MICROPROCESSOR SYSTEM FOR DETERMINATION INDICATOR OF THE EASE OF MOTION FOR RAILWAY VEHICLES

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The present paper examine the basic moments with the realization of microprocessor system for monitoring of The indicator ease of the motion for of railway vehicles. The system is developed on the basis of method of Sperling for examination of the ease of the motion. The basic problems with this sort of measurement are scrutinized, and software and hardware for solutions are given.

Keywords: indicator ease of the motion, accelerameter, acceleration, current-loop interface.

1. INTRODUCTION

The indicator ease of the motion for of railway vehicles characterizes the heaping of passengers' tiredness resulted by the horizontal and vertical accelerations of the in the body of the carriage. For determination of that indicator, the theory of Sperling is used for analyze of the spring up accelerations in the vehicle during the motion in railway in accordance with given parameters.

A physiological dependency of the influence of the hesitating processes over the human organism. It is necessary the frequency of the fluctuation to figure as argument in the analytical expression , due to the expression, the human organism as a mechanical system has a determinated frequency characteristic, it reacts against the fluctuation impact in accordance with that characteristics

The indicator ease of the motion is given by Sperling with the follow formula

$$W_{sp} = \sqrt[10]{M((W_{sPs}^{10}))}$$

where $M(W_{sPs}^{10})$ is the mathematical expectation powered to tenth of the accidental quantity (W_{sPs}^{10}) , determinated for harmonious hesitating processes with frequency f in Hz and amplitude b in cm/s² :

$$W_{pSp} = 0{,}896\sqrt[10]{\frac{b^3}{f}F(f)} \ ,$$

The function $F(f)$ reflects the reaction of the human organism to the hesitating processes over the human with equal amplitude of the acceleration and different frequency.

The gained signal from the accelerator is normalized by a low-pass filter and an amplifier. Purposely decreasing the impact of the surrounding environment's noise, which the experiment is done in a current-loop interface – 4-20mA- is chosen. It is implemented on the basis of integral circuit – AD694 – from Analog Devices. The transformed into current signal is transferred to the microprocessor system. It is constructed with microcontroller MSP430F149. It has the role to transfer the gained from the sensor signal into digital, and also to send it over the USB-interface to personal computer.

2. PROBLEMS

Within the measurement of indicator ease of the motion for of railway vehicles there different kind of problems. The most common are related to the importing some errors as:

- transferring analog signals through relatively long distances (≥10m.);
- during the computation, the principle of integration of influence of transitory values of the acceleration is used. Due to the accepted formula of Sperling, the value of the acceleration is powered to three, it is necessary to remove the acceleration of gravity component when the motion is in tilt area of the way. This component is a result from the exceeding of the outer rail in the given section, which can reach up to 150mm.

It is also necessary to implement a fast interface to transfer the gained data to personal computer.

2. DECISIONS

Due to the fact the measurement is done in very noisy environment and thenecessity of transferring analog signals through long distances, it is necessary a special precautions. In this connection it is felicitous a suitable interface to be chosen for interconnection between the accelerometer system and microcontroller system. For building this block a special integral circuit is used – AD694 from Analog Devices. It converts the incoming voltage into current signal 4-20mA. The integral circuit places the possibility for working with output current signal 0-20mA with additional power supply. The vendor company recommends the follow schematic, which is shown on fig. 1.

With the realization of the current interface, an error of self-heating is gained, during the transmission process. This problem is avoided by a additional driving transistor Q4.

It is necessary microprocessor system, which possesses the folow possibilities:

- enough computational power, and resources necessary for the processing of the received data from the measurement;
- integrated analog to digital converter with muliplexor and resolution at least 10 bits;
- serial comunnication channel for connection to personal computer and high speed of data transmission – 1Mbps.

The output signal from the accelerometer, supplied with 5V is 2.5V when no acceleration is presented.

