COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Columbia Integrated Systems Laboratory

MOSIS

Contacts:

Daniel de Godoy Peixoto
dd2697@columbia.edu

Miguel F Costa
mfc2141@columbia.edu

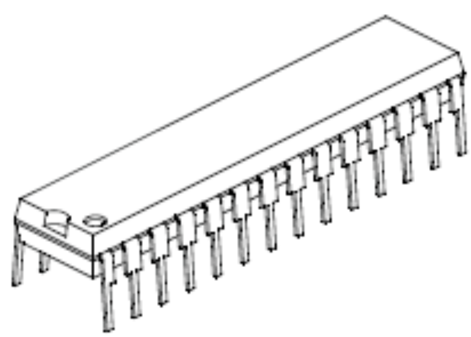
DM6350 Datasheet
Portable Ultrasonic Distance Sensor Driver

REV_1.0

System Datasheet

Features:

- Tunable frequency of operation
- Compatible with most ultrasonic transceivers
- Ultralow power consumption: 1mW



Applications:

- Object detection
- Distance Sensor
- Densitometer
- Flow meter

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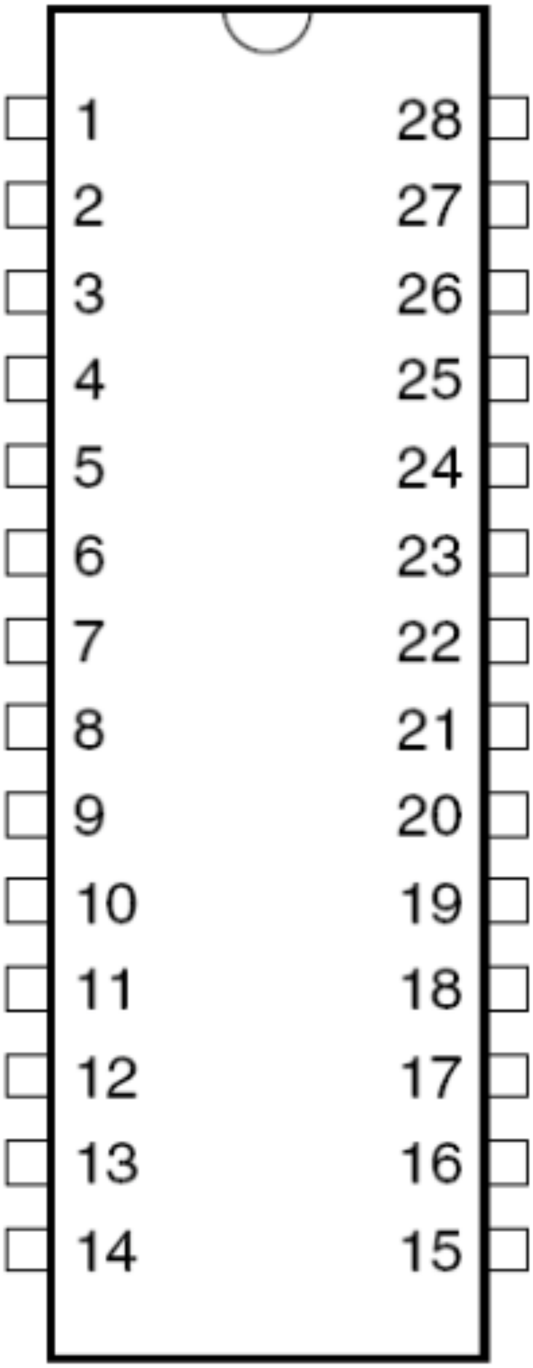

Figure 1: Pin Diagram

PIN1	VDD
PIN2	VDD
PIN3	Front_End_Out
PIN4	DC_Feedback
PIN5	Vsig
PIN6	Not Connected
PIN7	Vcm
PIN8	IBIAS1
PIN9	IBIAS2
PIN10	Not Connected
PIN11	Vcomp
PIN12	OUT
PIN13	Not Connected
PIN14	GND
PIN15	GND
PIN16	Not Connected
PIN17	Filter_Out
PIN18	OTA_Filter_N
PIN19	OTA_Filter_P
PIN20	Not Connected
PIN21	Mixer_out_1
Pin22	Not Connected
PIN23	Mixer_out_2
PIN24	Not Connected
PIN25	Not Connected
PIN26	Buffer_out
PIN27	Buffer_in
PIN28	VDD

