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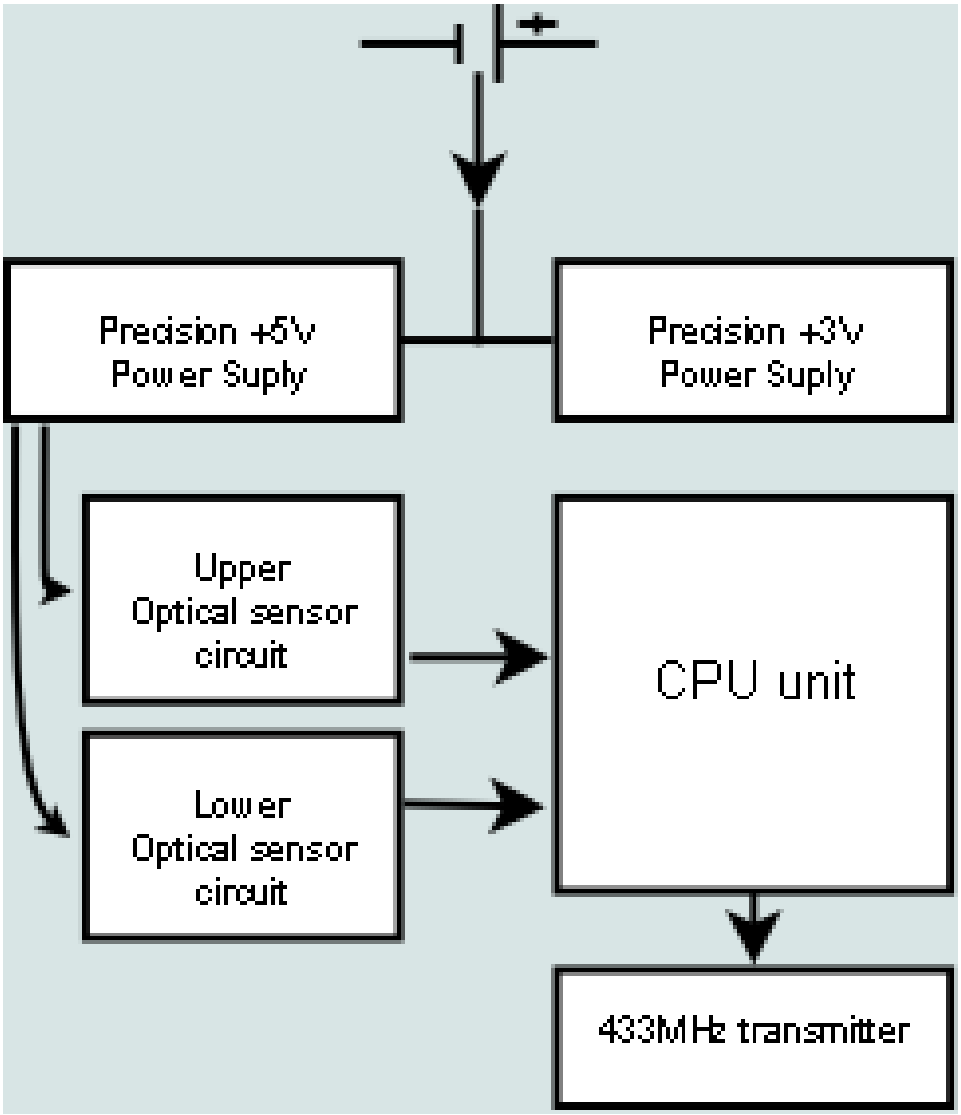
DEÁK DELTA IPARI KERESKEDELMI ÉS SZOLGÁLTATÓ KORLÁTOLT FELELŐSSÉGŰ TÁRSASÁG

Software documentation: Commanding of the sensors and initial data processing

Introduction

Our objective is to detect and count falling small granules – from the viewpoint of an electronic circuit designer. The sizes of the granules have to be estimated. Further requirement is the least possible current consumption, because the whole system must work on battery power source for several months.

The design is built on two main parts. Analog sensor circuitry detects the falling particles with the help of several optical sensors. Once something has been detected, the signals will be analysed by a microcontroller.



Power Supply Design

The power source of the system will be sealed lead acid battery. With relatively frequent battery exchange there is always a risk of connection with the wrong polarity. A serial diode would solve the problem but at the price of some voltage drop. To avoid this voltage drop we choose a reverse parallel Schottky diode with a series 1 ohm resistor as a fuse.

