Texas Instruments

Application Report
SLAA742–June 2017

MSP430FR6047 and Ultrasonic Software Based Water Flow Meter Measurement Results

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ABSTRACT

This document summarizes the results of the measurements with the RevA MSP430FR6047 device with the ultrasonic software library for water flow meter.

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1 Introduction

Thank you for requesting the MSP430FR6047 sample kit. This document summarizes the results of the measurements with the RevA MSP430FR6047 device with the ultrasonic software library for water flow meter.[1]

2 Test Setup and Configuration

The measurements were performed on a 3rd party (Audiowell) brass pipe and transducer that is easily available and can be obtained independent of Texas Instruments. This Audiowell pipe housed transducers that have a nominal excitation frequency of 1 MHz. They also make use of the U-type reflecting structure for the ultrasonic wave. More information can be found in Reference [2]. More details on the ultrasonic flow sensor housed inside the pipe can be found on the Audiowell website.

The tests were performed using an evaluation module (EVM) designed specifically to support water flow meter application[3] and documentation on the EVM is available as part of this sample kit.

The transducer excitation frequency of 1.030 MHz was used for the Audiowell pipe under test. Even though the transducers are rated nominally for 1 MHz, we obtained better signal level at the output of the ADC for 1.03 MHz for the same gain setting of the on-chip gain amplifier on the MSP430FR6047.[4]

The software is configured to use an ADC sampling frequency of 3.6 MHz. This is based on an on-chip PLL frequency of 72 MHz that is generated from the 8-MHz resonator (USSXT) that is populated on the EVM.

A measurement rate of 1 Hz (1 measurement per second) was used to obtain the flow rates on water that was at room temperature.

Even though the MSP430FR6047 device and the Ultrasonic SW library can accurately measure flow rates in excess of 40 GPM and as low as 0.002 GPM (0.5 lph), we measured flow rates at 0.01, 0.05, 0.1, 0.25, 0.5, 1.0, 2.0, and 3.4 GPM (GPM = gallons per minute; lph = liters per hour).

2.1 Test Bench

The test setup includes a water tank, a motor to pump the water from the tank up into the pipes connected to the unit under test, reference meters, and the pipe under test. The motor is immersed under water in the bottom tank. Figure 1 shows the high-level image of the test bench.

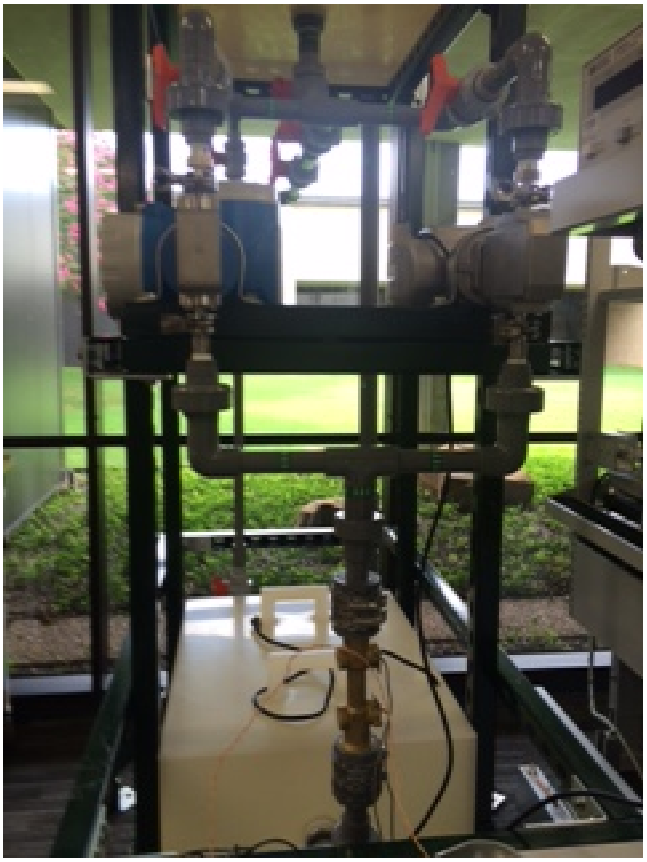
Figure 1. High-Level Image of Test Bench: Tank, Immersed Motor, Reference Meter, Unit Under Test

