Welding Turns Digital: Electronics and FPGA-based Design to Actuate a Linear Welding Work Cell

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Abstract—**We present the electronics and register-transfer level (RTL) design that allows the conversion of an analog linear welding robot into a digital programmable equipment. The Bug-O Modular Drive System (MDS) is an industry standard, widely used 2 degrees of freedom Welding Robot. The robot is usually applied on Metal Inert Gas (MIG) and Metal Active Gas (MAG) welding processes. Therefore, it has to be integrated with a welding power source and a wire feeder. In conjunction, the three welding equipment are able to perform a linear welding. For this application case, a Lincoln® Flextec power source and a Lincoln® LF-33 wire feeder have been used. The results show the applicability of the proposed solution to convert the analog control in a digital control, making it a reliable platform for further automation.**

Keywords*—*embedded, electronics, robotics, automation, sensors.

I. INTRODUCTION

Welding is a recurrent activity in the manufacturing industries. Therefore, augmenting the level of robotization and automation arises is a desirable way to enhance the productivity, reproducibility, standardization, and reduce operational costs. On the human side, considering the operator does not have to adjust the parameters during the process, the digital interface favors safer and healthier working conditions. Fumes, ultraviolet radiation, and heat have, over the years, been associated with many lung diseases such as pneumonia, occupational asthma, metal fume fever, and even cancer [1], as well as skin and ocular malignancy [2].

One specific application of welding, which is highly demanded in the naval and offshore sectors, is the welding of large and thick steel plates. Among other use cases, these steel plates are used to build ships, oil extraction platforms, and gas piping systems. In the Brazilian naval industries, the welding process is often mechanized (or semi-automatic), which means a 3 Degrees of Freedom (DoF) robot is used to perform the welding although all parameters are controlled manually during the process execution.

In this work, we focus on the Bug-O Modular Drive System (MDS), a linear welding robot that runs on rails fixed in a position that is parallel to the welding groove. The Bug-O MDS is able to perform movement through actuators in two axes: parallel to the groove, and orthogonal to the groove. The distance between the iron plates and the welding torch is adjusted manually before the arc is opened. Once adjusted, the height does not change during the process.

The Bug-O MDS is used in combination with a welding power source and a wire-feeder. A Lincoln Flextec 450 ® power source is responsible for providing the voltage and current to keep the welding electric arc open. A Lincoln LF-33® provides the consumables at the proper speed. A detailed description of this architecture has been previously presented in [3] and [4]. Additionally, an E30 incremental encoder, by SE Instruments, is used to obtain the current speed of the wire feed. An LEM DVL250 voltage transducer and an LEM HTR500-SB current transducer are used to obtain the voltage and current behavior during the welding operation.

In this paper, we show the electronics and implementation details which enable us to replace the analog interface of the aforementioned equipment with a digital one. The digital interface is added to the existing architecture with minimal changes to the original hardware. As the original connectors, voltage levels, and overall structure are not modified, the proposal can be easily adapted to convert robots that are already operating on the shop floors. Therefore, with minimal investments, we are able to provide an improved interface, which is more controllable, less dependent on human interaction, and can store the variables that describe the equipment behavior for further processing.

II. SYSTEM DESCRIPTION

A. Sensors

Sensors are devices that obtain information about a physical variable, being able to discern changes in an environment. They can perform the conversion of mechanical changes, magnetic and thermal conditions, among others, in voltages and electric currents. Usually, the sensors are specified as the greatness that they can measure and play an important role within systems of control and supervision [5].

The robot Bug-O MDS has a set of sensors to acquire information on speed and position. In the tractor module, which performs a longitudinal movement along the welding groove, the information about speed and displacement is acquired through an incremental magnetic encoder directly attached to the motor shaft. As the robot moves, the encoder sends voltage pulses to the microcontroller through two channels. Depending on which of the channels has its value changed first, the micro-controller determines the rotation direction of the motor. For the calculation of the speed, we count the time between pulses of each channel, taking in account the mechanical reduction made by gears between the motor shaft and the rack is responsible for moving the robot.