Table 1: Pin Assignment

Active Pin Descriptions

VDD	Power Supply
Front_End_Out	Output of the front end
DC_Feedback	Input for the DC value of the front end
Vsig	Input from the ultrasonic transducer
Vcm	Common mode voltage for the two Op-Amps in the front end
IBIAS1	Bias current for the current mirrors
IBIAS2	Independent bias current for the level shifter
Vcomp	Threshold voltage of the comparator
OUT	Digital output signal
GND	Ground
Filter_Out	Output of the low-pass filter
OTA_Filter_N	Negative input of the low-pass filter
OTA_Filter_P	Positive input of the low-pass filter
Mixer_out_1	First output of the differential mixer
Mixer_out_2	Second output of the differential mixer
Buffer_out	Buffer output
Buffer_in	Buffer input

Table 2: Pin Descriptions

Specified Operating Conditions

Power Supply	**1.8V**
Biasing Current 1	**40µA**
Biasing Current 2	**40µA**
Temperature	**-40°C – 125°C**

Table 3: Operating Conditions

Functional Block Diagram

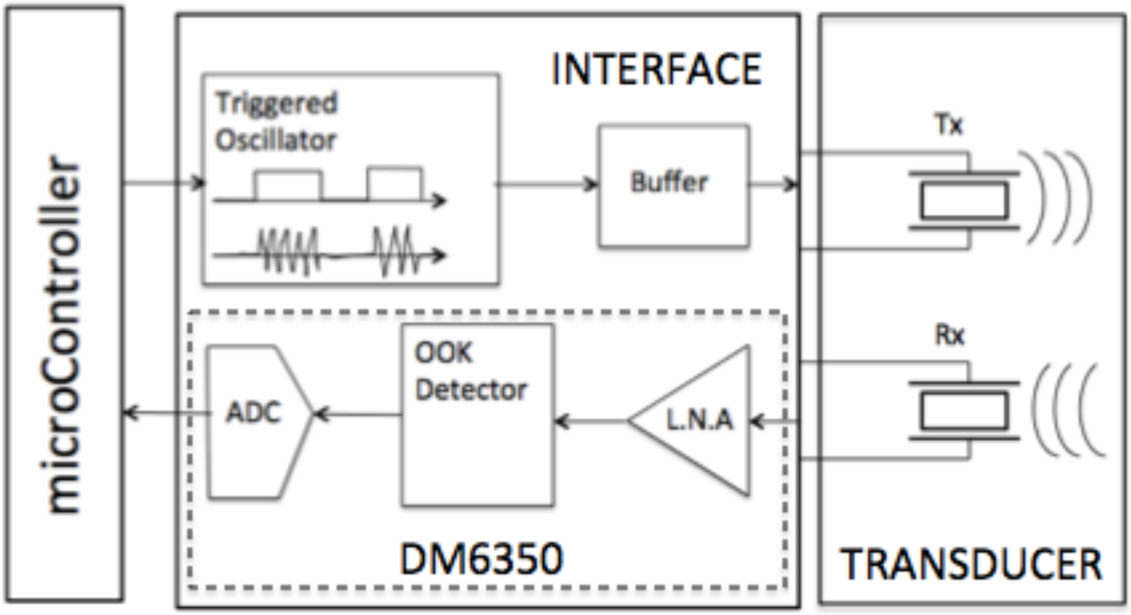

Figure 2: System Functional Block Diagram

Specifications

Pin Configuration and Function Description

The system is packaged in the DIL28 form factor. This package provides 20 active pins for interface and testing purposes. Given the demonstrative nature of the circuit, 1 pin is used to handle transceiver input and 1 for output. 3 pins are used to connect the supply voltage of 1.8V and 2 to connect ground. 2 additional pins are required to supply 40μA bias currents. The remaining 11 pins are dual-purpose: they facilitate connection of external resistors and capacitors while also serving as test access to signal sampling points interspersed throughout the circuit. A more detailed overview of pin connections is provided in the sample circuit section.

