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Automotive Electrical Transient Suppression for Vehicle Tracking System

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ABSTRACT

The use of tracking a vehicle become critical in many applications including personal vehicle security, public transportation systems, passengers' safety, fleet management and others. Also, it is expected to rapid increase of vehicles on road globally. Therefore, the development of vehicle tracking system as per Automotive Industry Standard (AIS-140) using the Global Positioning System (GPS), Indian Regional Navigation Satellite System (IRNSS) and Global System for Mobile Communications/General Packet Radio Services (GSM/GPRS) modem is undertaken with the aim of enabling users and government bodies to locate the vehicles to monitor and control in an ease and efficient manner. The user also can track, monitor and control their vehicle remotely through mobile network. This paper is intended for the development of the vehicle tracking system's hardware prototype as per AIS-140. Specifically, this paper proposes the architecture for protection of power input against the automotive electrical transients as per ISO 7637-2 (2004). It includes under voltage cut off and pi filter to make the system electromagnetic compatible with vehicle electronics sub system.

Keywords – *AIS-140, GPS, IRNSS, Load dump, Transient, Vehicle Tracking Unit,*

1. INTRODUCTION

To provide quality, efficiency, safety, comfort and to optimize the current transport infrastructure; the globally proven Intelligent Transport Systems (ITS) are deployed. Having realization of ITS systems importance, many Indian organization and other Government bodies started working towards development and implementation of various parts of ITS across the country.

The electronics of the ITS system fitted with 24V or 12V which will part of commercial vehicles and passenger cars shall be compatible to both radiated and conducted electrical transients [2].

1.1 TYPICAL FEATURES OF VEHICLE TRACKING SYSTEM

- GNSS-SBAS position engine with application processor

- Dual / Quad band GSM / GPRS modem
- SOS button for Emergency service
- Anti-theft control
- Electrical transient compatibility as per ISO-7637-2
- Digital I/O's with optical/buffering isolation and Analog input
- Input power supply range of 8V to 32V
- Internal GNSS and GSM antenna
- Location transmission over SMS and / or GPRS
- Supports unit configuration through Serial / SMS
- Supports HTTP, TCP / IP and UDP / IP protocols
- Non-volatile memory for data logging
- Battery backup for stand-alone operation
- Firmware upgrade over the air (FOTA)
- Supports RS-232 based sensor integration

1.2 DEVICE TO BACKEND COMMUNICATION MECHANISM

The Global System for Mobile communication is the core communication media with GPRS as a primary connectivity with SMS fall back used by Vehicle Tracking Device to transmit data to Backend Control Centre as per defined protocol. The data from devices are getting delivered to Backend Control Center after it travels over the telecom service provider network. The overall architecture is shown in Fig1. The SIM cards on the devices should have a valid communication plan and should support for the automatic network switching between multiple telecom network service providers. This is to increase the active state of the device over the network and to increase the network coverage across the globe. Whenever the emergency situation arises, the device starts sending data to emergency server which is maintained by Government body as a highest priority than default server. This is to provide the emergency actions to the victims by the best possible means. If the GPRS connectivity is poor, the device will automatically fall back to SMS and sends an SMS to authorized emergency numbers. The communication protocol is defined in AIS-140[1].

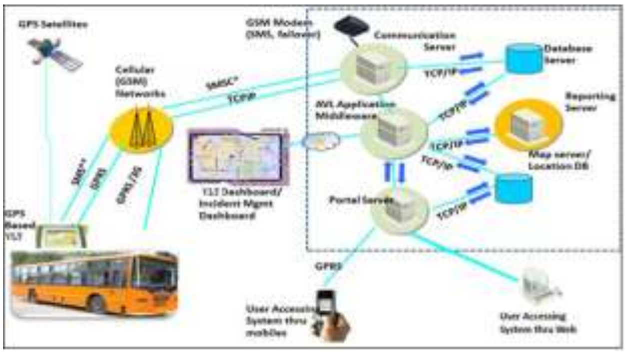

Fig 1: Architectural view of complete system

In order to avoid the unauthorized device data to Backend Control Centre, a suitable control mechanism should be established so that only authorized devices shall be able to send the data.