Beyond low supply current low noise is a primary requirement because it directly affects sensor sensitivity. As a result the LP2951 micropower voltage regulator IC has been chosen. To further decrease the noise level, tantalum electrolyte capacitors are used in the optical amplifier stages to bypass power supply noise

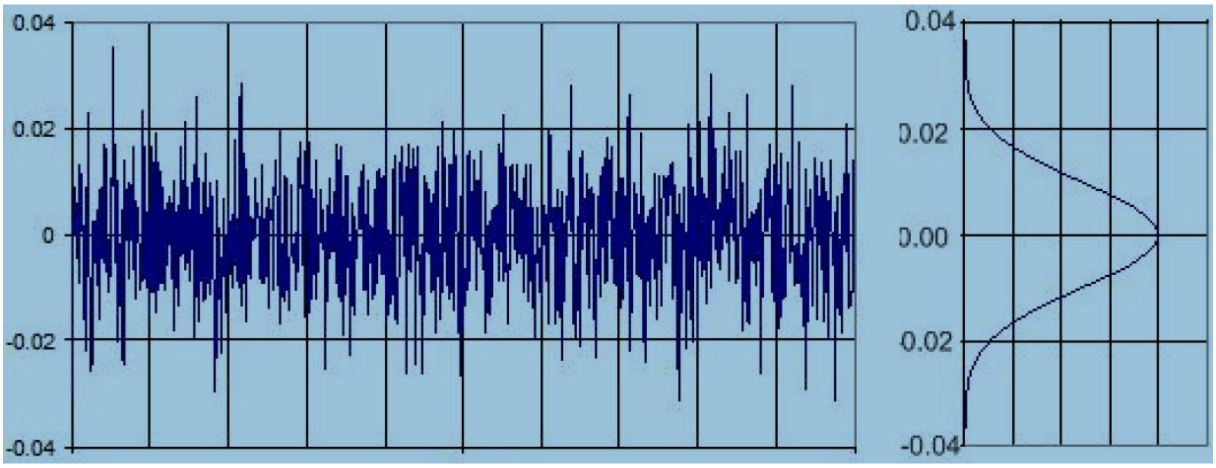
Photo-sensor circuit

The work point of the photodiode is set by a controlled current generator (see Q1 in the schematic of photo-sensor circuit). The generator current is controlled by a negative feedback from the first operational amplifier, which interfaces the photodiode to the rest of the signal conditioning circuits. The feedback signal has a low-pass characteristic with a cutoff frequency of about 200 Hz. Thus, the feedback will not cause attenuation in the amplified signal’s useful frequency range, but will follow fast enough any disturbances caused by temperature alterations or any other electrical instability. The actual useful frequency range depends on what kind of objects are falling from what height. Initial investigations showed that faster then 1 ms, and slower then 10 ms will not move anything at the optical sensors. After the first amplifier stage two more stages are necessary to achieve the required signal amplitude.

The output of the photo-sensor circuits is fed to the CPU unit. The analog pulse amplitude will be integrated by the firmware and used to estimate the size of the falling object.

The photo-sensor circuit’s noise amplitude shows a Gaussian distribution (see the diagram below). This explains the phenomenon that was experienced during the development. No matter how high the detection level was set above the noise amplitude, after enough time has passed there was always some false detection.

To make the system more reliable and sensible we decided to use two photo-sensor circuits with the sensors below each other at 20 mm. This way a real object causes detectable output signals at both sensors, while the probability of higher amplitude noise pulses to occur within the specified time interval is greatly reduced.



Analysis of output signals

The resulting signals of the photo-sensor circuits contain information about the size of the detected objects. The first figure shows the output of the photo-sensor circuits as a smaller object is falling through. The upper curve is the output of the upper detector and the middle curve comes from the lower sensor. The third pulse is a test response from the CPU.

The delay from the upper to the lower sensor is about 8 ms.

The second figure shows the results of a larger object. The amplitude is higher, the pulse is wider and the delay time is about twice as much as with the smaller object.

Schematic of photo-sensor circuit

If you want to see this picture, you have to log on.