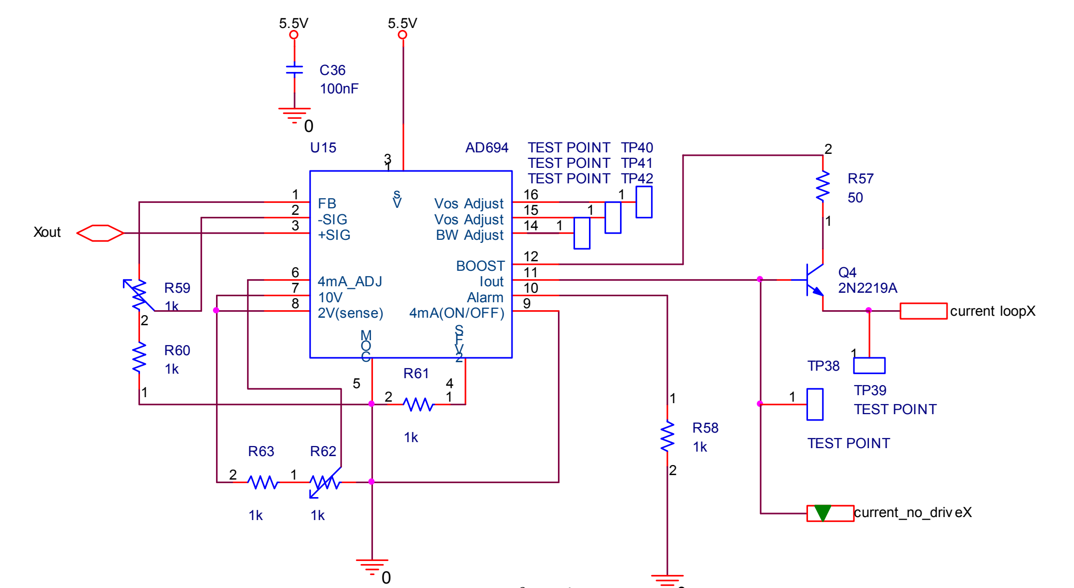
5.5V
5.5V
C36
100nF
0
U15
AD694
TEST POINT TP40
TEST POINT TP41
TEST POINT TP42
FB
-SIG
+SIG
Vos Adjust
Vos Adjust
BW Adjust
BOOST
Iout
Alarm
4mA_ADJ
10V
2V(sense)
4mA(ON/OFF)
Xout
R59
1k
R60
1k
R61
1k
R63
1k
R62
1k
R57
50
Q4
2N2219A
current loopX
TP38
TP39
TEST POINT
TEST POINT
R58
1k
current_no_driveX

fig. 1

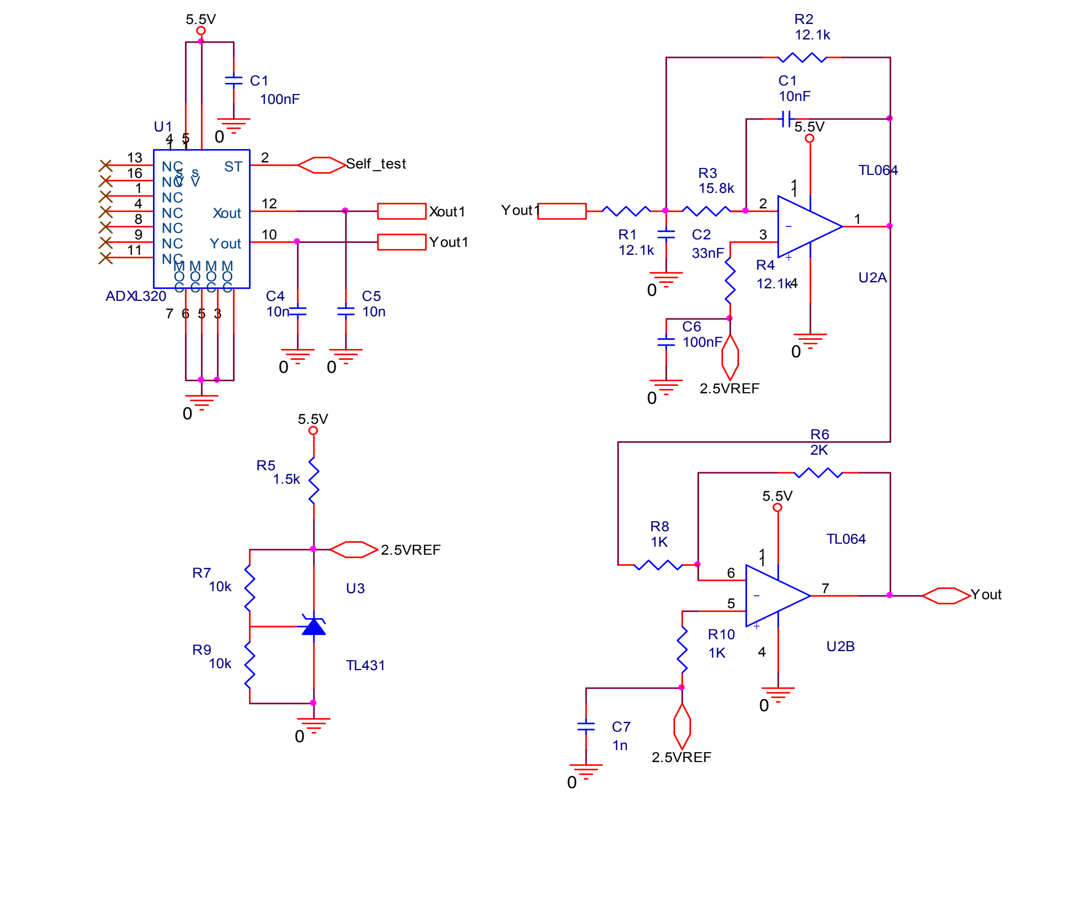
5.5V
C1
100nF
U1
ST
Self_test
Xout
Xout1
Yout
Yout1
NC
ADXL320
C4
10n
C5
10n
R2
12.1k
C1
10nF
5.5V
R3
15.8k
TL064
Yout1
R1
12.1k
C2
33nF
R4
12.1k
U2A
C6
100nF
2.5VREF
R6
2K
5.5V
R5
1.5k
2.5VREF
R7
10k
U3
R9
10k
TL431
R8
1K
5.5V
TL064
Yout
R10
1K
U2B
C7
1n
2.5VREF

