Comparison of the heated wash design:

Current Production
AlphaTherm AT37
versus
OEM-GM MH35

July 2010

Clear Driving Technology

AT37 Improvement

The AT37 is a new generation of the heated windshield washer system that has been developed to improve the functionality, manufacturability and durability of the unit.

- **PCB** – re-designed for maximum durability:
  - Increased circuit protection
  - Strategic component and copper trace placement
  - Electronic components upgrade

- **Main Body** – modified to reduce water ingress and the plastic material has been upgraded to increase rigidity and durability.

- **Main Cover** – a rubber bead and water deflector were added to improve water management.

- **Electrical Connections** – modified and coated to prevent potential galvanic reaction.

PCB – Printed Circuit Board

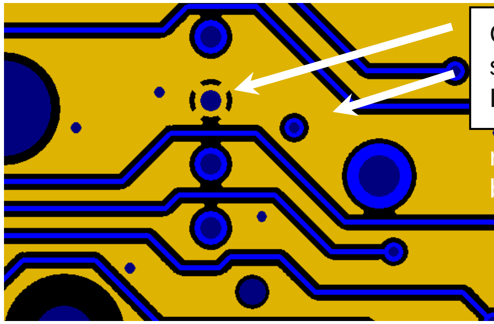
The changes listed below were implemented to increase reliability and enhance manufacturability of the AT37 design:

- Negative transient protection circuitry rating increased from 200V to 400V
- Surface mount fuse added to protect the low current ground return
- All on-board low power electronics supplied by Vbat routed through thermal cut off fuse
- Copper ground plane removed from top and bottom layers
  - Copper ground plane clearance on inner layers increased
- All components, grounds and un-fused traces eliminated within 100 mil of the Vbat supply region
- Component geometries reduced to increase space between circuit elements
  - High current and low current circuitry separated to different regions of the PCB
- Thermal relief added to all through-hole component solder lands and drill size adjusted

PCB – Printed Circuit Board (continued)

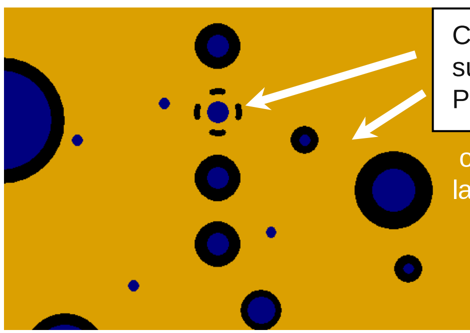
Fusing Low Current Ground

MH35 (OEM-GM)



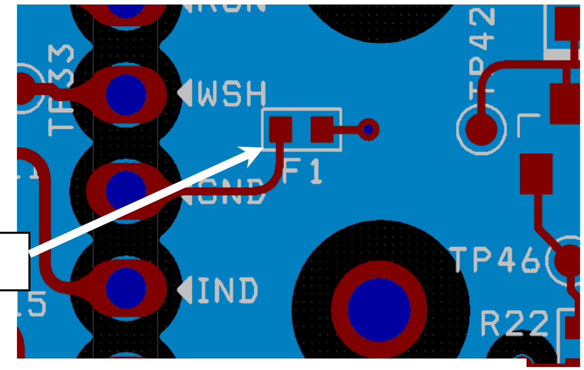
Connector pin and surrounding copper on PCB bottom layer

Copper ground pour in orange

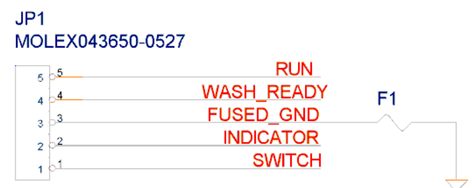


Connector pin and surrounding copper on PCB ground plane layer

AT37



Surface mount fuse F1



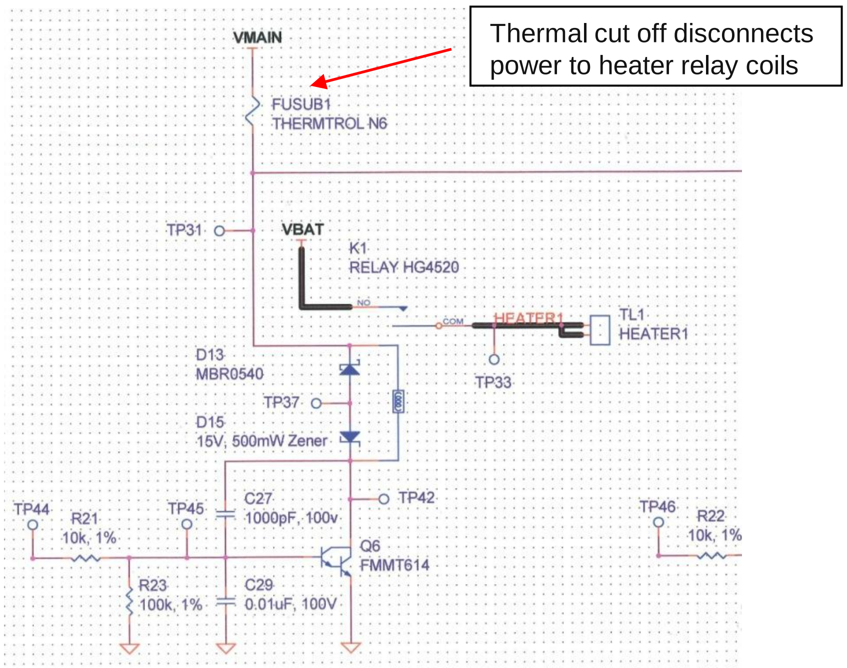
- The low current ground connector was soldered directly to the on-board ground plane and can carry substantial current in a fault condition without an overload protection circuit.

- In the AT37, a surface mount 3 ampere fuse was added between the low current ground pin and the on-board ground plane. This will protect the unit and vehicle in the unlikely event that a short circuit does develop between a positive potential node on the PCB and low current ground. The low current ground plane (blue, in inner layer) terminates to one side of F1 on the top side of the board (red). The low current ground connector pin terminates to the other side of F1. No direct connection between the connector pin and ground plane exists. The capacity to carry current is limited to the rating of the fuse.