1.3 PROBLEM DEFINITION

The available aftermarket vehicle tracking devices are not complied with any of the automotive standards, no security and safety built in. By analyzing the current infrastructure and by considering the safety and security of the passengers the Government has come up with new regulation Automotive Industry Standard (AIS-140), Intelligent Transportation Systems (ITS) - Requirements for Public Transport Vehicle Operation that every public transport vehicle must be equipped withAIS-140 complied ITS. The major requirements of AIS-140 are

1. Safety – All the public transport vehicles must be communicated to Government server
2. Security – All the public transport vehicles must be equipped with emergency buttons (SOS)
3. Electronic safety – The electronics must be complied to ISO 7637-2, ISO-16750 and AIS-004 standards.

a. ISO 7637-2: The ISO 7637 specifies bench tests for testing the compatibility to conducted electrical transients of equipment installed on passenger cars and light commercial vehicles fitted with a 12 V electrical system or commercial vehicles fitted with a 24 V electrical system [2].

The various transients expected in road vehicles are categorized into five pulses which are shown below,

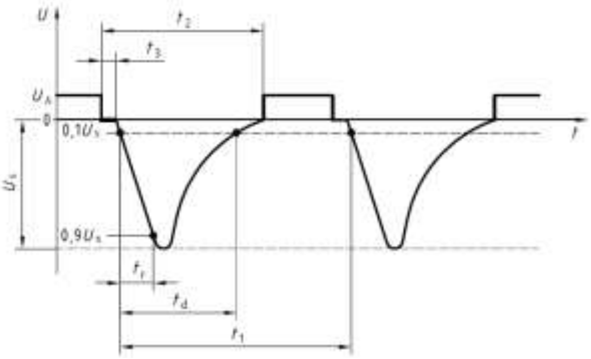

Fig 2: Pulse1

Table 1: Parameters of Pulse1

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Parameter	12 V system	24 V system
U_s	–75 V to – 100 V	– 450 V to – 600 V
R_i	10 Ω	50 Ω
t_d	2 ms	1 ms
t_r	$\left(1^{\ 0}_{-0,5}\right)$ µs	$\left(3^{\ 0}_{-1,5}\right)$ µs
t_1 [a]	0,5 s to 5 s	
t_2	200 ms	
t_3 [b]	< 100 µs	

[a] t_1 shall be chosen such that the DUT is correctly initialized before the application of the next pulse.

[b] t_3 is the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.

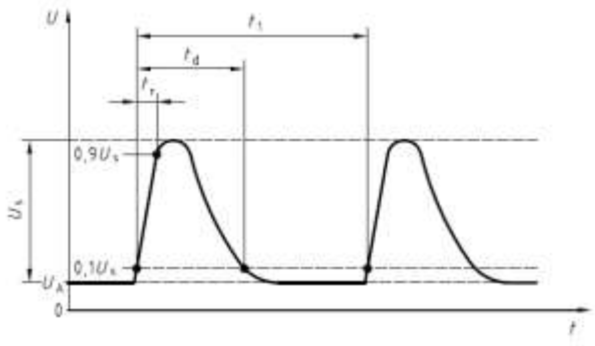

Fig 3: Pulse 2a

Table 2: Parameters of Pulse 2a

Parameter	12 V system	24 V system
U_s	+ 37 V to + 50 V	
R_i	2 Ω	
t_d	0,05 ms	
t_r	$\left(1^{\ 0}_{-0,5}\right)$ µs	
t_1 [a]	0,2 s to 5 s	

[a] The repetition time t_1 can be short, depending on the switching. The use of a short repetition time reduces the test time.

