INCREASING ALL TECHNICAL PERFORMANCE OF EXPERIMENTAL EQUIPMENT FOR STUDYING METALIC AND SEMI-CONDUCTING MATERIAL SURFACE

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ABSTRACT
In this paper we used a simulated device, created with the "Measurement and Automation Explorer" in NI-DAQmx 8.1. This allows one to develop a program on one computer even if there is no data acquisition hardware installed and transfer it with few or no changes to where it's supposed to run. The proposal is about extending the card output resolution beyond 16 bits (effectively 15 bits; see the file), using a simple electronic circuit and two output channels.
Keywords: acquisition process, output voltaje, input parameters

1.INTRODUCTION

All late research have been made for turning this device more fashionable, for increasing technical performance of experimental study equipment for metallic and semi-conductors material surface. Moreover, the main target were those materials subject to superficial nitriding treatment.
In that concern, we have designed and fulfilled the programme step by step, for ascertaining current working parameters of the equipment and identifying any possibility of increasing its performance.

2. THE OUTPUT VOLTAGE

NI PCI–6221 has two analog output channels, each with 16 bit resolution and output range –10V to 10V. Since the required output range is –10V to 0V, only half of the card's range will be used. Using the card's native representation for signed numbers (two's complement signed integer), the output voltage for a channel looks like this:

$$V_A = V_{LSB} N_A = 2^{-15} V_{max} N_A = 2^{-15} V_{max} \left(-2^{15} a_{15} + \sum_{i=0}^{14} 2^i a_i \right)$$ (1)

where:
- $a_0 \div a_{15}$ are bits (i.e. 0 or 1), a_0 being the least significant one
- V_{max} is the maximum output voltage (10V)
- N_A is a signed integer number, between -2^{15} and $2^{15} - 1$ (–32768 and 32767)
- $V_{LSB} = 2^{-15} V_{max}$ is the smallest possible variation of the command voltage (~ 0,3mV; LSB stands for "least significant bit")

It's obvious from (1.1) that the sign of V_A is determined by the most significant bit: $V_A < 0$ if and only if $a_{15} = 1$. Which means that a_{15} will be constant and we only have 15 bits, not 16?
Labview uses 64-bit floating point numbers (IEEE 754) for its analog output channels, which are internally scaled and rounded to signed integers which are sent to the card. This could be confusing: I ask for and expect a –3V voltage, but get a slightly different one because –3V is not a multiple of V_{LSB} (this is also known as quantization error). The real output voltage is usually different from the desired one:

$$V_A = V_{LSB} \cdot \text{int}(V_{Acmd} / V_{LSB})$$ (2)

where int() is the "nearest integer" function. This is a problem if we want to scan a very narrow range, like 1520V to 1525V, because only about 55 points are within this range. The resulting graph would certainly look like a "stair".

There is a simple way to avoid this, using both analog output channels and an electronic circuit. In the following formulas V_{Ccmd} is the desired voltage, V_C is the resulting output voltage, V_A and V_B are output voltages for the A and B channels.

$$V_A = V_{LSB} \cdot \text{int}(V_{Ccmd} / V_{LSB}) \tag{3}$$

$$V_B = V_{LSB} \cdot \text{int}(m \cdot (V_{Ccmd} - V_A)/V_{LSB}) \tag{4}$$

$$V_C = V_A + V_B / m \tag{5}$$

The first two relations are implemented in software; the third one needs an electronic circuit like this:
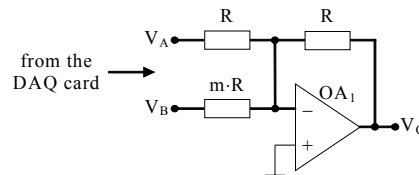

Figure.1 Electronic circuit

Since 6221's output current drive is 5mA, R must be at least 2kΩ. The value "m" is any integer between 2 and 32768, larger is better. Although most operational amplifiers should work, it is preferable to use one with a negligible input current (e.g. CA3140). The OA's differential power supply should cover the output voltage range, e.g. ±12V.

