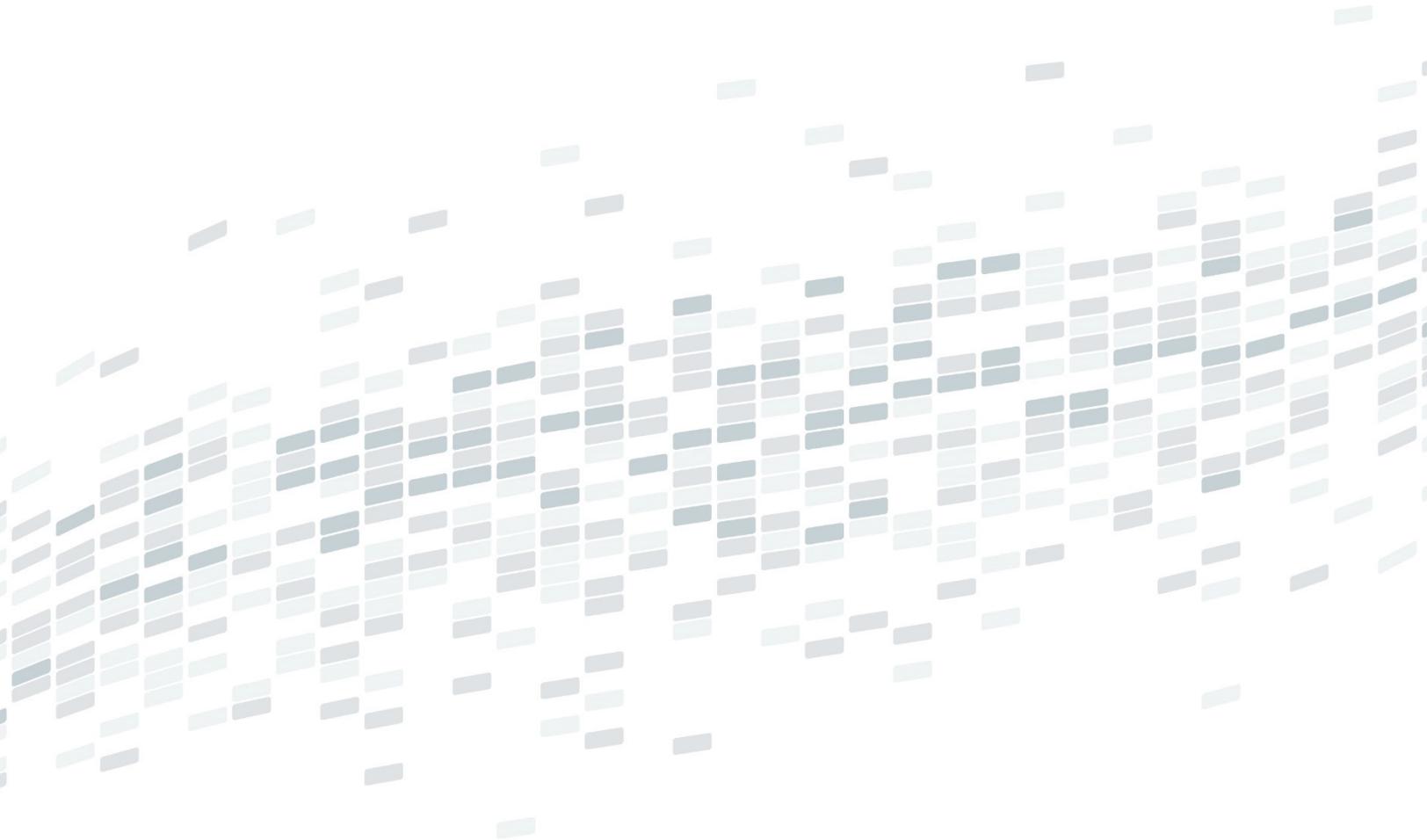


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# Parasitic Battery Drain Problems and AUTOSAR Acceptance Testing



# Parasitic Battery Drain Problems and AUTOSAR Acceptance Testing

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## Abstract

Battery Drain problems can occur in the vehicle due to improper network management between electronic control units (ECUs). Aim of this paper is to identify the factors that cause transmission and cease of transmission of a network management message of an ECU along with its application messages that controls the sleep/wake-up performance of other ECUs in the network. Strategy used here is, based on the root cause analysis of problems found in Display unit in vehicle environment, the functional CAN signals impacting sleep/wake-up behavior is re-mapped along with the state flow transition of AUTOSAR NM Algorithm. A re-defined test case design and simulation for vehicle model is created. Especially it focuses on validating the impact of functional CAN signals on DUT's sleep/wake-up performance. The result includes, design and development of use case matrix(mapped with specification) to validate the impact of network management messages, its flow of transition as well as the impact of functional CAN messages on the sleep/wake-up behavior of DUT and on the system as a whole. Also a new set of system level defects identified across Audio and display units-based on the re-designed network management test procedure and simulation with Vector Canoe model (comprehensive software tool for development, test and analysis of entire ECU networks and individual ECUs.). This paper provides relevant design guidelines for acceptance testing of any communicative network that follows AUTOSAR standard and this can be deployed across programs/products. It concludes validation of network management functionality (AUTOSAR) shall not be restricted only to the transmission of network management (NM) message of an ECU, as well as shall consider application messages that triggers NM messages of other ECUs in the network.

