Realtime Indoor Positioning System

By the Bit Shifters

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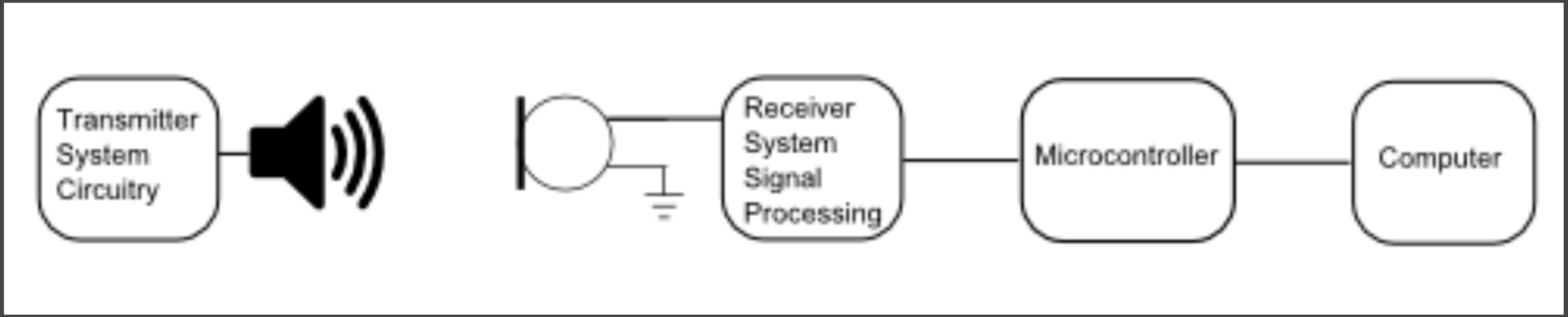
http://groups.google.com/group/bit-shifters

Contents

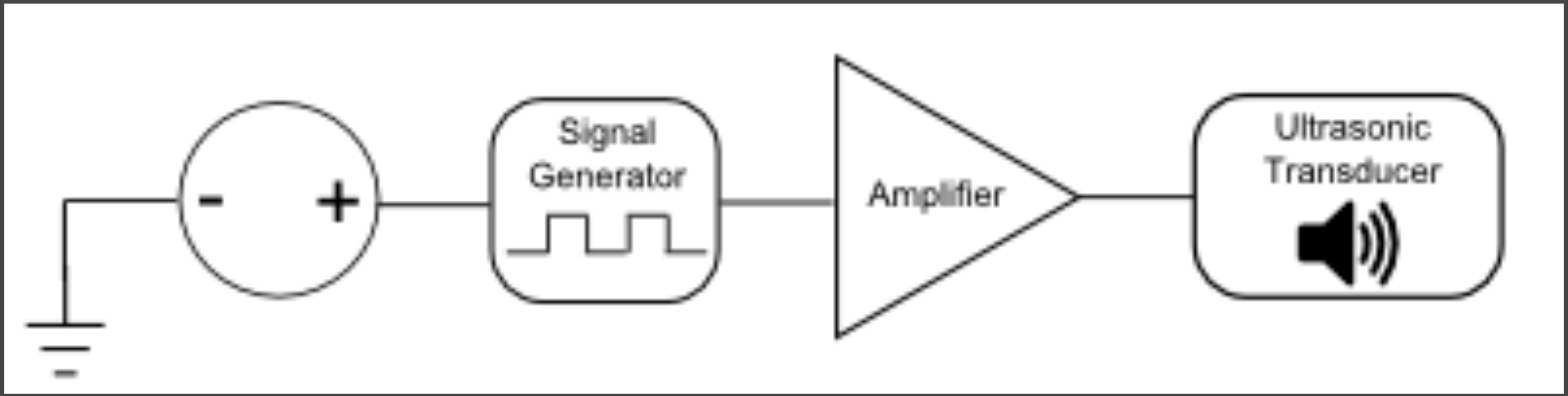
System Overview

- Trackable objects are equipped with a transmitter that emits a high frequency, inaudible pulse to a base station.
- The base station is equipped with four microphones, using a technique called Multilateration can pinpoint the location of the transmitter in 3D space.
- The receiver system hardware records the signal time-of-arrival differences for each of the microphones and provides the data to the computer for analysis.
- In software, the computer will use some complex math to find the location of the object in 3D space.