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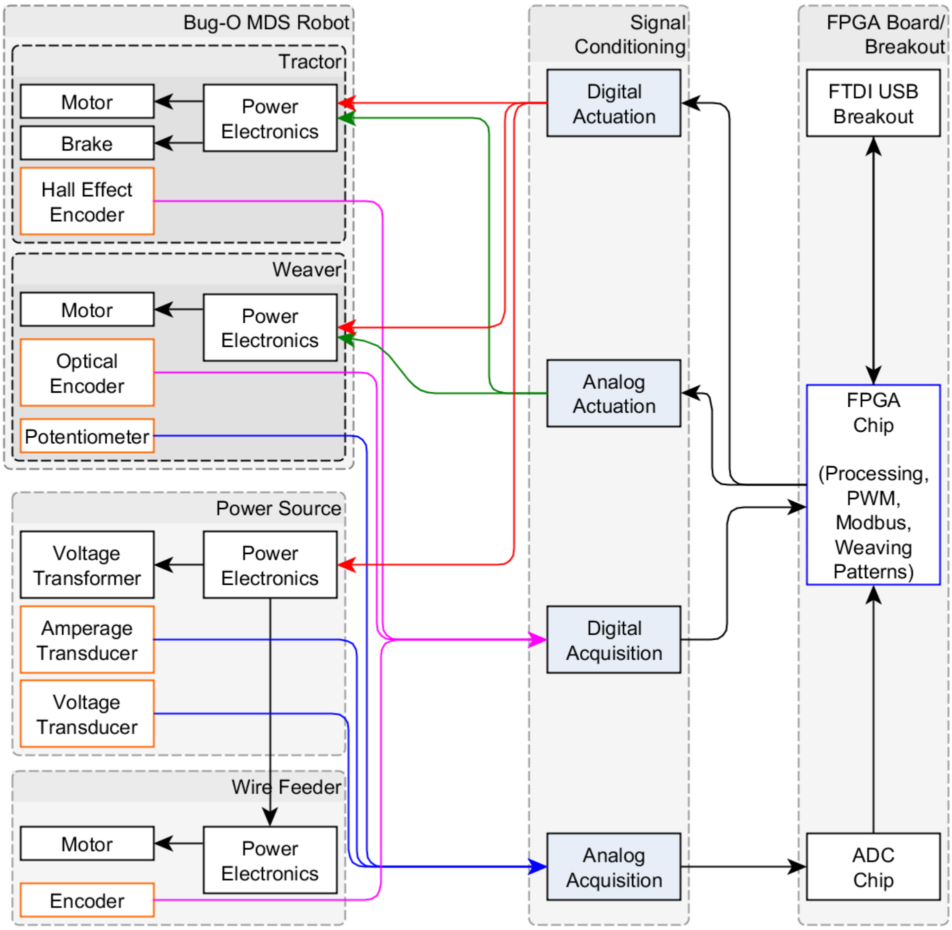

Fig. 1: Design Overview

Already in the case of the weaver module, which performs the weaving (an orthogonal movement along the welding groove) has an optical encoder, connected to the motor shaft through a set of gears that should be taken into consideration to calculate the speed. This module also feats a multi-turn potentiometer that provides the exact absolute position of the arm of weaving. Although, the potentiometer does not provide the high precision and resolution as the encoder.

B. Hall Sensors

Over the course of a research about the characteristics of the force that acts on a conductor carrying a current in a magnetic field, Edwin Herbert Hall, in 1879, verified that when a conductor is immersed in a magnetic field, there is the appearance of an electric field across this conductor [6]. This way, Hall showed that in a conductor subjected to a magnetic field, followed by an electric current, there is a difference of potential between the ends of the conductor, which is proportional to the electric field and the current. Thus, after the observation, Hall indicated the presence of a state of stress in a given region which is known as voltage Hall [7].

Hall sensors are composed of semiconductor devices that suffer the influence of a magnetic field and determine its magnitude [8]. Hall sensors can also be used to detect the proximity and intensity of a magnetic field. In industrial applications, which involve the determination of speed and rotation direction of the motor shaft, these sensors can be used to detect fluctuations in the magnetic field. So, when the sensor is touched, either by a magnet attached to its rotor or even the teeth of a gear, it generates an impulse that can be used to monitor the operation of the motor [5].

C. Encoders

The term encoder is used to describe any instrument able to convert the position of a rotation in a digital output through the opening and closing mechanical contacts, so it is considered an electromechanical device [9].

Encoders, also known as impulse generators, are instruments that transform a linear or angular displacement (rotation) in a train of square wave pulses, i.e., they measure or produce electrical pulses based on the movement of an axis. The encoders can be divided into two main types: i) the incremental, and ii) absolute. The basic difference between the two types is that the absolute encoders are able to determine the initial position without requiring a reference point, while the incremental encoders, on the other hand, need a point of orientation [8]. The incremental encoders are used to indicate the direction of rotation, angle, speed and the number of rotations [10]. They do not store their position since they can only indicate the displacement in relation to an initial point of reference. In other words, this implies that when the machine is switched on, it may be necessary to set a point of reference [8].

D. Potentiometer

A potentiometer is an electronic component that allows the variation of the electrical resistance between its terminals, through the mechanical displacement (linear or angular) of a cursor on a resistor. The potentiometers usually present three terminals. They can be applied for measurement of a position or displacement by varying the resistance. Linear potentiometers produce a resistance proportional to the displacement or position. The element of resistance can be powered by a DC or AC voltage, and the output voltage is ideally a linear function of the displacement [11].

E. Operational Amplifier

An Integrated Circuit (IC) is a complex component that contains numerous resistors, transistors, and diodes in its casing. During the manufacturing process, the components of the IC are interconnected. One of the first ICs to be manufactured was the operational amplifier [12].

An operational amplifier, or op-amp, is a device that can perform mathematical operations such as addition, subtraction, multiplication, division, differentiation, integration and a logarithm, as well as comparison, and amplification. An op-amp can provide high gain, with high input impedance and low output impedance. The basic circuit is built using a difference amplifier with two inputs (positive and negative) and at least one output. The Fig. 2 shows a basic op-amp. Some operational amplifiers will only work properly when fed by a symmetric voltage, i.e., with tensions both positive and negative in relation to circuit ground (GND). [13].