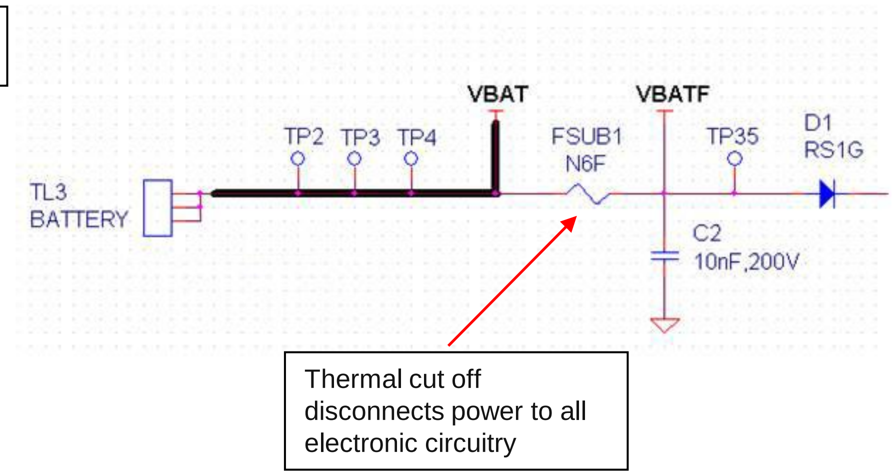
PCB – Printed Circuit Board (continued)

Change in use of the on-board thermal cut off

MH35 (OEM-GM)



AT37



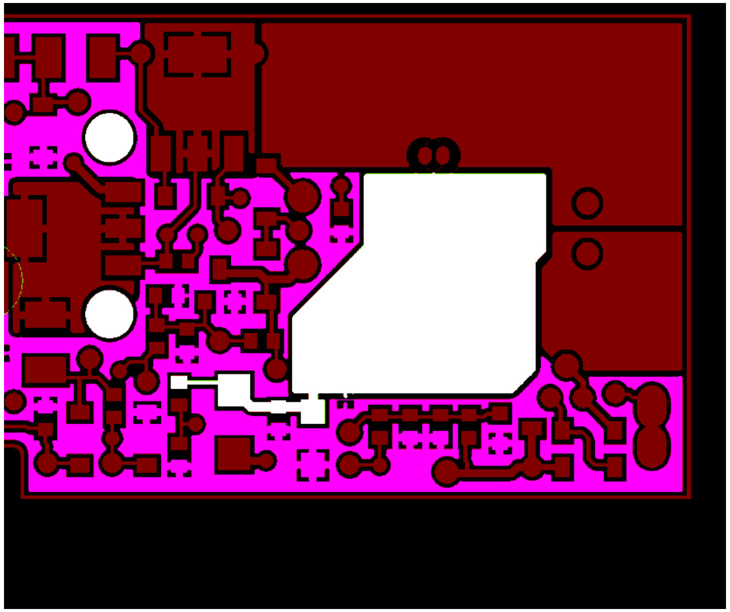
- In the MH35, a thermal cut-off was used to cut power to the relay coils in the event of a thermal run-away condition. More specifically, if the microprocessor lost control of the relay drivers, the heaters could be shut down in a safe fashion by breaking the circuit supplying current to the relay coils. The problem being that the fault that originally caused this condition still may exist on the board and the heater drivers may be receiving power.

- The MH 37 design eliminates the issue of possibly having power on the board after a thermal run-away condition by routing all low current on-board power through the thermal cut-off. This includes power to the microprocessor, voltage regulator and relay coils.

PCB – Printed Circuit Board (continued)

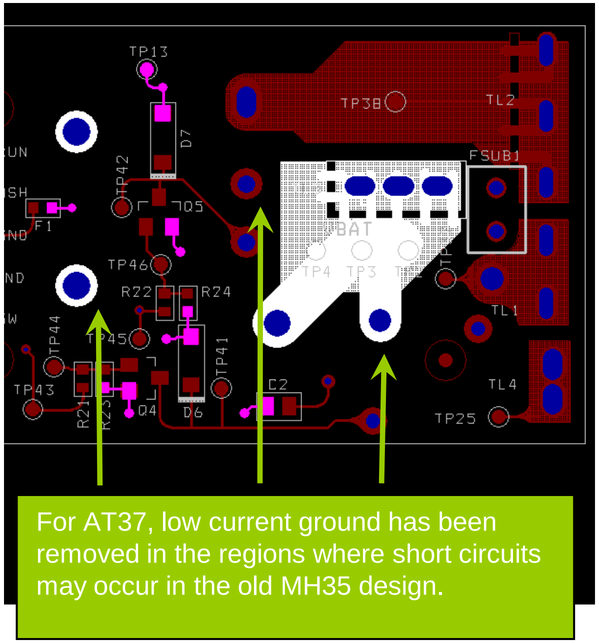
Removing copper ground plane from top and bottom layers

MH35 (OEM-GM)



Low current ground is shown in Magenta. Vbat plane is shown in White for both the MH35 and AT37

AT37



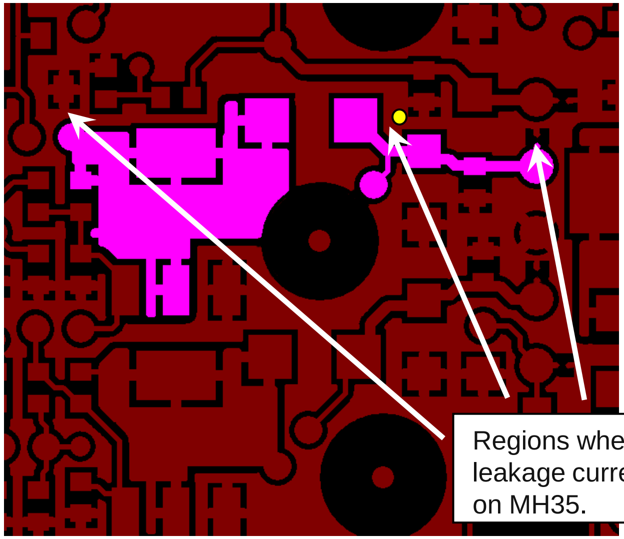
- Copper pour is typically done to expand ground plane to all nooks and crannies on the board to aid in EMC. On the MH35 board the ground copper sits approximately 10mil from Vbat potential copper in a number of locations. Under normal circumstances this is not an issue. However, the board can be susceptible to short circuits forming between Vbat and ground when outside factors are taken in to account.

- In the AT37 design, the copper pour connected to the low current ground plane on the top and bottom layers was removed. By removing ground copper in this region the possibility of a current short circuit to form is eliminated.
- A significant distance has been added between Vbat and ground.
- More recent designs have proven that inner layer ground plane alone provides an outstanding, robust, grounding structure for the unit and ensures EMC compliance.