System Overview

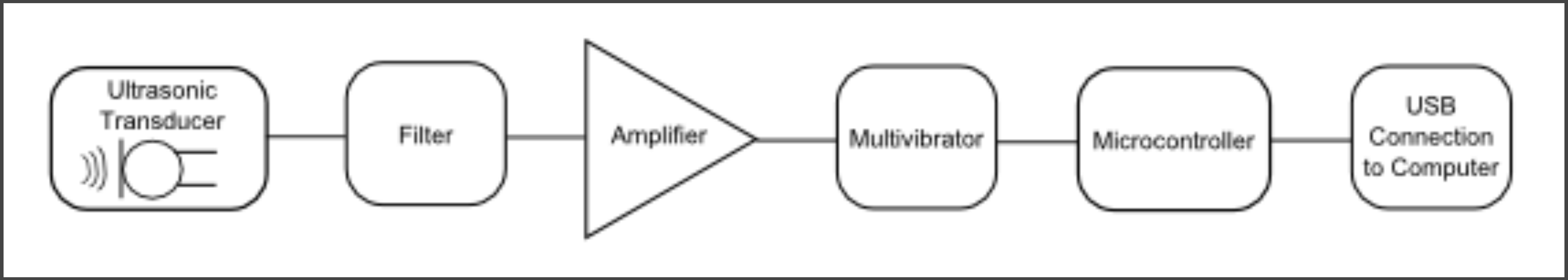


Transmitter System



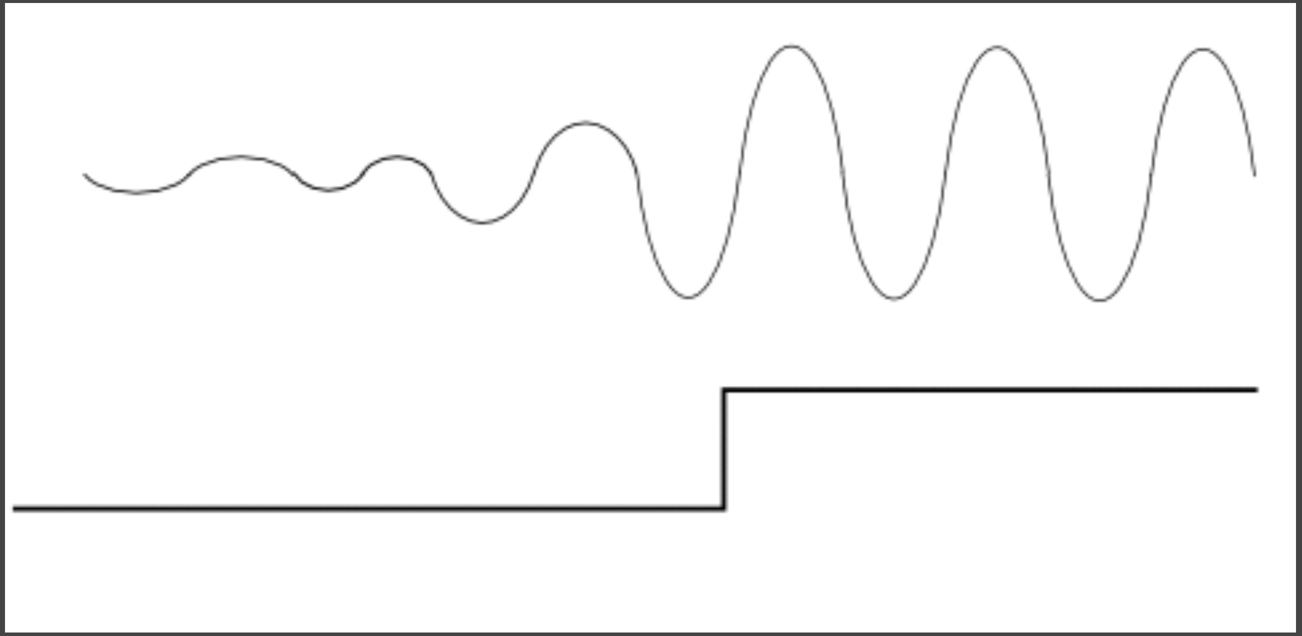
- The signal generator is powered by a battery or power supply and it produces a square wave at 40 kHz.
- The generated signal is put into an amplifier to give the transducer maximum output strength.
- The crystal in the ultrasonic transducer resonates and transmits 40 kHz signal.

