EA03-007
8/29/03
GM Letter
to ODI
Book 2 of 2

Attachment "17"

GM638A
EA03-007

ATTACHMENT "19"

Drawing

GM638A
EA03-007

ATTACHMENT "DELPHI"

DELPHI

Product Regulations & Investigations
Michael J. McKale
Manager

CL03-009-001

memo

DATE: August 28, 2003

FROM: Michael J. McKale

SUBJECT: 2002 Envoy and Bravada Engine Stall NHTSA Investigation EA03-007 (GM 638a)

TO: Michael Plotzke

Attached is Delphi's response to questions 7-9, 15, 16 and 20-24 of the NHTSA Investigation EA03-007 (GM 638a) concerning engine stalls on the 2002 Chevrolet Envoy and the 2002 Oldsmobile Bravada.

If you have any questions, please do not hesitate to call me at 248 813 3362.

Michael J. McKale
Manager
Product Regulations and Investigations

Question 7. Describe all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries and/or evaluations (collectively, "actions") that relate to, or may relate to, the alleged defect in the subject vehicles that have been conducted, are being conducted, are planned, or are being planned by, or for, GM. For each such action, provide the following information:

a. Action title or identifier;
b. The actual or planned start date;
c. The actual or expected end date;
d. Brief summary of the subject and objective of the action;
e. Engineering group(s)/supplier(s) responsible for designing and for conducting the action; and,
f. A brief summary of the findings and/or conclusions resulting from the action.

For each action identified, provide copies of all documents related to the actions, regardless of whether the documents are in interim, draft, or final form. Organize the documents chronologically by action.

Answer: Delphi Delco Electronics previously responded to this question with our answer to Question 8 of the NHTSA Information Request PE03-001, a copy of which is provided below.

" Concerted actions related to the alleged defect were organized under the auspices of a Root Cause Analysis Team (RCAT) formed to address and reduce general warranty for the "L6/P10" Powertrain Control Module (PCM.) The specific failure mode most likely associated with the alleged defect is referred to as an "IVR" failure. Specific assessments, analyses, etc. related to IVR failures are identified and included in the attached documents under the [PE03-001 "Attachment Delphi" Response] section title "Question 8." The RCAT related to this action operated from August 2001 through February 2002. The Interface - Variable Reluctance (IVR) integrated circuit (IC) is supplied by Texas Instruments and includes a number of different functions such as the conversion of low level currents generated by magnetic sensors to more powerful signals capable of being transmitted to and used by digital circuits. Electrical transient damage occurred to this device sufficient to cause interruption of the Powertrain Control Module's normal operation leading to possible engine stalling. The formal conclusion of the RCAT activity is coincident with, and further detailed in, the answer to [PE03-001 "Attachment Delphi" Response] Question 11."

Our response to Question 11 was as follows:

"Delphi believes that a voltage transient of greater than 60 volts is produced during actuation of the level ride compressor; and that this transient is coupled from the level ride controller (ECAS) circuitry into the vehicle speed sensor (VSS) output circuit of the Powertrain Control Module (PCM) by way of the vehicle wiring harness. This voltage transient causes excessive currents to flow within the IC, causing the IVR IC to latch up and become permanently damaged (electrical overstress / EOS.) Depending on the extent of damage, circuits associated with the engine control function may also be damaged, resulting in an unexpected engine stall."

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Question 8. Describe any modification or change made by, or on behalf of, GM in the design, material composition, manufacture, quality control, supply, or installation of any component, from the start of production to date, which relate to, or may relate to, the alleged defect in the subject vehicles. Include detailed information about the interim change implemented in October 2001 and the final production change implemented in December 2001. Organize each modification chronologically in a timeline. For each such modification or change, provide the following information:

a. Exemplar drawings of the modification or change as incorporated into vehicle production;
b. The date on which the modification or change was incorporated into vehicle production and the VIN of that vehicle;
c. The reason(s) for the modification or change;
d. A detailed description of the function of the original and the modified component;
e. The life expectancy of the original and the modified component;
f. The part numbers (service and engineering) of the original and modified component;
g. The design verification and prove-out analysis of the original and modified component;
h. Whether the original unmodified component was withdrawn from production and/or sale. If so, provide the withdrawal date from both production and sale, and explain why the component was withdrawn. If not, explain why the component was not withdrawn;
i. When the modified component was made available as a service component;
j. Whether the modified component can be interchanged with earlier production components; and
k. The effect of the design, production and component changes made in December 2001.