fig. 2

The limitation of the frequency bandwidth of the output signal from the accelerometer is done by externally added capacitors – C4, C5. On their basis and the internal resistor a low-pass filter is implemented. Their values are calculated with the follow formula:

$$F_{-3dB} = \frac{1}{2\pi(32k\Omega \times C_{(X,Y)})} = \frac{5\mu F}{C_{(X,Y)}}$$

The basic values are presented in the table 1.

Bandwidth (Hz)	Value of the capacitor (μF)
1	4,7
10	0,47
50	0,10
100	0,05
200	0,027
500	0,01

Table 1

The necessary value of the frequency for the output signal from the accelerometer is up to 10Hz. In the present case the frequency is chosen to be 500Hz, purposely for using the algorithm for integrating the output value and removing the constant component raised by the acceleration of gravity.

The full range of this signal should be scaled to the for the power supply range.
For this purpose an amplifier block is synthesized shown on fig. 2.

It is built on the basis of operational amplifier MCP519 from Microchip. The first step is built as a low-pass filter. The frequency band of the accelerator is 2.45kHz. The filter is calculated to have cut frequency at 480Hz.

For a source of reference voltage it is used precise low-power output TL431. It has a good temperature coefficient – 50ppm/°C, suitable for the working environment, where the measurement is done.

The second part of the amplifier block is the real amplifier – fig. 2. It gives the necessary gain of the signal, before it is lead in the current interface.

The second main block, used in the acceleration measurement is the microprocessor block. It is built on the basis microcontroller MSP430F149 from Texas Instruments. It is a special microcontroller dedicated for mobile applications, where the consumption - 280uA @ 1MHz active mode. It has built in eight channel analog-to-digital converter with 200 kilo samples per second.

The microprocessor system is furnished with an USB interface on the basis of the special integral circuit – FTDI245 – with possibility for data transfer to personal computer at speed 1.0Mbps. It makes the parallel eight bit interface to usb conversation. It has internal buffers for the send and received data, and flow-control opportunities, avoiding data overrun. The block chart of the whole system is presented on fig. 3.