Schematic of CPU board

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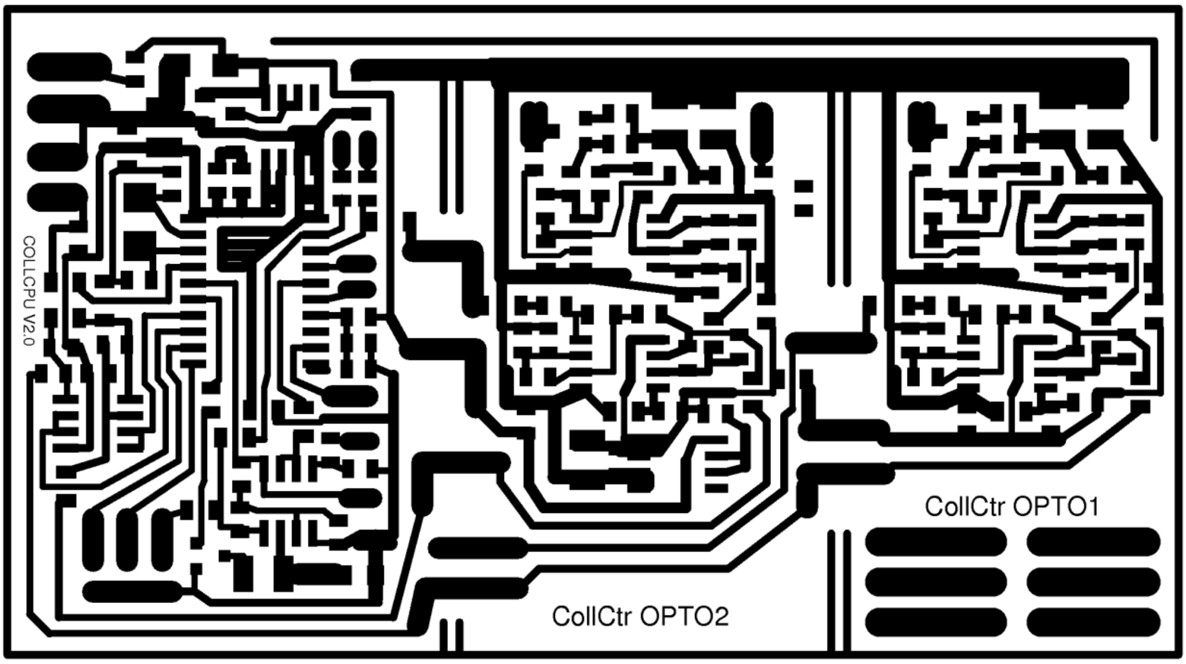
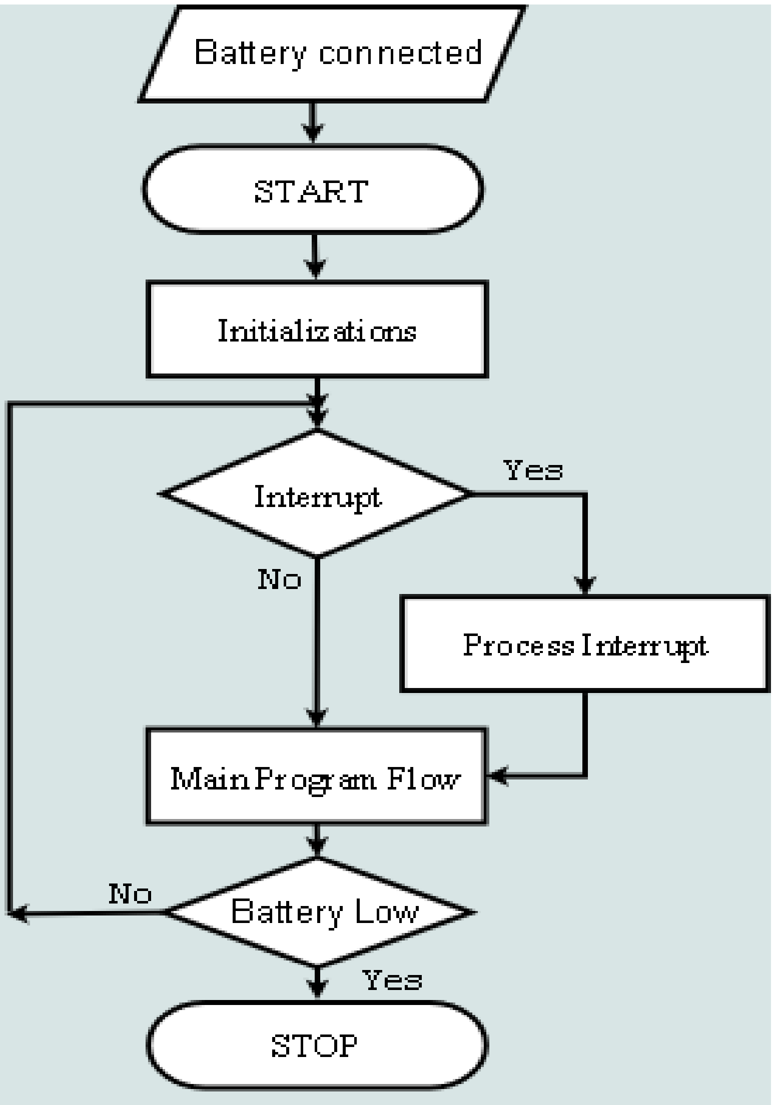
Printed circuit design of CPU and sensor circuits



