An Ultrasonic/Optical Pulse Sensor for Precise Distance Measurements

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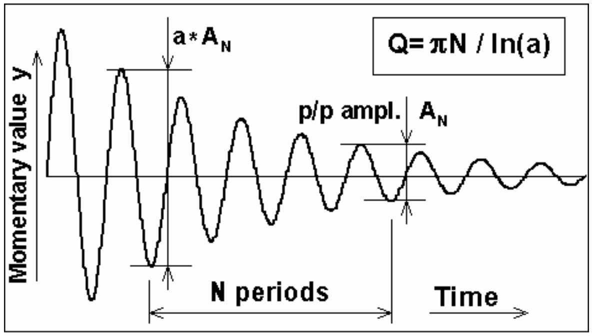
Goals

- Develop an ultrasonic transit time distance sensor with an optical sync signal
- Demonstrate a pulse cancellation technique for shaping transmitted and received ultrasonic pulses.

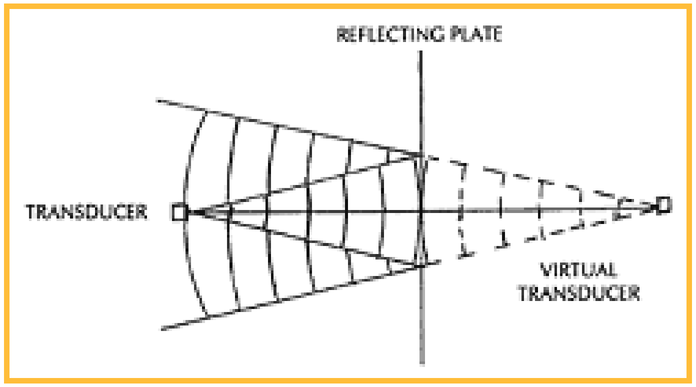
Ultrasonic Transmitter/Receiver Transducers

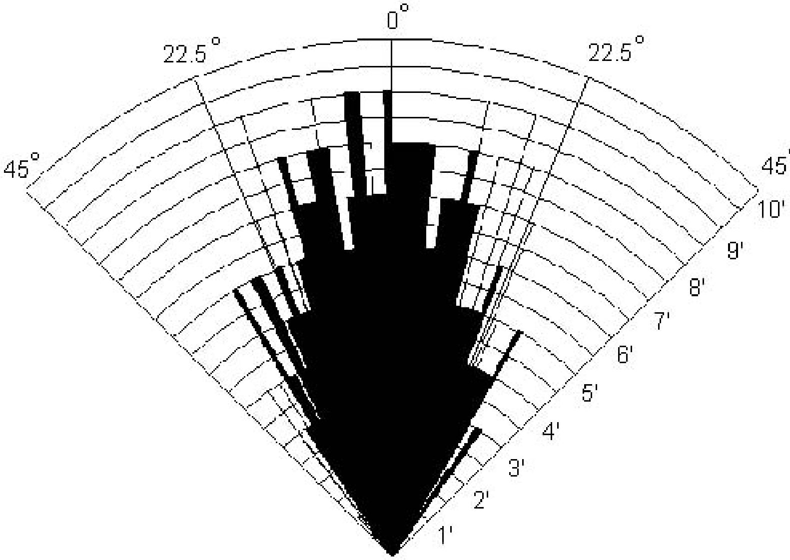
- Transducers are piezoelectric crystals (quartz, ceramic, piezofilm)
- Single or separate transmitter and receiver transducers may be used
- Typical Frequencies used for air transmission are 40 to 100 kHz
- Single pulse produces ringing because of crystal mechanical resonance



- Often a pulse train (4 to 20 cycles) is applied to transmitter to increase transmitted sound amplitude