PCB – Printed Circuit Board (continued)

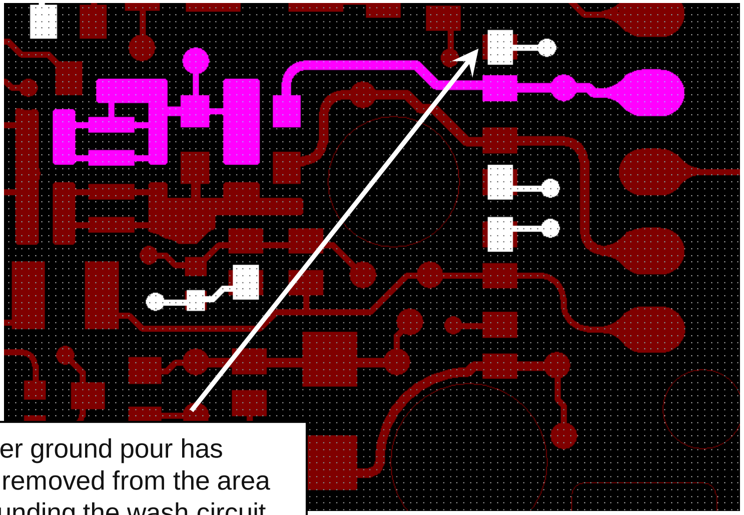
Removing copper ground plane from top and bottom layers

MH35 (OEM-GM)



"Wash Ready" circuitry is shown in Magenta for both the MH35 and AT37.

AT37



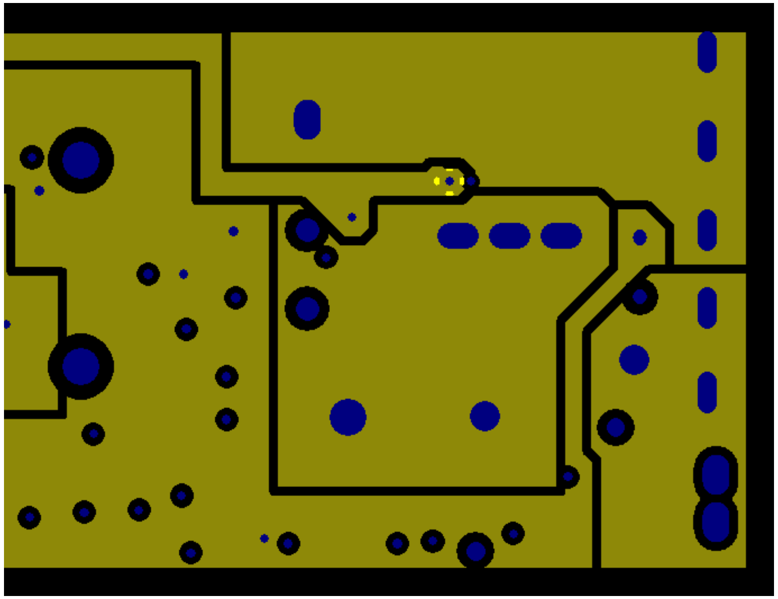
- Having top and bottom side copper ground pour may provoke possible dendritic growth in the regions shown above. Notice the copper ground pour surrounding the "Wash ready" circuit. The path from the output circuit to nearby grounds is 10mil. This is normally not an issue if each conductor is covered in solder mask. Solder mask creates an environmental seal between electrically conductive elements. However, exposed copper at Vbat and ground potential in the form of ground vias, solder pads and spark gaps are present in close proximity to each other in the "Wash Ready" circuit. When combined with a little bit of moisture and a warm environment, the exposed conductors may become a breeding ground for dendrites.

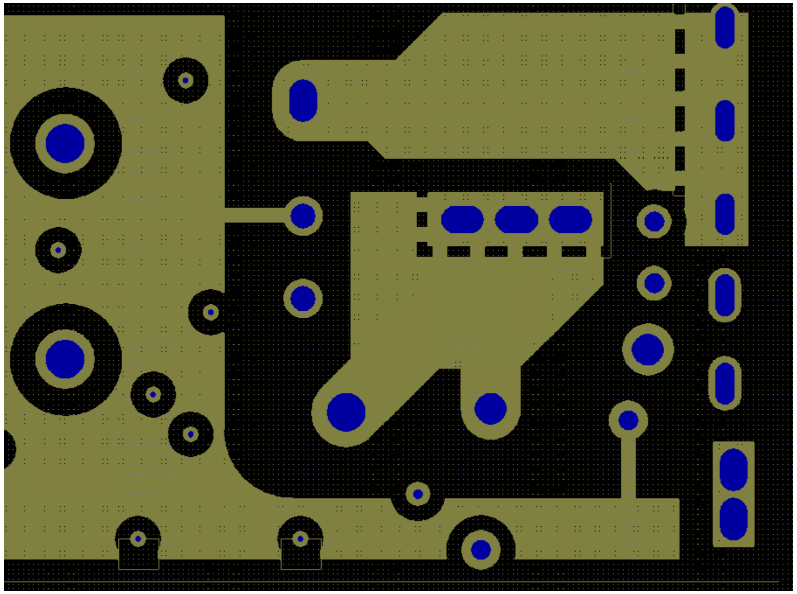
- The AT37 design eliminates possible issues with dendrites by moving or removing ground conductors from all susceptible regions on the board.

PCB – Printed Circuit Board (continued)

Global copper clearance increased on inner layer

MH35 (OEM-GM)	AT37





- The MH35 design has spacing of 20mil between high current conductors and 15mil between small signal conductors in inner layers.

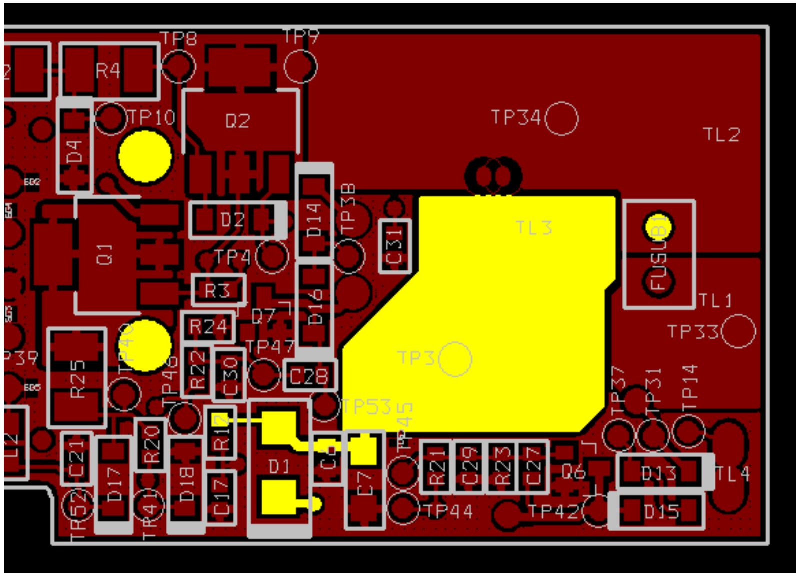
- In the AT37 design, spacing between all internal conductors has been significantly increased. Global spacing for high current conductors is kept between 50 – 100mil and for small signal conductors is set at 30mil or greater.