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## 1. Motivation

The list of issues that can cause a car battery to die is so long as to approach never ending, but virtually every battery killer out there can be shoehorned into the following basic categories: battery problems, electrical system problems, simple user error (leaving Hood, Door, window, trunk in open position during park, key in ignition cylinder/proximity key states) extreme weather conditions and issues with power train codes [1, 2]. Some newer vehicles are designed to leave the headlights, dome lights, or even the radio on for a while after shut the engine off and remove the keys which will shut off on a timer [3]. In today's Auto world, the software components are high and hence this paper focuses on software code issue that causes battery drain problem in the vehicle.

Section 1 describes the possible ways of occurrence of parasitic battery drain problems in vehicle. Section 2 describes basic functionality of CAN NM and power consumptions at various levels in a vehicle. Section 3 talks about the test procedure currently followed by ECU suppliers whereas Section 4 explains the system (Infotainment) used for study and analyze battery drain issues reported from vehicle. It also relates current test method with the reported issue. Section 5 is a proposal to avoid test escape of a set of battery drain problems from supplier and it details developed simulation model and test case design (TCD). Section 6 compares the existing TCD along with recommended one and picturizes the issues identified by the proposal. Section 7 concludes this work.

## 2. Introduction to AUTOSAR

This paper describes importance of AUTOSAR acceptance tests and design of acceptance test suite. It explains the relationship between acceptance and interoperability, interoperability of ECUs in a vehicle, and the need to avoid diverging acceptance test standard by the ECU supplier in their engineering process.

### 2.1. Design of AUTOSAR CAN NM [4]

The AUTOSAR CAN NM is based on a decentralized direct network management strategy, which means that every network node performs its activities self-sufficiently depending on the network management protocol data units (PDUs) that are received or transmitted within the communication system.

The main concept of the AUTOSAR CAN NM algorithm can be defined by the following two key-requirements:

- Every network node in a CAN NM cluster shall transmit periodic network management PDUs as long as it requires bus-communication; otherwise it shall transmit no network management PDUs.

- If bus communication in a CAN NM cluster is released and there are no network management PDUs on the bus, in a configurable amount of time which is determined by  $CANNM\_TIMEOUT\_TIME^1 + CANNM\_WAIT\_BUS\_SLEEP\_TIME^2$ , bus goes to sleep followed by shut down of ECU.

### 2.2. Sleep Mode, Current Consumption Considerations

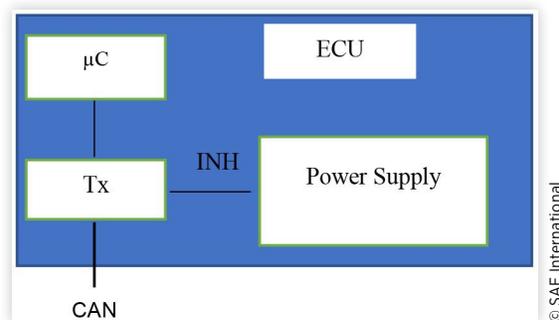
During shut down, internal power supply of every ECU is disconnected, only the transceiver (Tx) at physical level is active. This in turn, cumulatively reduces power consumption at vehicle level. When wakeup event is detected, Tx switches on internal power supply of ECU via INH pin [Figure 1].

As long as network PDU transmits in CAN network, ECU power supply stays connected and determined sleep current measurement cannot be achieved. Sleep current measurement at various levels are shown in Table 1[5].

## 3. Existing Test Method

Currently standard acceptance test suite is followed by ECU suppliers. Standard acceptance tests are written at the specification level, intended to validate the implementation of the AUTOSAR platform at its interfaces. Executing these tests validates the interoperability of the basic software stack-under-test with AUTOSAR application software components

**FIGURE 1** Physical level bus wakeup.



**TABLE 1** Current measurements.

Various levels	Current requirements
Car level	40 mA
ECU level	100-200 $\mu$ A
Physical level	18-30 $\mu$ A

<sup>1</sup> Wait time for no NM message present in bus.

<sup>2</sup> Wait time for no application message present in bus.

and interoperability at the vehicle network level on the other [6]. In bus level, the scope of acceptance tests includes [7]

- Bus behavior (e.g. transmission behavior, bus off handling, state management)
- Bus protocols (e.g. transport protocol, network management, diagnostic communication)

In addition to this, Product suppliers shall derive their own test suites with their permutation and combination, as a part of self-declaration of acceptance of the product. [8]

### 3.1. Pitfalls of Existing Test Method

ECUs continue to transmit NM message and keeps the bus awake even after sleep conditions are met. The strategy used to test the network management section focuses only on transmission of network message during startup/shutdown.

