

Section 5. Working papers

AN OPEN HARDWARE ELECTRONIC CONTROLLER FOR MOTORIZED ROTARY INJECTION VALVES USED IN FLOW INJECTION ANALYSIS

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Abstract: This work presents the design, development and the implementation of a motorized injection valve used in Flow Injection Analysis systems. The built prototype has been developed based on the open hardware, software and firmware, emergent philosophy thus helping the development of a free and independent science. This policy creates a platform of open projects that feed each other, contributing to scientific and technological development while sharing knowledge. The proposed design project can be modified to implant it in other devices or projects according to the needs of each one. Also, the open project can be a great help as teaching material in Universities, since open hardware projects are fully described and documented.

Keywords: Open source hardware, open code software, flow injection analysis, chemical lab instrumentation.

1. INTRODUCTION:

The Flow Injection Analysis (FIA) methods are rapid and versatile analytical methods that consume small amounts of sample and reagents and can perform routine procedures in short times. Therefore, they are commonly used in Clinical, Quality Control and Production Control laboratories, where the speed with which results are obtained plays a critical role. Nowadays FIA is one of the most used methods in analytical labs, because they can do automatic

chemical analysis with relatively cheap instrumentation when compares with similar analytical performance chromatographic methods. Even there are several official methods of analysis that using FIA, specially in clinical analysis, food and water quality and environment control. Unfortunately, the modules of FIA devices are not completely inexpensive, they are specific for a company and not completely compatible (i.e., a complete set of modules should be acquired in total to ensure compatibility) and also their designs are a “black box” being hard to know how they works. The injection valve is a main part of FIA systems, whose function is loading precise volumes of sample into flow channel. This type of valves is also used in autosamplers, solvent selectors/mixers and so. Usually, these valves are automated with a stepper motor which provides speed and precision. In this context many academic and research institutions have decided in the last times to develop open-form hardware, software and firmware, thus helping the development of a free and independent science. Supporting this fact, they are large free projects like GNU, Linux, GitHub, Wikipedia, Arduino, Raspberry Pi or RepRap. This policy creates a platform of open projects that feed each other, contributing to scientific and technological development while sharing knowledge.

This work presents the design of a motorized injection valve, an open and low-cost device that anyone can be built without disbursing much money. The valve

implements a simpler and cheaper DC motor, reused from computers or consumer electronics parts. This is not the common solution in a motorized rotary valve, so they are not DC-motor controllers suitable for this use. So, to control the valve a DC motor-driver should be developed. The driver design includes a Flip-Flop memory to save the bit status, an H-bridge to control the motor-spin direction and a monostable to set the actuation-time of rotation. The valve can be manually actuated by pressing a button, but also in a remote mode with an external TTL signal.

The original project can be modified to implant it in other devices. Also, the open project can be a great help as teaching material in Universities. All the necessary documentation, including electrical and connection diagrams, source code of software and firmware routines is placed in an accessible web (www.uhu.es/OSHW). This information can be used and/or adapted under Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (cc by-nc-sa 3.0) and GNU-GPLv3 licenses.

2. MATERIALS AND METHODS:

The minimal basic FIA system consists of a pump, an injection valve and some kind of detector. These three modules are in all FIA systems, but something so basic is not common. Usually, there are a sample preparation module between the injector and the detector as a reactor or a chromatographic column. Secondly, there could be several valves, pumps or even detectors. In automatic system there is too autosamplers, this is frequent in Clinical analysis laboratories, where it's continuously analyzed a lot of samples. As can be seen, the possibilities and versatility of FIA are countless, because can be added and removed modules according to the interests.

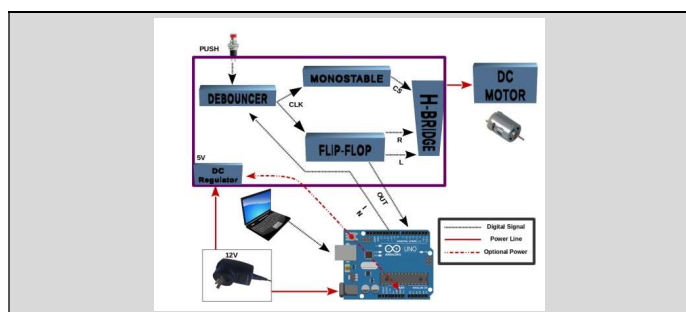


Figure 1. DC-motor driver block and external connections that should be made.