Collembola Counter Development

The Edapholog system is built upon several electronic collembola counter units. In the development of these electronic units the low current consumption was a primary goal. To achieve this, a so called nanoWatt XLP microcontroller has been selected from Microchip. This CPU with its XLP feature, which stands for eXtremely Low Power, is capable of switching its clock frequency on-the-fly.

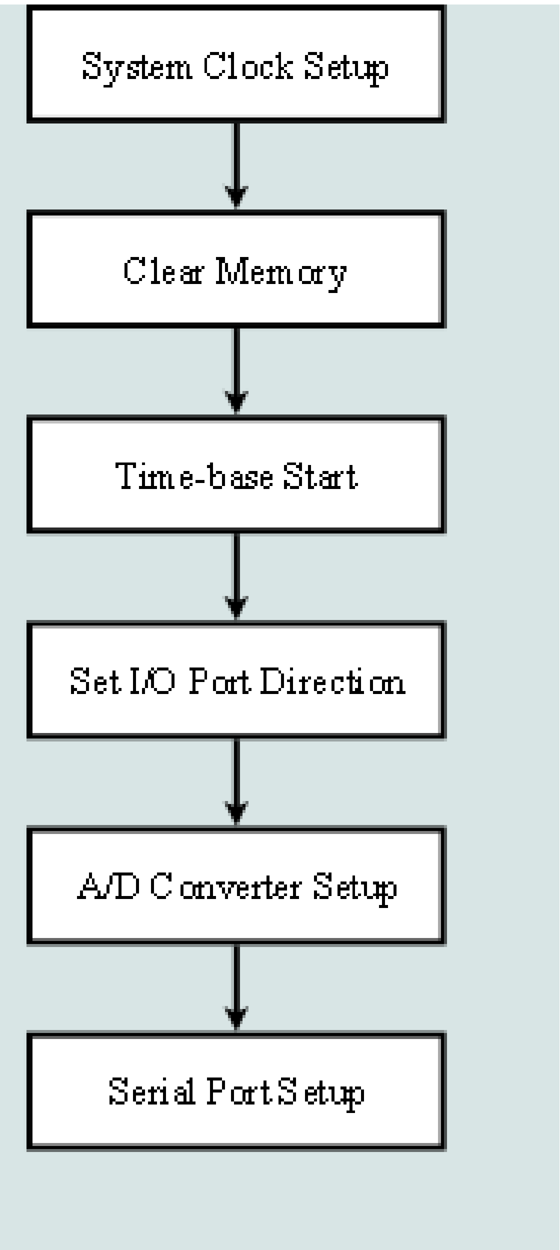
A top level block diagram of the firmware can be seen in Figure 1. First with initializations, the software as well as the hardware gets its initial settings.



Collembola counter top level program flow

Initializations

First the hardware features of the CPU must be set. Most of the I/O ports are configurable to be either input or output, analog or digital. The CPU core clock frequency must be set in accordance with the current computational needs to draw only the necessary power.



Collembola Counter Initializations

The ystem clock is setup so that a single instruction can switch between the 2 speeds. 32125 Hz will be used idle, i.e. the program only keeps track of time and waits for some event using minimal supply current.

On program startup the work memory is cleared to assure identical conditions with every start.

Timer 1 of the microcontroller is initialized to use a 32768 Hz crystal for the 1 second time-base.

Most of the I/O ports can be either input or output, analog or digital. These have to be setup here.

The A/D converter uses Timer 3 to start conversions at 10 KHz sampling rate.

The asynchronous serial port is programmed for 9600 Baud-rate.

Microcontroller structure

Main features that this project will make use of: several timer circuits, multi-channel A/D converter, program selectable clock frequency, several interrupt sources, sufficient RAM and flash memory.

