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Networked Embedded Systems Eliminate Safety Hazards in Rail Journey

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ABSTRACT

Introducing R&D into Rail transport is a good way to make sure that Railway decisions reflect the needs of passengers. Putting in place a foolproof security architecture and best brand components in the design of a safety system can ensure railway commutation in a high security environment. Managing security through proactive monitoring and event management is the key for achieving desired results. Safety and Punctuality — the two watch words of Indian Railways (IR) can be simultaneously achievable. Through technological innovations excellence at both ends are possible. To begin with, the age-old and ineffective alarm chain pulling (ACP) system of MEMU coaches with electromechanical design can very well be replaced by a system of networked microcontroller boards interconnected by the existing electrical wirings. An accurate digital signal processing in an electrically flashy environment, has been planned for execution. The innovations described in this work combine P89C51RD2 microcontroller's powerful instruction repertoire and other outstanding features like open-ended architecture and communications in RS-485 mode in the networked configuration, backed up by a sound Analog-Digital Engineering. Simplicity in design, use of inexpensive [Neil Geoff. Good Simple and Practical Systems that are used by all-Pilbar Rail Journey to Safety focused culture. Available at http://www.intlrailsafety.com/Perth/Pres/Neil-paper.pdf] industry standard hardwares and a non-blocking communication in the networked environment either in polling or interrupt mode, and compact assembly level programming can make this product design very cost effective, highly reliable, and MEMU worthy. The detailed design blue prints will describe the design, its implementation to prove how passengers' safety is unfailingly ensured during an otherwise unsafe and vulnerable journey through electric trains (MEMUs). ACP indication circuitry engineered appropriately and mounted at the rear end of each compartment of a moving carriage will not only provide an audio visual indication on the dashboard of the motorman of the moving train but will also provide much more vital information that can be recalled later.

Keywords: *Main line Electrical Multiple Unit (MEMU), alarm chain pulling (ACP), Indian railways (IR), four coach unit of MEMU (rake), noise margin (NM), comptroller and auditor general of India (CAG), British broadcasting corporation (BBC), line card send receive (LCSR) Unit, zero harm rail travel (ZHRT), anti-collision device (ACD), human resource development (HRD)*

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THE NEED OF THE HOUR

The Comptroller and Auditor General of India (CAG) has indicted Indian Railways (IR) for its failure in installing ACD, modernizing signaling, telecom, maintenance, inspection and training of HRD in telecom and signaling networks ([TOI-22.7.10]). Railways in USA spend 30% of its budgetary allocation for passengers' safety while IR spends only 2%. The Hindu reported in August 2000 that out of the 200 recommendations by various safety commissions set up after fatal train collisions, none were ever implemented. There are not many track circuiting systems–an essential safety feature in any complex Railway system, that ensures that no train is allowed into a section of a track without a firm confirmation that the preceding train has completely crossed the zone. Budgetory allocations of IR have dropped down to 5.9–6.9% for the last three plan periods in comparison to 11.5–15.5% for the previous three plan periods [1, 2].

BBC news [29, Oct, 2005] has correctly pointed out that many accidents could have been averted by using modern technology and reducing human involvements particularly in signaling and switching of tracks. Full conversion from mechanical to the state-of-the-art technology will need massive investments and time. Therefore, a planned and systemic approach towards localized modernization of sensitive areas and gradual safety enhancement is the need of the hour. During a train dacoity, terrorist attacks, etc., helpless passengers undergo a hell of torture and cannot communicate with the motorman for instant help and the crime scene is not video recorded either despite the availability of miniature digital cameras and related instrumentations. This project aims to fill up this void and demonstrate its field worthiness.

THE UTILITY OF THE MICROCONTROLLER

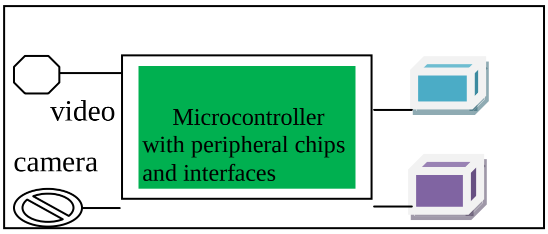
The motorman of a moving train can be theoretically contacted with mobile phones, power line communication, and microcontroller-based digital communication (currently under consideration).