Following are the drawbacks in current test method.

- On change event (signals) from nodes that controls the sleep character of other ECUs to keep the bus awake for the necessity of the network are not considered for sleep/wake up performance.
- Also the performance of the ECU wakeup due to disturbance that happens during the bandwidth of bus idle phase mostly not considered by ECU suppliers.

## 4. Description of System, Issues and Analysis

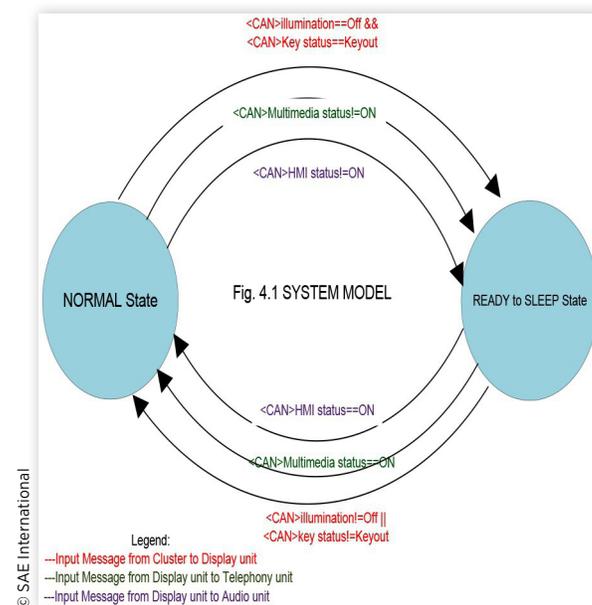
### 4.1. System Model for Study

Figure 2 shows the system model taken to study the problem. IPC unit is the master of the system while the Display unit is the intermediate gateway module that serves for the communication between master and other nodes in the system. Any node which needs to stay active, keeps the bus alive with the transmission of the network message. As long as any NM message present in the bus, other ECUs remain to be in ready to sleep state and continues transmit its application message.

Figure 2 depicts how the Display unit depends on application events <CAN>illumination status, <CAN>Key status (from Cluster unit), Audio Unit depends on <CAN>HMI status (from Display unit), and APIM looks for <CAN>Multimedia status (from display unit) for the transition of different network states of the respective ECU.

Generally, when battery drain problem is reported in the vehicle, it causes suspicious that the ECU which draws more current is a babbling node in the vehicle. For the below reported issues, initial assumption is transmission of message by any node in the network during bus idle phase causes deadlock in the system by continuous transmission of a NM message. When the occurrence is not known, simulation

**FIGURE 2** System model.



model is developed to create disturbance in the bus idle phase with varying duration of milliseconds, which resulted in failure identification. However, executing standard acceptance tests for network management and startup/shutdown tests does not help to recreate it.

### 4.2. Reported Issues Considered from Vehicle

**4.2.1. Battery Drain Issue due to Illumination Status** A software design change implemented in cluster unit, between two CAN signals <CAN>illumination status and <CAN>dimming status, the order in which they set their status to sleep ready state before enter into ready to sleep state. As the display unit designed to check dimming level status instead of illumination status, This change leads to failure in Display unit ability to set its ready to sleep state.

**4.2.2. Battery Drain Issue due to Multimedia Status** Another battery drain issue reported in the vehicle stated that failure of the display module to set its on change event to a default value (in a specific case) before entering into “ready to sleep state” causes another ECU (Telephony unit) in the network to remain in active state. This, in turn, causes the entire network in the system to remain active.

In both the cases, one ECU looks for the state of health/data from another ECU in the network which is ready for sleep/whose job is already done correctly or incorrectly. While car makers and AUTOSAR consortium works for the concept called “Partial Networking with Selective Wake up” [9] which saves energy even during functional state of a vehicle, energy drain during non-functional mode, due to deadlock in single ECU leads to the failure of entire E/E Architecture.

**TABLE 2** Matrix for signals and guards of different states for other ECUs from FCDIM

Signals/ECU	States	
	Ready to sleep	Normal state
<CAN> Multimedia status (Telephony unit)	OFF	ON
<CAN> HMI status (ACM Unit)	OFF	ON

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With respect to the scope of interoperability, we need to clearly focus on the correct behavior of an ECU within the network that mainly relates to the handling of defined states, timing and data on the dedicated buses which is driven by OEM-specific design decisions, so-called “Communication Matrix”, shown in [Tables 2](#) and [3](#).

[Table 3](#) shows the value of guards (external ECU sleep control CAN signals) that an ECUs in infotainment system needs to maintain at different states, as these signals controls the state manager of other ECUs in the system.

