

## DECEL week - 1st tutorial: Ultrasound board and Redpitaya ecosystem

### 1) Aim: Time of Flight (ToF) Acoustic Measurement (how deep is the bottom of the water tank?)

In this first part we propose to measure and digitize a single ultrasonic pulse/echo in water. To do this, we need a piezoelectric ultrasonic probe, connected to a pulser board, an oscilloscope, a trig signal generator and a reedpitaya board. Let's take in hand all this material.

### 2) Pulser board presentation

The pulser board is connected to the **Ultrasound probe**. The board allows the application of high voltage RF pulses to the ultrasonic probe and the measurement of small amplified echo signals from the same transducer.

In fact, the pulser board generates RF pulses only when a square-wave trig signal comes in (ex : **TRIG IN**  $\leq$   $\square$ , 1kHz, [0-5V] ).

The echo signal is then received by the same probe, passes through RF switches, and is amplified. It can be measured on the dedicated pin (named **Ultrasound RF signal**).

The echo signal is compared to an adjustable threshold with a fast operational amplifier. Then the ToF time is transported between two binary states (like the PWM duty cycle information). Finally, this ToF information is converted and transmitted on an 8-bit data bus (8-bit echo time).

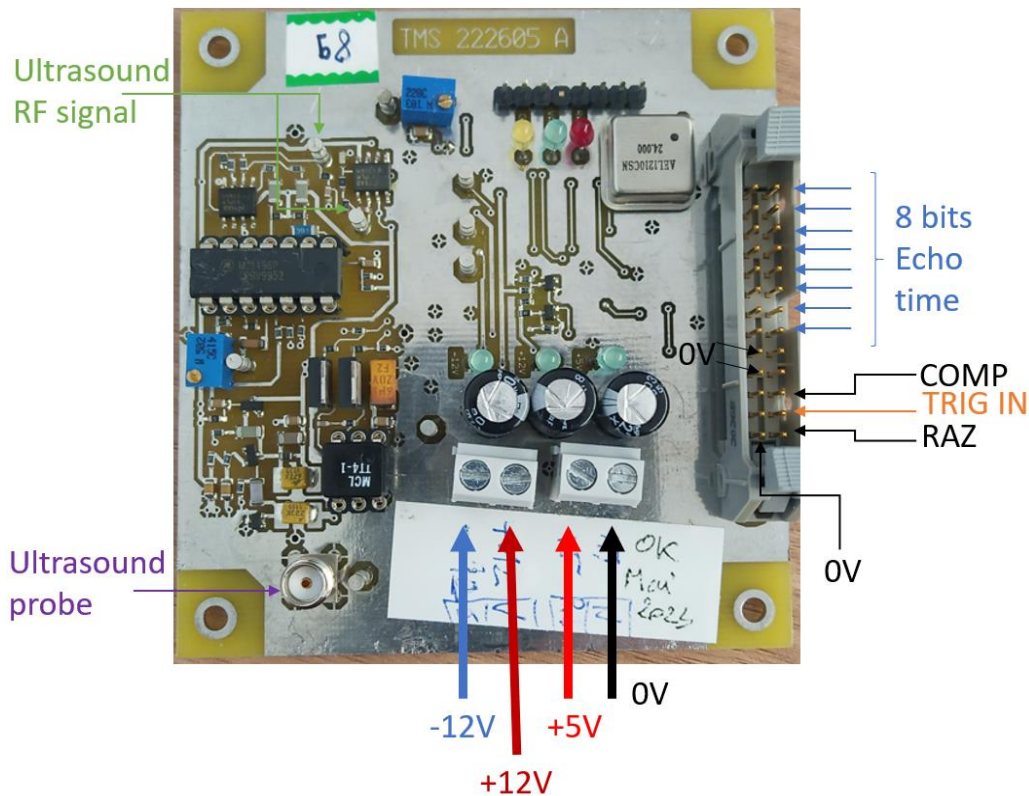


Figure 1 – Pulser board

### 3) Set up the ToF measurement

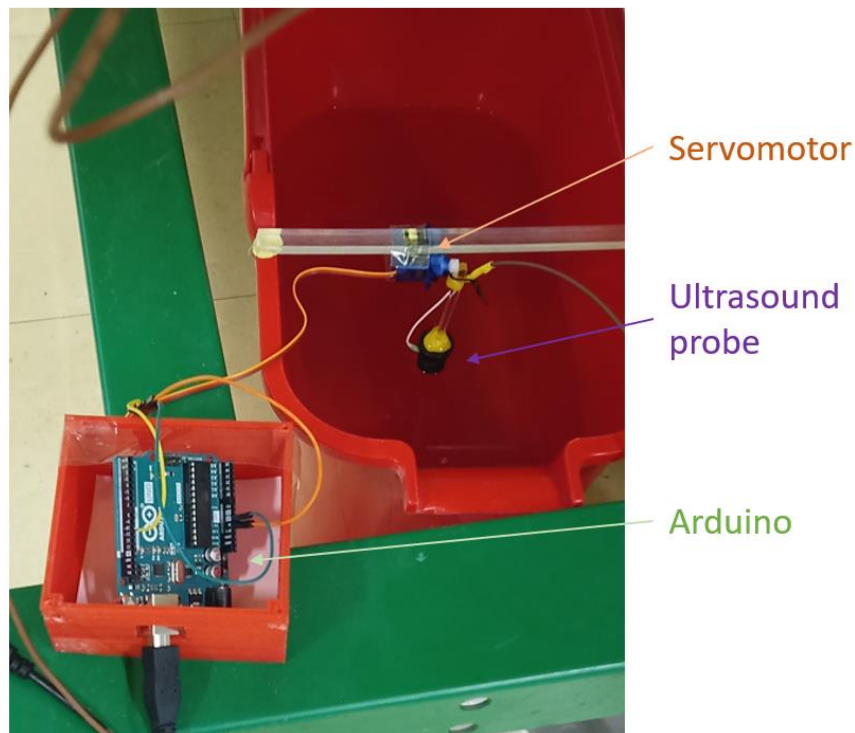


Figure 2 – Ultrasound Probe into water

In order to set-up correctly the ToF measurement several **actions must be followed carefully (electronics is fragile, be careful)**:

- Put the ultrasonic probe perpendicular to surface of water as shown in figure 2.
- Connect the **Ultrasound probe** to the Pulser board (SMA connector on figure 1)
- Prepare the Lab DC power supply as followed: tracking mode +12 V in order to get a -12V/+12V symmetric DC supply for the Pulser board. The +5V must be also setup on the auxiliary output of the Lab DC power supply. Once the Lab DC supply is correctly setup connect the wires (**+12V, -12V, +5V, 0V**) to the Pulser board.
- Connect the RAZ pin and the 0V pin of the BUS.
- Connect the **TRIG IN** signal to Signal generator and a 0V to GND of the instrument. Setup a square signal at 1KHz at [Low level = 0V ; High level =5V ] (⏏, 1kHz, [0-5V]).
- Using a x10 scope probe, connect the probe to the **Ultrasound RF signal** pin to the lab scope. **Check the signal. What are you observing? Are you able to see an echo?**
- **Change slightly the probe angle? What are you observing?**