As the range of flow rates that need to be tested (0.005 GPM to 4 GPM) is wide and varies over three orders of magnitude, a single reference meter is not sufficient to measure the entire range of flow rates of interest. We used two reference meters, one meter for the low flow rates on the left arm of the test bench and another meter for the medium flow rates on the right arm of the test bench. For calibration across the meters, we ensure that the two reference meters have a small overlap of supported flow rates. The reference meters were industrial-grade based on magnetometers from Endress+Hauser (E+H). Figure 2 shows the two arms and the arrangement.

NOTE: Left arm: 0.005 to 0.35 GPM; right arm: 0.25 to 8 GPM

Figure 2. Reference Meters

The pipe under test is in series with the reference meter to ensure that both meters see the same flow rate. As we have two parallel arms with the reference meters, only one arm is active while the second arm is turned off using the switches. For low flow measurements below 0.4 GPM, the left arm is enabled while the right arm switch is OFF. Similarly, for measurement of flow rates from 0.25 GPM to 8 GPM, the right arm is enabled while the left arm switch is OFF. Figure 3 shows the pipe under test and its position in series to the reference meters and the two arms.



NOTE: Two parallel arms. Only one arm is active for any given flow rate.

Figure 3. Meter Under Test

2.2 Parameter Configuration Using GUI

The Design Center GUI can be used to configure the parameters in the software that correspond to the transducer and pipe under test. Details about using the Design Center GUI and the individual parameters can be found in Reference [5].