## 5. Proposed Testing Method

[Figure 3](#) [7] provides a view of acceptance testing in the overall test activities. Basic network management testing involves standard acceptance testing and OEM specific qualification testing, which is sufficient to clear module acceptance of the product. But project specific tests - in combination with configuration - are missed to carry out which leads to startup shut down problems in the vehicles.

### 5.1. Test Guidelines for CAN NM Testing

In the above cases (discussed in Section 4.2), an application event has influence over the CAN NM algorithm and its transmission. Considering this as a network management testing, it will comprise into three parts:

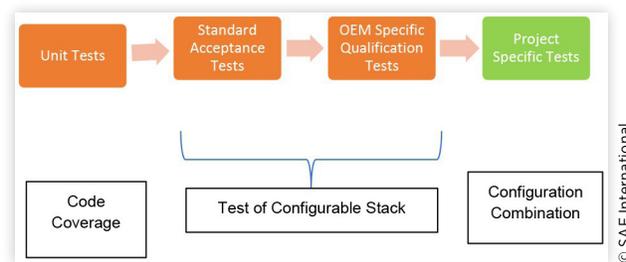
- Basic acceptance testing provided by the OEM (ECU Test Procedure Specifications)

**TABLE 3** Communication matrix for system with signals and guards.

Signals	<CAN> HMI status	<CAN> multimedia status	<CAN> illumination status	<CAN> key status	<CAN> ASR NM
Audio unit	Equals ON	X	X	X	TRUE
Telephony unit	X	Equals ON	X	X	TRUE
Display unit	X	X	Not Equals OFF	X	TRUE
Display unit	X	X	X	Not Equals keyout	TRUE

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Note: Normal state refers the state where ECU transmits NM message to hold the bus. Ready to sleep refers ECU transmits only application specific events in the bus.

**FIGURE 3** AUTOSAR NM testing.

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- Entry/Exit criteria from different network modes [3] (Appendix A.1)
- Project specific configuration combination tests

A test procedure is designed for this configuration's specific combination and implemented in various programs with the help of the simulation design shown here.

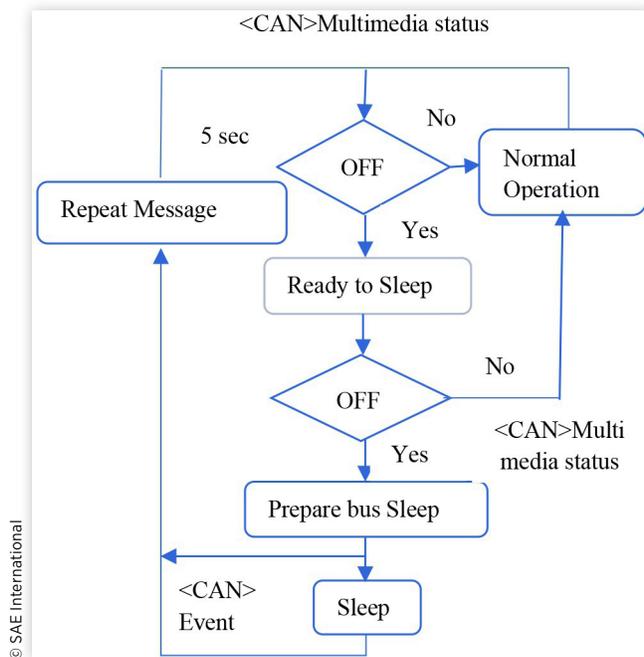
### 5.2. Simulation Model

With the solution identified in Section 4, test cases are designed for application events that impacts network messages of an ECU under test. Similarly, for battery drain problem described in Section 4.2.2, it is identified an application event from the device under test (DUT) that impacted the network layer of other ECUs in the network. But these events can be triggered in “n” number of combinations which cannot be predicted. E.g. multimedia system status changes during multiple user triggered events such as voice, telephony system, extended entry/exit mode, different multimedia state entry/exit conditions.

A simulation model was developed in accessory protocol interface module (APIM) node to monitor application events continuously and the node release bus (stops transmission of NM message), only when the desired event reaches the desired state ([Figure 4](#)). By any means, if the CAN event from the DUT does not reach sleep ready state, the simulation model does not allow the network to enter sleep mode.