Receiver System

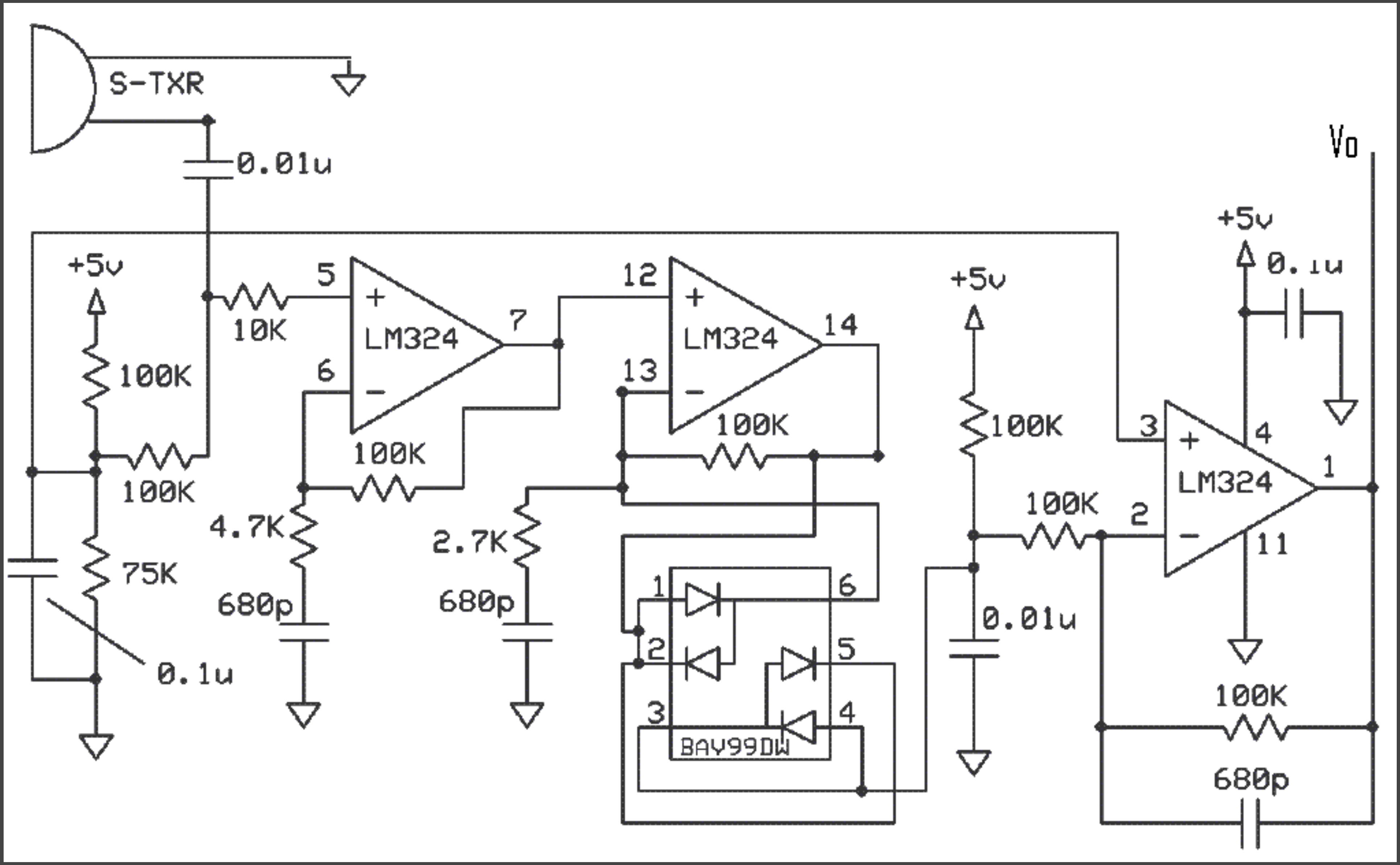


Raw Signal

After Multivibrator

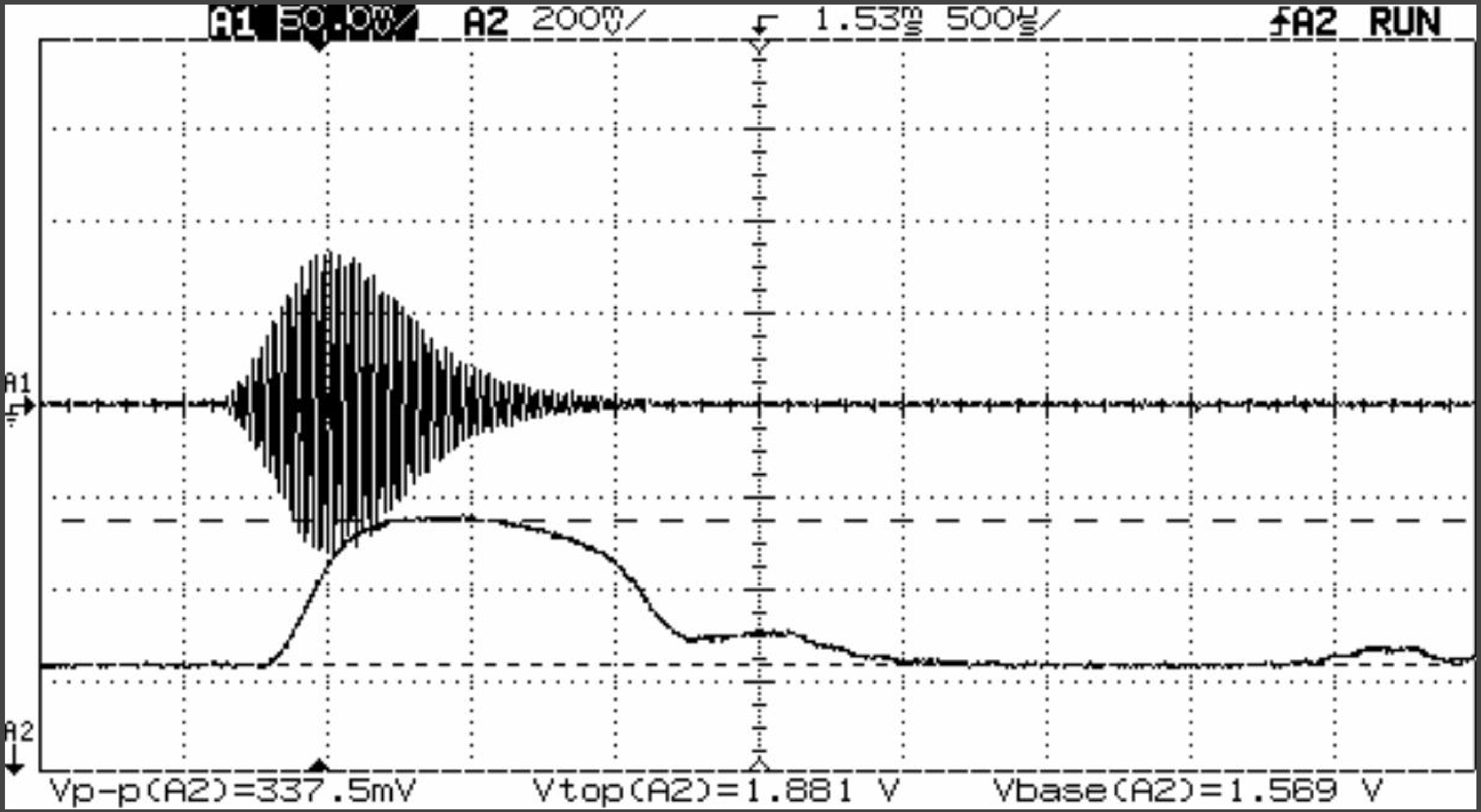


Amplifier



S-TXR
0.01u
+5v
100K
10K
100K
5
6
LM324
7
100K
4.7K
680p
75K
0.1u
12
13
LM324
14
100K
2.7K
680p
1
2
3
BAY99DW
6
5
4
+5v
100K
100K
0.01u
+5v
0.1u
3
2
LM324
4
11
1
Vo
100K
680p