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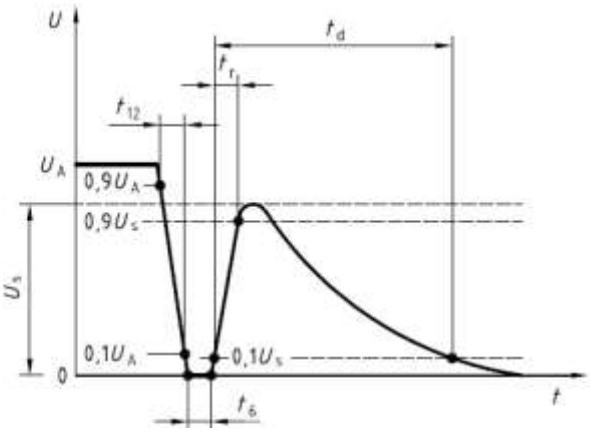

Fig 4: Pulse 2b

Table 3: Parameters of Pulse 2b

Parameter	12 V system	24 V system
U_s	10 V	20 V
R_i	0 Ω to 0,05 Ω	
t_d	0,2 s to 2 s	
t_{12}	1 ms ± 0,5 ms	
t_r	1 ms ± 0,5 ms	
t_6	1 ms ± 0,5 ms	

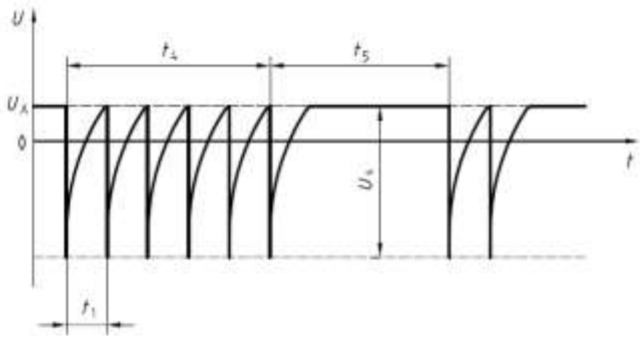

Fig 5: Pulse 3a

Table 4: Parameters of Pulse 3a

Parameter	12 V system	24 V system
U_s	– 112 V to – 150 V	– 150 V to – 200 V
R_i	50 Ω	
t_d	$\left(0{,}1^{+0{,}1}_{\ 0}\right)$ µs	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	

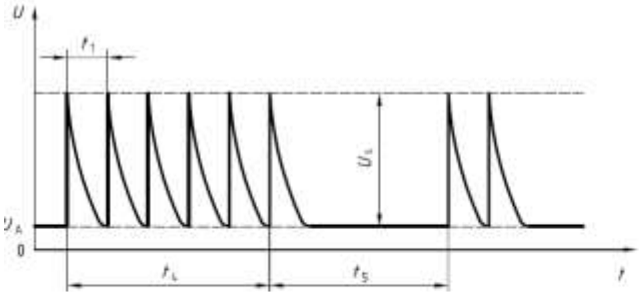

Fig 6: Pulse 3b

Table 5: Parameters of Pulse 3b

Parameter	12 V system	24 V system
U_s	+ 75 V to + 100 V	+ 150 V to + 200 V
R_i	50 Ω	
t_d	$\left(0{,}1^{+0{,}1}_{0}\right)$ µs	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	