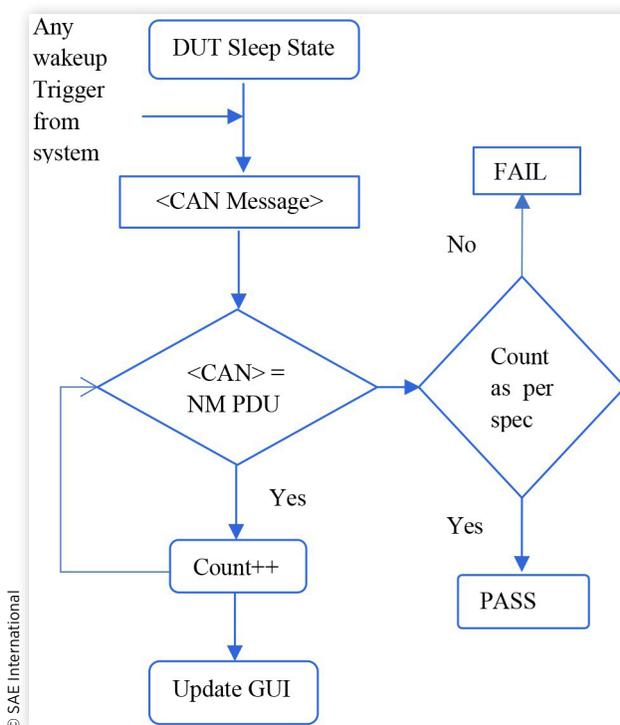
Different network states are considered during design; if the application event from DUT gets triggered at any state, designed telephony unit simulation wakes the network and keeps it alive.

**FIGURE 4** Telephony unit simulation to control CAN NM algorithm.



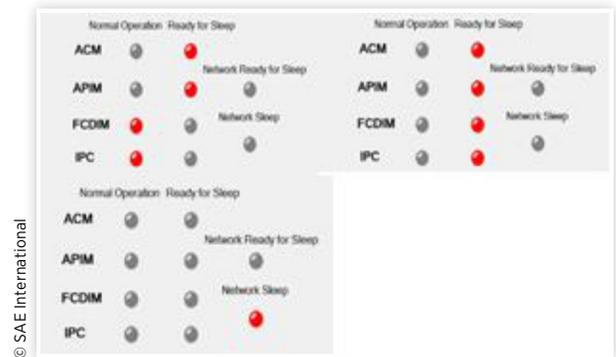
Also, simulation model is developed to continuously monitor NM message transmission (Figure 5) from the ECU. As the transmission of NM PDU, varies based on configuration and trigger events, number of PDUs are monitored

**FIGURE 5** Simulation to monitor NM DUT.



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**FIGURE 6** Different states of ECUs in network.



for each trigger and updated via GUI to user. It is set to fail, If the number of PDUs could not match with configuration aspect. This approach eases configuration based network testing methodology.

Various network states (normal operation state, ready sleep state, prepare bus sleep mode, bus sleep mode) are monitored from the system and presented in GUI. “On change” application events that can trigger sleep/wakeup are added here, where the tester can initiate any trigger at any states. The time duration for which node is active for individual wakeup triggers are also monitored from the CAN bus and outputted to the GUI.

Figure 6 is the panel monitors the status of ECUs in the network. It shows three different stages of infotainment network. In first stage, ECUs ACM (Audio unit) and APIM (Telephony unit) are ready to sleep state where they transmit only application messages. ECUs FCDIM (Display) and IPC (Cluster) are in normal operation state which transmits both application and NM messages to keep the network active. In second stage, all the ECUs in the network are reach ready to sleep state, transmits only application messages. In third stage, the network is in complete sleep state.

Figure 7 shows various wakeup triggers for display unit and gives the duration of NM transfer for each trigger to the tester.

**FIGURE 7** Wakeup trigger for display unit.



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## 6. EXISTING vs PROPOSED Testing Methodology

The objective of testing is to find defects when they are cheaper to remove. Current NM acceptance testing, involves communication and electrical level robustness tests, physical level fault tolerant tests (CAN\_H, CAN\_L). Communication robustness includes basic startup/shut down test and accuracy in transmission of on change, on write events of application messages in CAN bus. This forms the test suite for AUTOSAR acceptance testing.

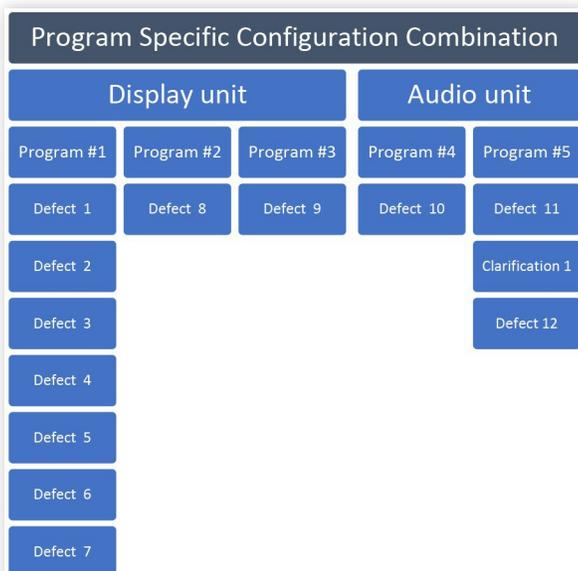
Proposed testing method is, Project specific configuration combination test and state transition test are missing in this standard testing method. This leads to occurrence of battery drain problems (due to issues in state manager) in the vehicle which is seen at customer fleet/end user that could be controlled at ECU supplier level.