#### 4) Recording the echo signal on the Redpitaya board

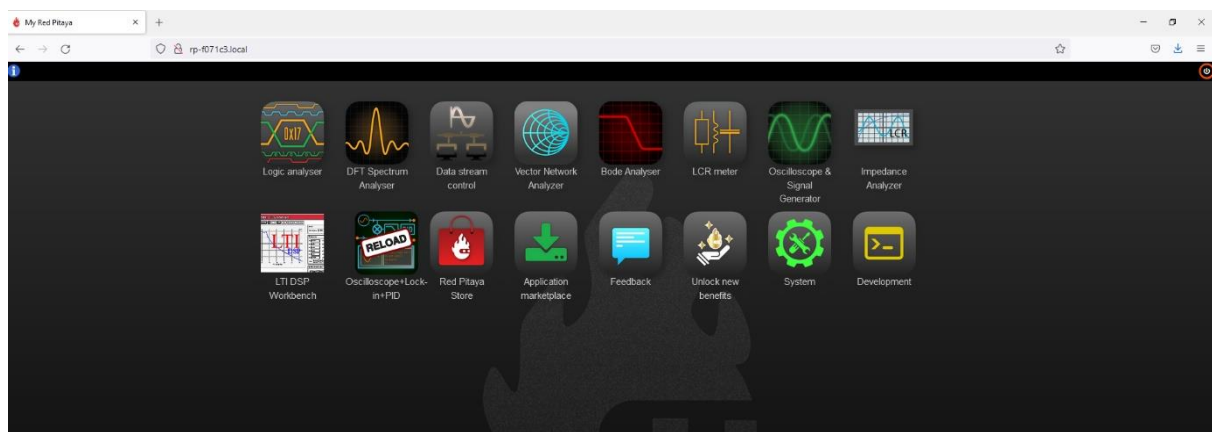
- Using a x10 scope probe, connect the probe to the **Ultrasound RF signal** pin to the Redpitaya board on **IN1**.
- Connect the board to ethernet and power the board
- Open a terminal on your computer (for example, type cmd.exe in the Windows search bar).
- Ping your redpitaya board (ex: ping rp-F0XXXX.local ; XXXX are number reported on your board on the Ethernet plug). Check that the board is responding.

```
U:\>ping rp-f07294.local

Envoi d'une requête 'ping' sur rp-f07294.local [fe80::226:32ff:fe0:7294%6] avec 32 octets de données :
Réponse de fe80::226:32ff:fe0:7294%6 : temps<1ms
Réponse de fe80::226:32ff:fe0:7294%6 : temps=1 ms
Réponse de fe80::226:32ff:fe0:7294%6 : temps=1 ms
Réponse de fe80::226:32ff:fe0:7294%6 : temps=1 ms

Statistiques Ping pour fe80::226:32ff:fe0:7294%6:
Paquets : envoyés = 4, reçus = 4, perdus = 0 (perte 0%),
Durée approximative des boucles en millisecondes :
Minimum = 0ms, Maximum = 1ms, Moyenne = 0ms
```

- Open a web browser and go to <http://rp-F0XXXX.local>, the following window should appear:



- Open the oscilloscope app, adjust the trigger and scales and signals should look like this:



- Measure the time of the first echo. If the sound goes at 1500 m/s, what is the ToF distance measured here?

5) Observe the echo time on the digital bus of the Pulser board using the Redpitaya

The Redpitaya can work as a scope as shown before, but the FPGA can also handle digital signals and can be used as a logic analyzer.

- Using the 8 wires bus in the box, connect the 8 bits echo time bus of the Pulser board to the 8 bits bus of the Redpitaya one (DIO\_[0-7]\_P, cf. figure 3). Don't forget to connect the mass of the two board together (if not already done).

