Micro-controller based oscillation monitoring system for the safety of railway vehicles with high storage capacity and real time warning facility

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An Advanced portable instrument to monitor, detect, and record the horizontal and vertical accelerations of the railway vehicles (railway coaches, wagons and locomotives, etc.) as well as of railway tracks has been designed and developed by incorporating the state of the art technology suitable for this purpose. The design/technology has been perfected by conducting repeated field trials on the instrument in association with the engineers of RDSO, Lucknow. The designed instrument based on 89C52 Micro-controller technology, is a major step in the direction of advance instrumentation for Indian Railways. Oscillation monitoring system continuously measures vertical and lateral accelerations at any desired location on the floor of a railway vehicle and simultaneous measurement of distance from fixed points of track on real time basis. It is an advanced portable instrument to measure and record oscillations of railway vehicle, while in motion. The system is so rugged that it can work in non air-conditioned environment and withstand vibration of ‘1g’ in all three orthogonal axes without any problem. Based on this measurement, analysis can be carried out on railway track conditions. The unit has been designed with large storage capacity and displays locations of bad spots along with other required information, which are registered over the threshold value.

Keywords: Micro-controller technology, Railway vehicles, Real time warning
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Introduction
Railway infrastructure is increasingly coming under the close scrutiny of the health and safety measures due to large number of incidents. These incidents may be due to track irregularities, continuous wear and tear of various components used in engines and wagons, negligence of operators, and carelessness of masses while crossing the unmanned railway crossing. In order to tackle this immediate problem, it is required that an attempt should be made to improve the current methods of linking particular types of track irregularities with derailments, etc. It is desirable that modern instrumentation system based on automatic detection techniques should be evolved to allow operators and infrastructure managers to monitor these irregularities more effectively and to direct maintenance over the long term. In order to make compliance with safety targets, we have taken the challenging task on design and development of Oscillation Monitoring System.

This system is mainly used for two purposes

- Monitoring of track
- Monitoring of railway vehicles (Railway coaches, wagons and locomotives, etc.)

The two purposes are fulfilled by way of continuous measurement of vertical and lateral accelerations at any desired location on the floor of a railway vehicle, (generally over one of the pivots of bogie frame) and simultaneous measurement of distance from fixed points of track (generally kilometer posts) on real time basis.

Oscillation Monitoring System Design
The system has the following subsystems:

- Micro-controller based main unit.
- Transducer assembly cum power pack unit.
- Detachable printer unit.
- Electronic rotary pulse generator (Tacho) unit.
- Corded event marker unit.
- External power supply cum-battery charger.

A block diagram of the complete system is given in Fig. 1.

Micro-controller Based Main Unit
Micro-controller based core system contains four basic parts

(i) CPU card.
(ii) Memory card.
(iii) Mother board.
(iv) Transducer signal processing card.

The main unit contains all the hardware parts like, 89C52 micro-controller, 12 bit Analog to Digital
Converter, Real Time Clock, LCD Interface, General Purpose I/O Lines Serial Communication with and without Handshaking, serial printer interface, Centronics Parallel Printer Interface, Keyboard Interface, External 128KB of EPROM, DC-DC converters, High Capacity Non-volatile RAM with in built Battery Backup, possibility for future extension. Block schematic with data lines, address lines and control lines is as shown in Fig. 2.

**Transducer Assembly and Power Pack Unit**

The transducer for this system is around accelerometers of adequate range of measurement, mounted in true horizontal and vertical positions. The mounting arrangements of the accelerometers have been designed in such a way so that it is able to produce true electrical output proportional to acceleration. This unit has required amount of circuitry for manual adjustment (for making zero error as well as the proportional error within the auto-correction range of the system). This unit is housed in a metallic box having adequate self-weight to prevent loss of contact when placed on the floor of moving railway vehicle. Accelerometers, used in OMS, are strain gauge based accelerometer designed for shock and vibration measurement. Accelerometers are very light, small and can accurately measure acceleration without any disturbance to vibration mode of test.
structure on which accelerometer is installed. The measuring range is up to ±2g and frequency from 0 to 10Hz.

**Detachable Printer Unit**

The detachable printer unit is a self-contained unit having arrangement for holding paper roll and discharge of printed paper, etc. This unit, as a whole, is plugged into the main unit through suitable connector. It is having perfect alignment by using suitable arrangement with the main unit. This unit has a provision of connecting an external printer also. Printing Paper shortage is detected and informed with SEL lamp blinking at 0.5s interval, when printing is suspended. As this time, power supply to the motor and printing solenoid is stopped with BUSY signals output in the host system.