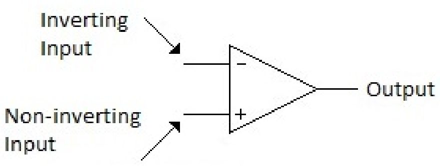

Fig. 2: Basic Operational Amplifier

To develop the interface of conditioning of signals from the robot we had to use a combination of op-amps which are listed in the following sections:

1) Constant-Gain Multiplier: This circuit provides an output with an accurate amplification. The most common configuration is the inverter multiplier shown in the Fig. 3, whose output is given by Eq. 1:

$$V_o = -\frac{Rf}{R1} \times V_i \tag{1}$$

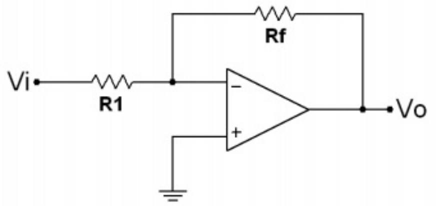

Fig. 3: Inverter Multiplier Scheme

Where:

- V_o is the output voltage;
- V_i is the input signal;
- the resistors Rf and R1 determine the constant gain applied to the input voltage.

Another possible configuration of this circuit is the noninverting multiplier, shown in Fig. 4, whose output is given by:

$$V_o = (1 + \frac{Rf}{R1}) \times V_i \tag{2}$$

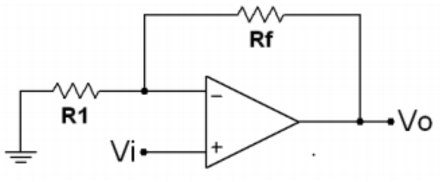

Fig. 4: Noninverting Multiplier Scheme

2) Summing Amplifier: Also known as Voltage Adder, this configuration is capable of adding the voltages of various signals, providing a distinct gain determined by the relation Rf/Rn for each one of them. The output is the sum of individual signals times the gain. Fig. 5 shows that circuit, whose output is given by:

$$V_o = -(\frac{Rf}{R1} \times V_1 + \frac{Rf}{R2} \times V_2 + \frac{Rf}{R3} \times V_3 + ... + \frac{Rf}{Rn} \times V_n) \tag{3}$$

3) Voltage Follower or Buffer: The Voltage Buffer works as an insulator, providing an output with unitary gain. A voltage Buffer gives a very high input impedance and a very low output impedance. The standard circuit is shown in Fig. 6.

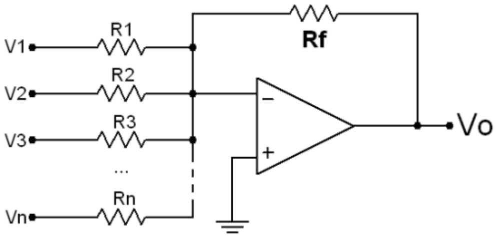

Fig. 5: Adder Amplifier Scheme

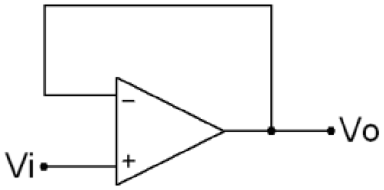

Fig. 6: Voltage Buffer Scheme

F. Zener Diode

A diode is among the most simple semiconductor electronic devices. It has only two terminals: the anode, and the cathode. The diode allows the passage of a current only in the anode-cathode direction (direct polarization) and prevents the passage of the current in the opposite direction (inverse polarization). However, there is a limit of voltage when the diode is inversely polarized (rupture tension). When the voltage limit is exceeded the diode is damaged and will then allow or stop the current flow in both directions.

A zener diode is a special case of diodes, created to work in the inverse polarization mode. When the difference of potential in the zener inverse polarized diode reaches the rupture tension, instead of damaging itself as the common diode does, the zener diode keeps conducting a current limiting the voltage according to their characteristics. The Fig. 7 shows the symbols of the diode and zener diode.

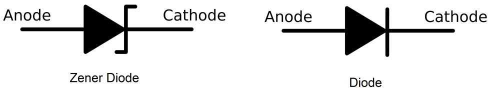

Fig. 7: Symbols of the Zener Diode and Diode

G. Voltage Divider

Another circuit used to transform the voltage of a signal is the voltage divider with resistors [14] shown in Fig. 8. This is a simple and efficient way to reduce tensions in cases where the difference between the input voltage and the output voltage is not too large. The value of the output voltage is given by:

$$V_o = (\frac{R2}{R1 + R2}) \times V_i \qquad (4)$$

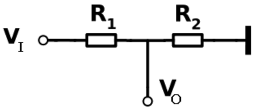

Fig. 8: Voltage Divider

III. SIGNAL CONDITIONING INTERFACES

The signal conditioning circuit is used to transform the signals obtained from the robot's sensors in accordance with the voltage levels of the microcontroller, as well as, transforming the signals generated in the microcontroller adapting them to the voltage levels of the robot. One of the main electronic components of this circuit is the op-amp, used to amplify the signals and isolate the circuit, protecting the microcontroller. Another important component used in the circuit is the zener diode, limiting the voltage of the signals, and ensuring that signals with a voltage level above the accepted values do not reach the microcontroller, therefore making sure it does not get damaged.