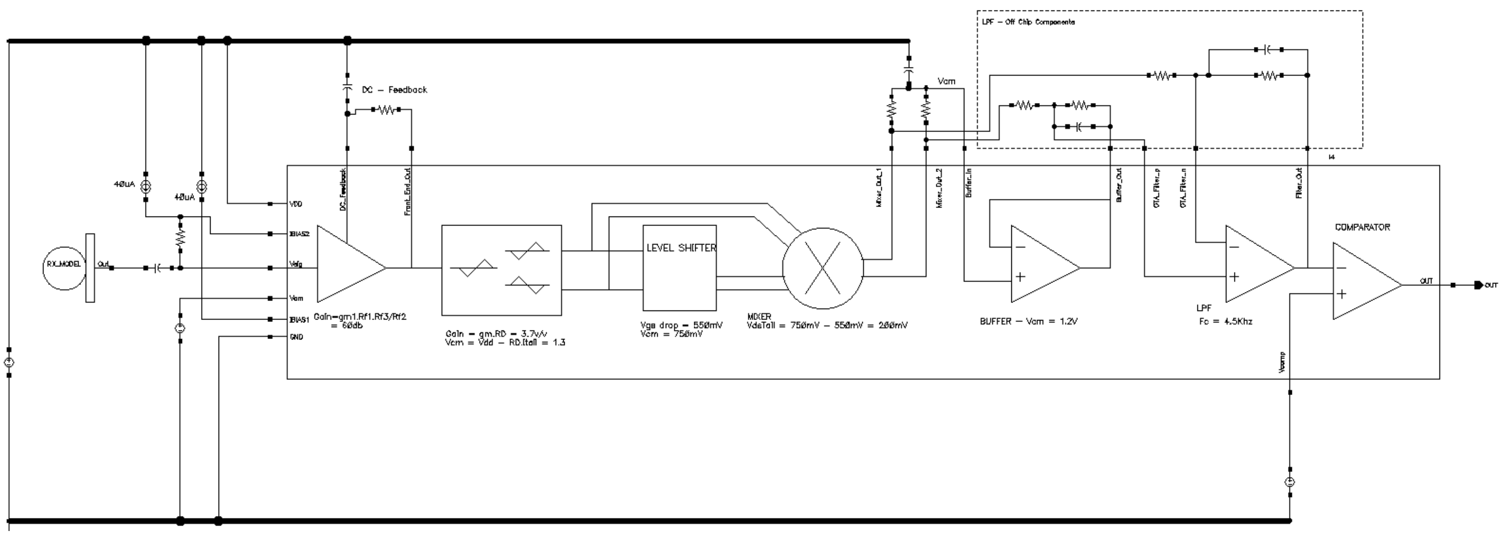

Figure 3: System Pin Configuration

System Specification

The following table summarizes the key parameters of the driver IC:

Parameter	Value
Detect Modulation Scheme	OOK
Supply Voltage	1.8V
IC Technology	0.18um CMOS
Chip Area	1.24mm^2
Package	DIL28
Active Power Consumption	1mW

Table 4: Key Specifications

Mechanism

Self-mixing Demodulator

The self-mixing scheme of demodulation refers to a scheme where the OOK signal is first amplified in a low-noise amplifier, self-mixed using a Gilbert cell to its basebanded equivalent, and then filtered with a low-pass filter.