Answer: Delphi Delco Electronics previously responded to this question with our answer to Question 9 of the NHTSA Information Request PE03-001, a copy of which is provided below.

"Two changes were made to the L6/P10 Powertrain Control Module by Delphi Delco Electronics Systems on behalf of GM which relate, or may relate, to the alleged defect. The first change involved the adding of transient suppression capacitors (identified as B72C2 through B72C7 on the attached drawings) to certain output pins of the IVR IC. Provision had been made for the installation of EMC filter capacitors in the original design, but they were not needed and were not installed (NOT INST.) Their location was used for the installation of the transient suppressing devices. The second change involved changing the Vehicle Speed (4Kppm/VEHSPD) signal output (provider) from the IVR IC to the more robust ODM [Output Driver Module] IC.

Dates and detailed descriptions of these changes are provided in the documents at the end of the [PE03-001 "Attachment Delphi" Response] section labeled Question 9, and summarized in the document "P10 / L6 Change Tracker," which also provides a summary and effective dates for the Delphi and GM part numbers involved. Schematic and assembly drawings are also provided showing the PCM before and after the changes.

Delphi cannot comment on the date the changes were incorporated into vehicle production, but can only address the date the component changes took effect." ... "We would also defer to GM the issue of whether current model product can be interchanged

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with earlier production components, as additional changes were made to the PCM to address issues not related to the alleged defect."

Additionally, the life expectancies of the original and modified components are not affected by the modifications and continue to be for the life of the vehicle.

The original component was not validated to withstand the imposed transient as handling a transient of this magnitude was neither required nor comprehended in the design. Special transient testing was performed to verify the improved robustness of the modified component, the plan and results for which were included in our response to NHTSA IR PE03-001. Our previous submittal did not include the validation plan and results for the original component, as this was not requested and did not appear to be related to the alleged defect. As Question 8.g does request this information, the Validation Report for the original component is provided as Attachment 1 of this document.

The effect of the design, production and component changes made to the PCM was to reduce or eliminate failures caused by compressor generated transients as evidenced by the substantial reduction in warranty returns attributed to this failure.

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Question 9. State the number of ECAS and PCM components or assemblies that GM has manufactured and/or sold to date for use on the subject vehicles, by component name, part number (both service and engineering), supplier (name and address), and model/model year and approximate number of all vehicles for which they were intended.

Answer: Delphi Delco Electronics previously responded to this question with our answer to Question 10 of the NHTSA Information Request PE03-001, a copy of which is provided below:

"Delphi Delco Electronics Systems is not able to determine the number of Delphi components actually sold by GM, nor are we aware of the mix of installed ECAS systems and specific PCM part numbers. We are able to identify the number of each part manufactured by us for the 2002 model year (August 2002 - July 2002) as shown in the following table:"

Comp. Name	Part Number	Version	Quantity Built
L6/P10 PCM	12575331	Original Design	62,370
"	12576161	EST Caps.	34,351
"	12571178	EST Caps (Service)	2,879
"	12576462	All Fixes	230,103
"	12576463	All Fixes (Service)	300

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Question 11. Furnish copies of all communication between GM and each supplier of a component identified in Request No. 9 that pertain to the design, manufacture, performance, durability, quality, testing, or modification of any such component(s). If any communications on this subject were oral, provide a written transcript or summary of each such communication, and include a statement that identifies the participants and the date of the communication.

Answer: All documented communications between Delphi Delco Electronics and GM that are, or might be, related to the alleged defect were provided as part of our response to NHTSA IR PE03-001 (see "Attachment Delphi").

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Question 18. Describe in detail the "investigations conducted by GM Powertrain, Delphi Delco Electronics (DDE), and GM Truck engineers over the period of three months in the summer and fall of 2001", identified in GM's response to Request 11g of the PE IR and state the reason(s) why the investigation was initiated and the goals of the investigation. Identify by name, title, company affiliation and telephone number, each engineer or other GM or Delphi employee who initiated or participated in this investigation, and state the role that each individual identified played in the investigation.