**Electronic Rotary Pulse Generator (Tacho) Unit**

This unit generates digital pulses when mounted on the axle of the railway vehicle. It generates seven pulses per revolution of wheel, which is duly conditioned and sent to the main unit for further processing by it. It is so rugged that it can withstand vibration and harsh outdoor environment during run of railway vehicles at a speed of 160 km/h. This unit is connected to the main unit through a properly shielded composite cable, suitable for outdoor application, fitted with a MIL-grade connector at both ends. It is having a disc with slots, which is used as an interrupter to Opto-electronic device. The built in amplifier makes the pickup immune to electromagnetic-interference, even if long cable lengths between pulse generator and oscillation monitoring main unit.

**Coded Event Marker Unit**

This unit has nominated micro switches on their key pad for recording all the following events like, kilometer posts, Telegraph posts/Electric masts, Level crossings, Points and crossings, Start of bridges, End of bridges, Entry of curve, Exit of curve, Switch expansion joints, and Special events. Event marker is capable to operate from a distance up to 10 m from the main unit. Pressing the nominated switches for the particular event shall signal various track features. The unit is connected with the main unit by means of connecting cable of adequate length. The cable is shielded to prevent any electromagnetic interference.

**External Power Supply cum Battery Charger**

This is a highly versatile regulated power supply, which operates on AC and DC input voltage. There is a separate power supply with universal AC/DC (110V ±20 per cent and AC 220V±20 per cent) to operate the system and also input supply for charging the battery fitted in the transducer assembly cum power pack unit. Other different voltages (±12 V, ±5V and +10V), which are required for different modules/cards are generated through a DC-DC converter of high efficiency. Overall, picture of system is shown in Fig. 3.

**Specifications of the System**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Normal ± 50 cg (cg=9.8cm/s²)</th>
<th>Expanded ± 100cg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.5 cg (Normal range)</td>
<td>1 cg (Expanded range)</td>
</tr>
<tr>
<td>Resolution</td>
<td>7 pulses per revolution of wheel</td>
<td></td>
</tr>
<tr>
<td>Time measurement</td>
<td>100 ms (for time sampling)</td>
<td>1 ms (for sampling intervals)</td>
</tr>
<tr>
<td>Battery voltage measurement monitoring</td>
<td>0 to 20V</td>
<td>10mV</td>
</tr>
<tr>
<td>Sampling rate per channel</td>
<td>100 samples /s/channel for recording acceleration</td>
<td></td>
</tr>
<tr>
<td>ADC resolution</td>
<td>12 bit</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Description</td>
<td>Details</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7</td>
<td>No. of channels</td>
<td>8 Channels</td>
</tr>
<tr>
<td>8</td>
<td>Display Type</td>
<td>7 × 5 dot matrix LCD with backlighting and wide viewing angle</td>
</tr>
<tr>
<td></td>
<td>Size</td>
<td>16 × 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Char size 7.7 mm(h) × 4 mm (w)</td>
</tr>
<tr>
<td>9</td>
<td>Power supply</td>
<td>Internal: Built in 12 V (nominal) maintenance free battery pack for 10 h continues operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External: 12 V (nominal) DC through panel mounted polarized socket for connecting external power supply cum battery charger</td>
</tr>
<tr>
<td>10</td>
<td>Environment</td>
<td>0 to 50°C, 95 per cent rh (non-condensing) and dusty on moving vehicles</td>
</tr>
<tr>
<td>11</td>
<td>Immunity to EMI</td>
<td>Immune to electromagnetic interference from walkie talkies working nearby and electric traction, etc.</td>
</tr>
<tr>
<td>12</td>
<td>Total weight and dimension</td>
<td>15 kg, 50 x 35 × 20 cm (nominal)</td>
</tr>
</tbody>
</table>

**Software Components**

The system is totally interactive and operated through menu-driven instructions with the help of its resident software program, loaded into EPROM. Software is modular to execute all the requirement of the system efficiently.

System has a provision to transfer the data stored into battery built in RAM to IBM compatible PC through RS-232 interface, to port data in ASCII format for further analysis and preparation of various types of summaries for information management.

Complete system software is divided into following parts:

(a) Configuration, (b) Diagnostics, (c) Calibration, (d) Run, (e) Utility, and (f) Exit

Software is password protected and user has the facility to change it at his choice. The system has the diagnostic facilities for the entire hardware of the whole system, including all the units like, Memory test, Printer test, Serial communication test, Event marker test, ADC test, Transducer test, Tachometer test, Battery voltage test, Keypad test and display and indicator test.