The whole thing, from V_{Ccmd} to V_C is equivalent to a single digital-to-analog converter with enhanced resolution. Its V_{LSB} is "m" times less than the original. Since the above circuit is an inverter, V_A and V_B need to be positive (0 to 10V).

When we designed the program, we considered several connections: the input is between AI0 and AIGND (single-ended), the V_A output is AO0-AOGND and V_B (if exists) is AO1-AOGND. But these can be changed in software in no time; it doesn't matter if there are already existent wires to other terminals. Also, there is no if the above circuit doesn't exist: the software was designed so that it's very easy to reconfigure.

3. THE ACQUISITION PROCESS

The acquisition of a single value starts by applying its corresponding command voltage. This transition is also generating a short-lived fault, known as a "glitch", which could be either a pulse (positive or negative) or a damped oscillation. According to 622x specification the maximum glitch is 100mV for 2,6μs, but we can assume it's larger and especially longer than that due to the fact that we don't apply the card's output voltage directly and/or we use two D-A converters. Fortunately, the output's variation is quite slow (≈100V/min) so it's possible to introduce a delay between output command and input acquisition. This could be done by simply ignoring several of the first samples, and calculate an average from the rest (see figure below).
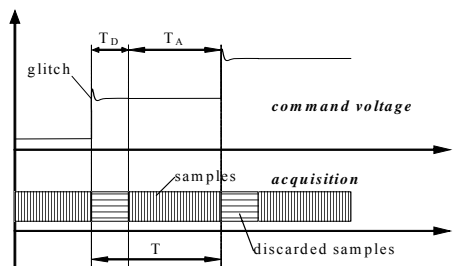

Figure 2. The acquisition of a single value

In the program, T_D is never below 1ms and – if possible – T_A is rounded down to a multiple of 20ms, which nullifies any perturbation with a 50Hz (or multiple) frequency. The sampling frequency is a multiple of 1 kHz, between 1 and 200 kHz. There is an option to let the program choose the sampling frequency, if this option is active f_s is chosen so that the number of samples (in both T_D and T_A) is the largest below 4096.

4. THE APPLICATION

NI's "Measurement and Automation Explorer" is able to create a bogus device, that is, simulate the presence of a specific acquisition card. We used this to design the program without having a real 6221 card. The virtual driver is somehow limited: analog inputs are always not connected (they get some noise, just like a real card does) and hardware timing is incorrect. But it's very useful anyway.
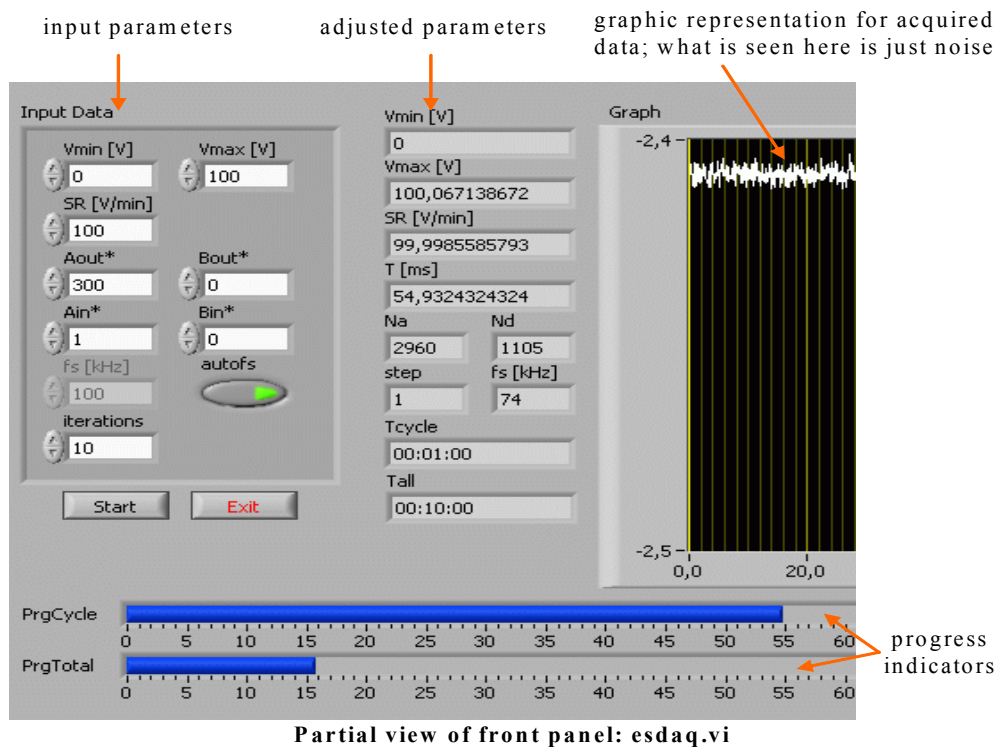
4.1 Input parameters