Alpha Therm

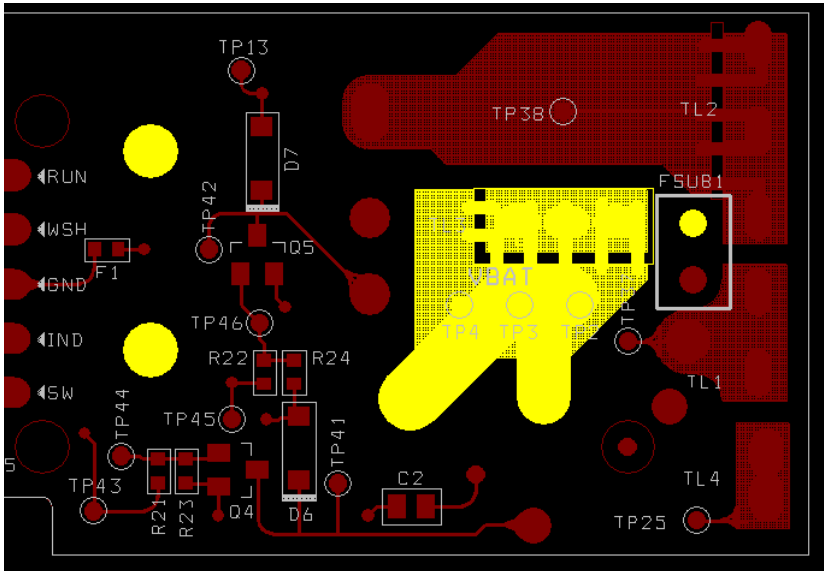
PCB – Printed Circuit Board (continued)

Moving all components and copper traces 100mil away from Vbat

MH35 (OEM-GM)



AT37



Vbat shown in yellow for both the MH35 and AT37

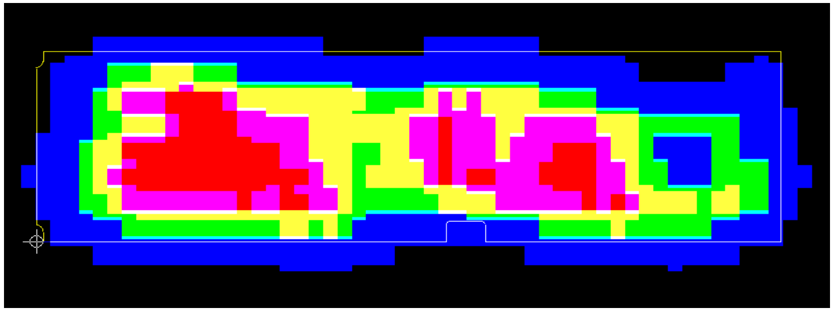
- The MH35 design was densely populated. Packing electronics close to Vbat can form parasitic leakage between Vbat and a number of circuit nodes surrounding it.
- The AT37 design has electronic components and copper traces moved 100mil away from Vbat copper.

PCB – Printed Circuit Board (continued)

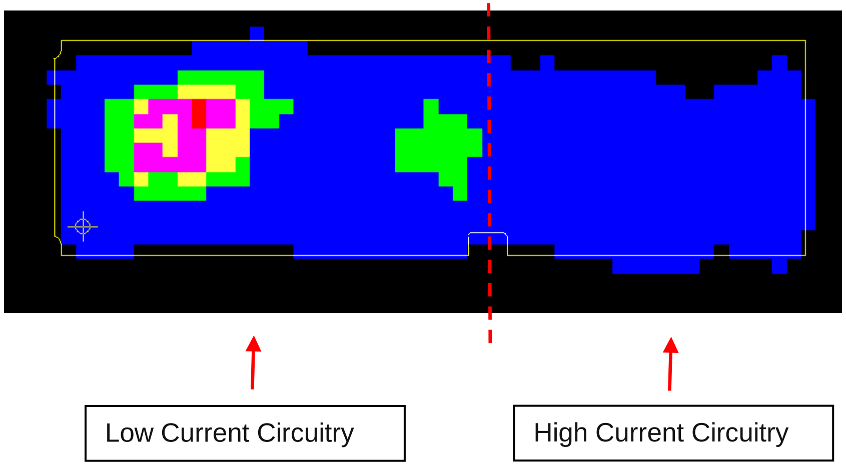
Component geometry reduction

Below is the MH35 vs. AT37 component density plot. Red is most dense, blue is least dense.

MH35 (OEM-GM)



AT37



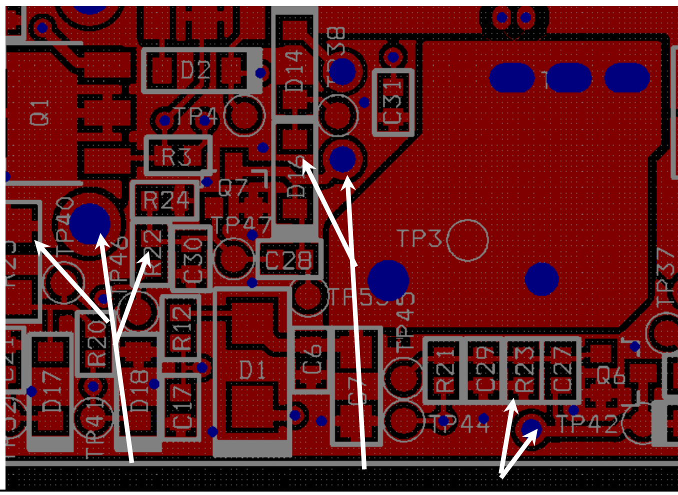
- The MH35 design was densely populated.
- Low current and high current circuitry were interlaced throughout the entire PCB.

- Electronic component geometry reduction allowed spreading components out on the board thus maintaining reasonable space between them. It helps to minimize points where contamination or dendrites can form parasitic leakage current on the board.
- Low current and high current circuitry is separated to different regions of the PCB.
- Less components density aids in manufacturability as well.

