# 1 Introduction

This section describes the design and implementation of the Inertial Measurement Unit (IMU) used to capture the movement of the wheel loader’s cabin. The reason for developing the IMU was that it was deemed too expensive to buy one. The starting point for the design was Xsens’ MTi-10 IMU, adapted to the needs of the project, and Mikael Larsmark’s AVR development board.

# 2 Hardware Design

## 2.1 Components

It was decided to use the Atmel AT90CAN128 microcontroller as MCU, because of the students’ familiarity of it from earlier work. The gyroscopes chosen were Analog Devices’ ADXRS450, which gives digital outputs via SPI communication. The chosen accelerometer was Analog Devices’ ADXL325, which gives an analog output. Among all the sensors investigated these were the ones that most closely matched the specifications of the MTi-10[1].

For the communication between the IMU and the wheel loader PC, it was decided to use serial via USB, using FTDIs UART-to-USB converting chip FT232RL.

The power supply to the IMU can be switched between power from the USB and external power. Both of these are filtered and regulated to 3.3 V. Meaning that the entire card is driven at 3.3V (except for the FT232RL which takes 5V directly from the USB and 3.3V to drive its I/O to the microcontroller).

For the programming interface to the microcontroller both the ISP and the JTAG pins were put on the card as pin headers, for further work it could also be possible to write a bootloader and thereafter program the MCU via USB.

The resistors and capacitors are all of size 0603 except the 0 Ω resistance connecting the analog and digital ground planes, which is 1206.

### 2.1.1 Gyroscopes

The ADXRS450 can only measure rotation along one axis [2], so three of them were needed. There are two packages available, one standing (LCC\_V) to measure the x- and y-axes, and one lying down (SOIC\_CAV) to measure the z-axis.

Apart from a performance close to that of the gyroscopes on the MTi-10, there were several other reasons for choosing the ADXRS450. The first was that it is digital, and because of this it is possible to include information other than the angular rate data in the SPI transmission. It has for example a self-test function which can report problems during operation and thus it is possible to flag potentially flawed data.

According to the data sheet they need a few external components to work properly [2]; these are shown in Figure 1, and included on the IMU. Of these components the inductor between supply voltage and pin VX deserves special mention since it is required to be 560 µH rather than 470 µH when operating at 3.3 V. The diode chosen was Diodes Inc.’s 1N4148W, simply because of it having a breakdown voltage higher than 24 V, and other reasonable specifications.

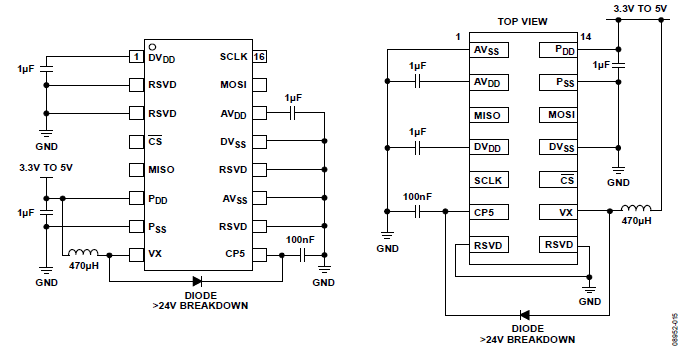


Figure 1 Gyroscope application circuits

### 2.1.2 Accelerometer

The accelerometer chosen for the IMU was Analog Devices’ ADXL325. This measures in the desired range of ±5 g with reasonable nonlinearity (±0.2 % of full scale). It also measures all three axes simultaneously, so only one was needed.

It is analog however, and one reason for this is that it is not recommended to use SPI communication with more than three devices. Also, rotations were considered more critical and more sensitive to measurement error, so better gyroscopes were prioritized and a cheaper accelerometer was chosen to reduce the total cost.

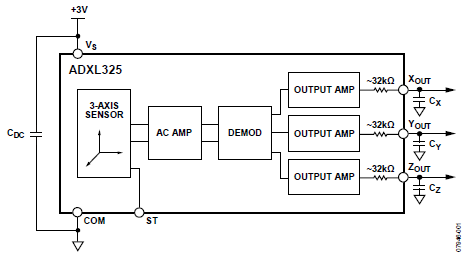


Figure 2 Accelerometer application circuit

The accelerometer needs capacitances on the outputs, as shown in figure 2, to implement a low-pass filter for antialiasing and noise reduction. Since the IMU was intended to mimic the MTi-10, its accelerometer bandwidth of 375 Hz was used for the calculations, arriving at capacitor values of 10 nF (formula for calculations taken from the data sheet [3]).