Due to overcrowding, all passengers may not be able to have knowledge of the mobile number they have to communicate to during an emergency. It is, on the other hand, humanly impossible for a motorman to remain in touch with the massive number of commuters during a rail journey. A speeding train sometimes goes through terrains where tower coverage is absent. During an organized crime, terrorists confiscate the mobiles at the outset. People do misuse phone numbers given to them. The assistant-driver may not have the time to respond to each SMS or phone call from the large number of travelling passengers. In case of power line communication, it is difficult to handle and is expensive besides being not so effective in processing high speed digital data accurately, during emergencies in presence of very high electromagnetic interference (EMI). In a good, simple [3], and practical way it is possible to quickly snatch an Alarm Chain Pull (ACP) if needed. It is very difficult to tamper with [by miscreants] an in-built digital communication device based on a microcontroller activated by a quick snatch of an ACP. It works silently, instantaneously, and decisively and in an error free manner. P89C52RD2BA — Philips made 8-bit microcontroller, because of its CMOS design and wide voltage operation, is useful for battery and power operations where a long standby mode performance is desirable, and is best suited for the existing electrical setup of MEMUs. Its powerful instruction repertoire provides flexibility in designing compact and error-free communication subroutines for this demanding situation. Its open architecture and bit processing capability greatly helps string operations.

DESIGN CONCEPTS

At the rear end of every railway compartment, an embedded microcontroller system with required memory and interfaces with a built-in power source has to be installed. These are named SLAVE units. Two MASTER units are installed on the motorman's dashboard and Guard's control panel respectively.The role of motorman and Guard are interchangeable. Two MASTERs are accordingly programmed. All these (12+2) circuit boards communicate through two potential free wires that run along the entire electric train through two thick cables that hang between compartment junctions. As soon as the rakes are powered up by pantograph, MASTER takes control of the data bus and interrogates each compartment regarding ACP (Alarm chain pull), smoke and other inputs if any and continues the polling after receipt of data from the just polled compartment. This continues throughout the journey of the train. In the interrupt mode, however, the compartment that has come across an emergency can interrupt to register its problem on the dashboard of the speeding motorman in form of a LCD display followed by a shot beep sound. This scheme shortens the time of receipt of a distress call. A trained motorman and his assistant will have to continuously review the changing situations around them and prioritize the actions to be taken at a particular moment during a particular journey. When the motorman is perfectly tuned to the signalling conditions, track circuitry, approaching stations, and other trains expected to pass over the same track including the safety information [1] of all his accompanying compartments, appropriate decision making at the right time becomes easy for him and the passenger' safety in that case can be said to be in safe hands. Due to error-free, crisp, fast, two-way digital communication between compartments and MASTER control unit, it is possible to initiate instant damage control activities in the event of a suddenly developed emergency. It is also possible to activate surveillance gadgets like overhead video cameras, already installed on the ceiling of the compartment, for recording of an organized crime being perpetrated on the passengers on a moving/stationary train. This design, if implemented, will revolutionize the concept of the safety level of rail journey in our country.

CIRCUITS AND PLEMENTATION:DIGITAL CIRCUITRY



Smoke detector

Fig. 1 Basic Configuration of a SLAVE Unit Installed in a Rail Compartment.

A typical SLAVE unit is described in the Figure 1. It consists of a Microcontroller board comprising P89C51RD2BA microcontroller and fitted with zip sockets for programming. The Controller is connected with PWM chip,

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ADC, Temperature sensor and an extra onboard memory for resident utility programs. 256K internal RAM, 12C EPROMs, 3 numbers of GP I/O ports decorated with a low profile keyboard make this board very functional even with lead acid batteries installed under the carriage. Due to structural simplicity of the unit, onboard LCD inputting of user data, developing and debugging many programs tailor made for each train etc. are possible with this board and can be used in networked communication for a long time without system failure.

INTERFACING CIRCUITS

U1 IC galvanically isolates and converts TTL pulses to +15V square waves. And U2 IC converts back +15V pulses to TTL waves after a similar isolation. MOV1 short circuits high energy spikes as soon as they are induced between the data buses. Transistor T1 transmits +15V pulses and Transistor T2 receives the same. Signal P1.5 prevents reception while transmission is ON. TXD is bit stream signals sent out. LED and D1 are status-displaying devices indicating transmission and reception respectively. D2 diode receives the signal for the high threshold gate comprising T2 and Z1.