For configuration testing, test suite shall be developed with possible use cases. A sample of use cases developed for display unit is shown in Appendix A2. Also test suite shall include use cases for state transition with entry/exit timings equals to boundary value conditions Appendix A1.

Interoperability testing and reuse of test suites is the main target when developing a solution for problems of any open standard. By reuse of these test suites and configuration specific combination testing, several new set of software defects has been identified across various programs in audio and display ECUs, which are listed in, [Figure 8](#).

[Table 4](#) displays the description of new defects identified in various programs.

**FIGURE 8** List of new defects with configuration combination.



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**TABLE 4** Description of NM Defects.

S. No	Issue	Description
1.	Defect 1	Display unit enters into active clock state for a non-wake up trigger
2.	Defect 2	Display unit does not hold the bus when power Mode > = Accessory
3.	Defect 3	Display unit does not stop Display NM Msg transmission in 11 sec after PM change to keyout
4.	Defect 4	NA region with Active clock enabled: Display unit stops transmission in 1 Hr 11 sec and not responds for power button
5.	Defect 5	Display unit exits active clock state before the expiry of AC timer when HLA =0
6.	Defect 6	CAN signal wakeup holds the bus for 11 sec
7.	Defect 7	Sleep Indication Table issues
8.	Defect 8	Program#1 - Sleep Indication table issues
9.	Defect 9	Program#2 - Sleep Indication issues
10.	Defect 10	NM Message not send in Network when chime is active
11.	Defect 11	AUTOSAR message not transmitted when power up chimes module is active
12.	Defect 12	Clarification on Network Management
13.	Defect 13	Audio unit sends NM message on CD source request

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## 7. Conclusion

This paper proposes to consider Application signals which impact other Nodes NM Behavior, as part of NM test suite. CAN signals shall be categorized into an application specific event and NM trigger events of other ECUs in the network. This boosts test depth and increases reliability of the product.

Along with standard acceptance testing Configuration specific tests need to be identified and executed. This approach will be useful to identify issues present in state manager of an ECU and provide a complete package of AUTOSAR acceptance test suite. With such test suite, several NM issues are identified which may impact entire system in the vehicle.

As a summary, AUTOSAR acceptance test identify and control the issue within the state manager of an ECU in the Network. Since the on-change application events from an ECU impacts state manager (present in system services layer of AUTOSAR Architecture [10, 11]) of other ECUs in the Network, every ECU specification shall contain communication matrix of entire Network in the system. This will aid to fulfill acceptance testing at a satisfactory level and control parasitic battery drain issues occurs in vehicle due to software failure.

Future work includes the extension of the application to CAN NM algorithm testing ([Figure A.2](#)). Multiple scenarios to be identified for the entry/exit criteria of these states and test design shall be improved further to test CAN NM algorithms as a part of network management testing.

## Definitions/Abbreviations

**ACM** - Audio Control Module  
**ASR NM** - AUTOSAR NM  
**APIM** - Accessory Protocol Interface Module  
**AUTOSAR** - AUTomotive Open System ARchitecture  
**CAN** - Control Area Network  
**CAN NM** - CAN Network Management  
**CAN\_H** - CAN High  
**CAN\_L** - CAN Low  
**DUT** - Device under Test  
**ECU** - Electronic Control Unit  
**ECUm** - ECU State Manager  
**E/E** - Electrical/Electronics  
**FCDIM** - Front Control Display Interface Module  
**GUI** - Graphical User Interface  
**HMI** - Human Machine Interface  
**IPC** - Instrument Panel Cluster  
**ICP** - Integrated Control Panel  
**INH** - Inhibit  
**NM** - Network Management  
**OEM** - Original Equipment Manufacturer  
**PDU** - Protocol Data Unit  
**SRS** - Software Requirement Specification  
**TCD** - Test Case Design  
**Tx** - Trans receiver  
**μC** - Microcontroller

## References

1. <http://www.wikihow.com/Find-a-Parasitic-Battery-Drain>
2. Miller, M., <http://www.searchautoparts.com/automechanika-chicago/commitment-training/parasitic-battery-drains>
3. <https://www.lifewire.com/why-car-battery-keeps-dying-4125506>
4. Specification of CAN Network Management\_4.2.2 (AUTOSAR\_SWS).
5. Wake Up for Automotive Communication Networks-BOSCH, [http://grouper.ieee.org/groups/802/3/RTPGE/public/july12/hoganmuller\\_02a\\_0712.pdf](http://grouper.ieee.org/groups/802/3/RTPGE/public/july12/hoganmuller_02a_0712.pdf).
6. <http://embedded-computing.com/guest-blogs/autosar-expands-activities-with-standard-acceptance-tests/>
7. <http://www.autosar.org/about/technical-overview/acceptance-tests>
8. Alain Gilberg, A., Bernd Kunkel, B., Alain Ribault, C., Philippe Robin, D., and Noë Spinner, E., “Conformance Testing for the AUTOSAR Standard.”
9. Liebetrau, T., Kelling, U., Otter, T., and Hell, M., “Energy Saving in Automotive E/E Architectures.”
10. Dhanamjayan, P.R., Kuruvilla, J., and Manjusree, S., “ECU State Manager Module Development and Design for Automotive Platform Software Based on AUTOSAR 4.0.”
11. <https://www.kpit.com/resources/downloads/kpit-autosar-handbook.pdf>