PCB – Printed Circuit Board (continued)

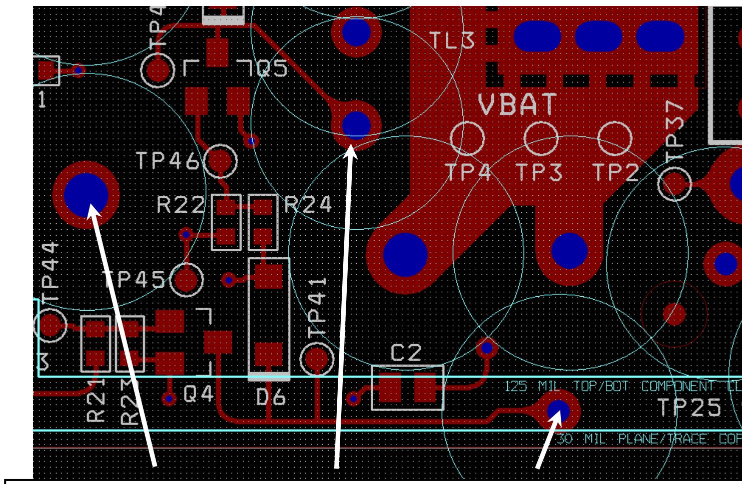
Component placement optimization

MH35 (OEM-GM)



Examples of SMT components located too close to a through hole solder joint to allow automated soldering.

AT37



The solder joints shown in the diagram above are now free of components within a 300mil diameter.

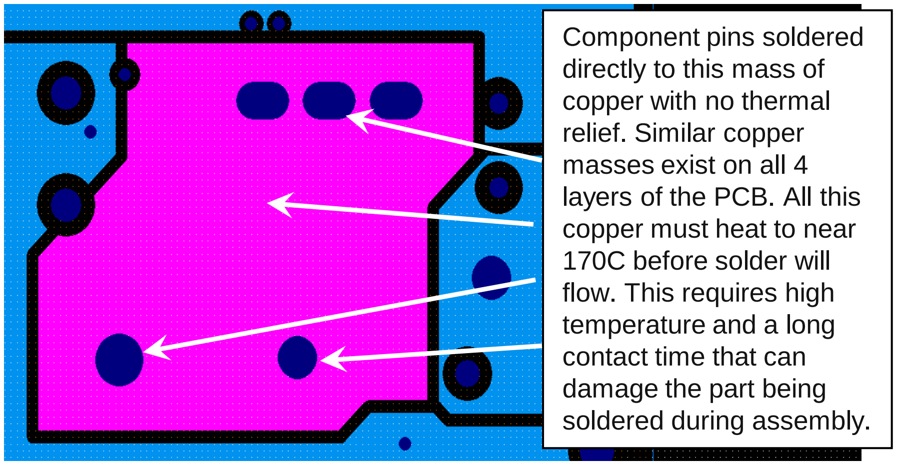
- SMT components crowded through hole solder connections in the MH35 design making it unfeasible to solder using automated machinery.

- SMT component placement was optimized in the AT37 design per contract manufacturer guidelines to facilitate soldering through hole components using automated soldering process. SMT components are kept at a certain distance away from a through hole solder connection to allow room for the machine to solder the through hole components without disturbing other components.
- The component placement optimization and re-orientation provides the capability of using entirely automated assembly process.

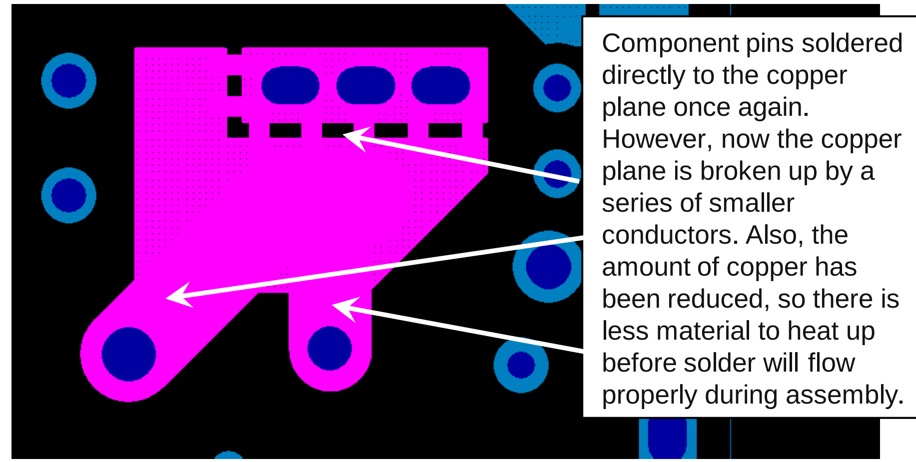
PCB – Printed Circuit Board (continued)

Thermal relief optimized for through hole solder lands

MH35 (OEM-GM)



AT37



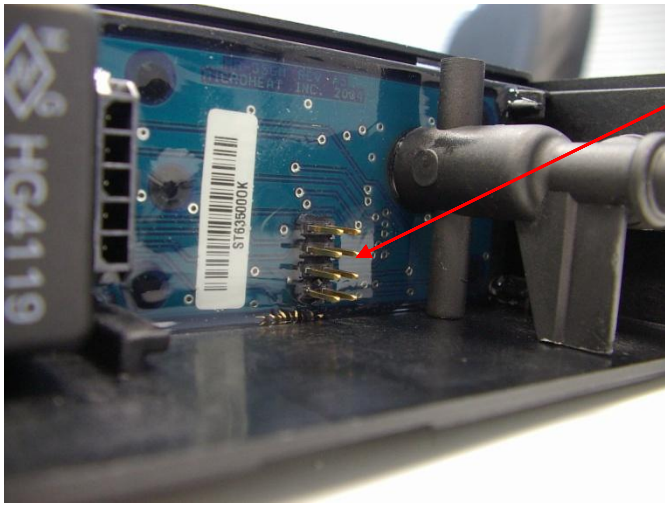
- The MH35 PCB does not have proper thermal relief on through hole solder lands. From an electrical engineering perspective no thermal relief is desirable. This helps to keep board temperature down by reducing the resistance of high current circuit paths. However, from a process engineering perspective it is a problem. Solder joints that lack adequate thermal relief are difficult to solder and prone to manufacturing fallout and defects.

- The AT37 design provides proper thermal relief on through hole components if they are connected directly to the copper plane.
- The copper plane was reduced wherever possible.
- Small through hole components are no longer connected directly to a large copper plane. Rather, a single thermal spoke connects to the solder land. At the other end a through hole via makes the connection to the copper plane.