Answer: With regard to our participation in the investigations cited, Delphi Delco Electronics previously responded to this question with our answer to Question 8 of the NHTSA Information Request PE03-001, a copy of which is provided as part of our response to Question 7 above. Supplementary details may also be found in the documents supplied as part of that response.

The Delphi Delco Electronics Gas Powertrain Product Line engineering group was responsible for conducting this investigation.

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Question 16. Describe in detail the laboratory testing of vehicles conducted by or for GM at the GM Electromagnetic Compatibility (EMC) lab at Milford and at the DDE lab in Kokomo IN. Describe in detail the laboratory testing at the component and IC level performed at the DDE lab in Kokomo IN. Provide all results of each test conducted.

Answer: As described in Question 7 above, a Root Cause Analysis Team (RCAT) was formed to address and reduce general warranty for the "L6/P10" Powertrain Control Module (PCM.) Specific assessments, analyses, and other laboratory testing related to the alleged defect, as well as testing results, were identified and included in the documents provided as part of our response to the NHTSA IR PE03-001 under the section title "Question 8." Several of the more useful studies can be found documented at PE03-001 "Attachment Delphi" pp. 704-770 (In Vehicle Testing); pp.773-870 (IVR Latch-Up Study); and pp. 518-585 (IVR Investigation.)

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Question 16. For each drawing submitted by GM or Delphi in response to Request No. 9 of the PE IR, provide a narrative description that explains the drawing and describes any changes between the component as shown on the drawing and the component as shown on the drawing of the previous version of that component.

Answer: Delphi Delco Electronics previously responded to this question with our answer to Question 9 of the NHTSA Information Request PE03-001, a copy of which is provided as part of our response to Question 8 above.

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Question 20. Provide a schematic showing the dimensions and tolerances for:

a. The original release ECAS compressor;
b. The ECAS compressor relay and its activation inputs and relay contacts;
c. The ECAS battery feed;
d. The ECAS battery circuits;
e. The connections of the ECAS compressor to the battery feed;
f. The ECAS module;
g. The wiring harness;
h. The PCM and ECAS battery circuits within the wiring harness bundle;
i. The PCM;
j. The 4K PPM output of the PCM;
k. The Ignition and Variable Reluctance (IVR) IC in the PCM;
l. The 4K PPM output buffer;
m. The Output Driver Module;
n. The placement of the 10uH inductor in the ECAS battery circuit, described in GM's response (Item No. 3), to Request No. 9d of the PE IR; and
o. The location of the relevant ground related to the move of the buffer for the 4K PPM output from the IVR IC to the Output Driver Module (IC), described in GM's response (Item No. 5), to Request No. 9d of the PE IR.

Answer: Delphi Delco Electronics Systems does not have sufficient information to adequately address items 20a - 20h and item 20n. Our response, therefore, only addresses items 20j - 20m and item 20o.

A schematic of the PCM is provided in Attachment 2 of this document. The 4K PPM output of the PCM is labeled as vehicle speed (VEHSPD) / Pin J2-A28, and can be found on sheet 3 of the schematic.

Because of the complexity of integrated circuits, overall schematics as such are not usually generated. Block diagrams are used, instead, to understand the organization of these devices. The block diagrams for the IVR and ODM integrated circuits are included as part of Attachment 2 of this document. The 4K PPM output buffers are alternatively shown as the "Speed Sensor I/O Buffers and Filters" for the IVR IC; and "Driver 2" for the ODM IC, depending on which IC is being used to buffer the 4K PPM signal. In the original component, the IVR performs this function; while in the modified component, the ODM carries out this task.

The "relevant ground" addressed in GM's response to PE03-001 is located within the IVR IC, and a photo-micrograph of the IVR ground structure is provided in Attachment 3 of this document. However, damage to the IVR ground structure is only one possible result of the electrical overstress (EOS) caused by large negative voltages (transients) applied to the IC inputs and outputs. Because of the highly integrated nature of ICs, these large negative voltages can cause excessive currents to flow in adjacent circuits (such as from the substrate, through the ground structure, or between proximate devices) and produce damage to functions not logically (although they are physically) related to each other. Moving the 4K PPM buffer function from the IVR IC (which was not designed for inductive loads and not designed to resist negative transients) to the ODM IC (which was designed to better protect itself from such transients) eliminated the risk of damage to the IVR; and hence to associated circuits, such as those involved in controlling the engine.