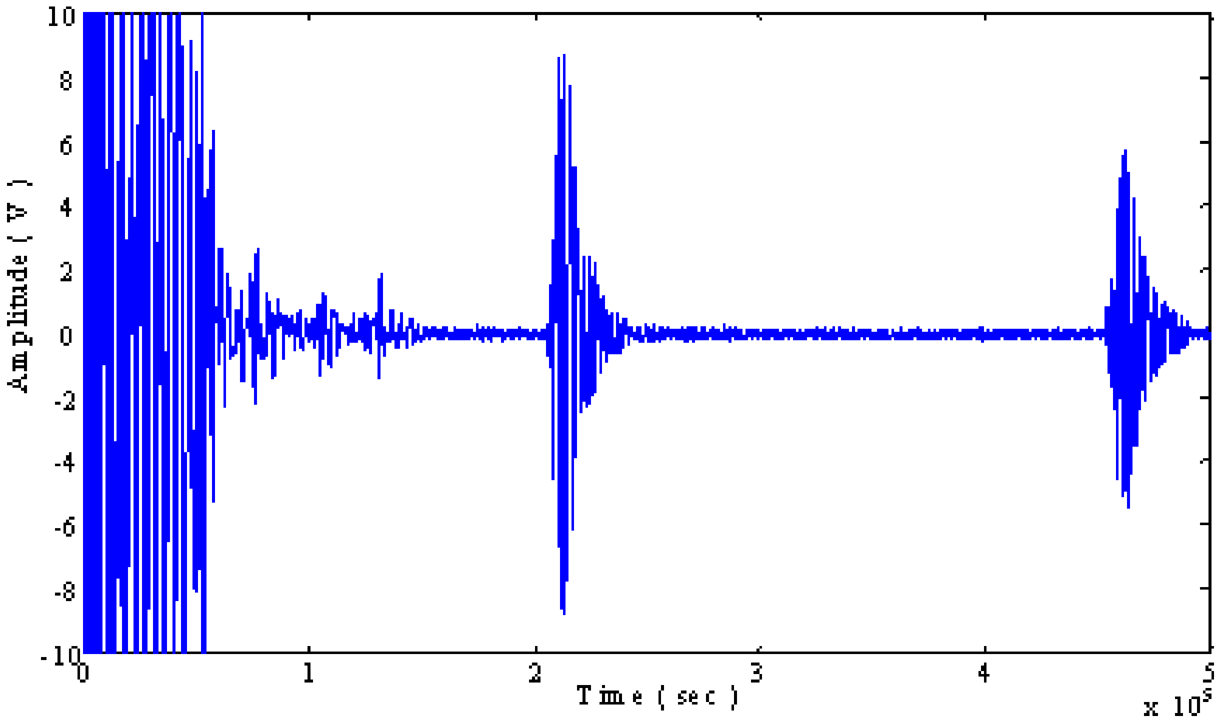
Conventional
Ultrasonic Echo Sensors





Speed of sound in Air @ 20 °C
343 Meter/sec

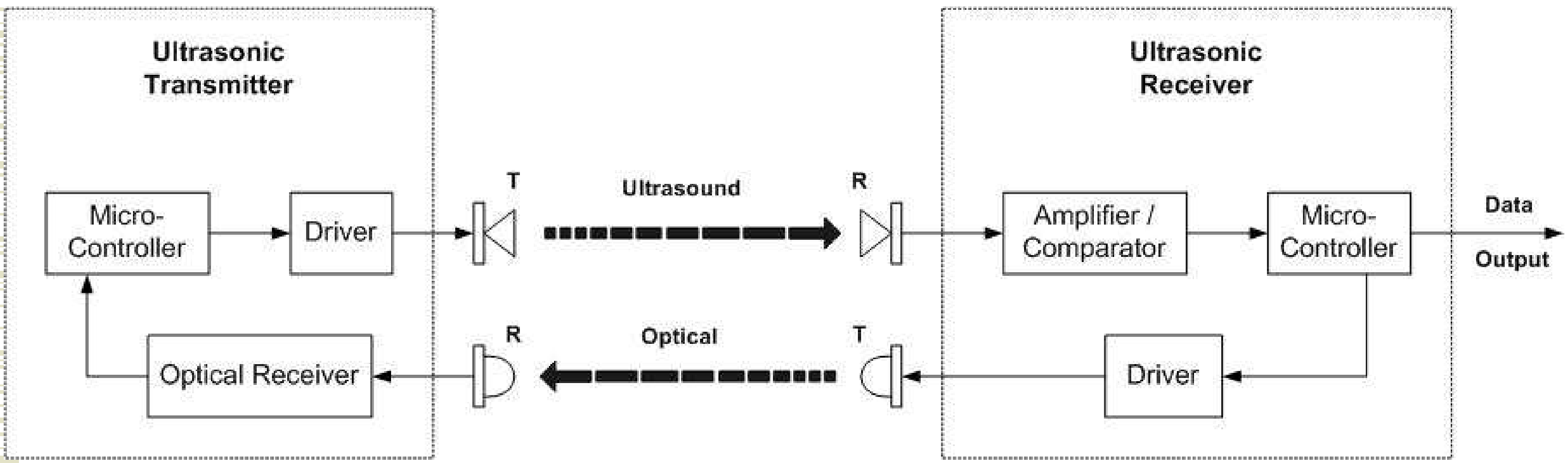
Typical US Echo Waveforms



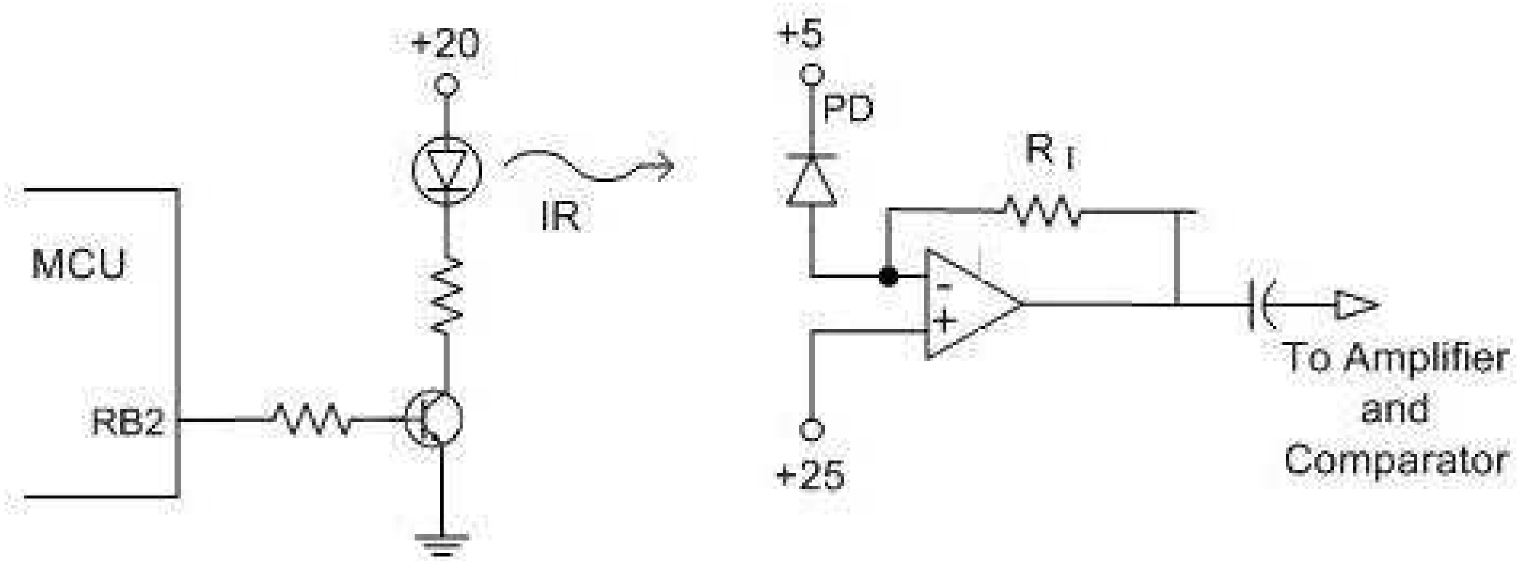
Limitations of US Echo Sensors

- Sound intensity decreases rapidly with distance (inverse square) – limit is 5 to 20 meters under ideal conditions
- Sound (echo) is small for many objects (e.g. cloth)
- Focused beams increase signal strength (and distance) but aiming is a problem
- Wind and air currents deflect sound (refraction) causing signal dropout (often after 1-5 meters)
- Slow rise of reflected signal amplitude limits distance resolution to 2 to 10 wavelengths (2 to 8 cm @ 40kHz)