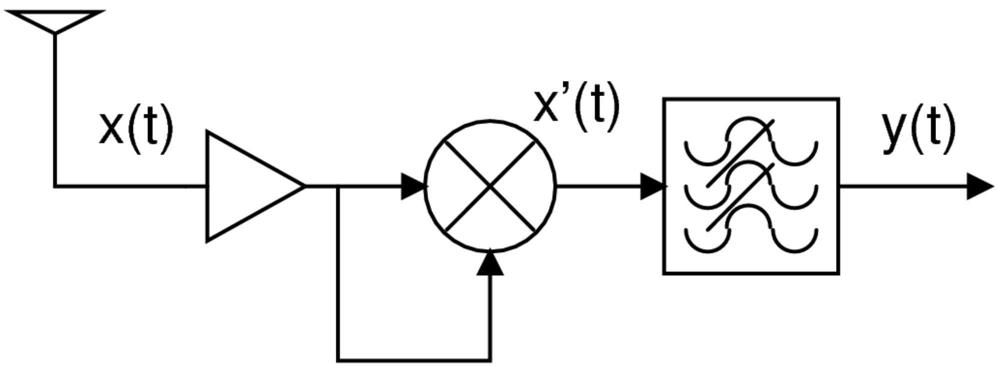

Figure 4: Self-Mixing Scheme

Assuming that the input signal is a pure tune:

$$x(t) = A.\cos(\omega t)$$

If the LNA has a linear gain of K_{LNA} and the mixer equation is of the form $x'(t) = \alpha_{MIXER}.x^2(t)$, the resulting signal after the mixer can be derived as:

$$x'(t) = (K_{LNA}A)^2.\alpha_{MIXER}\left(\frac{1}{2} + \frac{1}{2}\cos(2\omega t)\right)$$

If a low pass filter with a cutoff frequency lower than 2ω is placed after the mixer, the output $y(t)$ is:

$$y(t) = \frac{1}{2}K_{FILTER}(K_{LNA}A)^2.\alpha_{MIXER}$$

Note that the amplitude of $y(t)$ is proportional to the square of the input signal envelope. In this application the input signal is a 40 KHz OOK with a 200µs burst time and an interval of 2ms to 20ms.

System Waveforms

In typical operation the system functions as follows:

- The Microcontroller sends a 200µs pulse to the emitter interface that sends a 40Khz wave to the transducer while the pulse is on.
- Due to directly conducted vibration, the receiver and DM6350 sense this immediately and send a logic level high to be interpreted by the microcontroller.
- The ultrasonic wave is received again after rebounding off of an object in range. Another logic level high is produced by the DM6350 and sent to the microcontroller.
- The microcontroller calculates the interval between the rising edges of the pulses (Δt) and displays the distance based on the velocity of sound.

Even though the processing times for the driver and microcontroller are several orders of magnitude below the travel times for the ultrasonic pulse in operation, this “calibration” of the timing further enhances system accuracy.