Question 21. Explain in detail GM's statement in response to Request No. 11a of the PE IR that "the cause of the subject condition is a 70+ volt transient coupled onto the 4000 Pulse Per Mile (4k PPM) output of the PCM from the Electronically Controlled Air Suspension (ECAS) compressor battery feed."
Explain fully:

a. Where that transient arises;
b. The identity, length and configuration of the wire(s) (if any)
c. The range of voltages of the transient as measured and estimated at the 4K PPM output of the PCM and elsewhere where measured and estimated;
d. The distribution of the voltages as measured and estimated;
e. Where the coupling occurs and how the coupling on the 4K PPM output, as contrasted to an input of the PCM, disrupts the PCM when the compressor is activated, deactivated or otherwise operates or cycles.

Answer: Our understanding is that the transient arises from an interruption in current (perhaps through switch bounce) flowing into the ECAS compressor. Inductance in the compressor and associated wiring causes the current to continue to flow in the compressor circuit, despite the interruption, producing large negative voltages between the battery and ground circuits during the brief switch interruption. This transient is then capacitively coupled from the compressor battery/ground circuit into the 4K PPM circuit, which is routed in the same harness that contains these battery and ground circuits. This voltage transient is then conducted to the 4K PPM output of the PCM, and can cause latch-up of the integrated circuit (IVR) that drives this output. This latch-up is associated with excessive current flows within the IC (see Answer 20.c above) as the IC attempts to supply the high current levels forced by this large voltage. These currents may result in damage to the IC, including damage to circuits located within the IC but not directly involved in providing the 4K PPM output.

The transient values measured by Delphi Delco Electronics ranged from below 30 volts to approximately 70 volts as shown in the oscilloscope traces provided as part of our response to PE03-001 [Reference "Attachment Delphi", pp. 834-846. Other useful traces appear on pages 2315-2323 and 2364-2365.] We did not evaluate a sufficient number of vehicles to determine a statistically relevant distribution of transient voltages.

Question 22. Explain fully each of the bulleted factors identified in GM's response to Request No 11a of the PE IR as causal and contributory factors to the "subject condition", and how each such factor contributed to the "subject condition" as that term is used in GM's response.

a. Describe GM's specifications for the orientation of the wire(s) to the 4K PPM and the ECAS battery circuit wire and any other relevant wires in the wiring harness bundle. Describe all observations, surveys and assessments of the orientation of the relevant wires to the 4K PPM and the ECAS battery circuit wires, and any other relevant wires in the wiring harness bundle as built between start of production for the subject vehicles and the modifications of December 2001.
b. Describe quantitatively how age and condition of the compressor and relay contacts affect the voltage and current, including:

   i. Spikes in the ECAS battery circuit wires;
   ii. Voltage of the transient(s) to and at the 4K PPM output of the PCM;
   iii. Proportion (in terms of numbers of vehicles out of the population of subject vehicles or a subset thereof tested) of the vehicles with the transients;
   iv. Frequency and probability of temporary disruption of the operation of the IVR IC; and
   v. Frequency and probability of the transient causing a continuous reset state in the IVR IC.

Separately, for each causal and contributory factor identified in GM's response to Request No. 11a of the PE IR, describe all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries and/or evaluations related to each causal and contributory factors. Provide all documents related to each such factor.

Answer: Delphi Delco Electronics Systems does not have sufficient information to respond fully to this question; however, we can provide the following observations:

With respect to its immunity, the 4K PPM buffer contained within the IVR IC was not designed to drive inductive loads and therefore does not have isolation rings, clamp diodes or other special features to provide protection from the transient voltages usually associated with such loads. Because of the risk of low-level coupled transients even in driving non-inductive loads within a vehicle, a base level of transient protection is typically provided with all IC outputs that might be routed to the "outside world." The 4K PPM output has a specified absolute maximum applied voltage rating of 26.5 volts, and typically would be able to resist higher levels depending upon manufacturing variation.