Voltage required for switching T2 ON is given by-

Min Vm = Vd+Vbe+Vz = 2Vd+Vz = 6.2V+1.4V = 7.6Volts

Vd = Diode voltage drop, Vbe = Base emitter voltage drop of T2, Vz = Zener drop

Vd = Vbe = 0.7V;Vz = 6.2V

The minimum of ‘1’ level voltage was fixed at 7.2V (NM = 7.8volts) and maximum of ‘0’ level voltage was chosen as 6.8V (NM = 6.8volts) and 0.40V is the voltage range of uncertainty.

M was frozen as above after observations of large number of sample pulsed [transmitted and received].

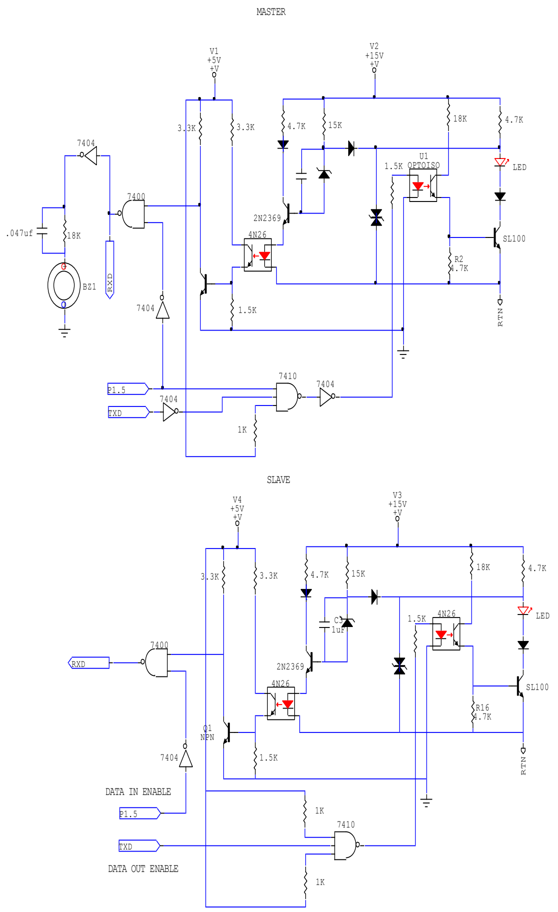


Fig. 2 Circuit diagram showing the interfacing and isolation scheme.

PARALLEL/SERIAL DATA TRNSMISSION AND RECEPTION

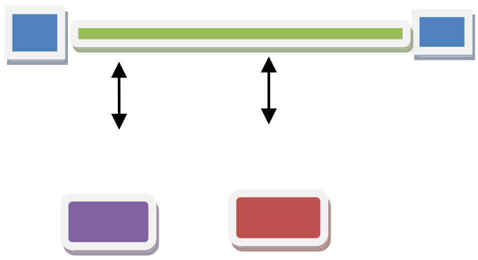
For the best operational result, 6/12-pair telephone wire cable has to be made a member of 30-core cable that hangs between joints of compartments of the train. This design modification [4, 5] will have to be done after approval from the Railway Board (Engineering). Else, we have to depend only on two conductors that have to be made potential free among the 30 conductors carrying various hazardous voltages. Advantage of the earlier option is that instantaneous (within 2/3 seconds) communication can be achieved by the distress caller. In the latter case, the design is rather complicated because it has to rely on two-wire half duplex digital communication. Error checking is, of course, has to be a part of software routines for both the options. SLAVE controller of each compartment has to be galvanically isolated from each other and from the rest so that failure in one coach does not functionally affect the communication with other coaches. Fire and Electrical hazards do not have any cascading effect over neighbouring compartments. Due to the presence of high aperiodic noise contents mixed with the pulses, logic levels have to be changed to high values [15V='1'; 0V='0'] and lines carrying digital information need a path free of EMI and distortions after ensuring that the interface circuitry is designed to have high built-in noise margins.

POWER SUPPLIES

SMPS power bloc provides the isolated and stabilized 5.25V and 15.15V DC power supplies needed by the controllers from 137V rms. voltage available from the generator room at the connector blocks placed on the rear side of each compartment. MASTER and SLAVE controllers are made in different FR-4, fibre glass double-sided PTH PCBs housing its own power supply and interface circuitry. DATA bus wires are connected across MOVs for arresting electrical spikes. In the absence of SMPS blocks linear power supplies work fine with the circuits at the cost of efficiency deficit.

SYSTEM STRUCTURE

Basic arrangement for handling ACPs is shown in the Figure 3.