PCB – Printed Circuit Board (continued)

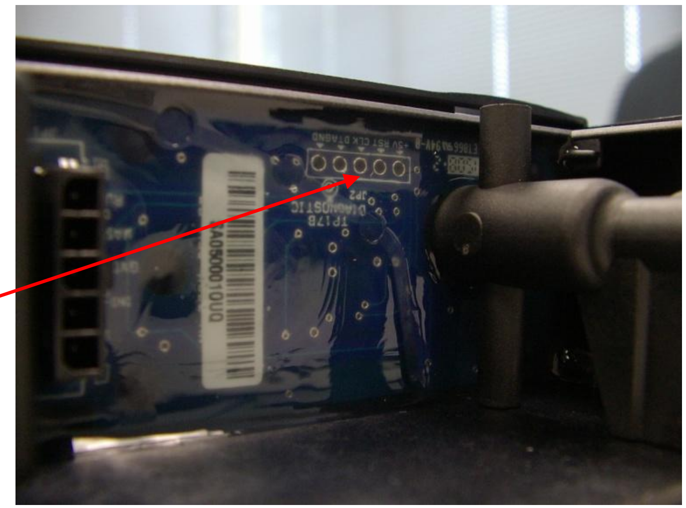
Programming connector removal

MH35 (OEM-GM)



Exposed
8-pin header
for programming

AT37



Sealed Vias for
programming

- The MH35 PCB design has an 8-pin connector that is used to program the unit on the assembly line. The pins of the connector are exposed and may be contaminated over time.

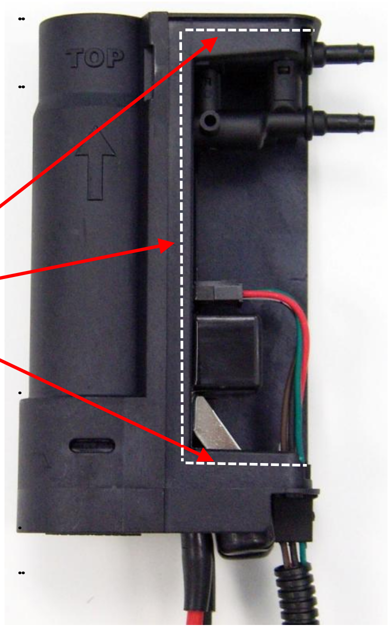
- The AT37 uses a pogo-pin approach for programming on the assembly line prior to potting .

Main Body

MH35 (OEM-GM)

AT37

These walls were enlarged for better water protection



- The AT37 main body was modified to improve water protection. The dotted lines on the picture show that these walls were enlarged to properly accommodate the rubber bead that has been applied on the main cover (see next slide for details)
- Plastic material was changed to increase rigidity of the heating chamber area and withstand higher temperatures. It is a special material (plastic manufacturer Dupont) Zytel HTN with 35% fiber glass. Plastic properties: melting point - 300°C (572°F); deflection temperature at 1.8 Mpa (264 psi) – 255°C (491°F), deflection temperature at 0.45Mpa (65 psi) - 285°C (545°F), flexural modulus – 9000 Mpa.

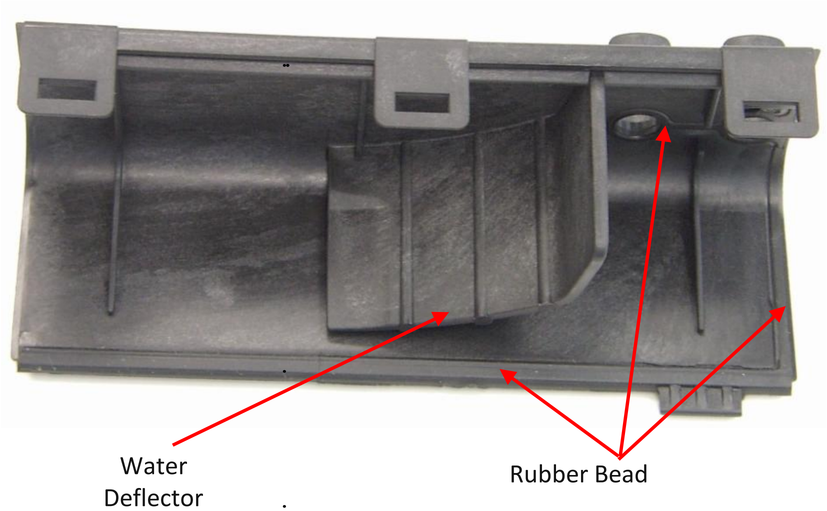
- Main body of the MH35 unit is made of general grade Nylon 66 with 33% fiber glass. Plastic properties: melting point - 257°C (496°F), deflection temperature at 1.8 Mpa (264 psi) – 249°C (480°F), deflection temperature at 0.45 Mpa is not available due to lower melting point, flexural modulus – 8620 Mpa.

Main Cover

MH35 (OEM-GM)

▪ Main function of the cover in the MH35 design is to protect internal components and washer system hose connection.

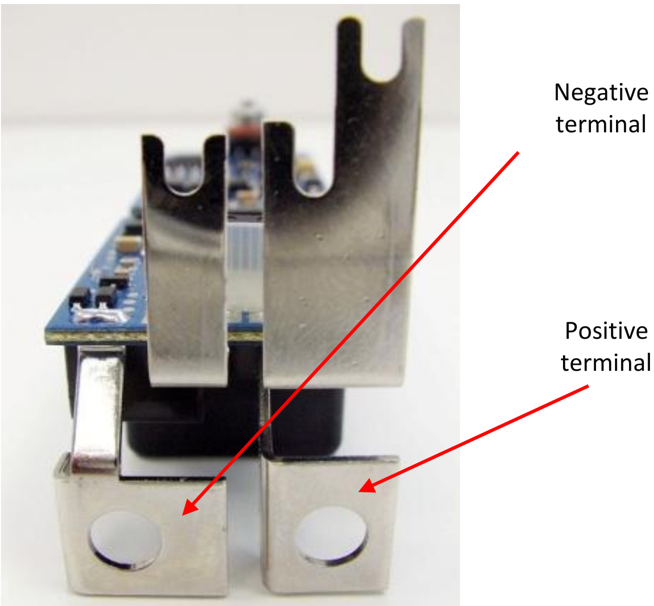
AT37



▪ Besides protection of internal components and hose connection, the AT37 cover has a rubber bead and water deflector to improve water management.