Amplifier

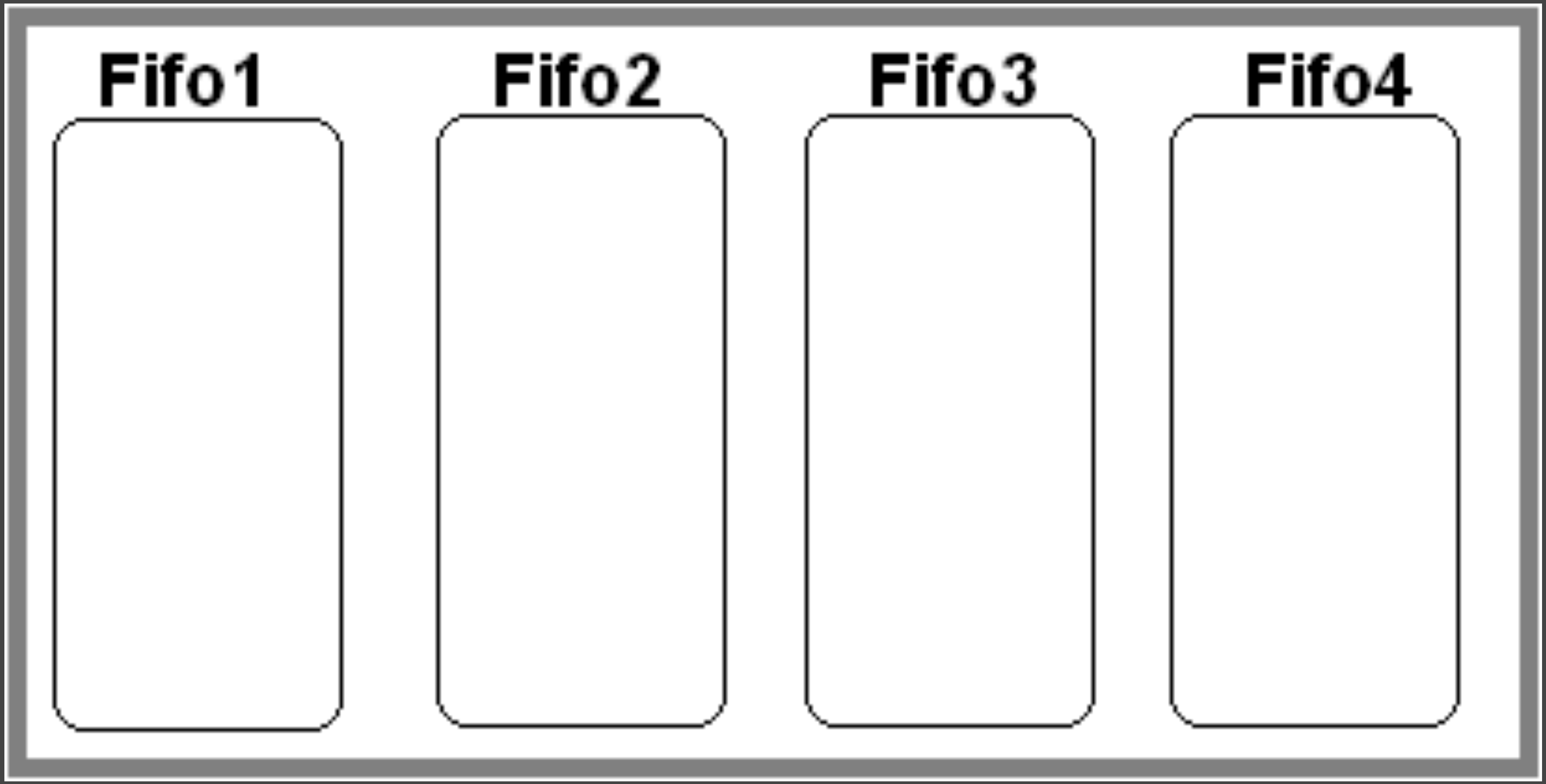


A1 50.0mV/ A2 200mV/ 1.53ms 500µs/ A2 RUN
A1
A2
Vp-p(A2)=337.5mV Vtop(A2)=1.881 V Vbase(A2)=1.569 V

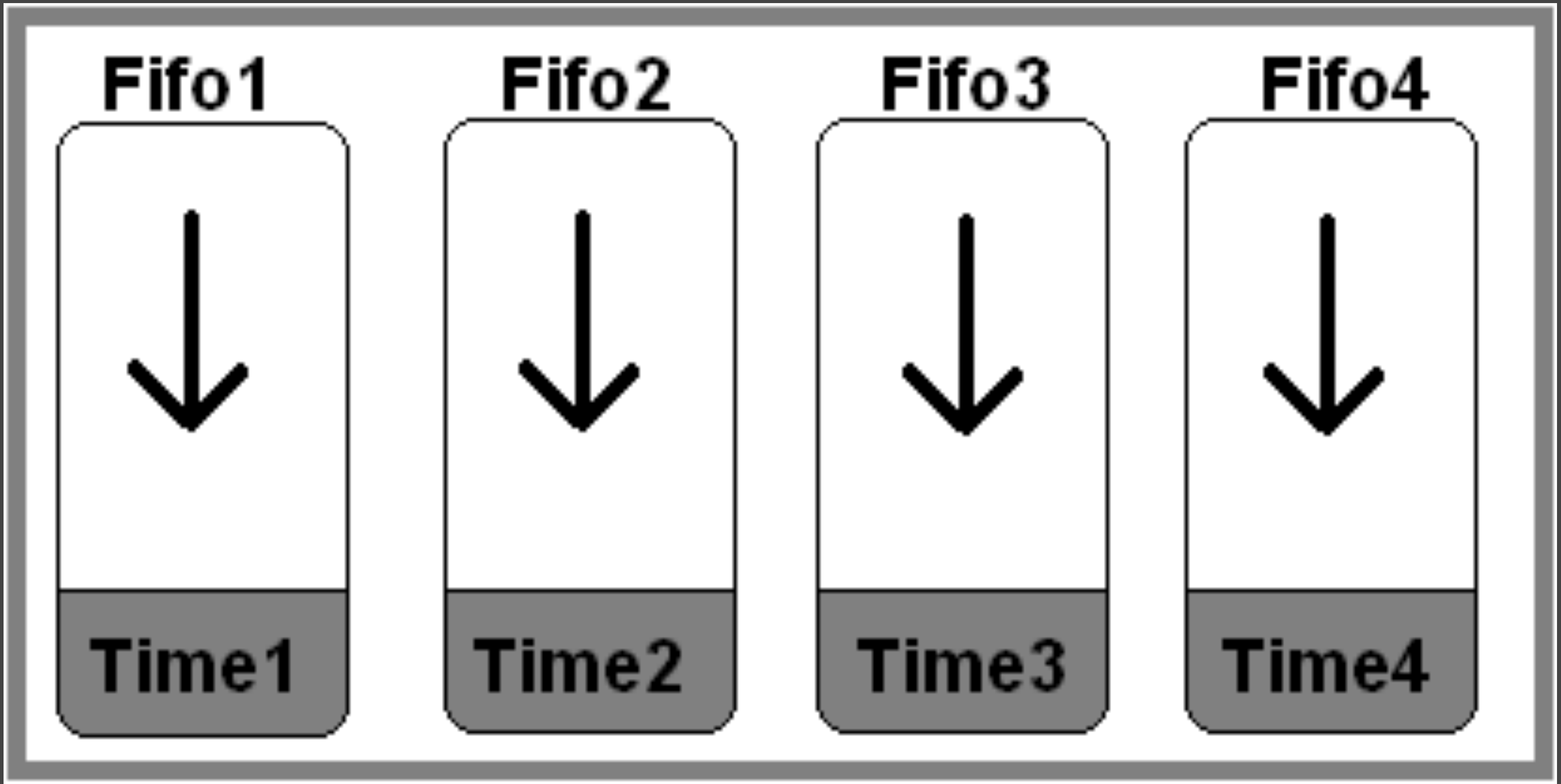
Microcontroller

- Use four input capture pins that latch an internal timer on rising edge of one of four inputs.
- Each input will place the timer value into one of four queues or FIFO.
- The Microcontroller will send four values at a time over the builtin USB interface to the computer.