M1 C1 ……. C2 M2

M1, M2: MASTER units
C1,…., C12: SLAVE units

Fig. 3 System configuration.

MASTER units are placed in the guard and motorman's cabin. Either one is enabled depending on direction of journey of the

MEMUs. SLAVE unit is placed in each of the moving compartments on the top inner side of its rear end. These are connected by two wire bidirectional data bus. MASTER and SLAVE units are almost the same except effecting few changes of jumper wires and additional hardware. Resident software [inside P89C51RD2BA] is also different for them.

INTERCONNECTIONS

Interconnection of a basic pair of MASTER and SLAVE unit is shown in the Figure 4 below:

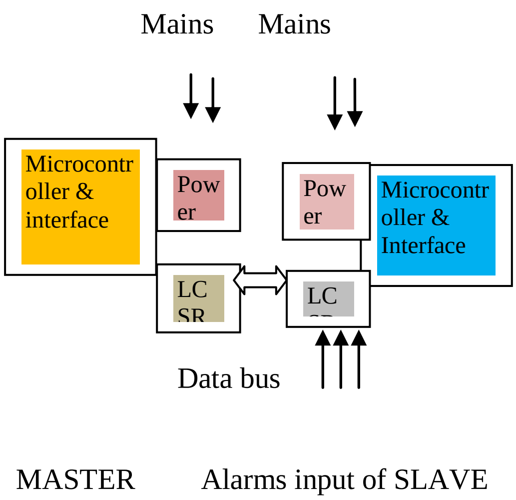


Fig. 4 Basic arrangement of one pair of MASTER and SLAVE unit.

Each of the MASTER and SLAVE unit has its own linear power supply, microcontroller board and LCSR interfacing circuitry for handling digital data. In MEMUs two potential free wires connected in half duplex mode are used for exchanging ACP and other data between one MASTER and maximum 12 numbers of SLAVE units installed in as many compartments using RS-485 mode of communication.

COMMANDS AND CONTROLS

When the pantograph touches the overhead wire, MEMU's generator starts working and MASTER and SLAVE controllers are placed on their respective power supplies. All the controllers are reset and the MASTER wrests the control and become bus master of the data bus. All SLAVES are placed in the listen only mode, waiting for interrogation commands from their MASTER. The messages that are displayed are given in Figure 5.

MASTER displays the following:

SENDING POS NO 01_

SLAVE unit displays:

WAITING……..

Fig. 5 Sign on messages of the MASTER and all SLAVE units.

MASTER transmits a interrogatory byte stream–SAAE–in bit serial form over the data bus meant for the Slave unit of address AA(H):

S	A	A	E

S: S stands for the Data meant for SLAVE units only

AA: Two bytes address of the SLAVE for which data is being sent.

E: End of transmission; the control of data bus is relinquished. The Data Bus is free.

This data is read by all SLAVE units. All the SLAVES except the one for which the programed address matches with the received address, ignore this interrogation command and wait for the next command to arrive with a header of 'S'. The addressed SLAVE responds by downloading following byte stream on the data bus, provided it has some information of distress signals with it. If it does not send any information within a stipulated period, the MASTER assumes that it has none and proceeds interrogating the next address.

M A A V W X Y Z L R E

M: This header means the data is intended for the MASTER. All slaves will discard this data.
AA: Signifies the address of SLAVE just interrogated
VWXYZ: Five digit number printed outside the coach being accessed
LR: The status information of left and right ACPs
E: Signals the end of transmission. The data bus is free for use by others.

Displays of MASTER and SLAVE are updated with the latest information, the MASTER has just collected from the coach number supplied by the SLAVE of address AA is as under:

MASTER displays

SENDING POS NO 01
COMP NO 57239 Y N

SLAVE shows as following on its LCD

COMP NO 57239 Y N

MASTER continues polling of the coach of next address and this process repeats itself in cyclic manner during the entire journey of the MEMU in one direction. Each time an ACP is engaged, the display of the MASTER on the dashboard of the motorman is updated with a short beep sound for drawing his attention to. 'Y' display indicates that the left ACP has now been engaged in the compartment whose number is visible in line number two. Line number one shows the coach position counted from the destination end. 'N' indicates that the right hand side ACP is not pulled.

Programs in MASTER and SLAVE units are tailored with large number of general purpose subroutines. Many of them are common for both. Nesting of subroutines are systematized by a powerful and field proven logic established by highly structured and compact machine level programming to make these units very user friendly and elegant.