Figure 3. Front panel

On the `esdaq.vi`'s front panel there is a sunken box containing these input parameters:
- V_{min} and V_{max} are the output voltage limits
- SR (from "slew rate") is the output voltage variation speed, in volts per minute
- A_{out}, B_{out}, A_{in}, B_{in} are coefficients for linear transformations applied to output and input voltages. These can be used for calibration.
- f_s is the sampling frequency, an integer between 1 and 200, in kHz. The autofs push button disables the f_s control and selects the sampling frequency automatically.
- iterations is obvious. Zero means infinity here; if iterations = 0 then the program must be manually stopped.

To the right of that sunken box are some numeric indicators containing input parameters adjusted for quantization errors, and some other values as well. T is the time required for a single value (in milliseconds). N_a and N_d are the number of samples that are averaged and discarded for a single value. Step is a multiplier for the output LSB: if SR is very large and it's not possible to achieve it scanning every possible value for Vout, then some values for Vout will be skipped. Tcycle and Tall are the estimated durations for a single iteration and the entire process.

4.2 Files and folders

It doesn't matter where the program (.vi) files are located, they could be anywhere but in the same folder. Data files are saved in a directory defined by Labview, called "default data directory" and – if the default wasn't changed – located in a "LabVIEW Data" directory under the "My Documents" shell folder. For English, default installations of Windows, this is:

C:\Documents and Settings*username*\My Documents\LabVIEW Data

For clarity, we will address that folder as `%DefData%`. When the Start button is pressed an `esdaq.ini` file is created there. It's a plain text file containing the input parameters, which are restored on subsequent runs. When an iteration is completed (Vmin to Vmax), a data file is saved under the `%DefData%\esdaq` folder. The file name is automatically created from the date/time when the start button was pushed: a file name like `20060830-125730.es` means that the acquisition was started on August 30, 2006 12:57:30. This file is also plain text, and it's overwritten every time an iteration is completed, with updated data.

There are two main program files: `esdaq.vi` does the acquisition, and `esview.vi` is for viewing and analysis of already acquired data. `Esdaq.vi` depends on the presence of a real (or simulated) 6221 card, `esview.vi` does not and it's possible to use it on any computer with Labview. Another important file is `const.vi`, which contains hard-coded constants, mostly determined by external circuits and software. Examples are the "m" factor (defined on paragraph 1), whether to use or not the circuit described on paragraph 1, and whether to use periods or commas as decimal separators in saved files (important if you wish to import data into another program).

5. CONCLUSIONS

The acquisition of a single value starts by applying its corresponding command voltage. This transition is also generating a short-lived fault, known as a "glitch", which could be either a pulse (positive or negative) or a damped oscillation. NI's "Measurement and Automation Explorer" is able to create a bogus device, that is, simulate the presence of a specific acquisition card. We used this to design the program without having a real card.

6. REFERENCES

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