System has an auto-calibration facility in which outputs from accelerometer, followed by required signal conditioning of both the channels shall be adjusted/calibrated for any possible zero error and proportional error of measurements automatically by the system by means of executing calibration function. After completion of calibration, “CAL DONE” message appears on the display and system is then be fit for accurate measurements and related calculations, etc. On successful completion, calibration status as well as calibration data along with time/date and calibration with accelerometer number shall be stored into the system for its use whenever the system is operated. If the calibration data becomes older than any predetermined time (say one week), the system shall not go to measurement (run) mode instead prompt for executing calibration function afresh. In the event of system being unable to successful calibrate itself, due to any problem such as gain and offset being out of range and/or unstable, it shall display the likely faults on display and terminate calibration function as incomplete. In the event of any incomplete and/or terminated calibration process the status previously stored in the system should automatically be set to calibration error and it shall not be possible to use for further operation till calibration is successfully done. In configuration mode, all the user-supplied data/parameters shall be entered and stored into the system in the form of a “set-up” called “configuration”. For recording operation (Run) the system shall automatically link all the required parameters from the configuration fed by the user. Option is also available to the user for taking the system into run with the already stored configuration set up or reconfigure.

**Reprint**

This feature will enable the user to take reprint of any run or part of run. The user can take the printout of total results/any part of results of the data. It is also possible to filter the results with respect to average actual speed, threshold limits of acceleration, kilometer posts, section, etc. at the time of taking reprints.

**Preparation and Printing of Summary**

It is possible to produce summaries of any run at a later stage from the results stored in the system. These
summaries are produced essentially by filtering of detailed results (stored in the system storage for each run) with respect to various values of acceleration peaks, segments of track in kilometers, section, etc.

**Memory Erase**

The system has facility to selectively delete data pertaining to any run from its storage memory device for making room to accommodate future date.

**Edit Time/Date**

It is possible to edit time and date of built in RTC.

**Pause/Restart**

It is possible to temporarily suspend any measurement run at any stage and again restart as when it is required but recorded data will not disturb. For this, a special key is provided.

**Run**

During run, vertical and lateral accelerations of moving railway vehicles within nominal bandwidth of 0.4Hz- 8 Hz are measured with the help of suitably mounted accelerometers in transducer assembly-cum power pack unit. To measure peak values of lateral and vertical accelerations with required accuracy, the system acquires acceleration data at the rate of at least 100 samples/s, simultaneously for both vertical and lateral channels. To remove shifting of average value of accelerations from zero line during run, due to any reasons like, drift of transducers and/or signal conditioners, centrifugal accelerations experienced at curves, tilt of vehicles, etc. the system has built in auto zero correction by means of software. From the acquired and (zero) corrected samples, peak values are determined at the rate of one each from every half cycles (i.e. samples within consecutive zero crossings) positive as well as negative for both vertical and lateral channels.

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All the peaks on a 200 ms stretch of track (user selectable) are used for RI computation by using the following formula:

$$ RI = 0.896 \times \sqrt{\frac{n}{\sum_{i=1}^{n} \left( \frac{b_i^3}{f_i} \times F(f_i) \right) \frac{1}{n}}} $$

where $n = \text{No. of completed half waves}$, $b_i = \text{Peak value of the } i\text{th half wave}$, $f_i = \text{frequency of the } i\text{th half wave } = 1/(2T_i)$, $F(f_i) = \text{correction factor for the } i\text{th half wave}$.

Correction factors for various frequency values are as follows:

For vertical mode:

- 0 for $f_i < 0.5$Hz
- 0.325$f_i^2$ for $0.5 \leq f_i \leq 5.4$ Hz
- 0.8$f_i^2$ for $5.4 \leq f_i \leq 20.0$Hz
- 400/$f_i^2$ for $20.0 \leq f_i \leq 5.4$Hz
- 1 for $f_i > 20$ Hz

For lateral mode:

- 0 for $f_i < 0.5$Hz
- 0.8$f_i^2$ for $0.5 \leq f_i \leq 5.4$Hz
- 650/$f_i^2$ for $5.4 \leq f_i \leq 20$Hz
- 1 for $f_i > 20$Hz

**Special Features**

Oscillation Monitoring System has been built up with modules/sub-assemblies using industry grade low power dissipating components and moisture proof
printed circuit board. All the PCB are plug-in-type and interconnected through connectors back plane PCB with suitable locking arrangements to withstand vibration and shocks during transit as well as operation on moving railway vehicles. It is immune to Electromagnetic interference. Complete system is housed in a dust-tight and dust-proof cabinet made of light metal (aluminum) with powder-coated paint. The whole system operates from single voltage in-built rechargeable power pack of 12V maintenance free battery. OMS software provides a good user interface so that operator can use the Oscillation Monitoring System very easily just by looking at front panel LCD and following the required instructions. OMS software is menu driven and easy to operate. Highly precise and accurate algorithms have been used to provide accurate results. Algorithms for the software program are precise. Hence the software requires very less memory space as compared to the cross-compiled assembly programs. Proper password protection has been provided with the software so that no person can temper/change the parameters and data without proper authentication.

Conclusions
The complete system has been tested in the laboratory under simulated conditions and later on installed in the Railway coaches for field testing at various routes suggested by Indian Railways and it was found that instrument was working satisfactorily. The results obtained by CSIO developed system were encouraging.

Acknowledgement
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