System Block Diagram

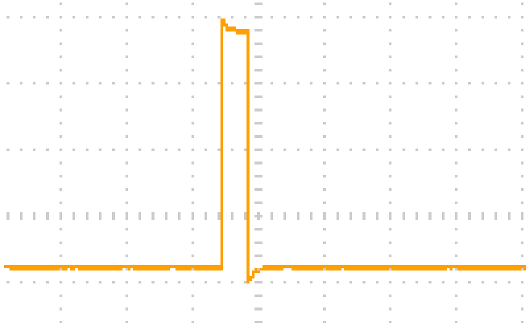


Optical Transmitter and Receiver



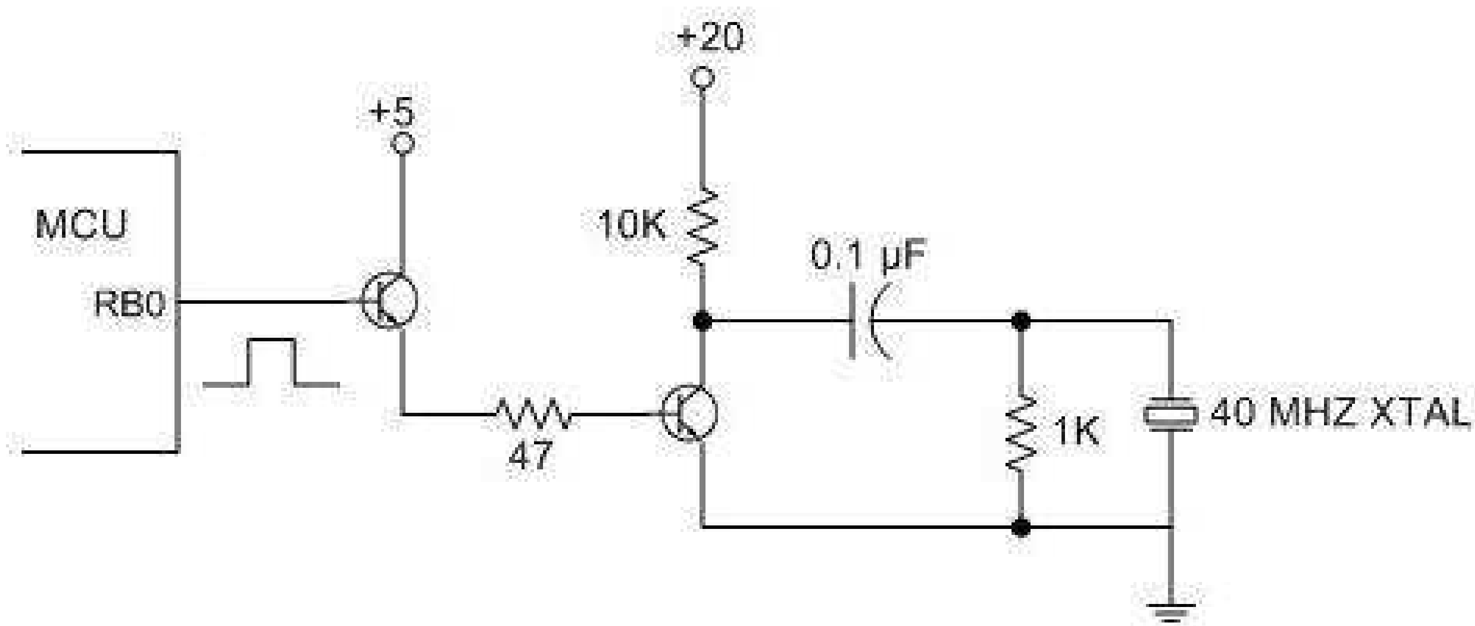
Optical Pulse Filtering

- Room illumination larger than optical sync pulses but dc or low frequency (mostly < 120 Hz)
- Sync pulse must be short, i.e., have only high frequency components
- Optical amplifier must have high pass filter