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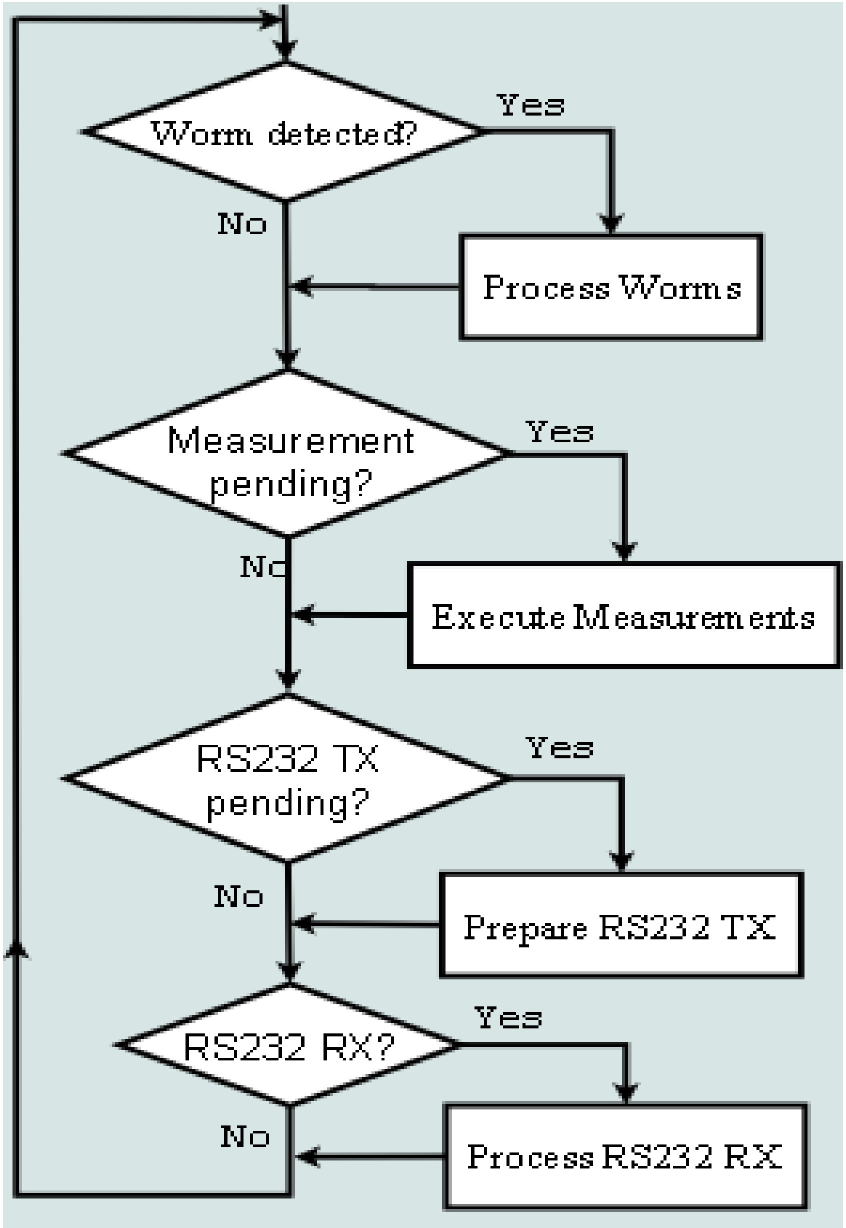
Main Program Flow



Main Program Loop

Timing is a critical part of the whole system. Hardware timers control and measure the events, which are mostly handled by interrupt handlers. However, only the time critical parts of any event can be handled in an interrupt routine. Further processing is needed out of the interrupt system, to leave time for other timely critical events in other interrupts. This further processing is organized in the main processing loop.

The firmware constantly scans the system flags in a program loop to see if there is any task to do. The system flags are set in the interrupt handlers and some also in the other tasks.