All the material used in the prototype development was chosen for their price and availability. Some of them were recovered and reused; e.g. the DC-motor, the state LEDs, the pulley and the belt belonged to an old DVD Player. The components and integrated circuits (ICs) used are the 60V single full bridge drive NJM2675D H-Bridge IC, the 2-input NAND logical gates with Schmitt-trigger inputs 74HC132N, the 74LS112N Flip-Flop a dual negative-edge-triggered master-slave J-K Flip-Flop with preset (PR), clear (CLR), and complementary outputs and the LM7805 DC regulator. These ICs were chosen for their low consumption, low cost, high availability and detailed documentation. Factors those are important in any open hardware project.

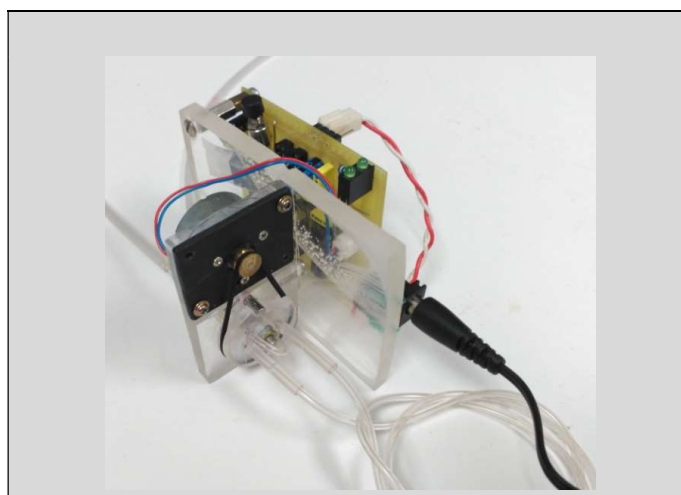


Figure 2. Final assembly of motorized rotary injection valve and the designed DC-motor driver. The showed assembly is for manual operation.

All plastic parts have been machined from a polymethyl methacrylate (PMMA) plate by using a rotary tool and a limited set of hand tools, but files for 3D printing with polylactic acid (PLA) or acrylonitrile butadiene styrene (ABS) are also available.

3. RESULTS AND DISCUSSION:

The electronic architecture is summarized in Fig. 1. It has been developed for working as a standalone system, although it also includes the possibility of remote actuation, enabling the synchronization with the rest of FIA modules for an automatic working procedure. An open source printed circuit board (PCB), including copper layer, silkscreen and components legend, was designed with a software suite for EDA

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(Electronic Design Automation). The PCB is pin to pin and size compatible with one of the most known and accessible microcontrollers, the Arduino UNO.

The rotary valve consists on a mobile part, having a set of holes connected to tubing, that moves by rotating a precise number of degrees, so that such holes are perfectly aligned with a complementary set of holes on a fixed part. Then, the valve has two positions (two states) reached when both set of holes are aligned. In a manual valve, the state is changed when a handle is pushed from one stop to the other; in a motorized valve that motion is provided with a motor, but the alignment is achieved too with a mechanical stop for each position (Fig. 2).

4. CONCLUSIONS:

Flow Injection Analysis is a versatile analytical method used in Clinical, Quality Control and Production Control laboratories. A main component of Flow Injection Analysis is the injection valve; its function is to insert a precise and reproducible amount of sample in the carrier stream. The quality of analytical signal recorded by the detector is influenced by the optimal operation of the injection valve, so attention should be place for better performance.

Our design considerably reduces the necessary investment in instrumentation to implement automatic chemical analytical systems, which contributes to making this technology more accessible while the quality and automation of systems is kept.

The built prototype has been developed based on the open hardware, software and firmware philosophy, thus helping the development of a free and independent science. This policy creates a platform of open projects that feed each other, contributing to scientific and technological development while sharing knowledge. All the technical information needed to reproduce the motorized rotary valve is web available and the design can be modified under a Creative Commons License to adapt it according to the experimental needs of each case.

5. REFERENCES:

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