This system was divided into modules to facilitate the organization and maintenance. The modularity allows the replacement and modification of small parts of the circuit, enabling quick upgrades and corrections. The final signal conditioning circuitry features a total of six modules. The first four, shown in the upper part of the Fig. 9 are applied to read the sensors and actuate on the Bug-O MDS robot. The remaining two modules are responsible for controlling and reading the parameters of Lincoln Flextec 450 welding machine: one for the acquisition of the values of wire speed, current, and voltage, the other to control the current and wire speed.

A. Acquisition Module for Digital Signals

This module has seven signal entries for the sensors on the robotś tractor and weaver modules. For the tractor module, there are four signals: two for the hall sensor, one for direction indicator, and one for showing if the tractor is stopped or moving. For the weaver module, there are three signs: two for the optical encoder and one for showing if the weaver is stopped or moving. All ports in this module consist of a voltage limiter with a zener diode, in which digital signals that vary from 0 to $15V$ are lowered to voltage levels from 0 to $3.3V$ to be suitable for the microcontroller, as can be seen in Fig. 10.

1) Tractor Speed: The goal of this circuit is to transform the analog signal coming from the robot, which ranges from 0 to $9V$ into a signal accepted by the microcontroller, which varies from 0 to $3.3V$. The circuit uses a buffer op-amp to isolate the signals coming from the robot and the microcontroller. Once the signal is isolated, a voltage divider (resistors R1

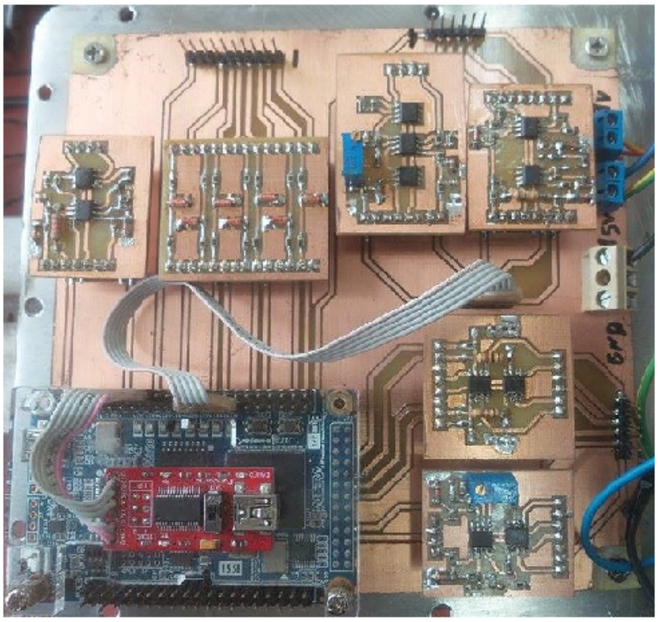

Fig. 9: Conditioning Board Prototype

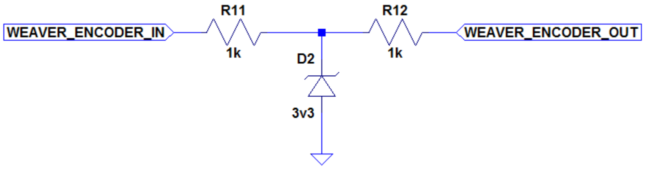

Fig. 10: Circuit of the Acquisition of Digital Signals

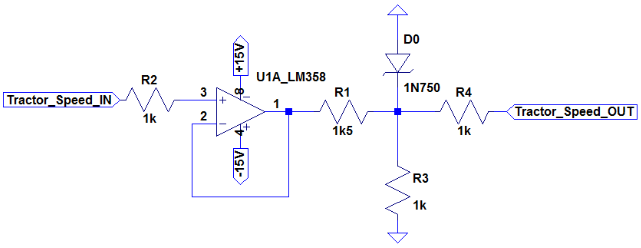

Fig. 11: Circuit of the Tractor Speed

and R3) adapts the signal to a voltage level compatible with the microcontroller. The zener diode ensures that the microcontroller is never submitted to a voltage greater than $3.3V$. The scheme is shown in Fig. 11.

2) Weaver Speed: This circuit is built to transform the analog signal coming from the robot, which ranges from -9 to $9V$ to a signal accepted by the microcontroller that ranges from 0 to $3.3V$. The circuit has three operational amplifiers: i) the configuration of buffering to isolate the signal coming from the robot and the microcontroller, ii) an adder amplifier with the goal of reducing the amplitude of the signal and adjust the offset, and iii) a multiplier inverter stage with a unity gain to reverse the signal. Finally, a zener diode is included to ensure that the voltage does not exceed the microcontroller accepted levels, as shown in Fig. 12.

