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DSP APPLICATION IN THE VEHICLE NOISE METER

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ABSTRACT
The new dual channel, handheld, battery charged, digital signal processor (DSP) based instrument dedicated for the vehicles noise measurement is described. One of its two channels is used for the noise measurement and the second – for the engine's rotation (rpm) determination. The algorithm developed for the evaluation of the rpm is shortly discussed. The block diagram of the instrument is given. The components of the measurement system as well as the preliminary data specification of the proposed instrument are also presented.

1 - INTRODUCTION

According to the UNO regulations for the common rules of vehicle acceptance (Regulation 51 from 1990), it should pass some special tests. One of those tests is the measurement of the noise generated by the non moving vehicle at the engine rotation equal to 75 % of the maximum power. The special requirements for the measuring instrument dedicated for that test comes from the obligation of the engine rotation determination in parallel to the sound level measurement. The sound level determination must be synchronised with the engine rotation speed. It is not easy task if the above mentioned measurements were not integrated into one device (the unloaded engine of the non-moving vehicle is extremely sensitive for the control at the required power level). Additionally sound level should also be traced when engine rotation is rapidly decreased (according to the standard measurement procedure).
Dedicated, dual channel and DSP-based instrument can easily fulfil all these requirements. And what is very important it allows to perform the engine tests by non-skilled single person personnel.

2 - THE ALGORITHM FOR THE RPM MEASUREMENT

Many different algorithms were considered including time, spectrum and cepstrum analysis to measure properly the rotation frequency of the vehicle's engine. First of all the spectral analysis of the registered signal was performed. Unfortunately in this case the resolution is not satisfactory. In order to increase the resolution one has to collect the big number of samples (more than 2000). Besides that, as many our investigations proved, the amplitude of the spectral line strongly depends on the point the sensor is placed on, the engine's type and its current rotation. So, the most frequently it is very difficult to determine which spectral line is related with the engine's rotation and this evaluation is not reliable. Also the cepstrum analysis does not provide the satisfactory results – the resolution in the interesting range is worst than for the spectrum analysis and the evaluation of the engine's rotation on the base of the cepstrum lines is not credible. That is why we finally decided to analyse the registered signal only in the time domain.
In our algorithm for the rpm determination the samples of the signal coming from the inductive or vibration probe pass through the integrating filter in order to cut off the noise. Later on the dynamic investigation of the averaged, maximal and minimal value of the signal is performed. After the determination of the maximal and minimal values the margins are established in order not to take under

consideration the noisy pins in the signal. The pass through these margins is registered. After one registration the next one can be taken into account after the dead time which is equal approximately to 2/3 of the period corresponding to the maximal rotation frequency of the engine. The total number of the passes through the established margins in a period of time, taking into account the correction coefficient, determines the engine rotation.
The mentioned above correction coefficient is related to the number of cylinders, engine's type (number of strokes), the way in which the sensor is connected to the engine. For example in the case when the probe is placed on the ignition cable on one cylinder in the four-stroke engine one impulse is taken after two rotations of the engine. In this case the coefficient is equal to two. On the other hand when there is a common ignition cable for four cylinders in four-stroke engine there are two impulses for one engine rotation. In this case the coefficient is equal to 0.5.
Theoretically the value of the rpm could be evaluated on the base of the acoustic signal only. In practise such measurement is possible when the vehicle's exhaust system is in the good condition. But in this case such measurement is not really required (the noise generated by the vehicle is at the acceptable level). When the car's exhaust system is damaged (the case in which the noise measurement is well-founded and reasonable) the acoustic signal analysis is extremely difficult and very often does not give the satisfactory results. That is why we decided to develop dual channel instrument in which the determination of the engine's rotation is done analysing the signal coming from the inductive or vibration probes (depending on the engine's type).