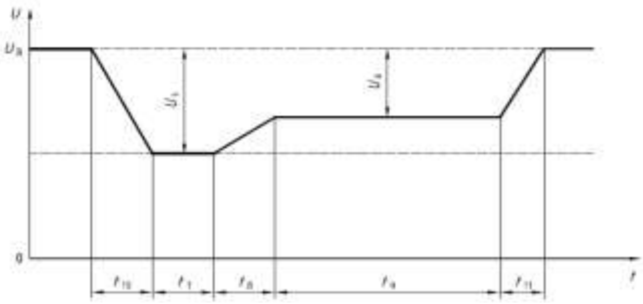

Fig 7: Pulse

Table 6: Parameters of Pulse 4

Parameter	12 V system	24 V system
U_s	− 6 V to − 7 V	− 12 V to − 16 V
U_a	− 2,5 V to − 6 V with $\lvert U_a \rvert \leq \lvert U_s \rvert$	− 5 V to − 12 V with $\lvert U_a \rvert \leq \lvert U_s \rvert$
R_i	0 Ω to 0,02 Ω	
t_7	15 ms to 40 ms [a]	50 ms to 100 ms [a]
t_8	≤ 50 ms	
t_9	0,5 s to 20 s [a]	
t_{10}	5 ms	10 ms
t_{11}	5 ms to 100 ms [b]	10 ms to 100 ms [c]

[a] The value used should be agreed between the vehicle manufacturer and the equipment supplier to suit the proposed application.

[b] t_{11} = 5 ms is typical of the case when engine starts at the end of the cranking period, while t_{11} = 100 ms is typical of the case when the engine does not start.

[c] t_{11} = 10 ms is typical of the case when engine starts at the end of the cranking period, while t_{11} = 100 ms is typical of the case when the engine does not start.

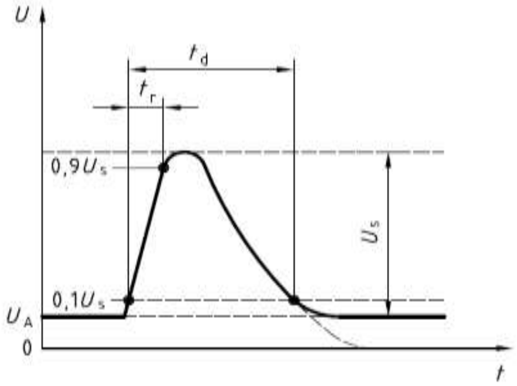

Fig 8: Pulse 5a

Table 7: Parameters of Pulse 5a

Parameter	12 V system	24 V system
U_s	65 V to 87 V	123 V to 174 V
R_i	0,5 Ω to 4 Ω	1 Ω to 8 Ω
t_d	40 ms to 400 ms	100 ms to 350 ms
t_r	$\left(10\ ^{0}_{-5}\right)$ ms	

The simulation of load dump transient represents Pulse 5a. This transient occurs during the event of vehicle battery being disconnected while the engine alternator circuit generating charging current and with all other loads are remain on the alternator circuit at this time. The pulse 5a amplitude is depends on the speed of the alternator and the alternator field excitation level at the time of battery disconnected. The pulse 5a may occur due to several reasons; poor connection, cable corrosion or an intentional battery disconnection when the alternator is running. The pulse 5a resembles half sine wave in which second half of pulse follows an exponential curve and it is interrupted at UA.

2. SYSTEM ARCHITECTURE

The system is based on Microchip's SAMV71 series microcontroller, 32bit ARM cortex M7 core and a high performance GNSS receiver.

The block diagram of the proposed receiver is shown Fig 9.

Fig 9: Architecture of a Vehicle Tracking System

The GNSS module on the VTS provides unmatched performance in terms of sensitivity and TTFF. The GNSS module supports both GPS and IRNSS constellation along with Satellite Based Augmentation System. The GNSS and GSM antennas are embedded within the enclosure thereby ensuring tamper–proof operation. The VTS consists of a multi-band GSM / GPRS modem for data communication. The device supports HTTP, TCP/IP and UDP/IP protocols for the communication with the server. Also, the SMS can be sent to intended numbers if server is not available. The embedded SIM is used in this design rather than the conventional SIM cards to avoid the tamper by driver or others.