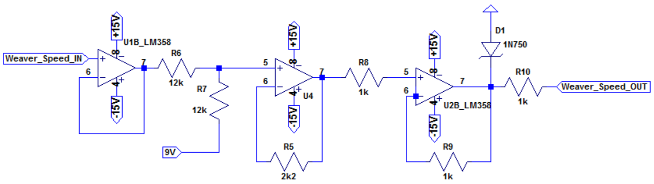

Fig. 12: Circuit of the Weaver Speed

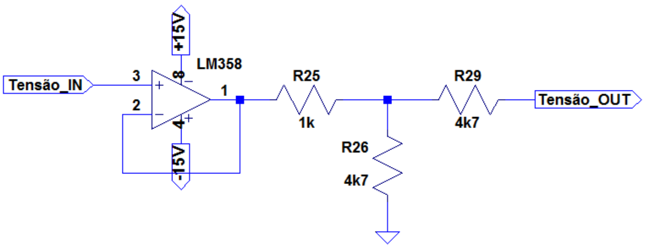

Fig. 13: Circuit of Module of Acquisition of Current and Voltage Values

B. Acquisition Module of Analog Signals

This module has two inputs of signals, one for the reading of the speed applied to the tractor motor and another for speed applied to the motor of the weaver.

1) Acquisition Module for Current and Voltage Values: It has two parts, one for the acquisition of the signals of a voltage transducer and another for the signs of a current transducer. The output signal of the transducers of voltage and current vary from 0 up to $4V$. To adapt this signal to the microcontroller the input signal from the transducer is connected to an op-amp in the voltage buffering configuration of tension by acting as an insulator to protect the microcontroller. There is also a voltage divider to reduce the signal amplitude of 0 to $4V$ to 0 to $3.3V$, ideal for the microcontroller, it is seen in Fig. 13.

C. Actuation Module for Digital Signals

Bug-O MDS robot uses digital signals to control the actuation and the motor direction of rotation in the tractor module and the actuation of the engine of weaver module. The voltage level of these signs varies from $0V$ (low level) to $15V$ (high level). By default of the robot, the motors actuate when the control signals are at a low level. Therefore, the circuits of this module have, at the positive entrance of the first op-amp, a "pull up" of $9V$, to ensure that the output starts at a high level. So, the signal conditioning keeps the robot stopped until the microcontroller starts. Together, there is a zener diode to ensure the voltage does not exceed $3.3V$ on the output of

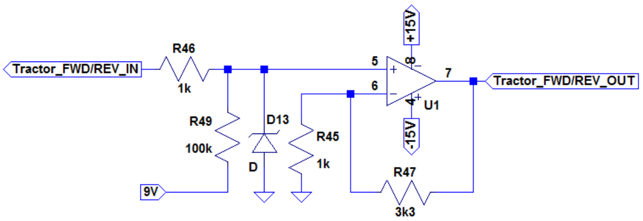

Fig. 14: Circuit of Control Digital Signals

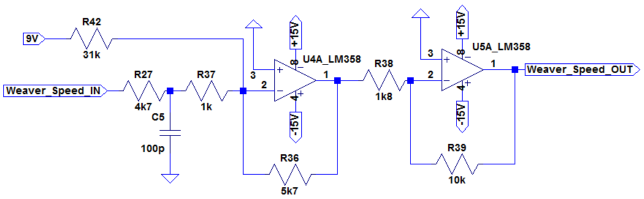

Fig. 15: Circuit of Control Module Weaver Speed

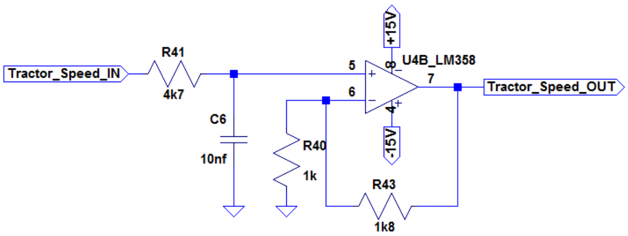

Fig. 16: Circuit of Control Module Tractor Speed

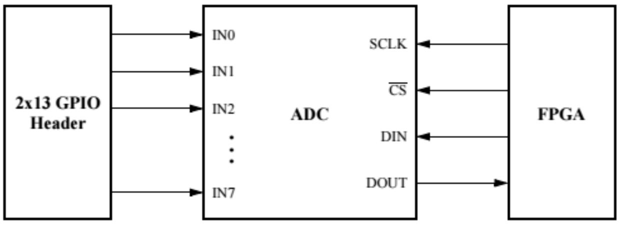

Fig. 17: ADC Chip Pin-Out

the microcontroller. Finally, a noninverting multiplier op-amp amplifies the signal to the levels accepted by the robot as shown in Fig. 14.

D. Actuation Module for Analog Signals

The analog actuation module is composed of two parts, one for the speed control of the weaver module and other for the speed control of the tractor module.

