

NHTSA's 1989 Pollard and Sussman Report Concluding Pedal Confusion is the Cause of Audi 5000 SAI is Wrong

by

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Abstract: NHTSA's 1989 report by Pollard and Sussman entitled "An Examination of Sudden Acceleration" (aka, the "Silver Book") defines sudden acceleration incidents (SAI) as "unintended, unexpected, high-power accelerations from a stationary position or a very low initial speed accompanied by an apparent loss of braking effectiveness". When Audi drivers in the 1980's reported that during their incidents the brakes lacked effectiveness, NHTSA tested the brakes under simulated conditions and found that they remained fully operable after the incidents. Therefore, NHTSA's report concluded that "no plausible mechanisms could be identified for temporary, self-correcting brake failure which are relevant to SAI". This led them to conclude that the cause of SAI in Audi 5000 vehicles was the driver confusing the accelerator pedal for the brake pedal when trying to stop the vehicle after the idle stabilizer initiated the SAI by suddenly opening to create an acceleration of less than 0.3 g for less than 2 seconds (excessive creep). In all subsequent cases of alleged sudden acceleration incidents, NHTSA has continued to deny petitions for an investigation of the vehicles involved by citing their 1989 conclusion that the driver confused the accelerator pedal for the brake pedal. This paper shows that NHTSA's 1989 conclusion of pedal confusion is wrong by explaining how the brakes of the Audi 5000 lacked effectiveness during an incident because the engine was operating in an RPM region where increasing the load on the engine by applying the brakes would cause the engine to respond by increasing its output torque, with the increase in engine output torque causing an acceleration that countered the deceleration produced by the applied braking load torque, making the driver feel that the brakes were losing their effectiveness. The effect is similar to engine operation while the cruise control is engaged, when going up a hill causes an increased load on the engine that causes the engine to respond with an increase in engine output torque to keep the vehicle speed constant. Therefore, the Audi incidents satisfy NHTSA's own definition of SAI with the idle stabilizer initiating the acceleration and the loss of braking effectiveness explained by an increase in the engine output torque. As a result, NHTSA's pedal confusion hypothesis is not needed to explain the incidents. And the driver's testimony that the brake pedal was applied, but the brakes lacked effectiveness, remains accurate testimony.

I. Introduction

During the 1980's many Audi 5000 drivers reported that their brakes had failed during their sudden acceleration incident. Some even reported that their vehicle seemed to speed up during the sudden acceleration incident when they pressed on the brake pedal. The Pollard and Sussman report examined the brakes after the incident and showed that the brakes remained fully functional after the incident. As a result, NHTSA concluded that the driver must have been pressing on the accelerator pedal instead of the brake pedal to cause the incident. Many drivers have disagreed with this conclusion because they are sure that they were pressing on the brake pedal during the incident and not on the accelerator pedal.^[1] But NHTSA investigators countered that drivers must have been mistaken during the incident, and merely believe that

1. A few drivers have claimed to have evidence that their foot was on the brake pedal and not on the accelerator pedal because either they themselves observed their foot on the brake pedal during the incident or a passenger in the car observed that their foot was on the brake pedal during the incident.

they were pressing on the brake pedal while they were really pressing on the accelerator pedal. As a result of NHTSA's conclusion of pedal confusion -- starting with their 1989 report by Pollard and Sussman entitled "An Examination of Sudden Acceleration" (aka, the "Silver Book"), and repeated in all subsequent denials of driver petitions for vehicle investigations after sudden acceleration incidents -- all vehicle manufacturers and their lawyers, police investigators, media reporters, and nearly all commenters on internet discussion groups believe that sudden acceleration incidents are caused by pedal confusion, and not by a vehicle defect.

Attempts have been made to explain the drivers' perceptions of brake failure during a sudden acceleration incident by citing the temporary loss of the brake booster during the incident. This can occur when a vacuum-operated brake booster loses manifold vacuum because of repeated pumping of the brakes. This can cause a four to five times increase in the required brake pedal force needed to stop the vehicle while leaving the mechanical brakes fully functional after the incident. This might explain some incidents in which a weaker driver could not apply a sufficient braking force to stop a vehicle with a powerful engine that produces a lot of torque. However, this explanation does not apply to newer vehicles with electrically-powered brake boosters, such as electric vehicles, and to many new ICE vehicles. Although some sudden acceleration incidents may be explained by the time delay needed to apply the brakes after an increase in engine RPM occurs due to a defect, no one has yet been able to explain how the brakes can fail during a sudden acceleration incident and still remain operable after the incident. The solution to this problem is that the brakes do not actually fail during a sudden acceleration incident. The brakes, however, do lose their effectiveness during an incident because the engine is operating in an RPM region where increasing the load on the engine by applying the brakes can cause the engine to respond by increasing its output torque, with the increase in engine output torque causing an acceleration that counters the deceleration produced by the applied braking load torque. This makes the driver feel that the brakes are not effective.

II. Perceived Cause of Brake Failure in Audi 5000's

This paper will now explain why Audi 5000 drivers perceived that the brakes were ineffective during a sudden acceleration incident and yet remained operable after the incident.

Figure 1 shows the engine torque versus engine RPM curve for a typical Audi 5000 vehicle as found on page B-5 of Appendix H of the Pollard and Sussman report.