## A. Appendix

**FIGURE A.1** Test procedure for project specific configuration based NM testing.

Test No	Pre-Condition	WAKEUP Trigger	Post Condition1	Wait Timer 1	Expected Behaviour 1
<b>Configuration = NA</b>					
1	BUS Sleep Mode	PJB_DriverDoorStatus Change to open.	Normal Operation State	11 sec	Ready Sleep State
2	BUS Sleep Mode	PJB_PassengerDoorStatus Change to open	Normal Operation State	11 sec	Ready Sleep State
3	BUS Sleep Mode	PJB_RightRearDoorStatus Change to open	Normal Operation State	11 sec	Ready Sleep State
4	BUS Sleep Mode	PJB_LeftRearDoorStatus Change to open	Normal Operation State	11 sec	Ready Sleep State
5	BUS Sleep Mode	Active Clock configured and user presses Multimedia button	Normal Operation State	1hr 10 min 11 sec	Ready Sleep State
6	BUS Sleep Mode	Active Clock not configured and user presses Multimedia button	Normal Operation State	1hr 11 sec	Ready Sleep State
7	BUS Sleep Mode	User presses ICP Eject button	Normal Operation State	5 sec	Ready Sleep State
8	BUS Sleep Mode	Change Lock status from Centrallock to Centralunlock	Normal Operation State	5 sec	Ready Sleep State
9	BUS Sleep Mode	Change Lock status from Centrallock to Driverdoorunlock	Normal Operation State	5 sec	Ready Sleep State
10	BUS Sleep Mode	Change Lock status from Doublelock to Centralunlock	Normal Operation State	5 sec	Ready Sleep State
11	BUS Sleep Mode	Change Lock status from Doublelock to Driverdoorunlock	Normal Operation State	5 sec	Ready Sleep State
<b>Configuration = EU</b>					
12	BUS Sleep Mode	PJB_DriverDoorStatus Change to open.	Normal Operation State	10 min 11 sec	Ready Sleep State
13	BUS Sleep Mode	PJB_PassengerDoorStatus Change to open	Normal Operation State	10 min 11 sec	Ready Sleep State
14	BUS Sleep Mode	PJB_RightRearDoorStatus Change to open	Normal Operation State	11 sec	Ready Sleep State
15	BUS Sleep Mode	PJB_LeftRearDoorStatus Change to open	Normal Operation State	11 sec	Ready Sleep State
16	BUS Sleep Mode	User presses Multimedia button	Normal Operation State	1hr 10 min 11 sec	Ready Sleep State
17	BUS Sleep Mode	User presses ICP Eject button	Normal Operation State	10 min 11 sec	Ready Sleep State
18	BUS Sleep Mode	Change Lock status from Centrallock to Centralunlock	Normal Operation State	10 min 11 sec	Ready Sleep State
19	BUS Sleep Mode	Change Lock status from Centrallock to Driverdoorunlock	Normal Operation State	10 min 11 sec	Ready Sleep State
20	BUS Sleep Mode	Change Lock status from Doublelock to Centralunlock	Normal Operation State	10 min 11 sec	Ready Sleep State
21	BUS Sleep Mode	Change Lock status from Doublelock to Driverdoorunlock	Normal Operation State	10 min 11 sec	Ready Sleep State
<b>Configuration = Any</b>					
22	BUS Sleep Mode	Change Ignition status from keyout to Accessory	Normal Operation State	10 min 12 sec	Normal Operation State
23	Normal Operation State	Change Ignition status from Accessory to Ignition2	Normal Operation State	10 min 12 sec	Normal Operation State
24	Normal Operation State	Change Ignition status from Ignition2 to Crank	Normal Operation State	10 min 12 sec	Normal Operation State
25	Normal Operation State	Change Ignition status from Crank to Running	Normal Operation State	10 min 12 sec	Normal Operation State
26	Normal Operation State	Change Ignition status from Running to Accessory	Normal Operation State	10 min 12 sec	Normal Operation State
27	Normal Operation State	Change Ignition status from Accessory to keyout	Normal Operation State	11 sec	Ready Sleep State
28	BUS Sleep Mode	Change Ill_Displ_HLA from zero to non-zero	Normal Operation State	10 min 12 sec	Normal Operation State
29	Normal Operation State	Change Ill_Displ_HLA from non zero to zero	Normal Operation State	11 sec	Ready Sleep State