1) Weaver Speed Actuation Module: The objective of this part is to amplify the output signal from the microcontroller that ranges from 0 to $3.3V$ to -9 up to $9V$. According to the specification of the robot, this signal also determines the direction of rotation of the motor. A negative voltage makes the motor axis turn clockwise, while a positive voltage makes it turn in a counter-clockwise direction. In this circuit, right at the output of the microcontroller, there is a resistor-capacitor (RC) low-pass filter to stabilize the PWM signal. In a second part, there is an op-amp in setting up an adder amp with the function of lowering the offset of the signal. To finish, the second op-amp amplifies the signal by adjusting the standard of the robot Bug-O System and this is shown in Fig. 15.

2) Tractor Speed Actuation Module: The objective of this part is to amplify the output signal from the microcontroller, that ranges from 0 to $3.3V$ to 0 to $9V$, required by the robot. In this circuit, firstly there is a filter RC to stabilize the PWM signal coming from the microcontroller. After there is a noninverting multiplier op-amp amplifying the signal from the microcontroller to the voltage standard of the robot, as the Fig. 16.

IV. RTL DESIGN

A. Robot Actuation

In order to convert the internal digital logic executed by the FPGA to the analog reference needed by the system, a modulation technique must be employed. For this system, the choice is Pulse-width-modulation (PWM). This technique used to encode information allows a microcontroller to control the voltage supplied to electrical systems. In this case, to the BUG-Os motors by switching the output signal depending on an internal logic. To generate the PWM signal the FPGA the logic implemented is a time-proportioning control. Such logic links a counter to the clock of the system, this counter reset as the system is turned on is increased brokenly at each clock cycle. Then a reference value generated by a proportional speed controller is compared to each clock to the counter if the reference value is bigger than the counter, the output signal is switched.

B. Analog-to-Digital Converter Chip

The FPGA DE0-nano board offers a built-in analog-to-digital converter (ADC). The analog-to-digital ADC128S022 chip has an eight-channel converter. The Fig. 17 shows the connection between the FPGA chip and the converter, through four wires. The wires are used to control which channel to read at each time and transmit the data between the ADC and the FPGA.

The ADC128S022 chip is a successive-approximation analog-digital converter built upon a charge distribution from a digital-to-analog converter (DAC). This architecture collects the analog input signal and stores it in an internal capacitor. A control logic connected to the DAC informs it to add or subtract voltage until the system becomes balanced. The digital word supplied to de DAC when both the DAC and the capacitor's voltage turn equal gives the representation of the analog input.

As shown in Fig. 18, the control of the chip's communication with the FPGA is performed through a bus connecting

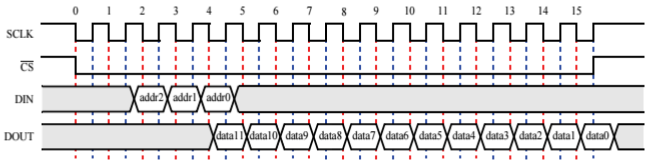

Fig. 18: FPGA–ADC Communication

the FPGA and the ADC. The SCLK wire provides the clock signal generated by the FPGA to synchronize both chips. The CS wire is an active-low signal where the FPGA can turn the ADC in an operative mode. The DIN and DOUT wires are used to send addresses and data between the chips. The FPGA uses the DIN wire to tell the ADC which channel to read by sending a three-bit address, one bit per SCLK cycle. The DOUT wire is used by the ADC to send the twelve-bit resolution digital value relative to the received address also in a serial manner, one bit per SCLK cycle.

The 128S022 AD converter operates in a 16-bit frame. To start the operation cycle the FPGA provides the SCLK for synchronizing the chips and set CS to zero to start the communication. For the correct use of the AD converter, the CS signal should be lowed in the first falling edge of SCLK, and rised in the last rising edge of SCLK. During the operational frame, the ADC chip captures the DIN value in the positive edges of SCLK. Once all address bits are collected the DOUT starts to send the value of the corresponding analog channel bit by bit.

The digital logic to control the chip bus has been kept simple. A counter controls a Finite State Machine which provides the input signals for the ADC chip and collects the DOUT wire following the operation frame. First sending the address bits for the chip and then reading the twelve-bits resolution value. This process collects the digital value relative to the first analog channel, this routine is repeated to read all channels one by one.

C. *Communication Interfaces*

Communication plays an essential role in the integration of the proposed digital interface with any external equipment. Therefore, we used an FT232RL FTDI Breakout Board produced by Future Technology Devices International Ltd. The breakout board enables us to work with the UART RS-232 serial protocol. One side uses pins that are connected to the DE0-Nano board GPIO pins, while the other side features a mini USB connector. Using a USB cable, the digital system can be connected to other devices. Further details on the design can be obtained in [4].

The UART protocol has been coded in VHDL, which permits a parallel execution. The implementation separates the receptor and emitter functions, enabling full duplex communication. Therefore, it is possible to send and to receive messages at the same time. Experimental tests have shown that a Phase-Locked-Loop (PLL) of 150 MHz offers the best cost-benefit ratio, providing a fast and reliable communication, with a low noise and low latency. Using this clock it is possible to achieve a transmission rate of 1500000 bits per second.