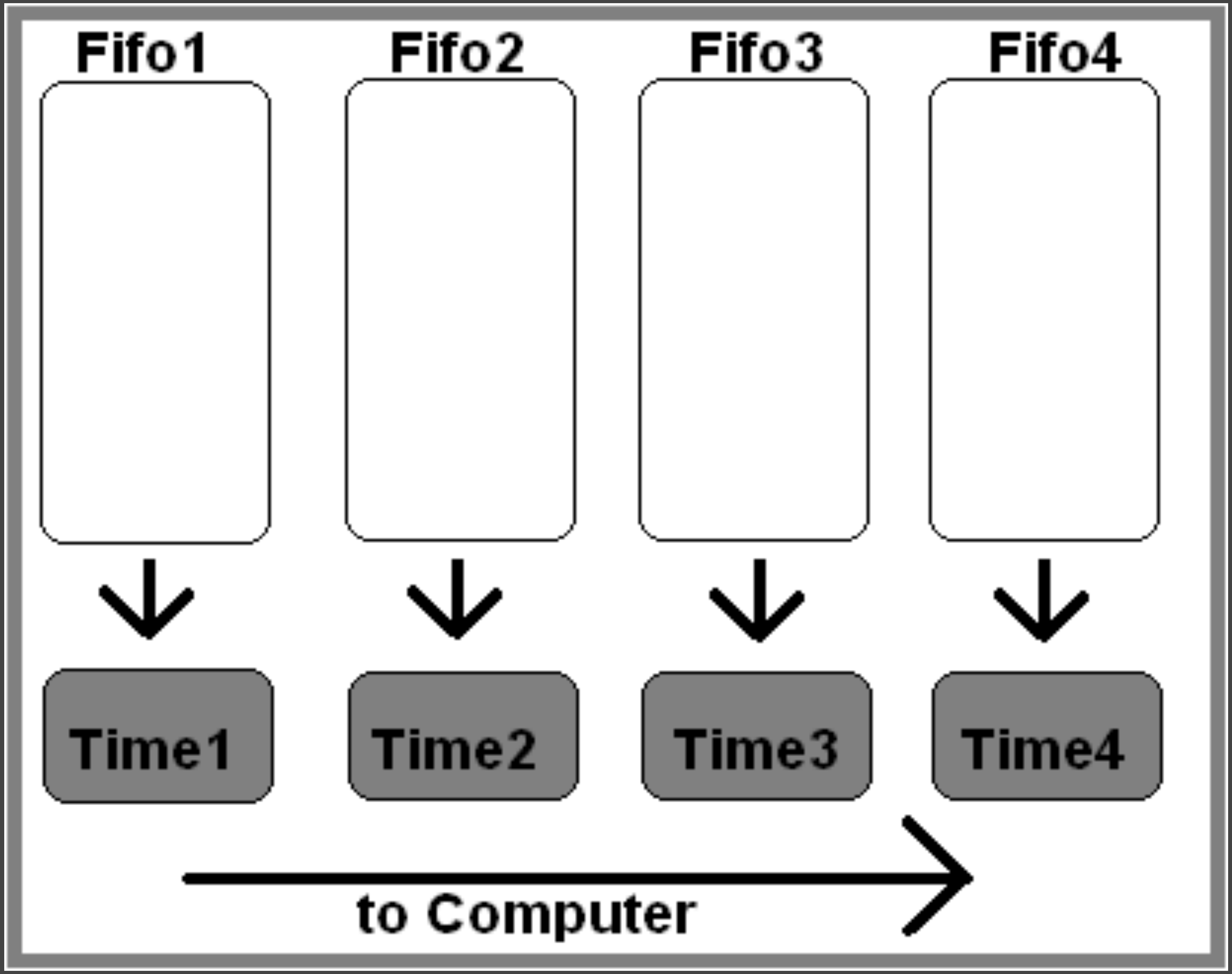
Microcontroller



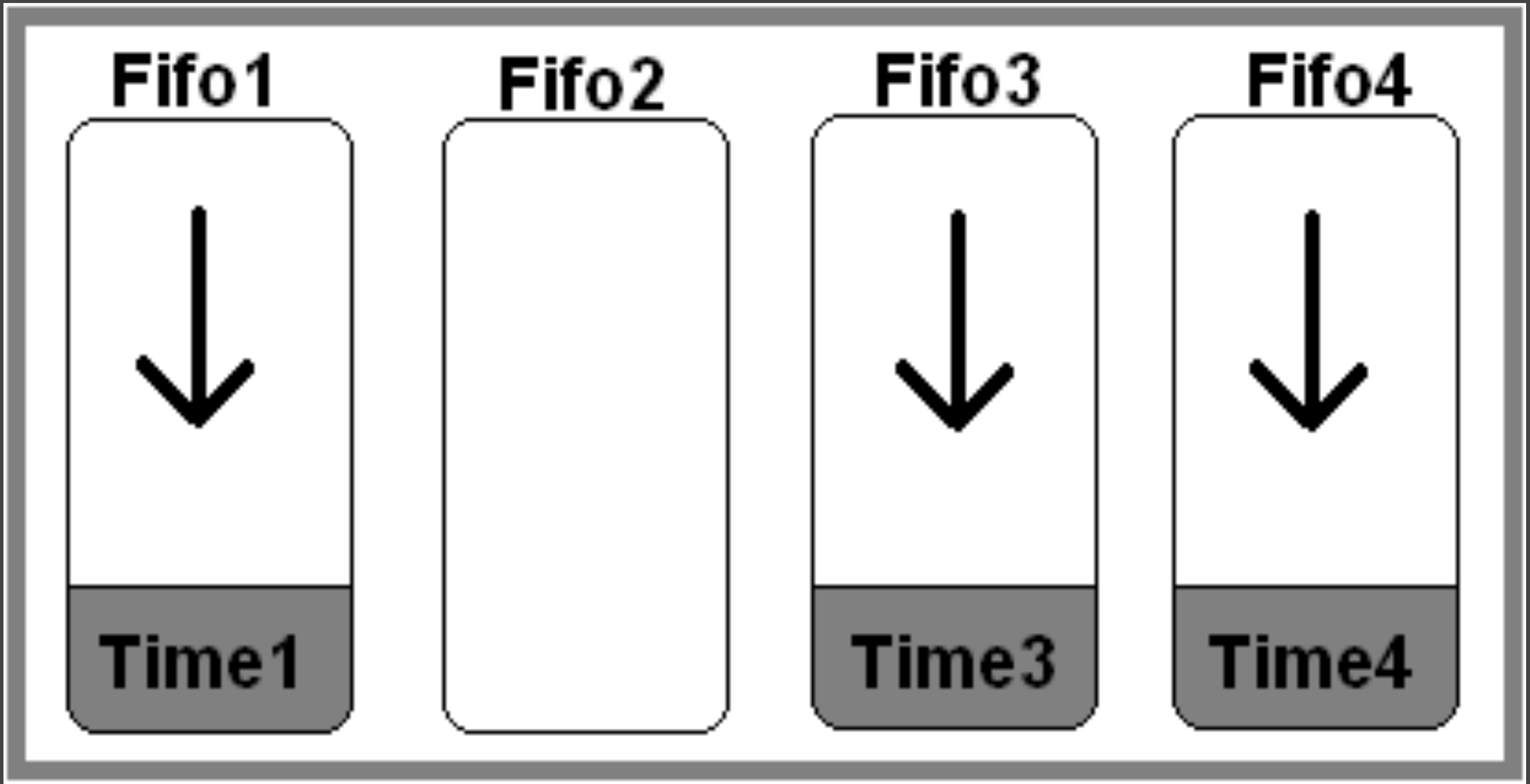
Microcontroller



Microcontroller

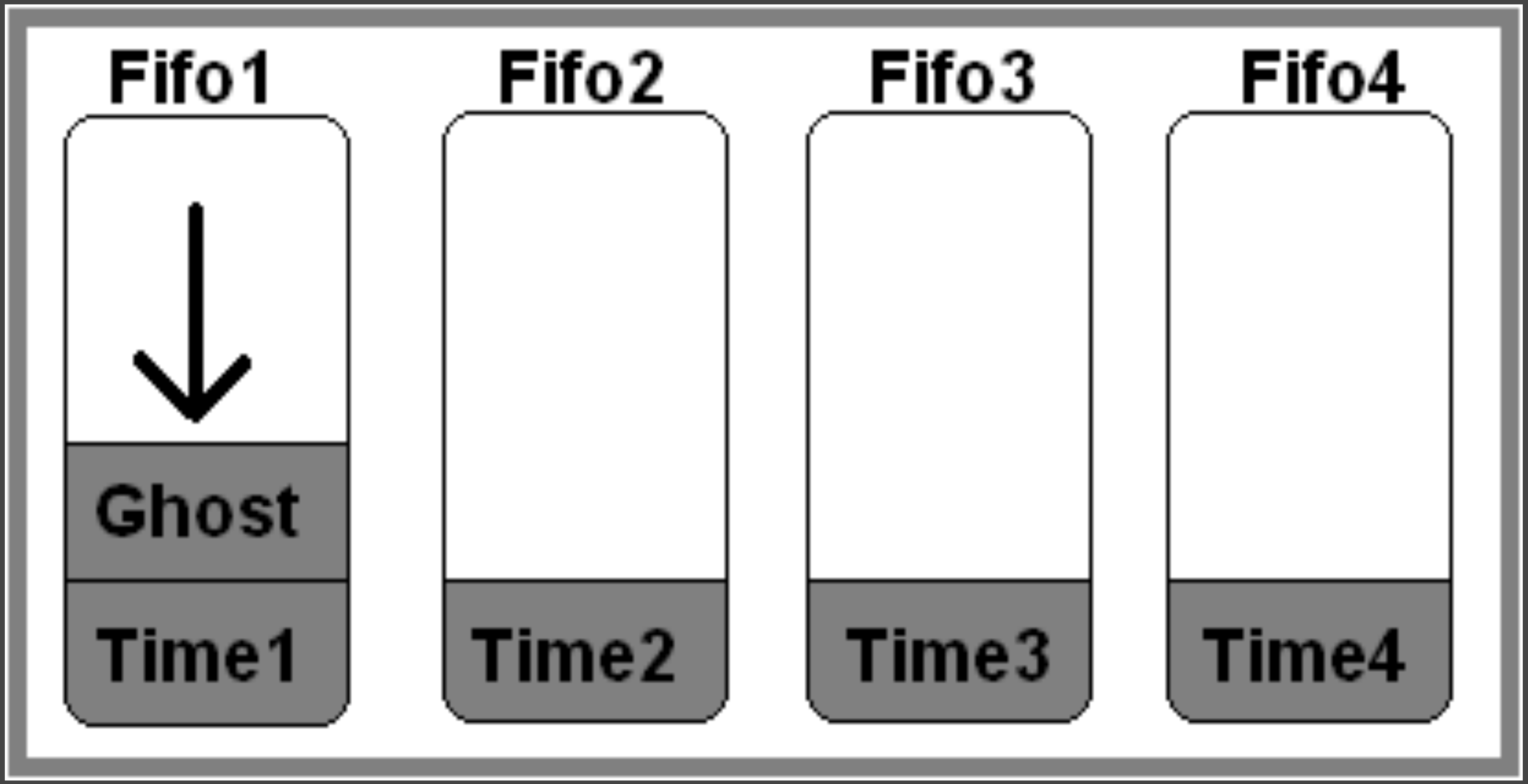


Microcontroller



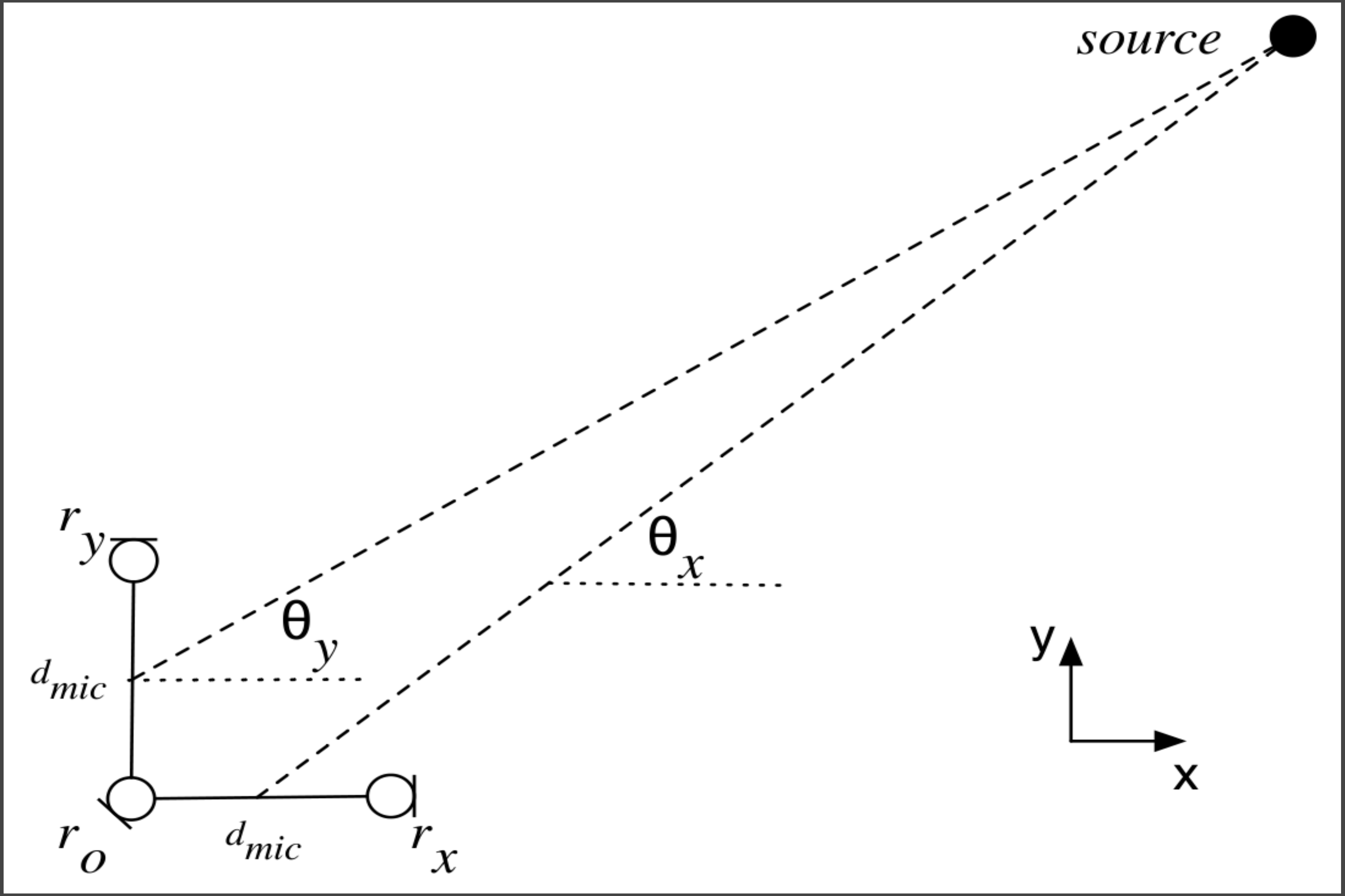
Missed Signal: if last signal is not received after calculated time (transducer spacing / speed of sound), Drop all timers due to missed signal.