The VTS supports CAN J1939 standard for the commercial vehicle segment. The parameters read through CAN interface would help in the maintenance of the vehicle, monitor driver behavior and to know the status of various modules in the vehicle. The general purpose I/O's of the system are conditioned and brought out to serve as digital I/O and analog inputs.

The power supply design has to be robust enough to handle the vehicle supply variations. It can operate from 8V to 32V and provide protection against surges, short circuit and reverse battery connection. VTS consists of 950mAH Ni-MH backup battery for operations when the main supply is intentionally/un-intentionally disconnected. The data logging flash is being used store the packets at the defined intervals whenever the device is in GSM shadow region. The stored packets will be sent to server once the device is able to establish the connection with server. Over the air firmware upgrade feature helps in upgrading the firmware of the device when the device is live on the field. It can be integrated with many accessories such as SOS button, temperature sensor, fuel sensor; RS-232 based active/passive RFID's and many more.

2.1 POWER SUPPLY ARCHITECTURE

The power supply architecture of the system is shown in the Fig 10. This section includes protection circuit, main buck regulator, and battery charger, automatic switch over circuit, other buck regulators, linear regulators and power switches. The system includes internal Ni-MH battery pack to supply power during the absence of vehicle battery. As per AIS-140 regulation, the device shall operate minimum of 4hrs using internal battery.

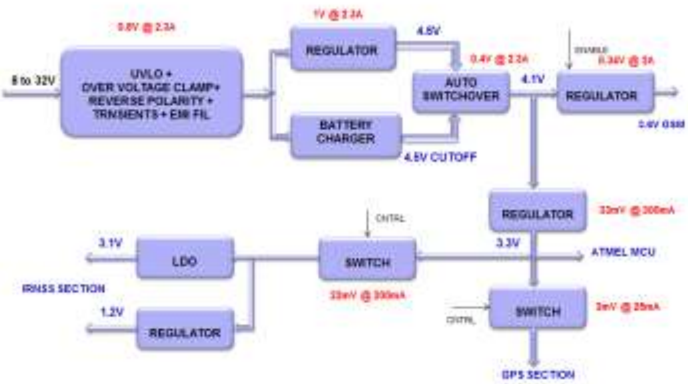

Fig 10: Power supply Architecture

The power switches are used to have the power control on individual sections to achieve different power down modes.

2.2 POWER INPUT PROTECTION

The power input protection is vital important in devices which are connected to vehicle electronics, since the major transients are expected on power leads connected to vehicle battery than other interface signals. As this paper intended more about electronics safety; the detailed architecture of power input protection is discussed in this section. The power input protection architecture is shown in below Fig11.

Fig 11: Power input protection architecture

The above architecture is defined to provide protection against the different transients defined by ISO 7637-2 [2]. The first stage is used suppress the high frequency transients by using shunt capacitor. The shunt capacitor along with series source impedance forms an RC filter which acts as a short for high frequencies. The Negative transients are suppressed by a combination of unidirectional TVS diode and a standard diode with reverse breakdown voltage of above -600V.

The schematic snapshot of the power input protection circuit is shown in Fig 12. The schematics is created by using OrCAD Capture Rev16.6 tool [8]. The electronics in the power input circuit must ensure the compatibility to conducted electrical transients of equipment installed on passenger cars and commercial vehicles fitted with 12 V or 24 V electrical systems along the power supply lines as per ISO-7637-2 standard.