3 - BLOCK DIAGRAM OF THE VEHICLE NOISE METER

The described above algorithm of the engine's rotation determination on the base of the samples in the time domain and other measurement functions are implemented in the DSP which plays the role of the control unit in the proposed dual channel vehicle noise meter. The block diagram of the instrument is presented in Fig. 1.
It is easy to notice that the instrument is fully digital. Internal dual channel architecture of the instrument is very powerful and flexible. Requirements for the computation power of the digital signal processor is rather high because of the concurrent, real time multitasking operation mode. That is why the powerful Motorola DSP56303 was selected.
The usage of the 18-bits A/D converters result in one range (from 40 dBA to 120 dBA) operation mode for the sound measurements. The determination of the engine rotation speed is not an easy task also because of the big amount of the different engine types. That is why the two different probes are used: accelerometer based for the Diesel engines and the inductive probe for the spark detection in the gasoline engines. The built-in real time clock (RTC) gives current date and time along with the results of measurement. The instrument is provided in the internal 1 MB of non-volatile memory for the measurement results. The meter's internal software can be modified by means of the RS 232 interface (thanks to the implementation of flash type memory). The RS 232 interface creates also a digital link to the PC world. The instrument is powered from the built-in rechargeable batteries or from the car cigarette lighter socket.

4 - THE DETERMINATION OF THE VEHICLE NOISE

The system for the determination of the vehicle noise is consists of the presented above vehicle noise meter equipped with the 1/2 " condenser microphone, the preamplifier with 10 m cable, the inductive probe for gasoline engines and the vibration probe for Diesel engines. The PC with the printer, the sound calibrator, the windscreen for the microphone and the tripod constitute the complete set.
The most important feature of the instrument is the automatic control of the measurement process which allows to perform the engine tests by non-skilled personnel. The user has to introduce to the instrument the type of the engine and the maximal rotation frequency of the engine.
The instrument measures in parallel noise and engine rotation speed and controls nominal rotation speed conditions. The noise measurement channel meets IEC 651 Type 1 requirements. The rotation measurement range is wide (it can be extended if necessary) with the good accuracy. Additionally, the noise level is traced during rapid reduction of the engine rotation speed (according to the standard requirements). If the maximum noise level measured during the engine tests exceeds the level corresponding to the nominal rotations it is not taken into account.
After setting the parameters of the measurement and of the tested vehicle (i.e. its name, engine's type, registration number, etc.), connecting the proper probe to the engine and placing the microphone with the preamplifier on the tripod in the required distance from the exhaust pipe, one has to start the vehicle engine and accelerate it. When the required rotation is achieved the instrument signals this state. The