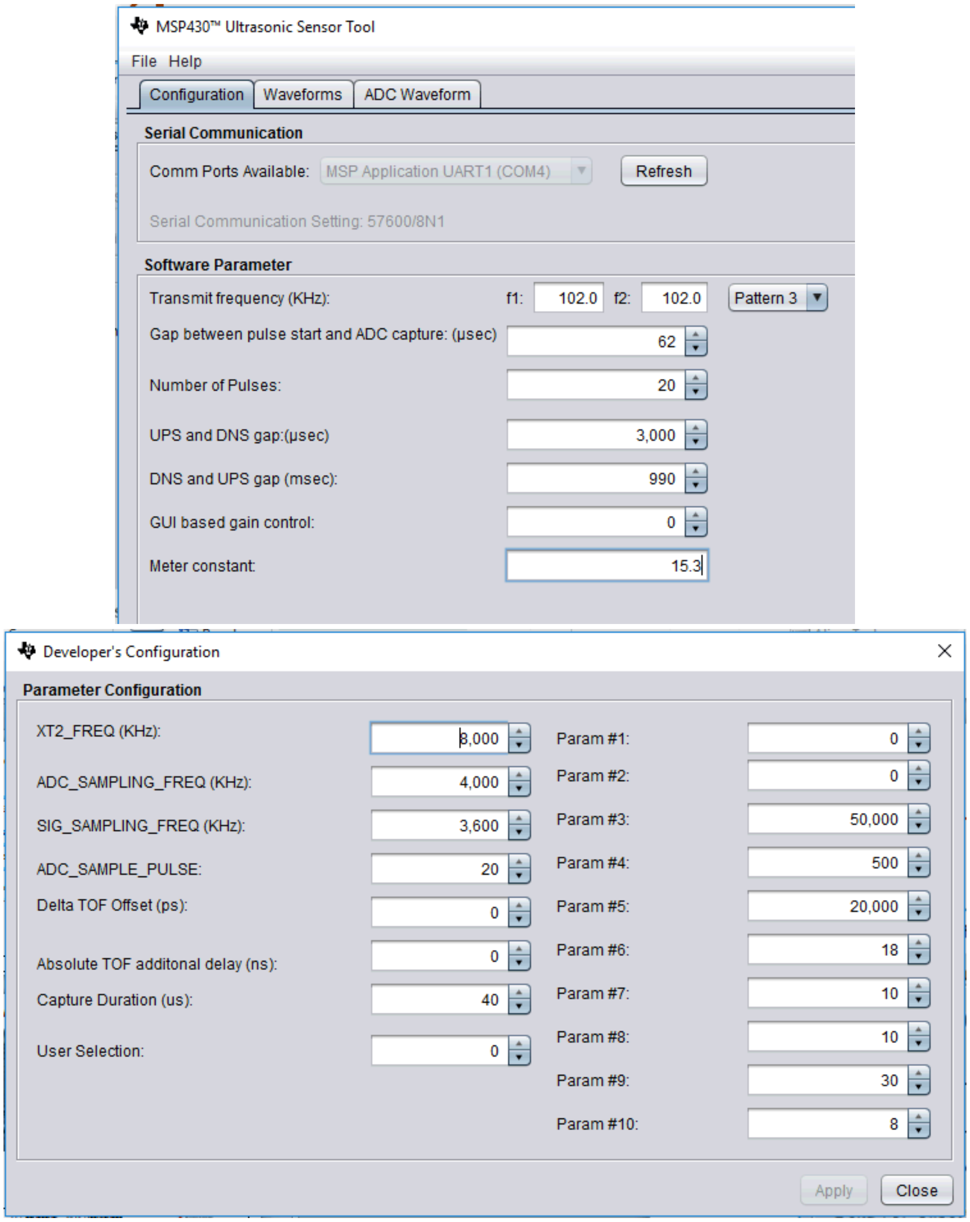


Figure 4. Design Center GUI Parameter Configuration for Pipe Under Test

3 Measurement Results

The flow rate measurements were done starting with the low flow rate of 0.005 GPM and progressively increasing to 0.35 GPM on the left arm (low flow) and then switching to the right arm from 0.05 GPM to 3.75 GPM. The flow rates overlap from 0.05 GPM to 0.35 GPM across the two arms.

Figure 5 shows the measured flow rate across the entire range and plotted along with the value as measured by the reference meters.

Figure 6 shows only for the low flow rates (left arm) as a zoomed in plot for better clarity.

Figure 7 shows the measured flow rate against the reference flow rate for the left arm (low flow rates).

It should also be noted that the variation noticed at the highest flow rates on both arms is primarily due to the vibration of the setup valve when set to the maximum open position.

NOTE: The flow rate curve must be calibrated at 2 to 3 different points on the complete flow rate curve for improved accuracy. This meter correction factor is part of the calibration procedure undertaken by the meter manufacturer.