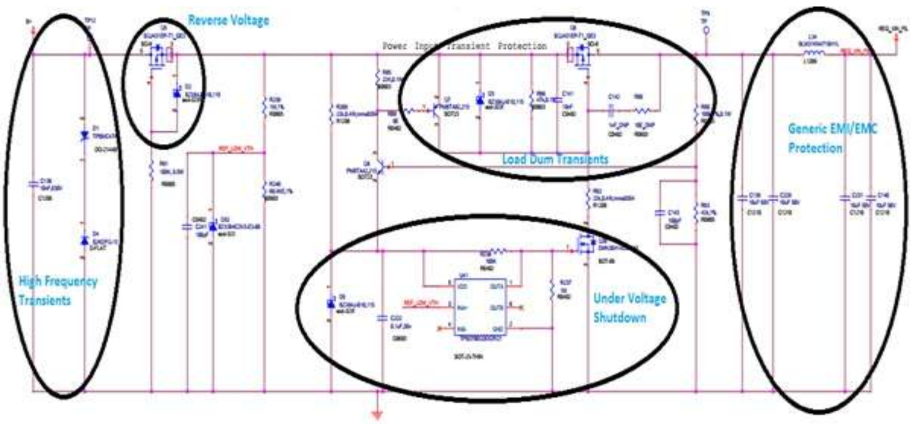

Fig 12: Power input protection circuit

As shown in the above circuit, the power input protection circuit has the following features;

- DC Negative Voltage protection up to -36V
- Negative Transient protection up to -600V
- Load Dump Transient protection up to 174V/200ms
- Under Voltage shut down at ~8V
- Standard EMI/EMC protection

The SQJ431EP is a 200V p-channel MOSFET and there are two SQJ431EP MOSFETS in series but with opposite orientation, the first MOSFET provides reverse voltage protection and next MOSFET provides protection against load dump transients that could last as long as 174ms. This load dump is the most severe transient that can be expected from road vehicles [2].

2.3 SIMULATION RESULTS

The power input protection circuit is simulated using TINA for all the pulses and the output voltage is monitored. The output voltage is clamped to lower voltage which is in operating input range of following regulator. The exact pulses are not used for the simulation since the transient pulses are exponential waveforms which require special hardware setup to generate. For simplicity, the similar pulses are generated using TINA and are used for the simulation. The simulation results for each pulse and also, for under voltage and reverse polarity protection are shown below,