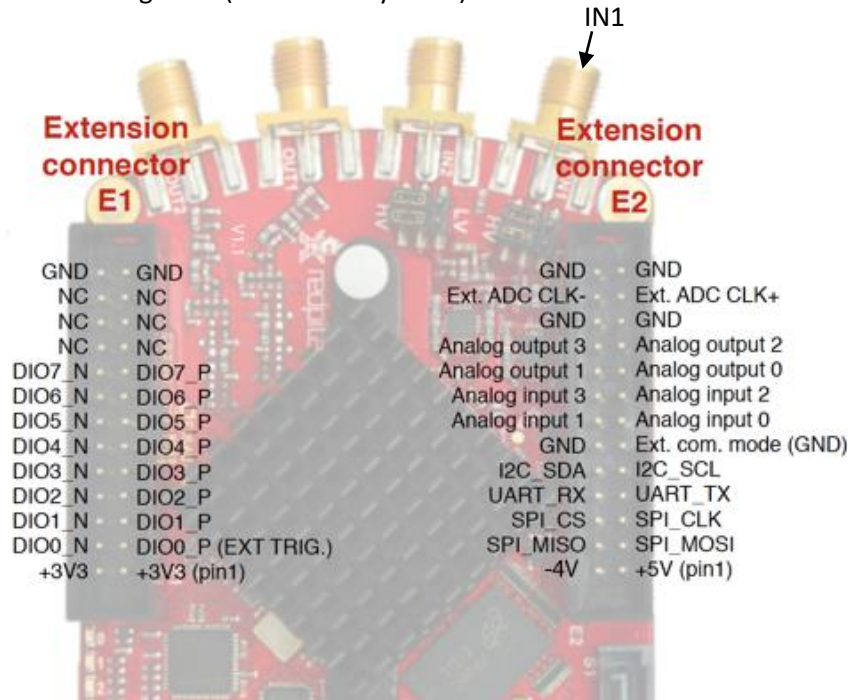
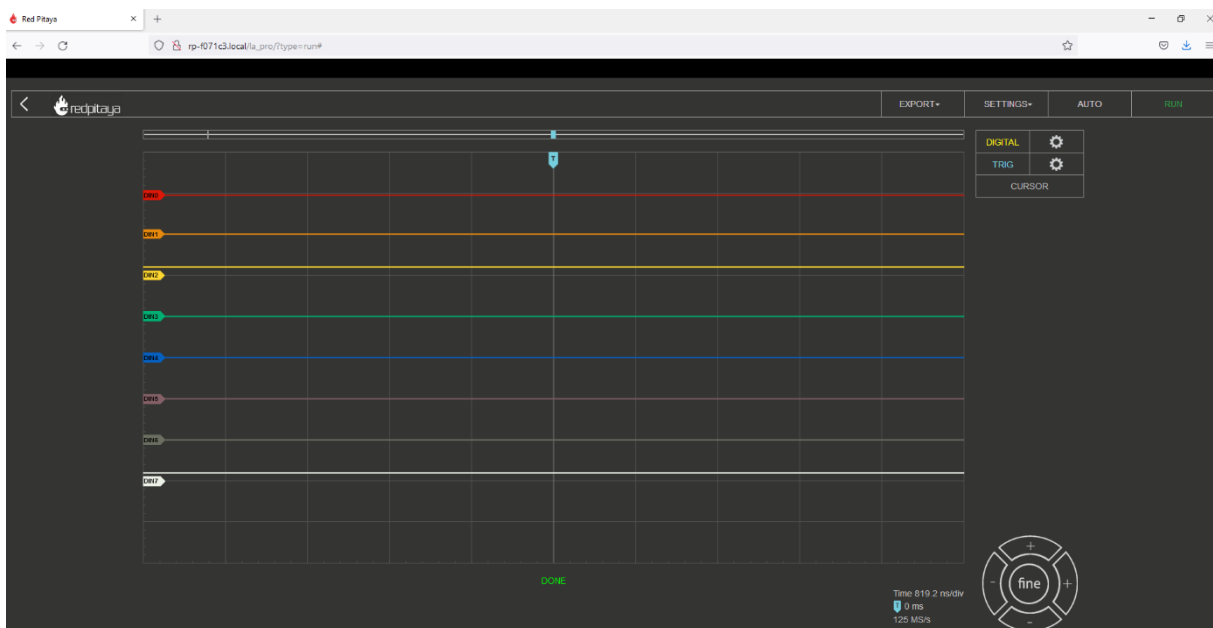


Figure 3 – Redpitaya Digital pinout

- Open the Logic analyser app and start acquisition:



- ⇒ What is the 8-bit word? Try changing the echo distance to observe any change.
- ⇒ Explains/Draw the digital architecture implemented in the pulser board that allows the 1st analog echo signal to be converted to an echo time encoded in an 8-bit register.