# Open-Source electronic board designed in South Africa for Africa

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**Abstract.** Several experiments require acquisition devices to read and elaborate the signals from the external environment. These devices can be interfaced with a computer through the serial communication. Because the continuous evolution of electronics changes the communication standard, e.g. from the standard RS-232 to USB, it is necessary to use an external adapter to connect laboratory equipment to a computer. Laboratory equipment is often expensive and not affordable for schools or universities in developing countries. Through the use of Open Source it is possible to design experimental equipment, without license fees and build proper electronic devices using inexpensive components. In this article we present an electronic board for prototyping using the Arduino features, called AFRICHINO. This board was developed based on our research experience, and represents a synthesis of what is necessary to have a complete experimental board.

## 1. Introduction

In the scientific world, physical quantities must be measured and collected to describe and understand natural phenomena. Most of the physical parameters e.g. temperature, light intensities and many others can be transduced as electric signals through a sensor. To measure and store this signal to be subsequently elaborated several proprietary devices can be used. Some of this laboratory equipment is expensive for schools located in development countries or for students that want to repeat some experiments to improve their personal knowledge. Some specific measurement devices can be used in conjunction with a personal computer through the serial protocol RS-232. In the latter case the last generation of personal computer use the USB port, and a converter USB-RS232 is required.

Following the Open-Source philosophy, in this manuscript we propose a board, called Africhino built based on of another famous Open-Source board called Arduino UNO 3R ® [1]. The core of the board is a micro-controller ATMEGA-328P. The micro-controller has six pins linked with a successive approximation Analog to Digital Converter (ADC) and fourteen digital I/O ports. The analog pins, can be used as a digital input output pin. The clock frequency is 16 MHz and due to the nature of the ADC, the time of conversion depends on the frequency of the micro-controller timing. In Africhino the micro-controller drive a TFT monitor with an SD card on board, a USB to RS232 converter and an external Static Random Access Memory (SRAM) of 32 kb. The board can be programmed using the Integrated Development Environment (IDE) of Arduino and, can be eventually used as an Arduino UNO 3R. This board can be considered as a Swiss army knife for electronic prototyping and electric measures.

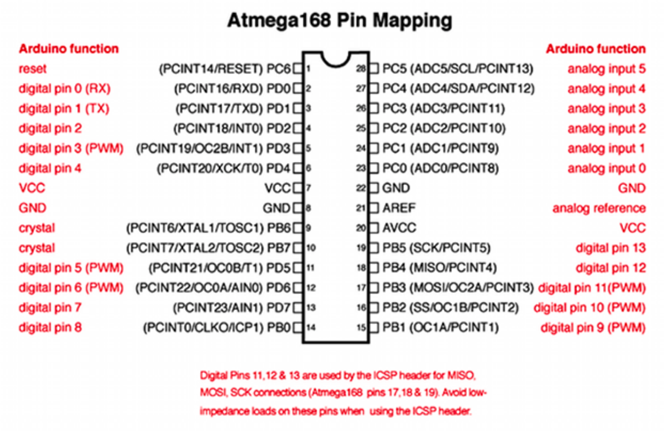


**Figure 1.** The Pinout of Arduino and the micro-controller Atmega-328 [2].

## 2. The Hardware

To use the Arduino ® IDE, the connections of the micro-controller with the electronics components follow the pinout of Arduino. The pinout of Arduino with respect to the micro-controller, are described in Figure 1. The different devices of the board can share a particular pin of the micro-controller. In order to avoid the conflicts of the different peripherals throught the switch-dip showed in Figure 2, it is possible to exclude one or more devices, for example the external SRAM when the screen TFT is used. If Africhino must be used as an Arduino ®, all the switches must be off. Arduino requires 5V but several devices, using in conjunction with, needs 3.3 volt and for this reason an external voltage regulator LM2937ET-3.32 is used for this task. Africhino is designed to be compatible with Arduino Uno board such as several open-source boards.

### *2.1. USB to RS232*

Several laboratory equipment has the serial port RS232 to communicate with other devices such as a computer. Unfortunately, recent computers adopt the USB port however Africhino has a USB to RS-232 converter. The serial cable of the instruments can be connected with Africhino, and the data can be stored on the SD card, displayed on the TFT screen or transfer directly to the computer. The circuits use an IC circuit MAX233CPP connected with the digital pin 2 and 3 [3]. The data, from the RS232, can be used from the micro-controller, or through the digital pin 0 and 1, connected with the serial to USB converter in order to transfer data to the

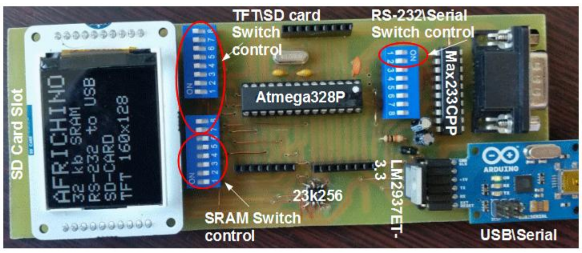


**Figure 2.** Overview of the entire board. The USB-Serial converter is an Arduino device. The USB to Serial converter is indicated on the board as USB\Serial. The red circles indicates the switch-dip to activate or deactivate the different parts of the Board.

computer. For this function the open-source library NewSoftSerial must be used [4].