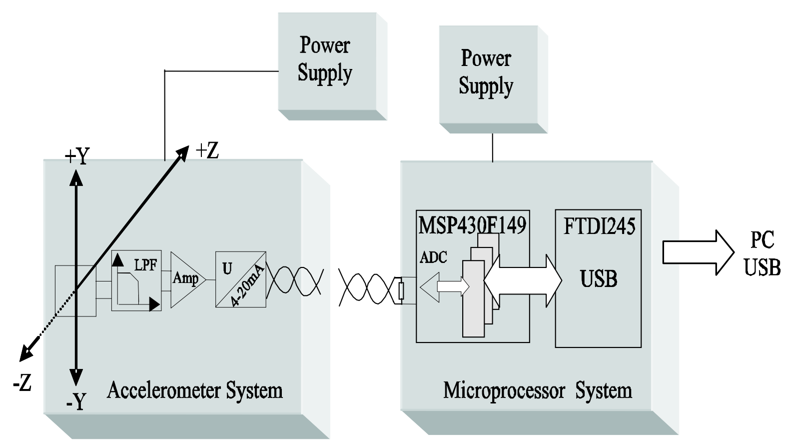

fig.3

3. EXPERIMENTS AND RESULTS

There are two lab experiments are done. The first expresses in a acceleration measurement of a small prototype of a vehicle. The acceleration at set out and stop are measured. The results are shown on fig. 4.

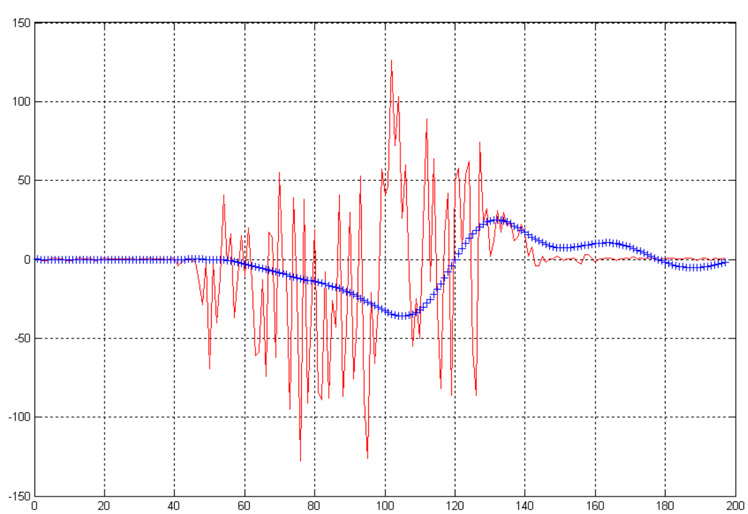

fig. 4

The presented signal is received directly from the accelerometer integral circuit. It has wide range of harmonics. For this purpose it is necessary to filter them. The additional signal, drawn with "+"represents the filtered signal.

The second experiment have for an object to measure the vibration with vector perpendicular to the plane of path of motion – fig. 5.

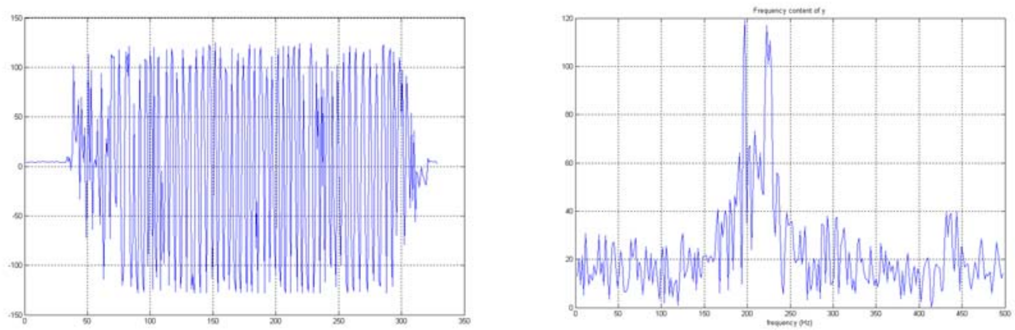

fig. 5

5. CONCLUSION

The system possesses the possibility for measurement of acceleration in wide range. There are also some additional precaution, which are implemented in the system to decrease the influence of the noise into the measurement, through using of current-loop interface.

A special algorithm for removing of the acceleration of gravity during motion in curve section of the railway, where the outer rail has exceeding is done

Laboratory test with the system are carried out, and now experiments real tests in railway vehicles will be done.

6. REFERENCES

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