Given the proposed application is developed to be used in a manufacturing environment the Modbus Serial RTU (Remote Terminal Unit) protocol was chosen, to avoid noise, reduce communication errors and standardize the communications. The Modbus operates on top of a UART finite state machine. Its standards are defined by the Modbus organization in [15].

The communication obeys a master and slave architecture. In this model, the communication is always started when master sends a requisition to the slave, which in turn, responds to the master. The Fig. 19 shows the parts of the message:

- ID: identify the receptor in the bus, from 0 up to 255.
- Function Code: the communication allows up to 255 different instructions. Each one has a different effect in the system. So far, 18 instructions were implemented.
- Payload: this part is the parameters or information. It is different for each function code. Some functions do not have this part, the biggest one has 128 bits.
- CRC (Cyclic Redundancy Check): this is used to check if have any error in the communication of the message.

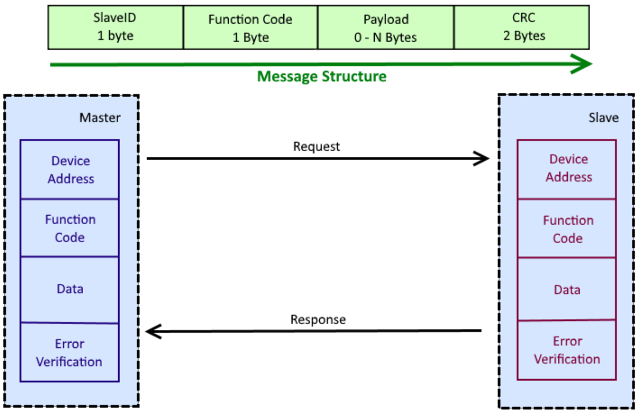

Fig. 19: Modbus Communication Protocol Structure

V. RESULTS

A. *Communication*

There are eighteen messages used in this communication. Some functions codes do not have an answer, just three messages the FPGA sends a response to the PC. In this implementation, we reached a bit rate of 1.500.000.000 bits per second without loss. The messages used and their functions are listed:

- 0x03 - Reset FPGA;
- 0x0B - Stop tractor;
- 0x10 - Stop Weaver;
- 0x13 - The Pc asks for the position of the weaver and tractor, and their times. This message has a answer, where the FPGA sends with the positions and times;
- 0x14 - Position desired for the tractor;

- 0x15 - Position desired for the weaver;
- 0x1B - The PC asks for a speed (mm/s) for the tractor and weaver. The FPGA answers with the current speed in the tractor and weaver;
- 0x1C - The wire feed speed desired;
- 0x1D - Welding machine voltage desired;
- 0x29 - Triangular trajectory welding;
- 0x2A - Square trajectory welding;
- 0x2B - Trapezoidal trajectory welding;
- 0x2C - Rectilinear trajectory welding;
- 0x50 - The PC asks for the information of voltage, current and time of welding machine.
- 0x51 - Turn off the welding torch;
- 0x52 - Stop All;
- 0x53 - Turn on the welding torch;
- 0x54 - Watchdog.

B. *Weaving modes*

The original robot has four weaving modes available, Fig. 20. In the process of automation, the weaving modes have been integrated into the FPGA. The PC passes which one has been chosen and its parameters. When the FPGA receives this instruction, it begins setting what is needed, the FPGA turns on the welding robot and it starts the welding using the weaving mode.

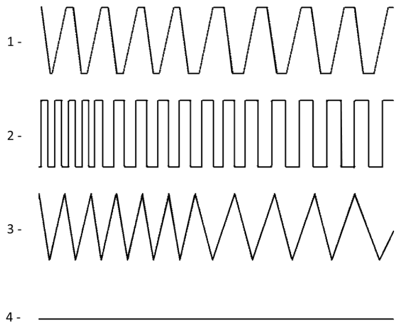

Fig. 20: Weaving Modes

C. *Evaluation of the Actuators Response*

The output voltage from the FPGA board ranges from 0 to 3.3 volts. However, to actuate the motors in the robot a range from 0 to 9 volts is used for the tractor and range from -9 to 9 volts is used for the weaver. Therefore, as stated in Sec. III-D, after the FPGA there is a signal conditional board. The PWM is implemented in the FPGA using 12-bit resolution, which allows 4096 different values. The tractor has three pins to the motor:

- brake;
- direction;
- speed: ranges from 0 to 4095, where 0 is stopped and 4095 the maximum speed.

In the weaver the interaction mode is different, it has just two pins (brake and speed). The speed pin has a different behave, zero is the maximum speed for one direction, 2048 is stopped and 4095 is the maximum for the other direction.

Fig. 21 shows a test where it is possible to see the PC communicating with the FPGA, which controls the operation of the tractor and weaver modules. The oscilloscope shows the pulses generated by the FPGA to the signal conditioning interface. The Fig. 22 shows a better view of these pulses in the oscilloscope, where the orange line shows the weaver signal and the blue one shows the tractor.