### *2.2. External memory SRAM*
The micro-controller ATMEGA328P has 32 kb of flash memory to store the programs and only 2kb of SRAM to store the value of the variables. The program loaded in the flash memory is loaded in the static RAM during the execution. If the memory needed exceeds the maximum amount, the micro-controller does not work properly or some values contained in the variable changes. Arduino contains the proper instructions to write the variable in flash memory, however datasheet guarantees the rewriting of the flash memory, no more than 10000 times. To use the external memory, the library SpiRam is necessary [5]. The RAM works at 3.3 V and a generic bi-directional level shift voltage is necessary to communicate with the RAM at the aforementioned voltage of 3.3 V.

### *2.3. SD card*
SD card mounted on the TFT monitor can be used to store data in a text file from the serial port or from the external sensors. The library of the SD card is native in Arduino IDE.

### *2.4. TFT monitor*
The analog signal converted by the internal ADC of the micro controller can be displayed on the TFT in a graphical or numerical form. The TFT library can be downloaded from the official Arduino website or numerous forum [6].

### *2.5. The electronic scheme*
The micro-controller requires a USB to serial converter in order to be programmed and communicate with a computer. The converter is indicated on the scheme as connector P2 as shown in Figure 3. The transmission pin (TX) is connected with the pin number 0 (RX). The receiver pin of the converter (RX) is connected with the pin 1 (TX). The 5 V for the board is taken from the converter, indicated with 5V in the scheme. The integrated circuit LM2937ET-3.3 provides the 3.3V for other devices. The corresponding pins of Arduino are shown by the red characters depicted on Figure 1.

## 3. How to use the board
Africhino is a versatile device to follow several experiments since it is easy to apply the analog and digital signal from the transducers or other digital devices. In this section it is shown how Africhino can print the data on the TFT screen and the possibility to generate random signals.

### *3.1. Generation of random curve*
Suppose that it is required to address a periodical signal $f(t)$ to a device with period $T$ defined as:

$$f(t) = 2.5 + 2.5 \sin t, \quad \text{for} \quad 0 \leq t \leq \frac{T}{2}, \tag{1}$$

and

$$f(t) = 2.5 - t, \quad \text{for} \quad \frac{T}{2} \leq t \leq T. \tag{2}$$

The curve can be built using a software such as Excel whereby each sample of the curve it is necessary to calculate the corresponding binary code. In this case the decimal number are utilised. For the 5V used, in conjunction with the 8 bit digital to analog converter, the minimum value of the curve is 0 which correspond to the value 0, and the maximum value in output is 4.98


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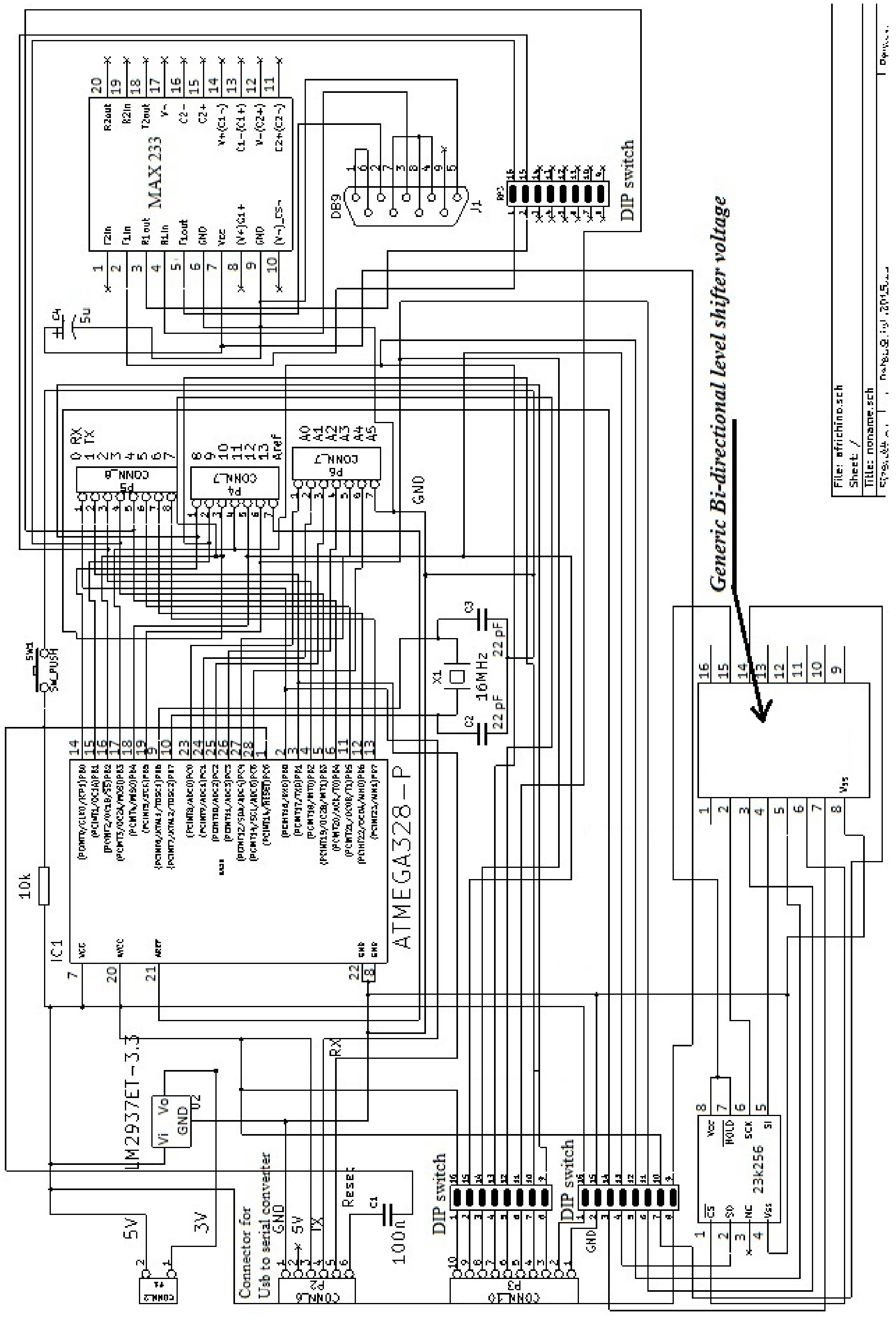