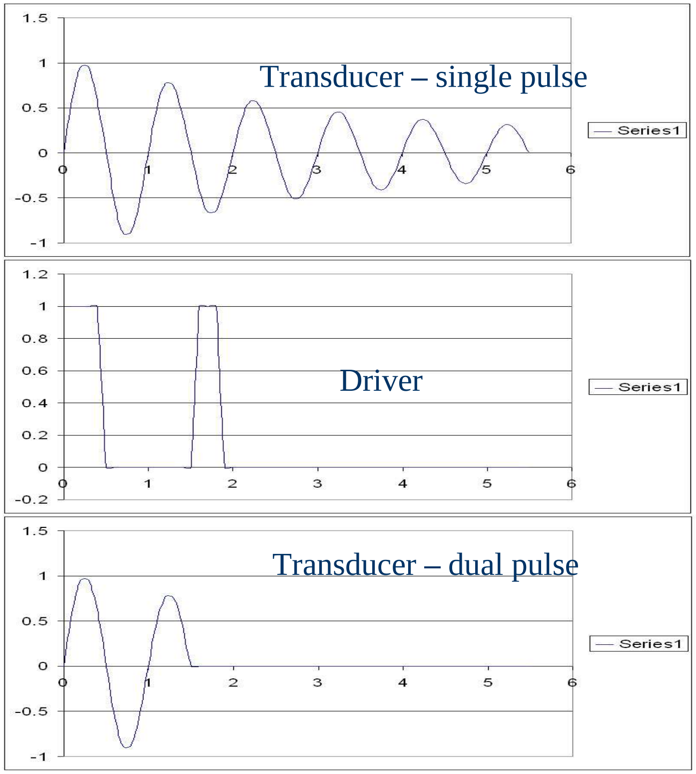


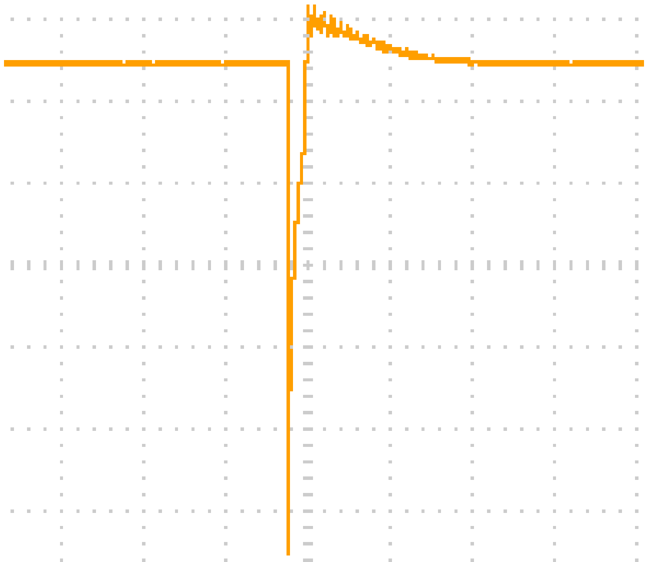
Received Optical Pulse

Ultrasonic Driver Circuit



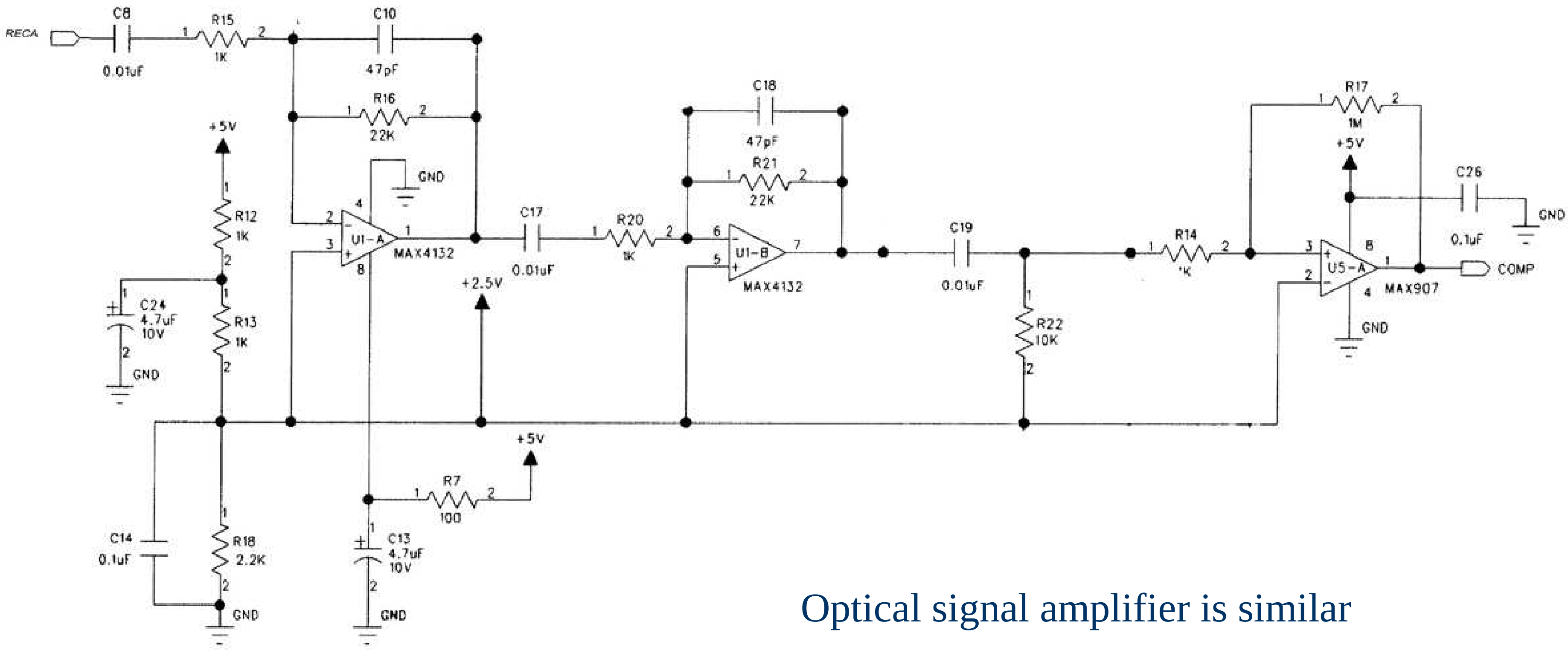