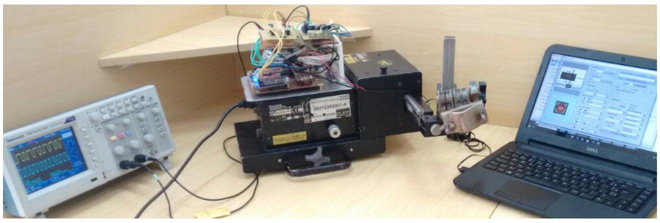

Fig. 21: System Tests and Debug Excecution

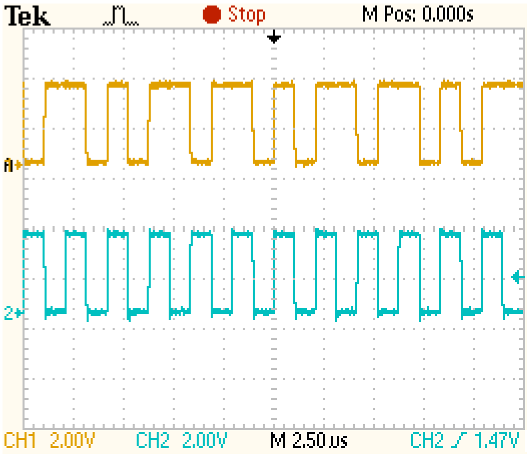

Fig. 22: Sample PWM Wave for Tractor and Weaver Actuation

Through tests, we were able to evidence a regular and constant relation between the FPGA output (average tension generated through PWM) and the resulting actuator speed (mm/s). Exploring this property of the pancake DC motors used in the robot we were able to use a direct relation between voltage and speed for the tractor (Fig. 23) and for the weaver (Fig. 24).

It is possible to observe an almost linear relation between the input voltage and the outcoming speed, both on the tractor (Fig. 23) and the weaver (Fig. 24). This linear relation is used to actuate the robot in the correct speed. The operator sets a speed in mm/s in the interface, and this number is transformed into voltage using $V_o = a \times Speed + Offset$. In order to improve the response and achieve the reference speed in a shorter time period, in a future work, we intend to use a closed loop controller. However, as the implementation would require many floating point operations and, as a consequence, a lot of

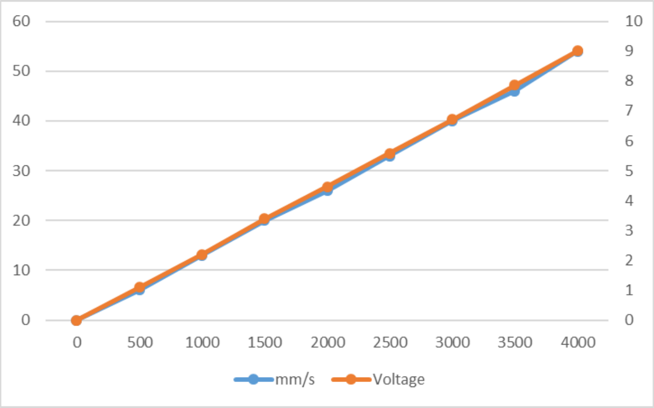

Fig. 23: Voltage Level versus Speed Outcome in the Tractor

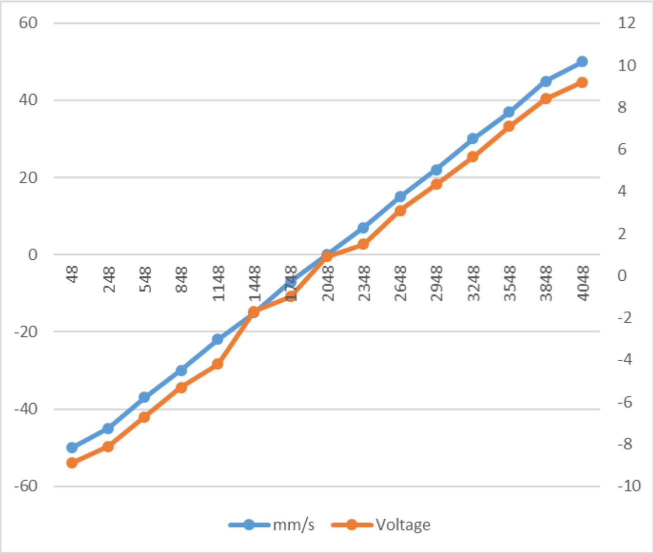

Fig. 24: Voltage Level versus Speed Outcome in the Weaver

logic cells to implement the Floating Point Unit (FPU) the controller has not been implemented yet.

VI. CONCLUSION

The electronics and register-transfer level shown in this paper open a wide range of applications. In one hand, due to the conversion of the analog/manual operated interface into a digital interface it becomes possible to debug the process variables and register the behavior of the controlled and uncontrolled parameters of the welding. On the same hand, the digital interface also allows the development of computer controlled welding, so that the robot is able to weld complex groove shapes.

The presented digital interface requires minimal changes to be adapted to the existing architecture. It preserves the original hardware specifications and is implemented in a black box fashion which makes it a suitable alternative to convert robots that are already operating on the shop floors. With the minimal impact and low hardware migration cost, the analog interface can be replaced bay a digital one, allowing control process data acquisition, as well as reduced exposition of the human operators to unhealthy conditions.

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