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Ultrasonic anemometry from very to low to high air flow speeds using a cw or long pulse ultrasonic wave

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Ultrasonic anemometers have a wide dynamic range, no moving parts and potentially high accuracies for measuring wind speed, but can also be used for indoor air flow monitoring. Some designs of ultrasonic anemometer already use flexural ultrasonic transducers (FUTs) – a sensor that is used extensively in car parking sensors as they are low cost, robust and reliable. Ultrasonic anemometers often use a method called transit time difference, where the different transit time generally with or against the air flow gives rise to a transit time difference, that can be used to calculate air flow speed.

In most conventional ultrasonic anemometers, each transducer in a pair is pulsed in turn, with one generating whilst the other detects, and then the roles are reversed by multiplexing. The ADC captured signals and are processed using cross-correlation (or similar). Arranging pairs of transducers at different angles facilitates 2D and 3D measurements of air flow speed – the most common being 2D anemometers. Both air flow speed and direction (velocity) can be calculated. Challenges with this approach include that ADC and signal processing needed are relatively power-hungry and expensive.

A bigger challenge for the conventional approach to ultrasonic anemometry is that transducer responses and resonant frequencies varies slightly, and can change with temperature. Ultimately the accuracy of the cross-correlation method or similar methods relies on the transducer responses being very similar when in operation, and this is generally not possible. It also assumes or relies on the flow profile being the same in the time between multiplexing the transducers - changes in flow profile between switching transducers limits accuracy.

Previous workers have reported using XOR logic gates to perform what is effectively a phase difference measurement, removing the need to use fast, more expensive and higher power ADC and signal processing. We have revisited this approach and implemented it in the design of a simple 2D ultrasonic anemometer that can easily be manufactured using 3D printing technology, and simple electronic components with a low component count and easily substituted components. The signals are acquired by a low power, low specification microcontroller, which in this case is an Arduinio to demonstrate the flexibility of the approach. Different transducer spacings or operation frequencies are required to cover the range of flow from a few mm/s to 90 m/s, because if speed increases beyond the limit where the phase shift is greater than half a time period of the ultrasonic frequency used, the range is exceeded over which the logic gate approach to measure phase difference. However, one rarely requires a single anemometer to cover this entire range of frequencies, but even then strategies exist for driving the FUTs at one of their different resonant modes.

The signals are usually digitized, and software processing performs a cross-correlation function to calculate time difference. We revisited the method to see if there is a lower cost and simpler solution to performing this measurement, that could reduce build cost and hence open up new applications such as indoor ventilation monitoring.