Delayed Pulse Shaping Method





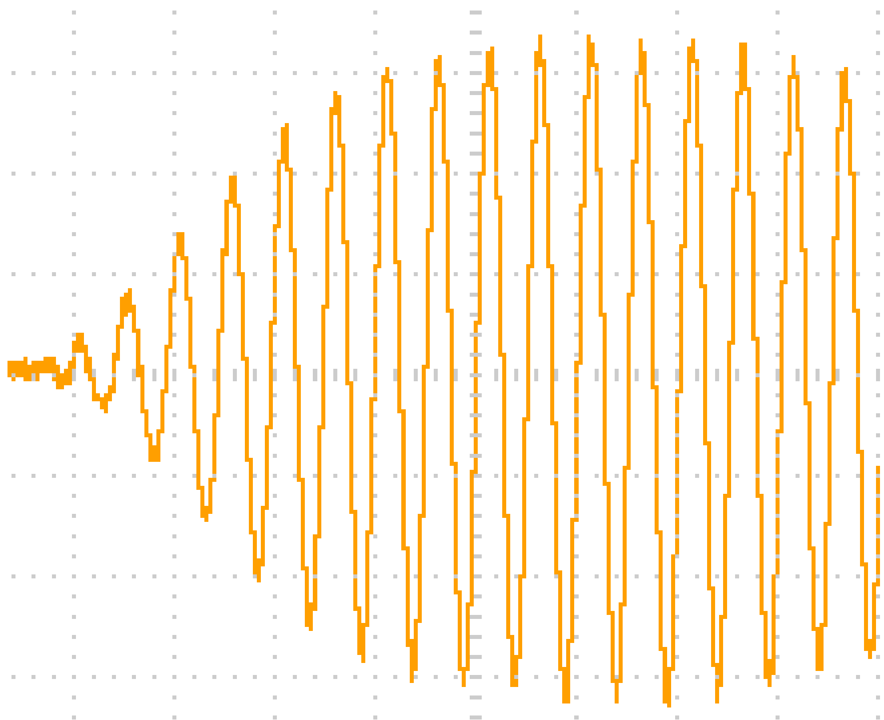
Measured Transmitter Voltage

Ultrasonic Receiver Circuit

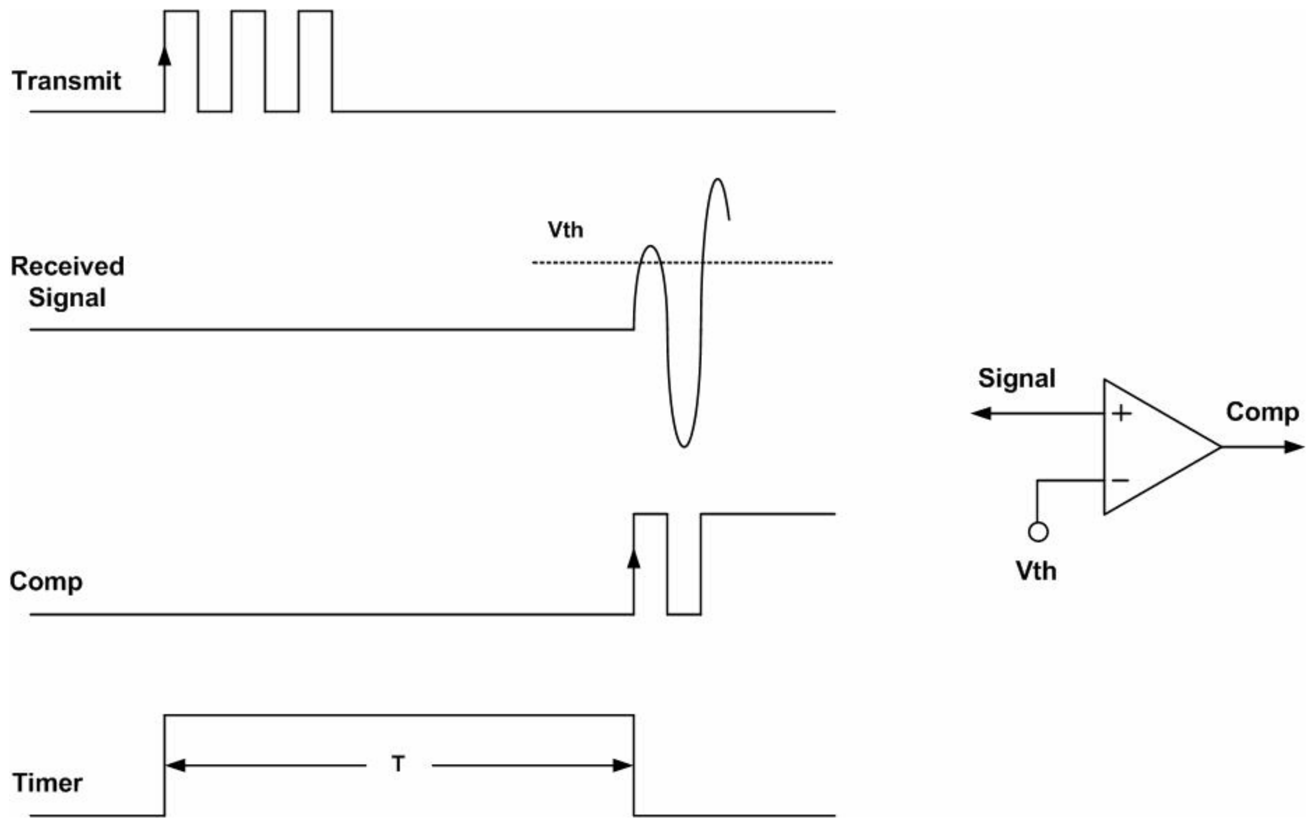


Optical signal amplifier is similar