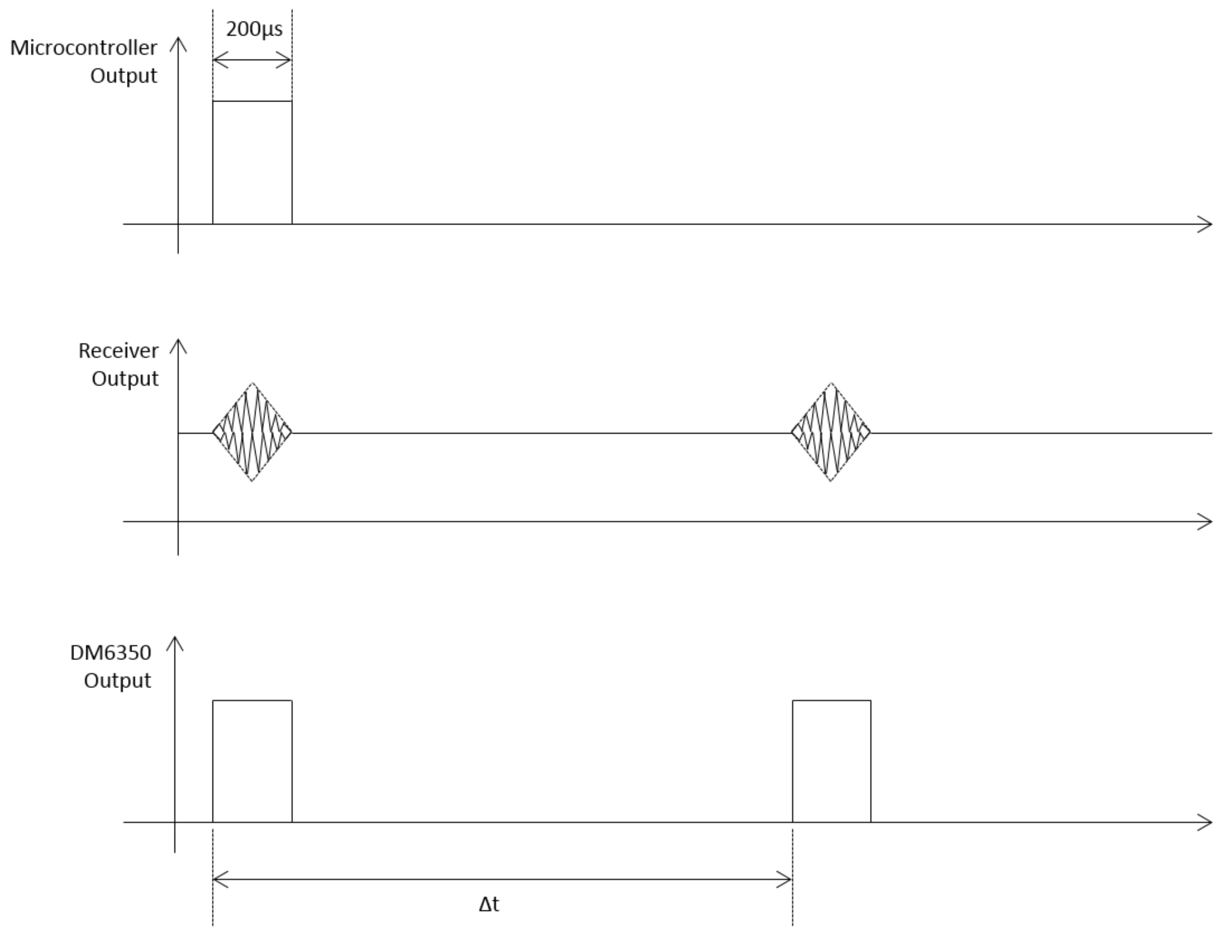

Figure 5: System Waveforms

Application Specification

The overall specification for a typical complete sensor application of the driver with readily available components can be projected with the following setup:

The microcontroller subsystem is implemented with an Arduino Uno as it can perform all required functionality at a low cost in a small footprint. A simple custom PCB allows all components to be connected in a similarly small area. The other components are readily available from suppliers.

The components and their costs are summarized in the following table:

Subcomponent	Cost (USD)
Arduino Uno	20
Custom PCB	10
Ultrasonic Transciever	2.5
Capacitors, Resistors, and Switches	2.5
Simple LCD	5
Miscellaneous Costs	5
Total Cost	45

Table 5: Demonstration Platform BOM

The overall functionality of the complete system is summarized in the following table:

Parameter	Value
Burst timing	200us @ 40kHz
Return time (Min/Max)	0.9-18ms
Detectable range (Min/Max)	0.15-3m
Maximum error (0-70°C)	12%
Active supply current	500µA
Active battery life (2x 800mAh AA)	3200h (133 days)

Table 6: Demonstration Platform Specifications

Receiver Sample Circuit

Direct Receiver Implementation

The following implementation provides a sample receiver hookup using the DM6350 with the Kobitone 255-400ST16-ROX ultrasonic transceiver.