Microcontroller



Ghost Signal: If data is ready, send data in groups of four, then empty out the queues.

Multilateration



Multilateration

Travel time to receivers:

$$T_A = \frac{1}{c}\sqrt{(x-x_A)^2+(y-y_A)^2+(z-z_A)^2}$$

$$T_B = \frac{1}{c}\sqrt{(x-x_B)^2+(y-y_B)^2+(z-z_B)^2}$$

$$T_C = \frac{1}{c}\sqrt{(x-x_C)^2+(y-y_C)^2+(z-z_C)^2}$$

$$T_D = \frac{1}{c}\sqrt{(x-x_D)^2+(y-y_D)^2+(z-z_D)^2}$$

Put site A at the origin:

$$T_A = \frac{1}{c}\sqrt{x^2+y^2+z^2}$$

Time difference of arrival to receivers:

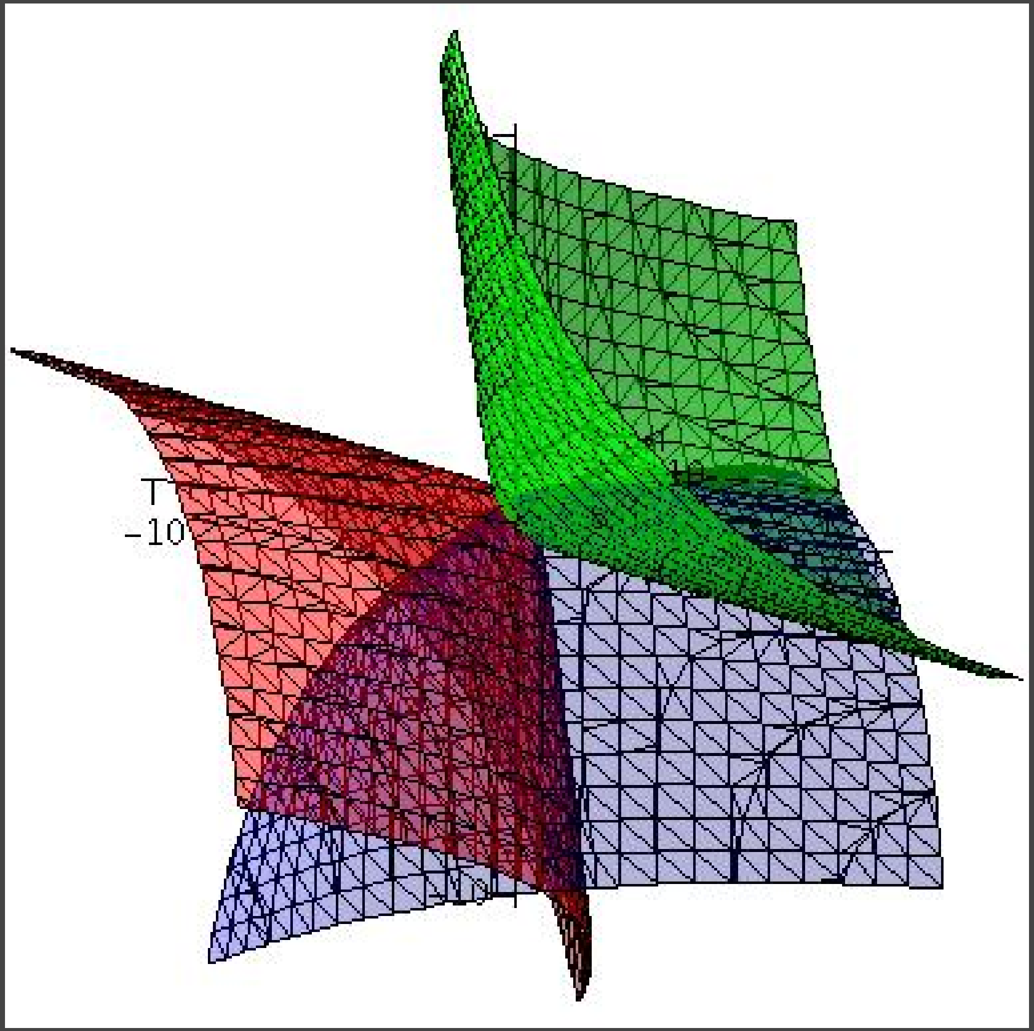
$$\tau_B = T_B - T_A = \frac{1}{c}\left(\sqrt{(x-x_B)^2+(y-y_B)^2+(z-z_B)^2} - \sqrt{x^2+y^2+z^2}\right)$$