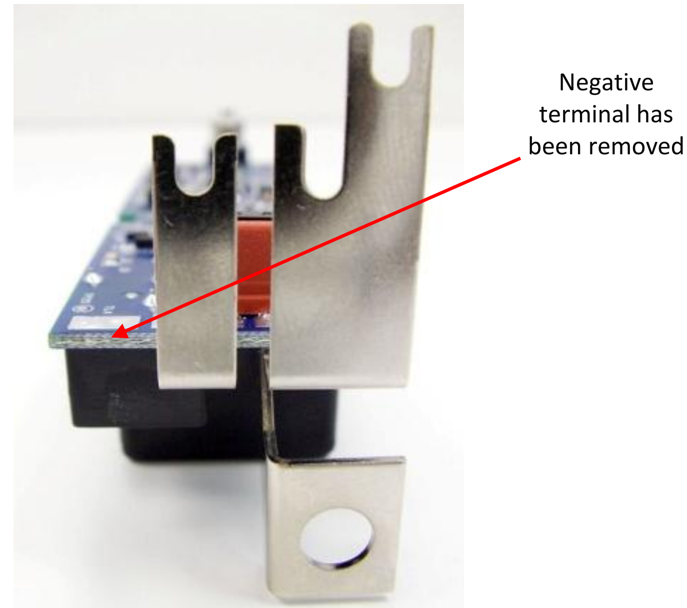
Electrical Connections
Negative terminal removal

MH35 (OEM-GM)



- The negative terminal in the MH35 design has been found redundant.

AT37

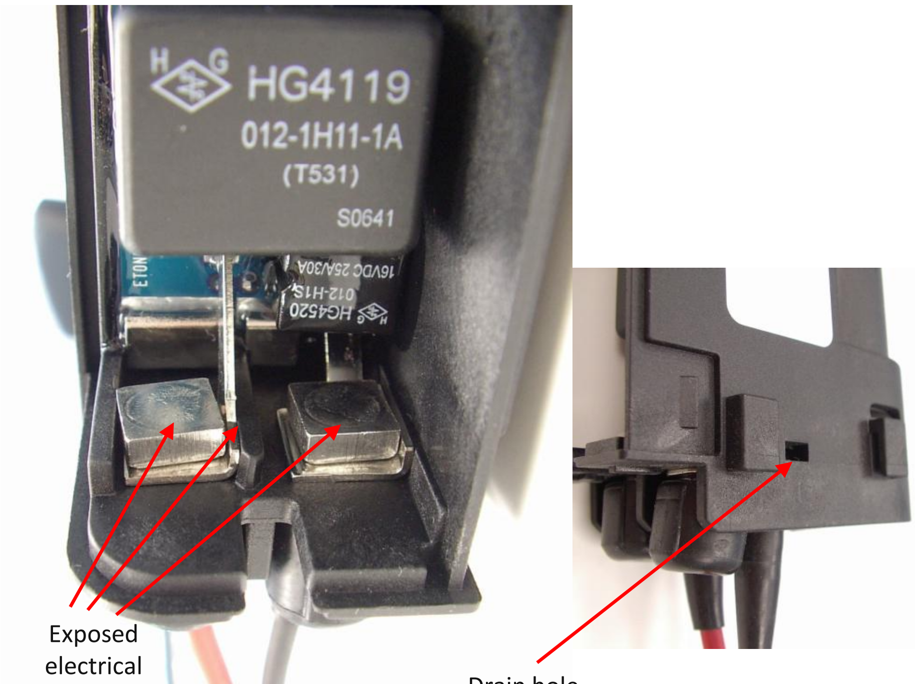


- There is no negative terminal in the AT37 thus possible galvanic reaction is reduced.

Electrical Connections

Coated bolts and drain hole enhancement

MH35 (OEM-GM)



AT37

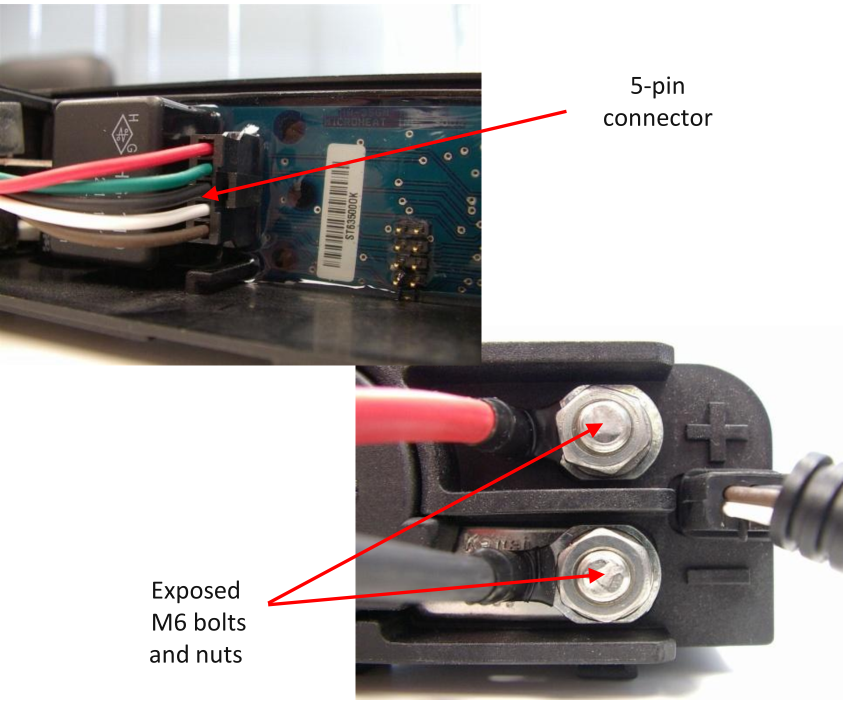
- All electrical connections are exposed to moisture and may corrode over time.
- The drain hole is located on the back side of the main body. In installed position on a vehicle, the unit's bracket may disturb proper drainage of water from inside the unit.

- Silicone coating applied on both heads of the M6 bolt and on the positive terminal.
- Location of the drain hole is changed and its size doubled.