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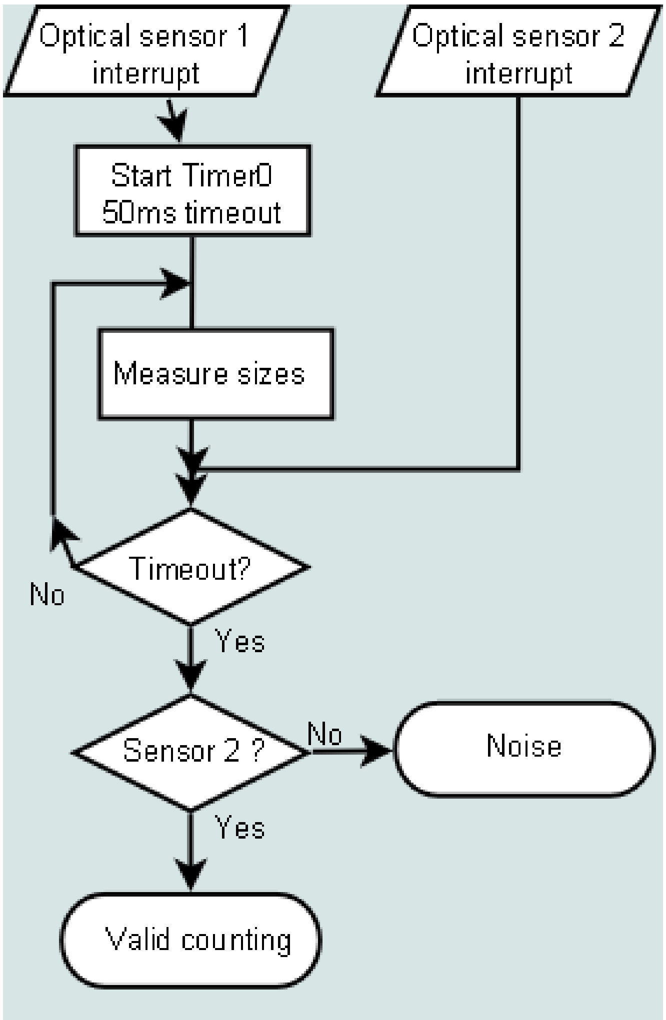
Dual optical sensor design



Noise filter with double optical sensor

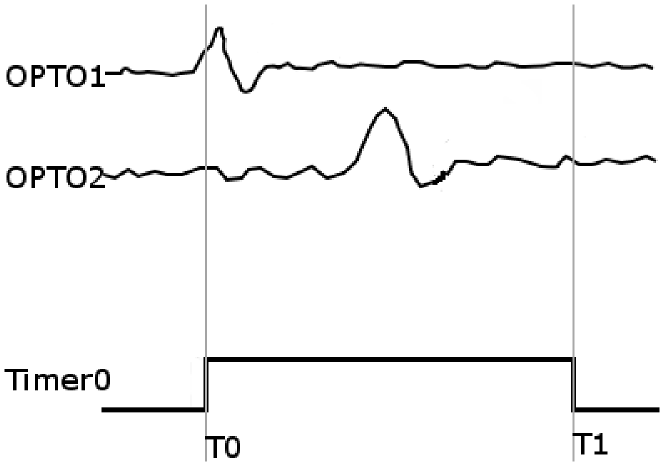
To be able to detect the smallest possible granules the detection voltage levels order of magnitude is in the range of the noise of the optical sensors. Because of the fact, that the electrical noise voltage amplitude follows the Gaussian distribution function, no matter how high the detection level is set, there is always some probability of a higher noise impulse. This means, that there would always be some false detection due to thermal noise in the electric circuitry.

To workaround this phenomenon two optical sensors are used 20 mm below each other. The software checks whether both sensors activate within about 50 milliseconds. If not, it was only electrical noise that triggered the sensor.

Sample measurements show, that this arrangement greatly reduces the probability of false detections. In 24 hours tests with only one sensor there have always been some false detections, no matter how high the detection threshold was set.

Test Nr.	Threshold	False count with 1 sensor	False count with 2 sensors
1	2 x noise	6	1
2	2 x noise	8	0
3	2 x noise	5	2
4	2 x noise	16	0
5	2 x noise	4	1
6	4 x noise	2	0
7	4 x noise	4	0
8	4 x noise	3	1
9	4 x noise	2	0
10	4 x noise	2	0

Filtering noise



Sensed within time

The upper photo-sensor circuit triggers the software measurement. Both time and amplitude of the output signal is measured. When a real object is falling through the detector field, it will trigger the lower detector within a finite time delay. The time until the object reaches the lower detector depends on its size and weight. Test measurements show that more then 50 ms is unlikely. The microcontroller firmware is preset so, that pulses from the upper detector will only be counted, if the lower photo-sensor also outputs a detector pulse within this 50 ms time interval. If only the lower detector outputs a pulse, it will be discarded.