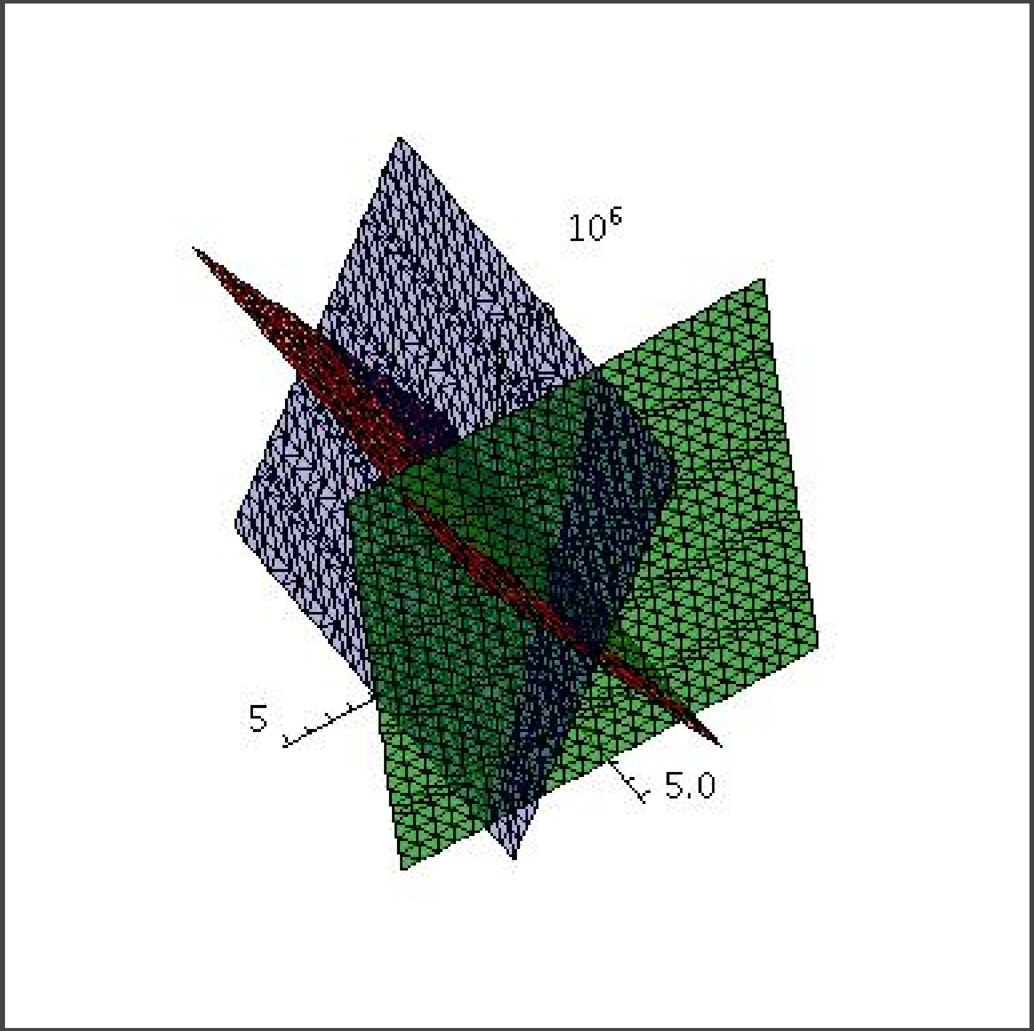
$$\tau_C = T_C - T_A = \frac{1}{c}\left(\sqrt{(x-x_C)^2+(y-y_C)^2+(z-z_C)^2} - \sqrt{x^2+y^2+z^2}\right)$$

$$\tau_D = T_D - T_A = \frac{1}{c}\left(\sqrt{(x-x_D)^2+(y-y_D)^2+(z-z_D)^2} - \sqrt{x^2+y^2+z^2}\right)$$

Source: Wikipedia

Multilateration





Risks

Risk: Our transducers are not omnidirectional
Mitigation: We will require the transmitter to be within line of sight, facing the receiver.

Risk: Noisy and attenuated signals reduce timing accuracy.
Mitigation: Aggressive filtering and amplification.

Risk: Microcontroller to Computer bandwidth limitations. We can send about 8 KBytes / s, Timer values only will be about 320 Bytes/ s. Computer load affects this.
Mitigation: Computer will be free of running programs / services. Other options include different MCU firmware that can be faster.

Risks

Risk: Input Capture might be delayed, If two Input Captures need to be serviced at the same time.
Mitigation: Test rigorously. External hardware latching.

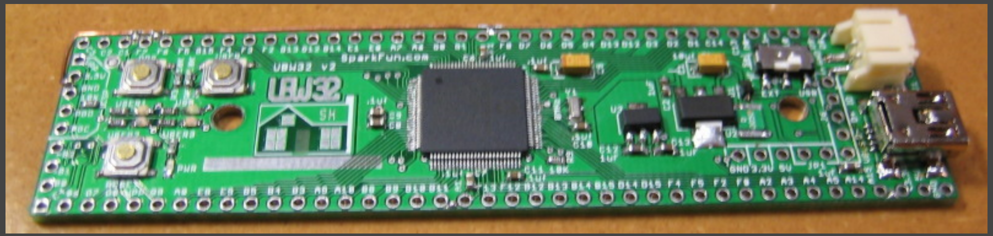
Risk: Missed signals and ghosts too frequent, causing gross errors.
Mitigation: Software side error correction. Sampling and averaging.

Bill of Materials

MaxSonar Range Finder: $24.95

MaxSonar Ultrasonic TransducersX4: $19.80

UBW32 $39.95



Questions?