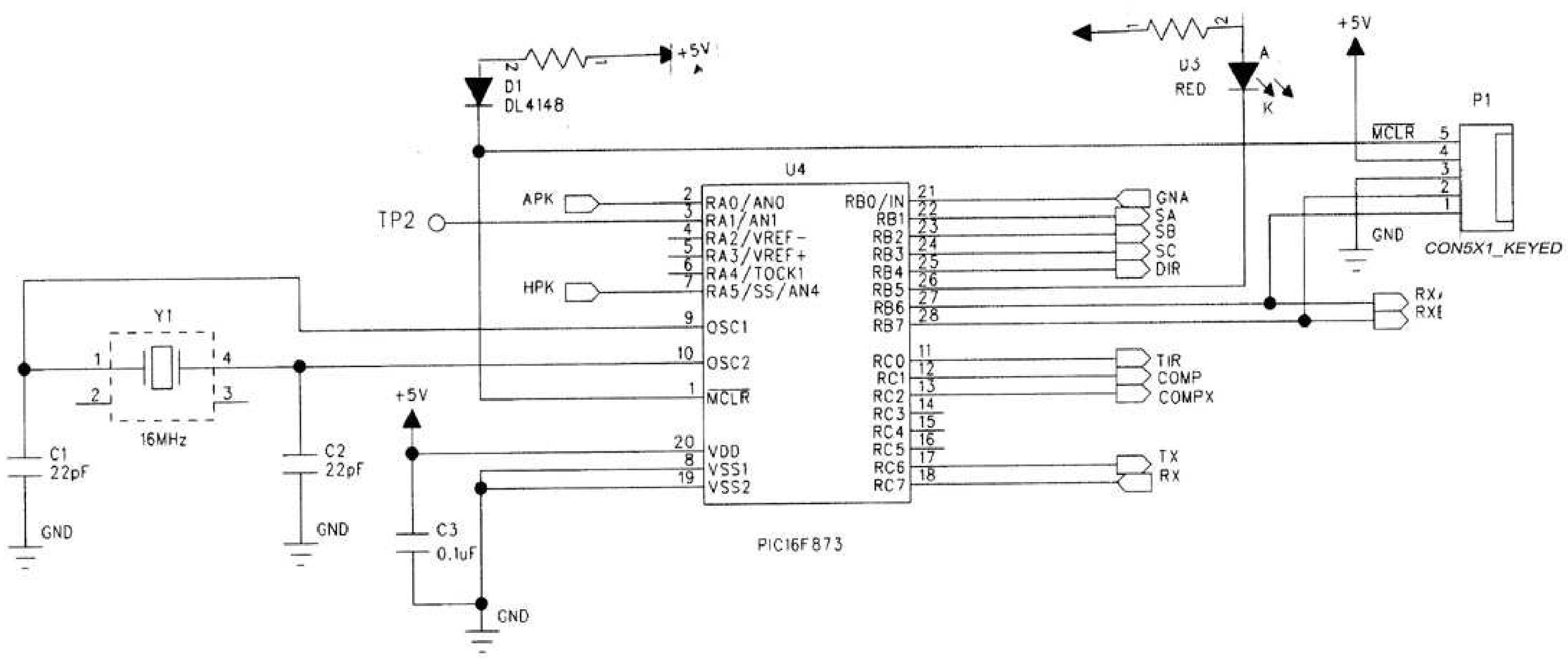
Received Ultrasonic Signal Waveform



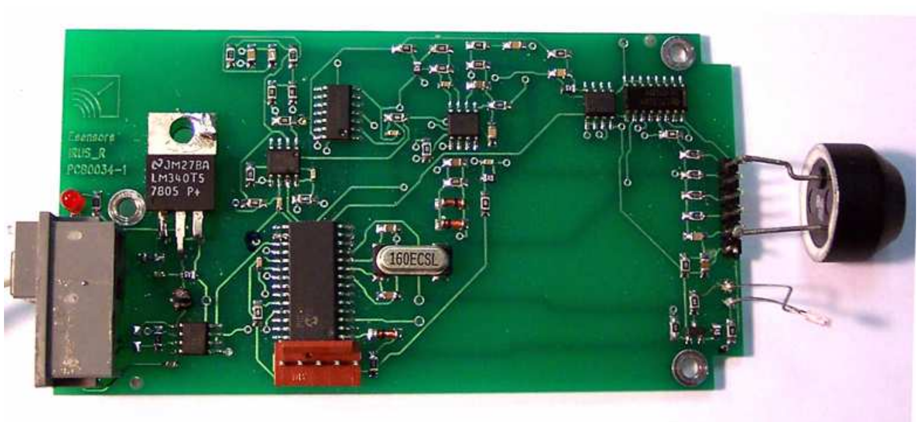
US Comparator and Transit Time Determination