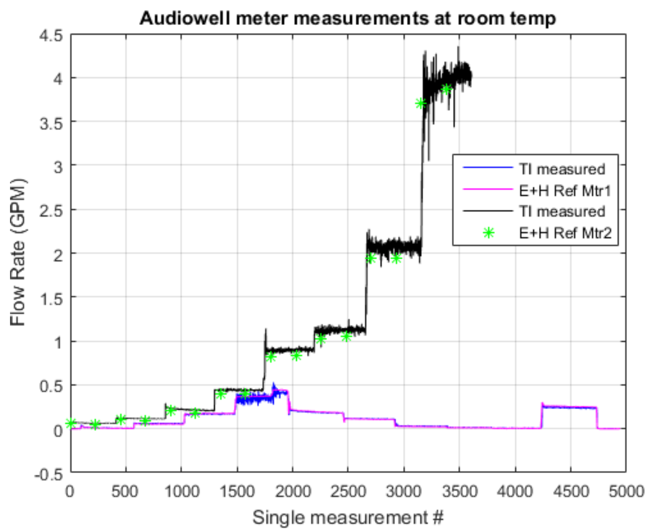


Figure 5. Measured Flow Rate and Reference Meter Flow Rates for Both Arms

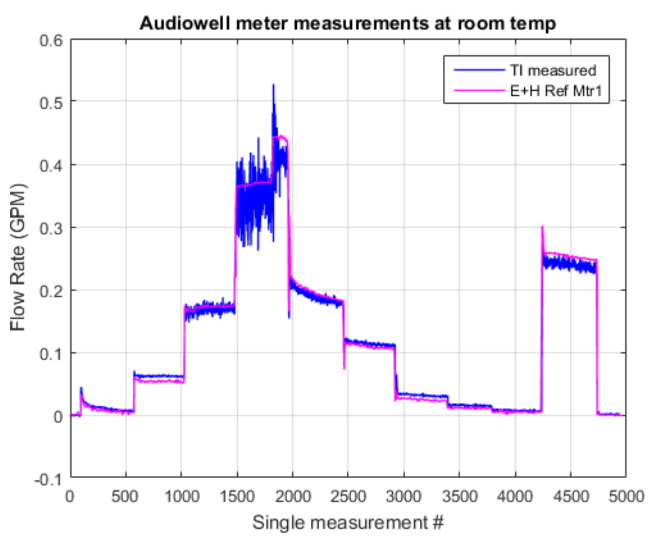


Figure 6. Measured Flow Rate and Low-Flow Reference Meter

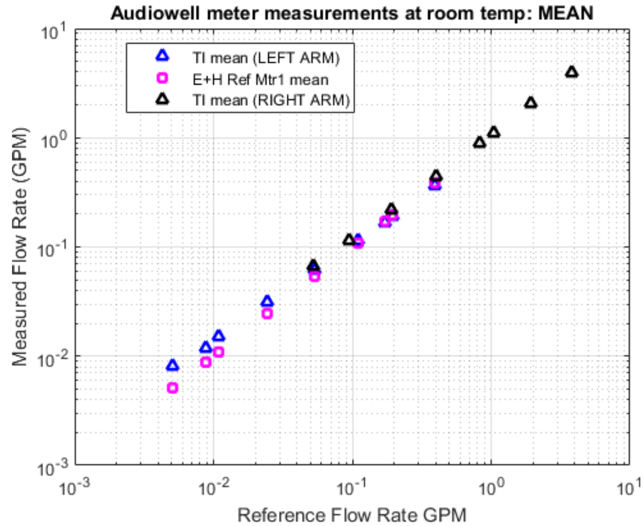


Figure 7. Measured Flow Rate vs Reference Flow Rate

3.1 Variation Over Time

Another parameter of interest is the standard deviation of measurements at a given flow rate. This usually gets worse as the flow rate becomes very low due to the increased contribution of noise on the measured flow rate. This is expressed as Equation 1.

$$\frac{\text{Standard Deviation of N measurements at Flow Rate R}}{\text{Mean of N measurements at Flow Rate R}} \quad (1)$$

Figure 8 shows the metric and the variation of the measured data is similar to that observed by the reference meter.

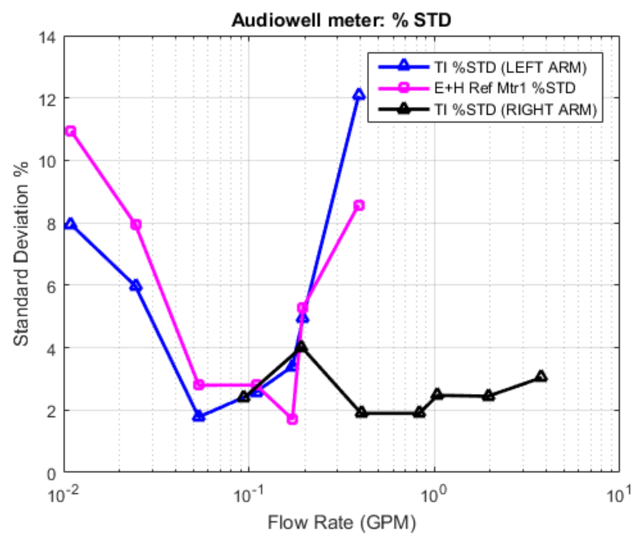


Figure 8. Variation Over Time Across Flow Rates

4 References

1. Application Software (SW) Architecture for MSP430FR6047-Based Ultrasonic Water Flow Meter
2. Audiowell DN25 Brass Pipe for Heat Meter (http://www.audiowell.com/en/product-detail.aspx?id=80)
3. EVM430-FR6047 Hardware Guide
4. MSP430FR6047 Mixed-Signal Microcontroller
5. MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide
6. MSP430FR6047 Ultrasonic Sensing Design Center Quick Start Guide