Testing and validations: Testing arrangement is shown in the Figure 6 below:

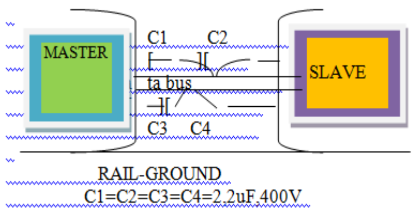


Fig. 6 Circuit set up for testing of interfacing between MASTER and SLAVE.

After wiring and connecting SLAVE controllers in a few coaches and installing a MASTER controller at the dashboard of the motorman the set up can be made ready for test and commissioning. As soon as the power is given, MASTER will start polling and ACP and other information (if any) will be received by the MASTER in response to its interrogation from the respective SLAVE controllers connected in the DATA path. Displays are flashed on the LCD screen of the MASTER and is always followed by a beep sound for calling attention of the motorman by the distress caller. Coach number (five digit number printed on the coaches) and the alarm chain (left or right) is displayed so that the motorman knows the exact coach which is calling for help [1]. Time to establish communication can be accurately measured with a stopwatch and UHF phones used in MEMUs. In the event of a persistent distress call by left and right chain pulling, the motorman can activate an overhead camera and ask for force (RPF) from the approaching Station Master after slamming the emergency brake for halting the speeding train.

In one of the rakes, electrical wiring was modified; two wires -32, 32A were made potential free and tested separately for digital signal transmission in respect of existing EMI after buzzing them separately and jointly. A pair of MASTER and SLAVE unit were wired up and ACPs were made operational after disconnection of their DC voltages. Times to receive the information on the display of the MASTER were measured after each ACP actuation with the help of UHF handsets used by Railway personnel. The results thus obtained given in Table I below.

Table I Test Data when MEMU was Moving Backward and Forward with Intermittent Breaks Applied to it.

Alarm Left (L) Right (R)	**Set / Reset**	**Display in Slave LED**	**Display in MASTER and SLAVE**	**Response Time in secs.**
L	S	L-ON	Position no 03 Comp. No. 37298YN	**37**
L	R	L-OFF	Position no 03 Comp. No. 37298YN	**39**
R	S	R-ON	Position no 03 Comp. No. 37298YN	**49**
R	R	R-OFF	Position no 03 Comp. No. 37298YN	**51**
L,R	S	R,L-ON	Position no 03 Comp. No. 37298YN	**43**
L,R	R	RL-OFF	Position no 03 Comp. No. 37298YN	47

Photographs of actual testing are shown below in Photograph I.

DISCUSSION OF RESULTS

The first trial was completed at 1200 bauds and the communication started failing at a speed of 4800 bauds. Speed was optimized after a large number of trials and analysis of averaged test results for a particular setup. In the interrupt mode of operation response time can be very much shortened. If an engineering modification of laying out a 4/6-twisted pair cable can be effected in MEMU's electrical wiring then the fastest audio visual indication of [within a fraction of a second] distress signal is possible for the speeding motorman. This requires the approval and order from the ministry of Indian Railway. The results are graphically shown in Figure 8.

SCOPE OF FUTURE WORKS

For working out an effective safety net for surface transportation, each passenger compartment must be fitted with adequate surveillance gadgets and electronically activated at the right time during exigencies. Processing of electronic alert signals, recording of data of crime scenes and calling for help etc. must be built-in and synchronously integrated to the alarm system of the speeding locomotive. Maintenance of contact with appropriate authorities by the moving motorman through RF modules must also be a part of the design upgradation.

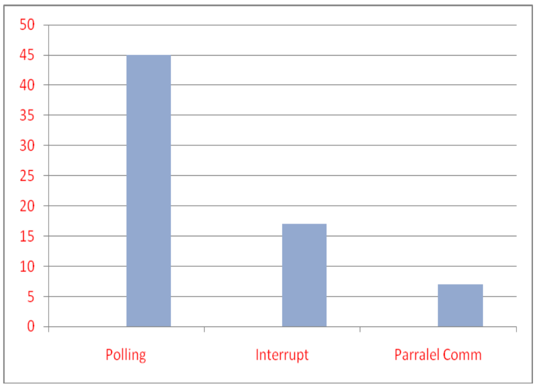


Fig. 8 Comparison of response times in seconds under different schemes of operation.

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