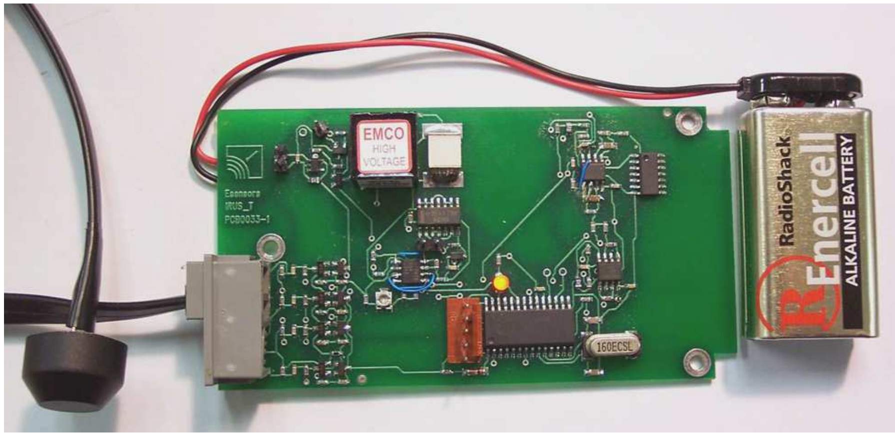
Microcomputer Circuit



Ultrasonic/Optical Sensor Circuit boards

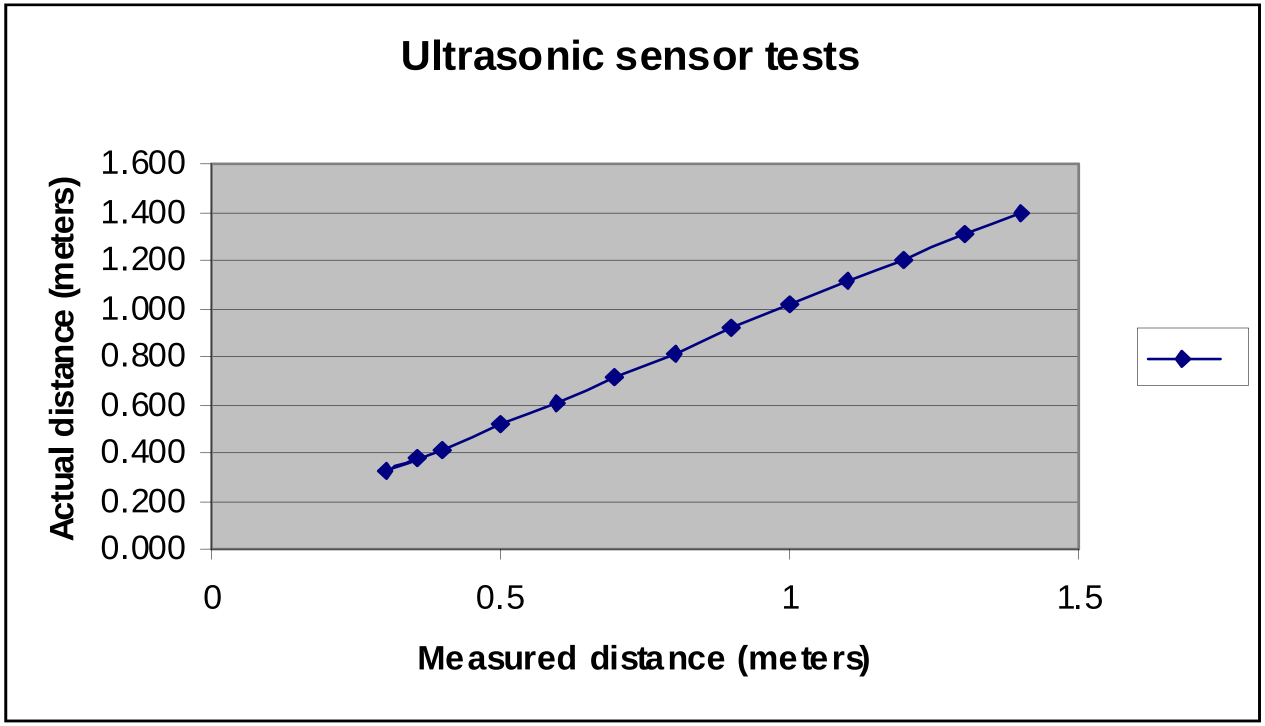


Ultrasonic Receiver
(optical transmitter)

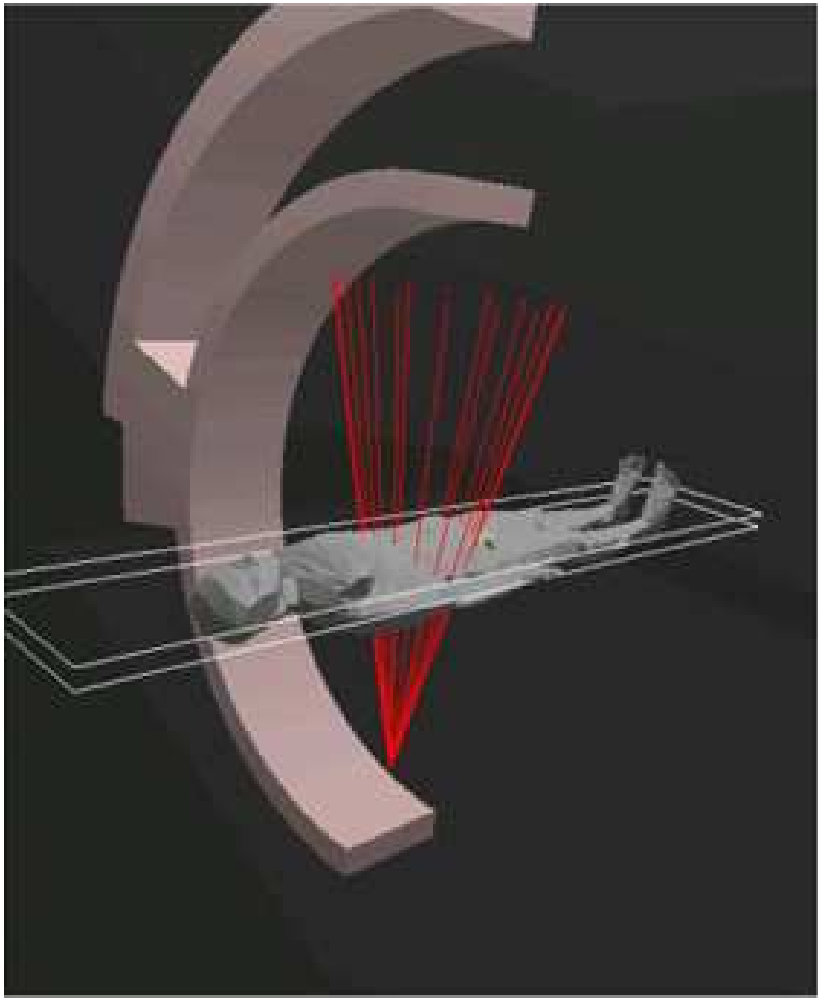


Ultrasonic transmitter
(optical receiver)

Measured Precision



Application ---
An x-ray Dose Monitor Positioning Sensor



Suggested Applications

- Virtual Reality

  Locate relative position of hands and other objects
- Robots

  Locate position of robots or small vehicles in a room
- Machine motion

  Position of moving parts of a machine can be measured

References

- R. John Webster and R. Pallas-Areny "Sensors and Signal Conditioning", 2nd Ed., John Wiley & Sons, 2001
- R. Frank "Understanding Smart Sensors", 2nd ed, Artech House (2000)
- G. Bucci and C. Landi, "Numerical Method for Transit time measurement in Ultrasonic Sensor Applications IEEE Transactions on Instrumentation and Measurement", Vol. 46 No.6, Dec 1997.

Summary

- An ultrasonic pulse shaping technique based on two delayed transmitted pulses was described.
- An optical pulse technique for synchronizing ultrasonic pulses was described
- The precision of the combined ultrasonic transit time distance sensor with optical pulse synchronization was demonstrated.

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