage is integrated.



Table 2: resolution(NPLC)

Table 2 was taken from chapter ‘[SENSe:]CURRent:DC:NPLC’ the .chm-file of the Agilent device.

To get an oversampling rate of 10, the sampling rate has to be

This leads to a NPLC of maximally

NPLC is chosen to be 2. The resolution results as 21 bits and we get 6½ digits.

### PWM acquisition rate

For the calculation of the necessary time resolution of the oscilloscope, the LEM transducer HAB 100-S/SP1 with PWM output is used. This sensor has a PWM frequency of 125Hz and a Duty cycle resolution of 125ppm. If the sampling resolution shall be 10 times finer (12.5ppm), there has to be a sampling frequency of

And the sample point memory has to have a size of at least

The Teledyne LeCroy 620Zi has a sampling rate of 2 GHz and a standard memory of 32M. That complies with the requirements.

## Combinations of sensor measurings

In the above-mentioned calculations it was assumed that there are always two sensors measured at a time: the reference sensor and one sensor under test.

Theoretically, it would be possible to measure several sensors at a time in order to save time and energy. The disadvantage of this method is that the digital multimeter has to sample multiple channels, which may not be possible at full accuracy. The exact behaviour will yet have to be evaluated.

Possible are the parallel operation three different sensors:

* The reference sensor by means of the DMM
* A CAN sensor over the CAN Adapter
* A PWM sensor by means of the oscilloscope

Also, several sensors with PWM output could be measured at a time, as the LeCroy oscilloscope has several inputs.

## Measuring current range

The “Fuelcon Evaluator B” test bench is able to drive a current of maximally 600 Amperes.

Note: As the channels cannot be operated in short circuit mode (because there has to be a minimum voltage), a module of four parallel batteries will be used as dummy load.

## Power supply

The reference sensor will be supplied with two standard power supplies with 15V each.

The sensor to be measured will be connected with a standard power supply with the appropriate voltage, for the CAB300, this is 12V unipolar.

## Positioning of battery module

The positioning of the battery module can be inside or outside of the temperature chamber. The chosen way depends on LEMs needs concerning the temperature range. If negative temperatures have to be measured, the battery module needs to be placed outside the temperature chamber, as the batteries must not be charged at negative temperatures.

If only positive temperatures will be measured, a reduction in cabling effort could be made by placing the battery module inside the temperature chamber.

## Cable diameters

The cable diameter has to be smaller than

,

because this is the diameter of the CAB-300-C SP3 lead through.

It however has to high enough to reduce power losses, which could heat up the sensors and influence their behaviour.

The power loss per meter cable is

This results in following values:



Table 3: power losses(cable cross-section area)

The power loss at 200mm2 would be 14.2W/m or 1.42W/dm. Without the exact knowledge of all the thermal coefficients, it is assumed that the heating up will not exceed a few degrees. As the reference sensor has an excellent temperature coefficient of 0.3ppm/K, there will not be a noticeable effect.

Therefore, a cabling with about this diameter will be evaluated.

## Postprocessing

As the clocks of the DMM, the CAN sensor and the PWM sensors are different, the particular current vectors will have different lengths. To find out the time resolution of the vectors, two additional current pulses were added before and after the actual signal. (as mentioned in section 3.4.1).

With the help of these two markers the different sources become comparable.

## Temperature chamber specifications

The temperature chamber has a maximal temperature range from -40°C to 180°C. However, there are several limits to these values:

* As mentioned in section 3.9, negative temperatures are only possible if the battery module is placed outside the temperature chamber.
* At higher temperatures the cable isolations will be damaged. Normal PVC insulations have allowed temperatures up to about 70°C. Special cables (for example from Nexans) are available with temperatures up to 180°C.
* The heating up and cooling down speeds of the empty chamber are maximally 3.5 °C/min.

## Timeline proposal

There are several points yet to be researched and developed. A first timeline proposal:



So if the project is started in the middle of January, the deadline is at the end of February.

## Further steps

The first research has showed that the requested measurements are possible. Now, further definitions of the present and future needs have to be made, so that the right studies can be made and the right material can be organized.

Biel, Bern University of Applied Sciences

12. December 2013

Patrick Haldi