**Figure 3.** Electronic scheme of Africhino.

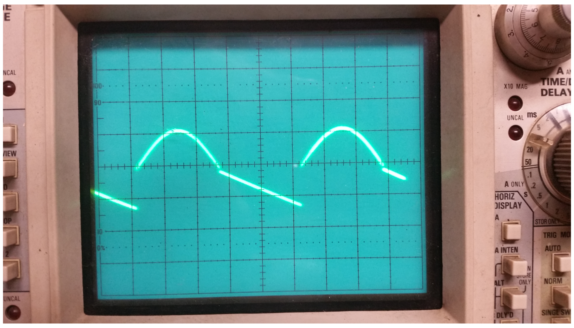

**Figure 4.** The curve generated by Africhino following the concept of Direct Digital Synthesis (DDS) [7].

V which in binary correspond to the decimal value 255. The desired output value in volt can be converted by the integer approximation of the function $N(V_{out})$ calculated by the Equation 3:

$$N = V_{out}\frac{255}{5}, \tag{3}$$

where $V_{out}$ is the desire output voltage. Each sample is sent in output using a particular delay in order to change the frequency of the reconstructed signal. For this experiment, according to Figure 1 the pin used ranges from 0 to 7. The curve mentioned in this section was measured by an oscilloscope as shown in Figure 4.

### *3.2. Visualize the data on the TFT screen*

Using the analog input of the micro-controller it is possible to visualize the evolution of a signal in time, as shown in Figure 5 by the numerically generated sinusoidal curve linked with africhino. Using the native TFT library of the Arduino IDE and by some modification of the algorithm it is possible to visualize the signal.

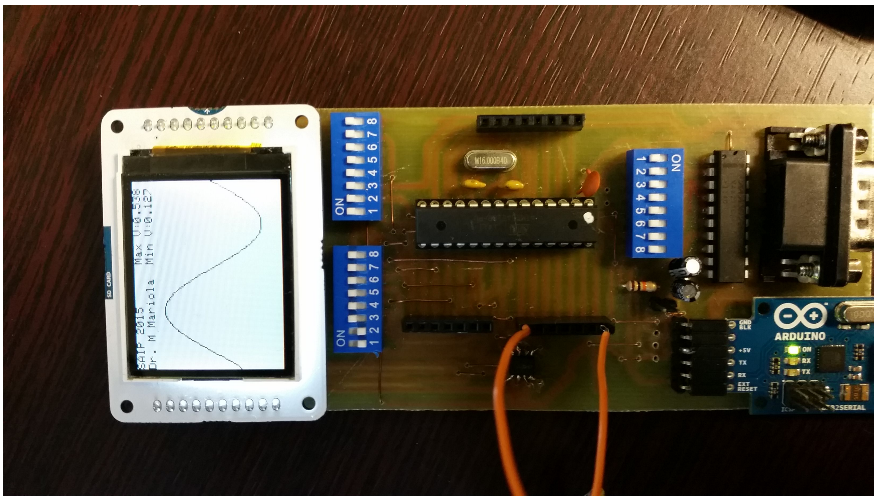


**Figure 5.** The figure shows the evolution of an analog signal generated by the DDS philosophy by an Arduino board coupled with a digital analog converter.

## 4. conclusion

With this technical work we propose a multipurpose electronic board, useful for research and teaching. This low cost board can be used as a multipurpose instrument in schools located in developing areas, where a lot of instruments are not affordable. The circuit is easy to build, and each component is visible for the student. The students have the possibility to improve their skill by building the board, or develop other feature that are not found on this board. Raspberry Pi ® and Arduino ®, was developed to teach programming and electronics, similarly Africhino was developed for the same purpose.

## 5. Acknowledgments

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