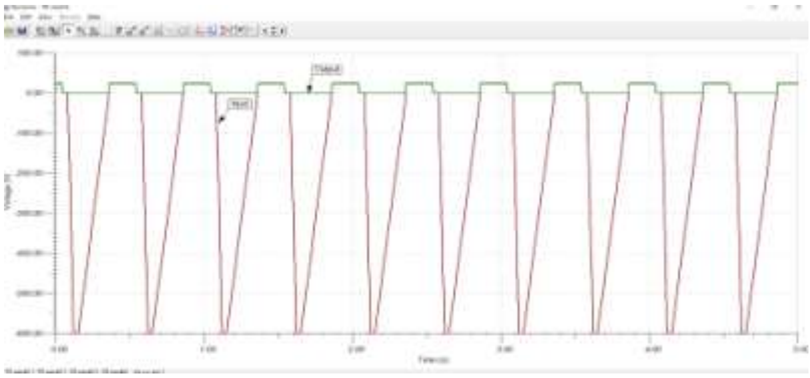

Fig 13: Simulation result for test pulse 1

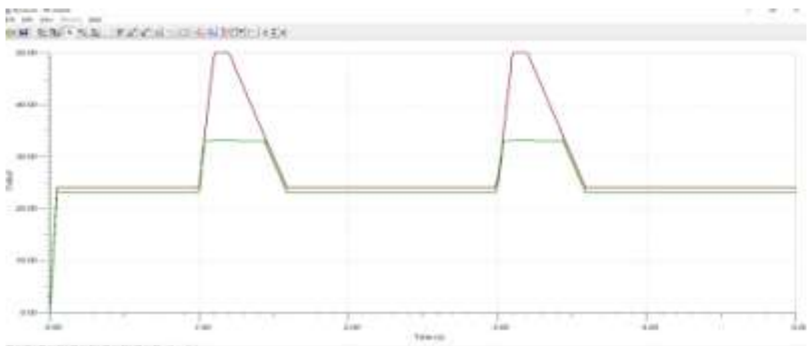

Fig 14: Simulation result for test pulse 2a

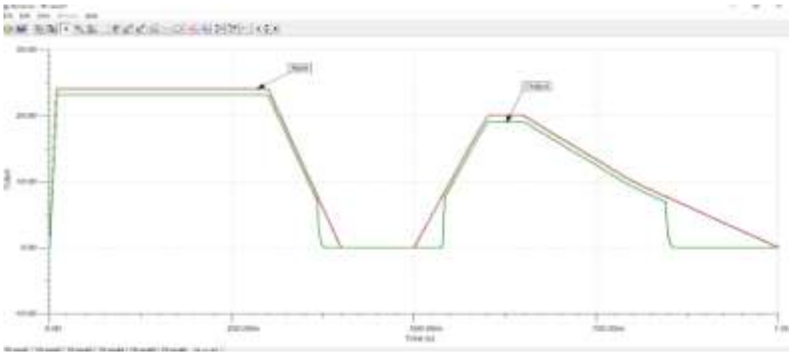

Fig 15: Simulation result for test pulse 2b

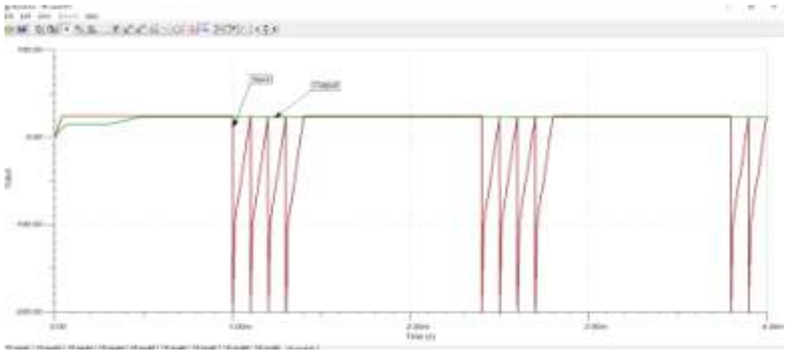

Fig 16: Simulation result for test pulse 3a

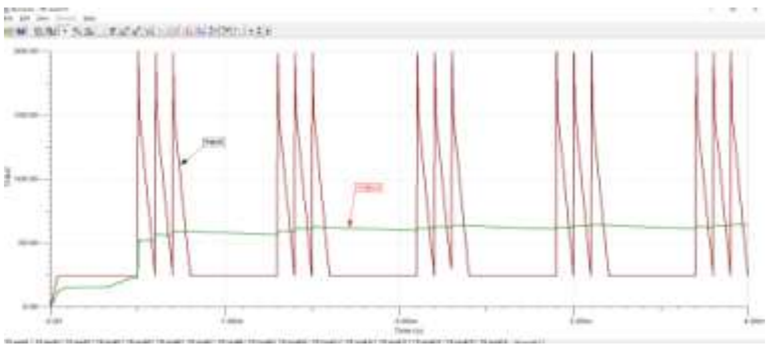

Fig 17: Simulation result for test pulse 3b

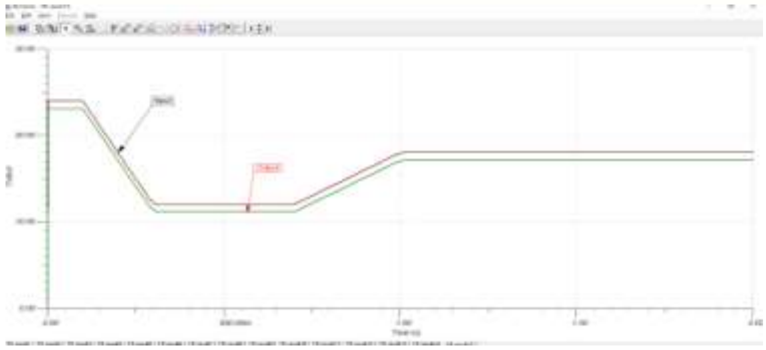

Fig 18: Simulation result for test pulse 4

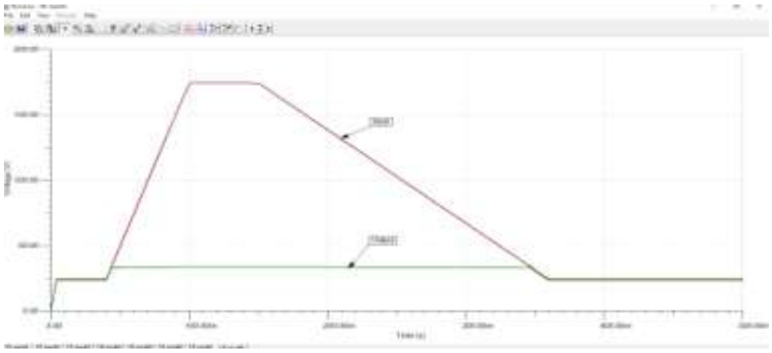

Fig 19: Simulation result for test pulse 5a

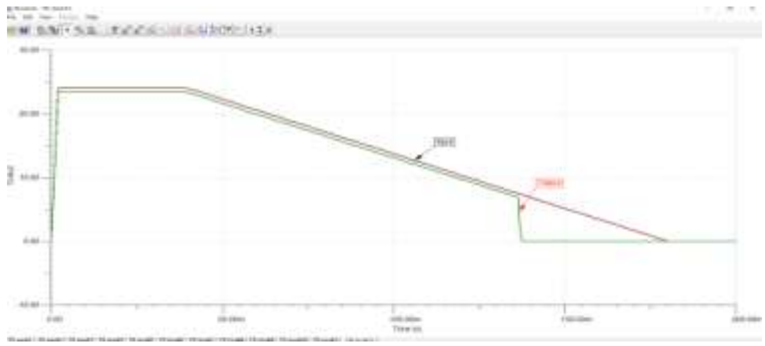

Fig 20: Simulation result for under voltage shutdown

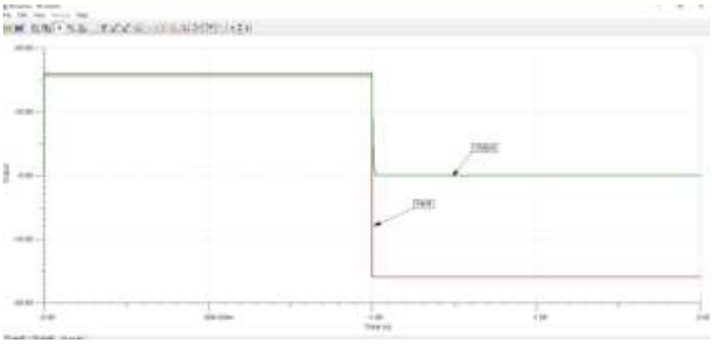

Fig 21: Simulation result for reverse polarity

3. CONCLUSION

The cold cranking and load dump conditions in the vehicle are lead to wide input voltage variations which will be applied on automotive electronic systems. The need for over voltage protection is particularly common where the over voltage is as high as 87V and 174V in 12V and 24V systems respectively. The architecture and the circuit is been captured for the Vehicle Tracking System with load dump, reverse polarity and under voltage shutdown protection. The defined architecture for power input offers the protection against power disturbances/transients generated due to various reasons [2] namely pule1, 2a, 2b, 3a, 3b, 4 and 5a. The output of the power protection circuit provides the uninterrupted voltage range of 8-32V during over voltage transients and load dump. This can be fed to front end regulator which operates over these input range. Another challenge in AIS-140 is IRNSS shall be part of Navigation system; this is addressed by using the IRNSS receiver from Accord Software and Systems Pvt Ltd.

4. AKNOWLEDGEMENTS

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