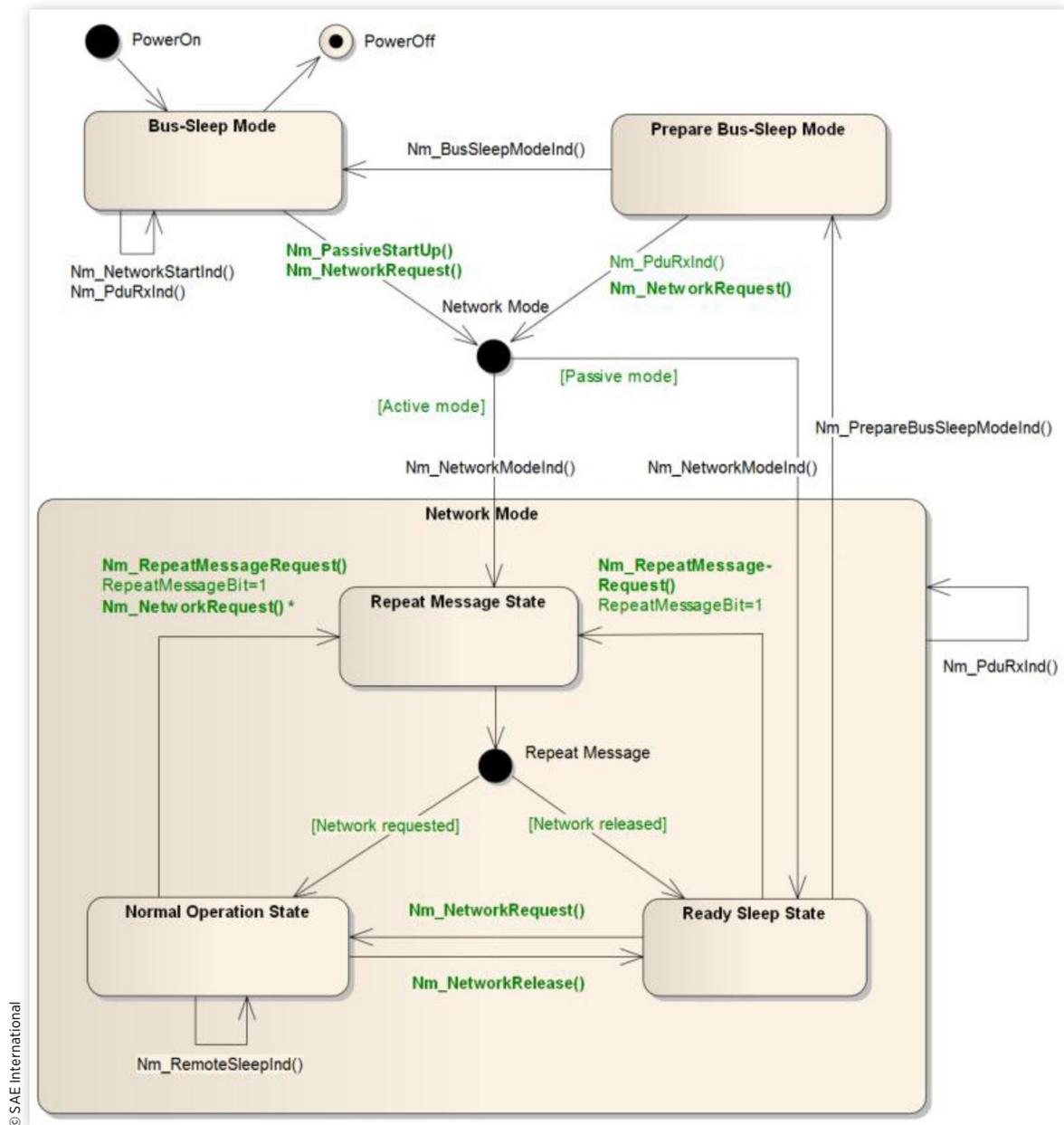
  

Total number of NM Message Transmitted	Expected Behaviour 2	Wait Timer 2	Expected Behaviour 3	Result	RTC ID	Comment	Reference (Clip Image from simulation panel)
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
4211	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
3611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
5	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
5	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
5	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
5	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
4211	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
611	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
612							
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612							
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				
612							
11	Prepare Bus Sleep Mode	3 sec	BUS Sleep Mode				

Note :	
Normal Operation State	Transmission of continous NM Message
Ready Sleep State	NM Message Transmsmission stopped and only application message in bus
Prepare Bus Sleep Mode	No message is transmitted in bus (Bus Load = 0)
BUS Sleep Mode	Lowest Power Consumption (Sleep Current < 100 μA)

Measured with the help of simulation panel after completion of Wait

**FIGURE A.2** CAN NM algorithm. Source: Specification of CAN Network Management\_4.2.2.

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