Because the performance of an integrated circuit is very process dependent, normal manufacturing variations would require that a very large number of parts be tested to determine a statistically significant distribution of voltages that would cause disruption of the IVR IC to any particular level; or cause continuous reset sufficient to disrupt a PCM engine control function. Delphi did not perform such an evaluation. Our objective was to reduce the probability of occurrence to 0%. The relative probability of such occurrences can be inferred from warranty data.

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Question 23. Explain in detail the function of the Ignition and Variable Reluctance Integrated Circuit (IVR IC) in the Power Control Module (PCM). Describe the "ground structure of the IVR IC", identified in GM's response to Request 11c of the PE IR. State the level or the approximate or estimated level of the "transient electrical spike" in terms of voltage, current, duration and frequency that is severe enough to cause damage to the ground structure of the IVR IC and a continuous reset state within the PCM, as described in GM's response to Request No. 11c and 11d of the PE IR. Explain how often and under what conditions a transient electrical spike develops in the subject components that is severe enough to cause damage to the ground structure of the IVR IC and to cause or contribute to a continuous reset state within the PCM.

Answer: A portion of the application document containing a detailed description of the functions of the IVR IC is provided as Attachment 4 of this document.

A photomicrograph of the ground structure of the IVR IC is provided as Attachment 3 of this document. Further discussion of the relevance of this structure to the alleged defect is provided as part of our response to Question 20.c above.

The level or approximate or estimated level of the transient electrical spike severe enough to cause damage to the IVR is discussed in our response to Questions 21.c and 21.d above. Additional information related to the specified susceptibility of the 4K PPM output to transient voltages is provided in our answer to Question 22 above.

Delphi Delco Electronics does not have definitive information sufficient to determine how often a transient electrical spike severe enough to damage the ground structure if the IVR IC may occur. Our understanding of the conditions that may lead to such an occurrence is provided in our response to Question 21 above.

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Question 24. Describe in detail GM's statements in response to Request No. 11e of the PE IR that "the subject condition results in a specific electrical stress footprint in the PCM..." and that "this footprint was the most prevalent cause of PCM failure in vehicles built before December of 2001." Include a complete description of the "specific electrical stress footprint" that GM believes to have caused PCM failure and a complete description of every other cause of PCM failure in subject vehicles that GM has identified in vehicles built (a) prior to December of 2001 and (b) after December 6, 2001. Explain whether or not repeated electrical transients at the 4K PPM output of the PCM results in an increased incidence of an electrical stress footprint in the PCM, and explain the criteria used by GM in response to this question. Also provide a timeline and a detailed narrative statement of every action that GM has taken to correct PCM failure in the subject vehicles.

Answer: As mentioned in our response to Question 20.c, transient damage can manifest itself in a variety of ways. The "specific electrical stress footprint" referred to by GM should be more properly referred to by the industry term "electrical overstress" (EOS), a condition commonly seen in the integrated circuit industry and normally associated with excessive voltages (including transients) applied to the IC pins. A more detailed discussion of these events is provided as part of our response to Question 20.c. Our previous response to PE03-001 [Reference "Attachment Delphi"] includes a number of descriptions and photographs of the various manifestations of this failure type, and an additional photomicrograph of the more common appearance of an IC that has undergone EOS is provided as Attachment 5 to this document. Our previous response to PE03-001 also includes an exhaustive list of the information available to Delphi Delco Electronics regarding other causes of PCM failure during the specified period.

Electrical transient failure at the 4K PPM output of the PCM is directly related to the sensitivity of the specific IVR integrated circuit installed. For a given IC, transients above a specific level (voltage, power and duration) can be expected to cause failure. Because of the range and variation of the level of transients generated, repeated transients can be expected to increase the likelihood that a transient of sufficient strength will eventually occur sufficient to damage the IC. It should be noted, however, that transients related to the alleged defect are believed to decrease in severity with the increasing age of the vehicle; and this would result in a reduced likelihood of transient damage with time.

Our previous response to NHTSA IR PE03-001 [Reference "Attachment Delphi"] includes narrative descriptions of each action taken by Delphi Delco Electronics to correct PCM failures with respect to the alleged defect in the subject vehicles. Several chronological summaries were provided.