Electrical Connections (continued)

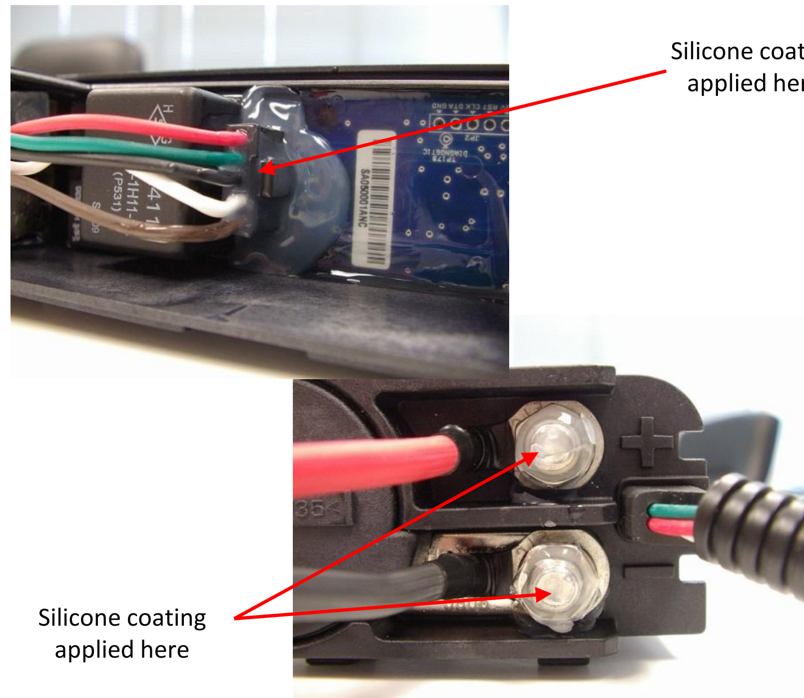
5-pin connector and M6 bolts are coated

MH35 (OEM-GM)



- The 5-pin connector on the PCB are not sealed and may get contaminated over time.
- M6 bolts and nuts are exposed.

AT37



- The AT37 design has the 5-pin connector, M6 bolts and M6 nuts coated with silicone.

Summary

MH35 (OEM-GM)	AT37
PCB designed to meet GM 2003 standard	PCB re-designed to exceed automotive industry standards
Over heat condition may show visual damage	Plastic material changed to increase rigidity and durability
Susceptible to water intrusion	Main body and main cover modified to improve water management
Electrical connections are exposed and may corrode over time	Electrical connections coated to prevent possible water intrusion and corrosion

Summary of AT37 Validation Tests

The following is a list of tests the AT37 unit passed during Design Validation (DV) and Process Validation (PV)

Environmental Tests per GMW3172 (February 2007) specification.

- **Mechanical shock**
  - an acceleration force of 100G for 11 seconds was applied on the unit to simulate a crush condition, 18 shocks on three (3) axes.
  - an acceleration force of 25G for 15 seconds was applied on the unit to simulate severe driving condition, 792 shocks on three (3) axes.
- **Vibration**
  - a random vibration with acceleration force of 2.84g and a frequency between 10 – 1000Hz was applied on the unit for 4 hours on each of three axes during a temperature cycle of -40°C (-40°F) to +105°C (221°F).
- **High temperature durability**
  - the unit was powered and subjected to a hot soak for 1064 hours at +115°C (239°F).
- **Thermal shock**
  - the printed circuit board (PCB) was subjected to a temperature cycle of -40C (-40°F) to +105C (221°F) for 1172 hours (cycle duration is 1 hour).

Summary of AT37 Validation Tests

Environmental Tests per GMW3172 (February 2007) specification (continued)

- **Power temperature cycles**
  - the unit was activated 321 times during a temperature cycle of -40C (-40°F) to +105C (221°F), cycle duration is 69 min.
- **Humidity cycling**
  - the unit was powered for 240 hours at 93% relative humidity and a temperature cycle of -10°C (14°F) to +65°C (149°F), cycle duration is 24 hours.
- **Humidity constant**
  - the unit was powered for 7 days at of 95% relative humidity and a temperature of +65°C (149°F).
- **Salt spray**
  - the unit was powered for 240 hours, 3 hours of salt spray was applied every 24 hour, 10 cycles.
- **Dew**
  - the unit was subjected for 240 hours to a temperature cycle of +1°C (34°F) for 2 hours and +40°C (104°F) for 22 hours, 10 cycles.
- **Dust**
  - a dust (per ISO 12103-1 A2 Fine) with a density of 2 kg/m3 was applied on the unit for 15 minutes every 8 hours, 32 cycles.

Summary of AT37 Validation Tests

Environmental Tests per GMW3172 (February 2007) specification (continued)

- **Water**
  - +80°C (176°F) water with a pressure of 1300 psi (8963 kPa) and a flow rate of 15 liters per minute was applied on the unit for 30 seconds, 4 times from different angles.
- **Thermal shock / water splash**
  - the unit was soaked at a temperature of +105°C (221°F) for 1 hour and then subjected to water splash at a rate of 4 liters per 3 seconds, for 3 seconds.
- **Component reliability**
  - the unit was activated 7,500 times at +0°C (32°F) and 1,350 times at +25°C (77°F) to simulate 10 year life test.

Summary of AT37 Validation Tests

Electrical Tests per GMW3172 (February 2007) specification

- **Parasitic Current**
  - parasitic current should not exceed 0.250 mA

- **Jump start**
  - the unit was subjected to a voltage of 26V for 1 minute.

- **Reverse polarity**
  - the unit was subjected to a negative 13.5V for 2 minutes.

- **Over Voltage**
  - the unit was subjected to a sweep voltage with the boundaries of +16.0V to +18.0V and a sweep rate of 1.0 V/min and sweep duration of 60 minutes.

- **Voltage drop**
  - 10.0V was applied on the unit and then the voltage was decreased by 5% intervals until 0.0V.

- **Superimposed alternating voltage**
  - 14.0V with a 4Vpp ripple was superimposed on the unit. The ripple frequency was 50 Hz to 20kHz, the sweep time was 120 seconds and the number of sweeps was 5.

- **Ground offset**
  - a ground offset of +/-1.0 V was applied at 10.0V and 16.0V on logic ground and high current ground lines.

Summary of AT37 Validation Tests

Electromagnetic Compatibility (EMC) Tests per GMW3097 (July 2006) specification

- **Power offset**
  - a power offset of +/- 1.0 V was applied at 10.0V and 16.0V on the ignition and Vbat lines.
- **Short-to-battery and short-to-ground**
  - Switch, Indicator, Wash Ready and Ignition lines were shorted for 60 seconds.
- **Intermittent short circuit**
  - a short circuit condition was applied for 5 minutes On, 3 minutes Off at a temperature of -40°C (-40°F) and +105C (221°F).Number of cycles was 60.
- **Radiated Emission**
  - RF service = medium wave, frequency range 0.53 to 1583 MHz, bandwidth 9kHz.
- **Conducted Emission**
  - RF service = medium wave / AM, frequency range 0.53 to 1.71 MHz, bandwidth 9kHz.
- **Radiated Immunity**
  - frequency range 1 – 30MHz, 30 – 400 MHz, 400 – 2000MHz.
- **Transients (Power lines, input / output lines)**
  - voltage spikes with different wave forms were applied on the unit’s high and low current lines.