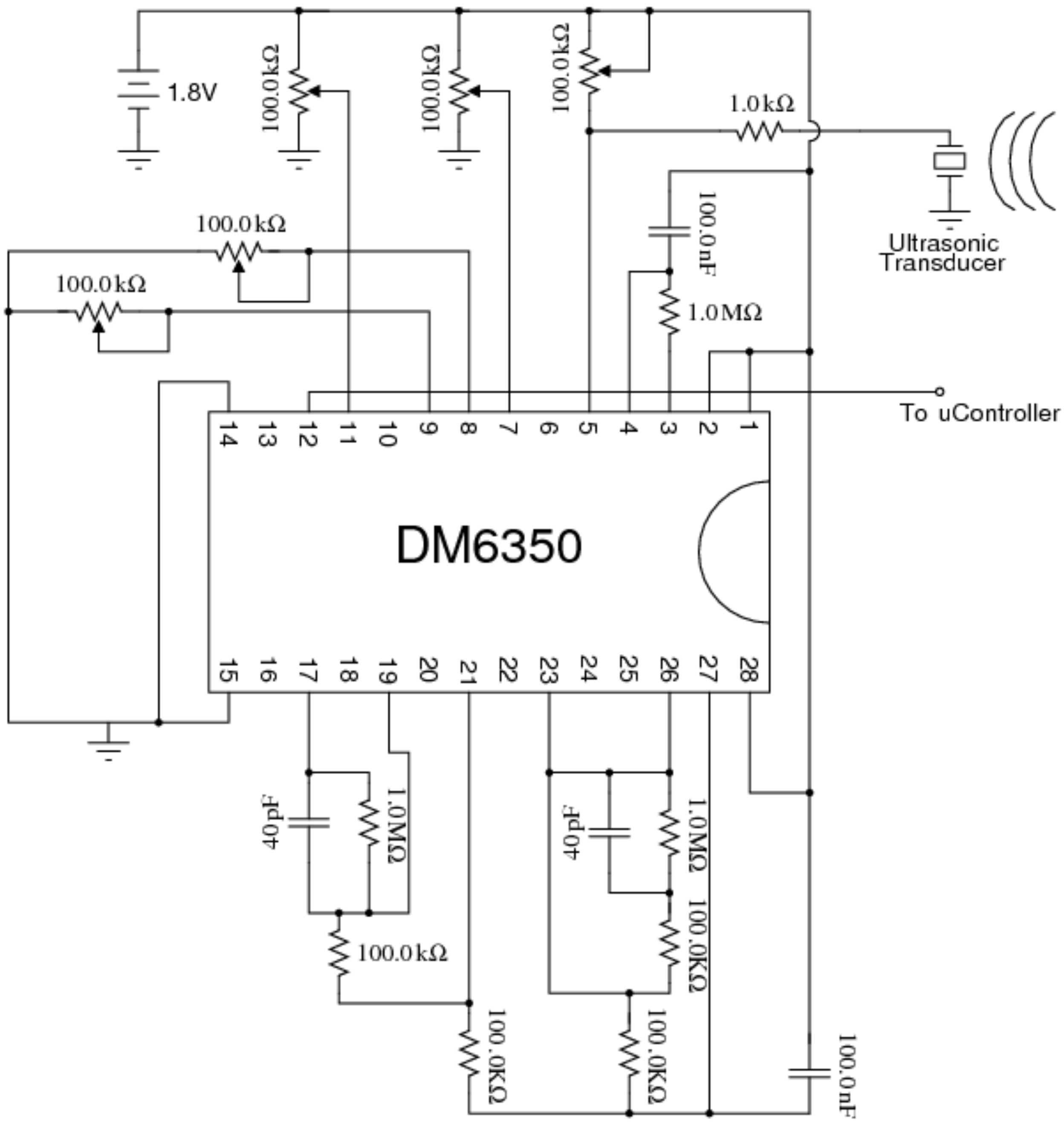

Figure 6: Receiver PCB schematic

This demonstration circuit delivers the following output waveforms in post-parasitic-extraction Spectre simulation:

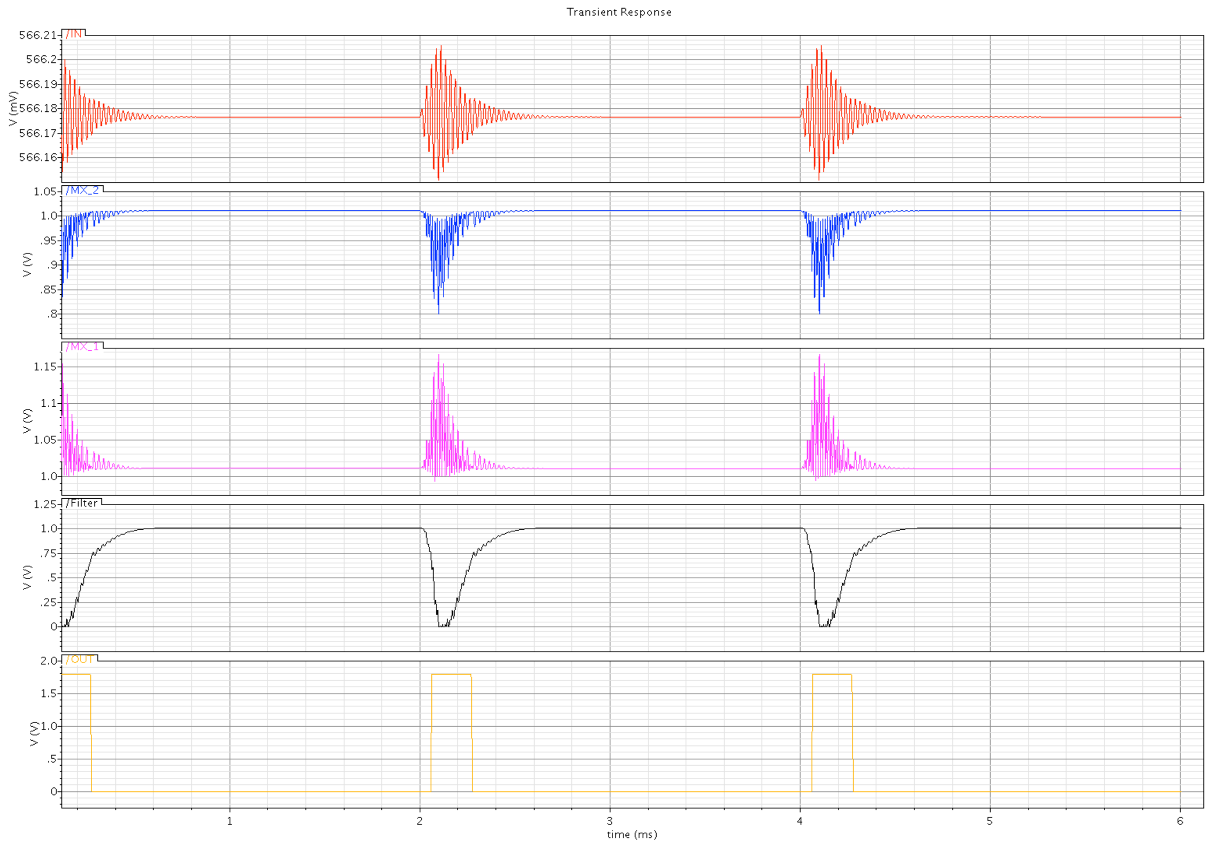

Figure 7: Receiver circuit simulation results

Here we provide an input signal of less amplitude less than 50µV, corresponding the transduced ultrasonic echo at the maximum specified distance of 3m. We can see that even with this hugely degraded signal we are able to achieve full switching behavior with full rise and fall transitions of less than 0.61 and 0.87µs respectively, which from the speed of sound at sea level correspond to a total contributed error of less than 0.53mm, a practically negligible contribution.

References:

Baradwaj Vigraham, Peter R. Kinget, An Ultra Low Power, Compact UWB Receiver with Automatic Threshold Recovery in 65 nm CMOS,

Kshitij Yadav, Ioannis Kymissis , and Peter R. Kinget, A4.4- Wake-Up Receiver Using Ultrasound Data

http://www.best-microcontroller-projects.com/ultrasonic-rangefinder.html

http://www.ichinoseki.ac.jp/satok/SATOK/ptc/ulm.html

http://www.maximintegrated.com/app-notes/index.mvp/id/4439

http://www.seattlerobotics.org/encoder/apr97/sonar.html

http://www.parallax.com/sites/default/files/downloads/28015-PING-Sensor-Product-Guide-v2.0.pdf