Attachment 1

(L6 (P10) Validation Report)

Confidential Material

Provided Under Separate Cover

Attachment 2

(Schematics and Block Diagrams)

Confidential Material

Provided Under Separate Cover

Attachment 3

(IVR Ground Structure)

Confidential Material

Provided Under Separate Cover

Attachment 4

(IVR Functional Description)

Confidential Material

Provided Under Separate Cover

Attachment 5

(IVR EOS Failure)

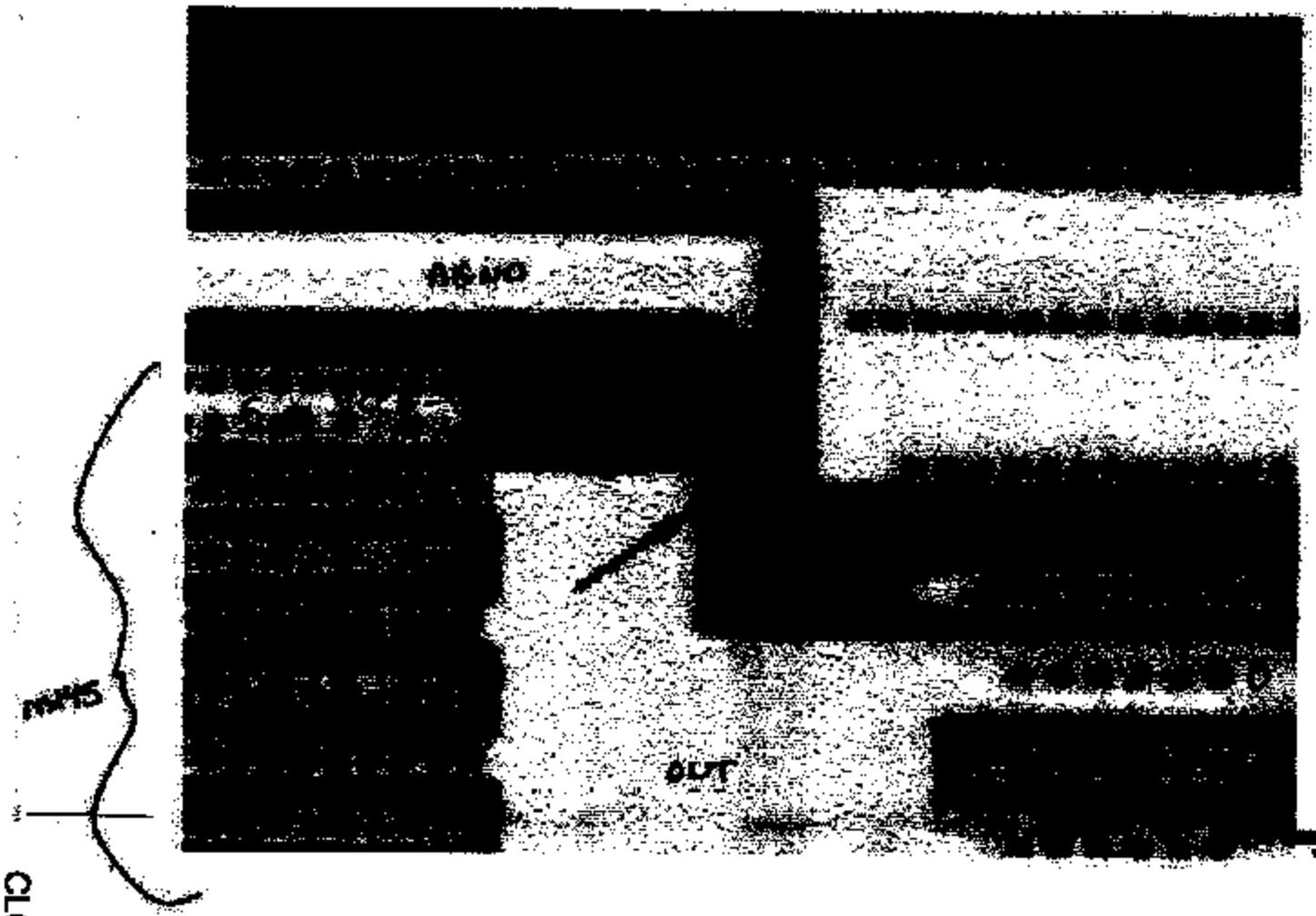

Figure Number: 5
Unit Number: 1
Layer: ILG

Image showing the fused open Metal1 VSS buss.

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