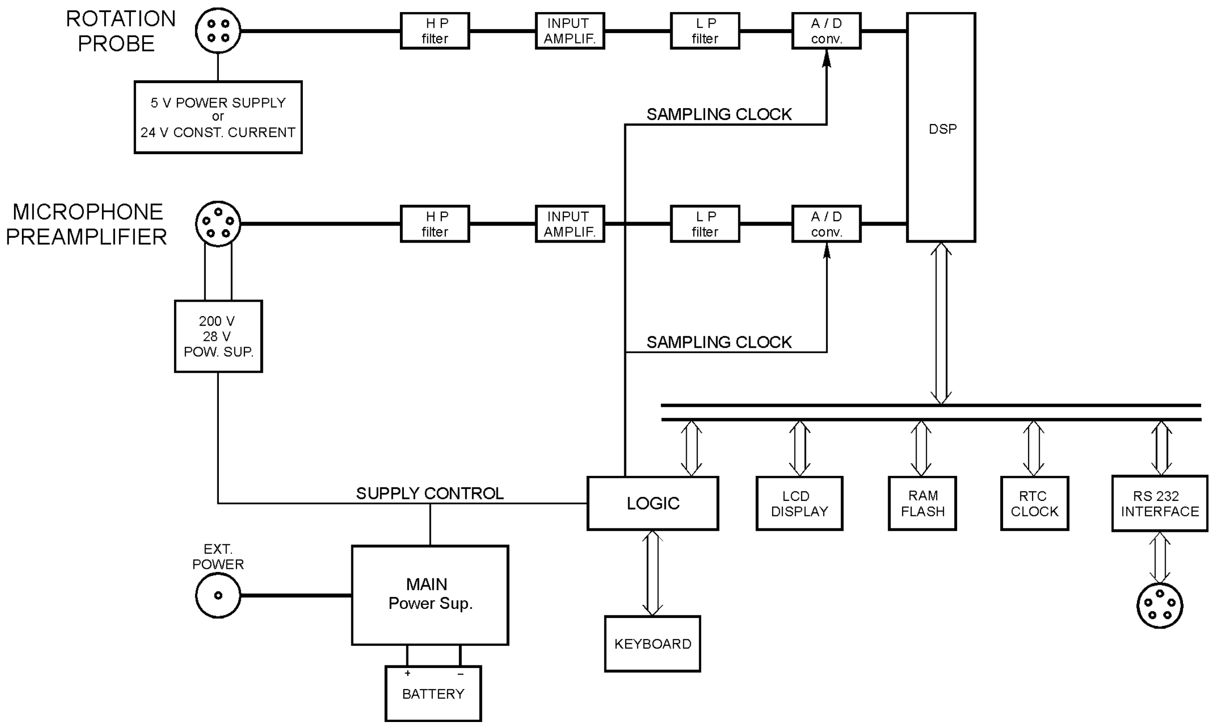

Figure 1: Block diagram of the proposed vehicle noise meter.

rotation should be the same for about 2 s. After this period one has to stop suddenly pressing the accelerator. The level of the measured noise (namely the value obtained from the Spl function − Sound Pressure Level implemented in the meter) is stored in the internal memory of the instrument along with the data of the verified vehicle.
The printed report from the performed tests can be made on the printer or/and the data can be transmitted to the computer.
The calibration of the system is possible as well as the measurement of the noise in the environment. The vehicle noise should be at least 10 dB higher than the background.
The very important feature of the presented approach is the easy way of the instrument's modification or adaptation to new regulations (if any appear in the future) − it can be done mostly by the change of the control program (using the RS 232 interface) without any change in the hardware of the presented meter.
Together with the instrument a PC software for the measurement data download, presentation and archiving is prepared. The creation of the data base containing the different types of vehicles together with their engines and the values of the maximal engine's rotation is also predicted.

5 - PRELIMINARY DATA SPECIFICATIONS OF THE VEHICLE NOISE METER

SOUND LEVEL METER	(Type 1: IEC 651)
Preamplifier input	5 pins LEMO type
Measurement range	40 dBA_{RMS} − 120 dBA_{RMS} (126 dBA $_{Peak}$)
Dynamic range	80 dB
Frequency range	20 Hz - 16 kHz (-0.1 dB)
Weighting filter	A (Type 1: IEC 651)
RMS detector	Digital True RMS, Fast time constant
Microphone	1/2" condenser microphone with the sensitivity 25 mV/Pa
ENGINE ROTATION METER	Gasoline or Diesel engine rotation measurement with the inductive or vibration probe
Probe input	4 pins LEMO type
Measurement range	600 rpm − 10000 rpm (accuracy better then 0.5%)
DISPLAY	2 × 12 characters with EL backlighting
MEMORY	1 MB non-volatile (flash type)
INTERFACES	RS 232
POWER SUPPLY	Built in rechargeable battery (3.6 V/1.5 Ah), External power supply 10 − 15 V DC / 800 mA
ENVIRONMENTAL CONDITIONS	
	Temperature: from -10°C to 50°C Humidity: up to 90 % RH, non condensed
DIMENSIONS	135 × 80 × 38 mm
WEIGHT	approx. 0.6 kg with internal battery

Table 1.