### 2.1.3 USB Chip

The FT232R UART USB chip was supplied by Larsmark and was the one used by him on his AVR board. This chip was probably not the best choice since it was used due to necessity because the USB UART chip was forgotten when ordering the other components.

### 2.1.4 Full Component List

All components used are presented in table 1.

Tabel 1 Component list

|  |  |
| --- | --- |
| **Type** | **Component** |
| MCU | AT90CAN128 |
| Gyroscope (z) | [ADXRS450BRGZ](http://www.digikey.se/product-detail/en/ADXRS450BRGZ/ADXRS450BRGZ-ND/2780620) |
| Gyroscope (x,y) | [ADXRS450BEYZ](http://www.digikey.se/product-detail/en/ADXRS450BEYZ/ADXRS450BEYZ-ND/2607351) |
| Accelerometer | [ADXL325BCPZ](http://www.digikey.se/product-detail/en/ADXL325BCPZ/ADXL325BCPZ-ND/2042672) |
| Regulator | [MIC5239-3.3YS](http://www.digikey.se/product-detail/en/MIC5239-3.3YS/576-1837-5-ND/1030749) |
| Rectifier bridge | [MB2S-TP](http://www.digikey.se/product-detail/en/MB2S-TP/MB2S-TPMSCT-ND/722464) |
| Polyswitch | [0ZCG0050AF2C](http://www.digikey.se/product-detail/en/0ZCG0050AF2C/507-1762-1-ND/4156148) |
| Transient-voltage-suppression diode | [SMAJ30A-TR](http://www.digikey.se/product-detail/en/SMAJ30A-TR/497-12778-1-ND/2873847) |
| USB connection | [61400416121](http://www.digikey.se/product-detail/en/61400416121/732-2108-ND/2060604) |
| Inductor 560uH | [1812R-564J](http://www.digikey.se/product-detail/en/1812R-564J/DN42140JCT-ND/1115687) |
| Capacitor 4u7 | [EEE-1VA4R7SR](http://www.digikey.se/product-detail/en/EEE-1VA4R7SR/PCE3962TR-ND/761838) |
| Capacitor 330u | [EEE-HAV331UAP](http://www.digikey.se/product-detail/en/EEE-HAV331UAP/PCE4730CT-ND/1718153) |
| Capacitor 100u | [EEE-1VA101P](http://www.digikey.se/product-detail/en/EEE-1VA101P/PCE3949DKR-ND/1838718) |
| Diodes for gyroscope | [1N4148W-13-F](http://www.digikey.se/product-detail/en/1N4148W-13-F/1N4148W-13FDICT-ND/2242774) |
| Inductor 100u | [B82432T1104K](http://www.digikey.se/product-detail/en/B82432T1104K/495-1755-6-ND/1244363) |
| DC jack | [PJ-002B](http://www.digikey.se/product-detail/en/PJ-002B/CP-002B-ND/96965) |
| Tactile switch | [B3F-1020](http://www.digikey.se/product-detail/en/B3F-1020/SW402-ND/44059) |
| Inductor 10u | [PM1812-100J-RC](http://www.digikey.se/product-detail/en/PM1812-100J-RC/M8531TR-ND/775070) |

## 2.2 Board

The design itself was done using CadSoft EAGLE. All components were connected as decribed in their respective datasheets, and the USB chip, and the power supply was connected as in Larsmark’s AVR board.

As mentioned previously, there are two ground planes on the IMU. This is because there are both analog (accelerometer) and digital (gyroscopes) signals, and in such cases they need two separate ground planes so that the digital noise does not interfere with the analog signals. They are connected using a 0 Ω resistance to make sure they have the same potential.

Choice of power source is done by connecting either pin 1 and 2 on JP1 (see schematic) for power through USB, or 3 and 2 for other source. Note however that in order to use the power jack, that cable has to be connected before the USB cable is inserted. This is to let the MCU start up before the USB chip. Otherwise, the USB chip will output a voltage on the pin connecting it to the MCU which sets the MCU in a state of operation in which it is unable to send any data.

Also not that there is another error in the design; pin 63 on the MCU should be connected to ground, but this is not the case for the IMU boards. On the assembled boards this is solved by a wire soldered between that pin and ground, and this has to be done for the unpopulated boards as well. In the EAGLE design however, this has been fixed.

## 2.3 Future Improvements

# References

[1] <http://www.xsens.com/en/general/mti-10-series>

[2] Analog Devices ADXRS450 Data Sheet

[3] Analog Devices ADXL325 Data Sheet