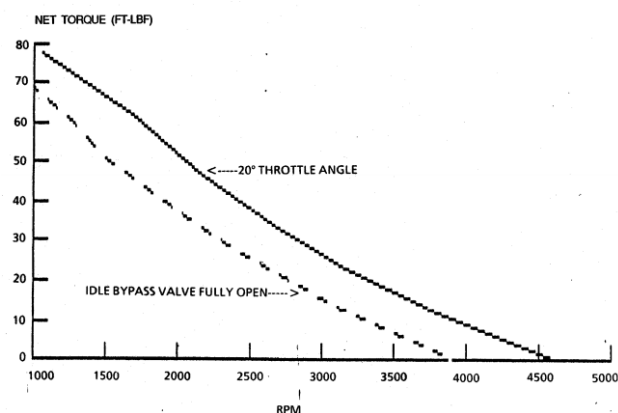


FIGURE B-4. NET ENGINE TORQUE (WARM)

Figure 1. Engine torque versus engine RPM for a typical Audi 5000 vehicle without turbocharger as tested by Audi engineers and documented as Figure B-4 in the Pollard and Sussman report. The dashed curve applies when the engine is operating with air supplied only by a fully open idle stabilizer valve.

The solid curve applies when the engine is operating using air supplied by a throttle opened to a 20° angle by pressing on the accelerator pedal. Much of the Pollard and Sussman report deals with trying to show that the engine torque achieved with a fully open idle stabilization valve is low and is easily overcome by a normal braking torque.

The reader may wonder whether Figure 1 is correct because engine torque usually increases when more air is added to the engine by pressing on the accelerator pedal. The reason it is correct is because it omits a region of the torque curve between 0 RPM and 1000 RPM, during which the engine torque increases as the RPM increases. The complete curve for an internal combustion engine like the Audi 5000 engine looks more like the one in Figure 2 below.

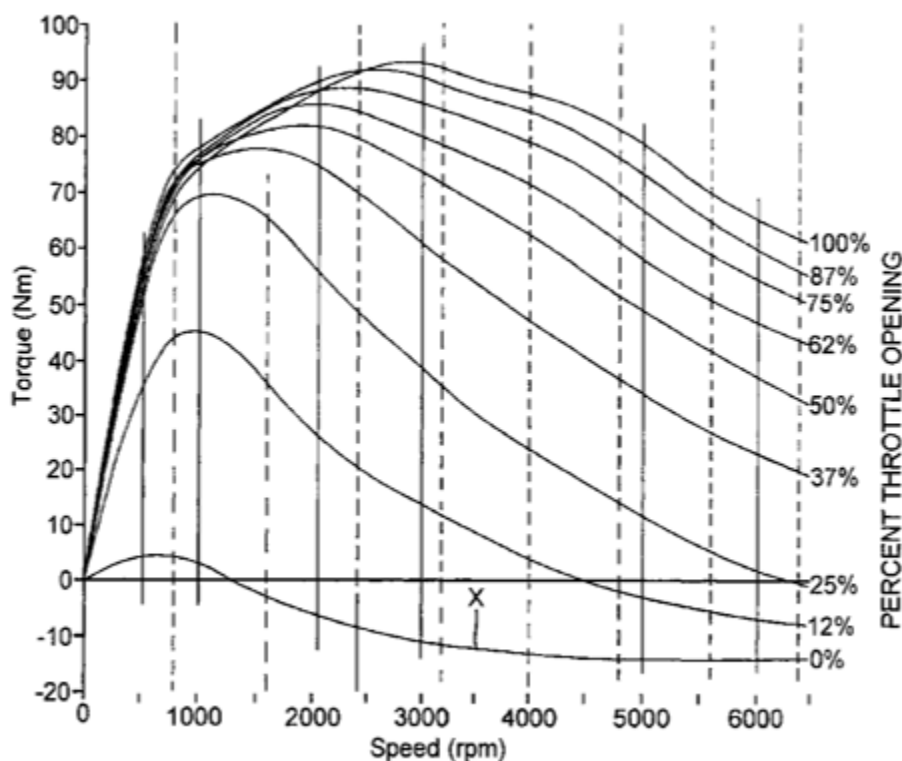


Figure 2. Engine torque versus engine RPM for a typical internal combustion engine, showing how engine torque varies with throttle opening. If the engine includes a turbocharger, then the maximum torque value will increase and the RPM value at which the torque is a maximum will decrease.

Therefore, Figure 1 is correct. It is unknown why Audi and NHTSA chose to omit the region between 0 RPM and 1000 RPM. But NHTSA's Pollard and Sussman report verifies that the Audi 5000 engine will operate at about 2000 RPM when the idle stabilizer valve is fully open, placing it right in the middle of this curve. And the report states further that this RPM allows a vehicle to reach vehicle speeds of 40 mph in a short time. Some drivers have even reported on the internet that their Audi 5000 vehicles will operate at up to 3000 RPM with the idle stabilizer valve fully open, which allows their vehicle to reach speeds of 60 mph in a short time. Therefore, an RPM range of 2000 to 3000 RPM is possible in an Audi 5000 with a fully open idle stabilizer valve. This is probably due to variations in the engine idle setting and variations in the idle stabilizer valve.

We will now consider the dashed curve in Figure 1, which shows the case when the idle stabilizer valve is fully open. This occurs when the control electronics gets overheated and causes a PNP drive transistor to fail suddenly, which sends a maximum current to the idle stabilizer valve. When this happens, the engine RPM suddenly increases from an idle value of 900 RPM to its maximum value and remains there, causing a high engine RPM of 2000 to 3000 RPM. In this case, the engine RPM remains high as the driver applies the brakes because the stabilizer valve opening remains at its maximum. When the driver applies the brakes, he expects to feel the normal deceleration of the vehicle as the brakes are applied. Engine RPM normally drops when the brakes are applied because the brakes add a load to the engine, which causes the engine RPM to drop. But with the engine continuing to operate in the negative slope region of the curve in Figure 1, a decrease in the engine RPM causes the engine output torque to increase. This increase in engine output torque causes an increase in the vehicle's acceleration that opposes the deceleration produced by the brakes being applied. The result felt by the driver is the algebraic sum of these positive and negative torques (or equivalently, positive and negative accelerations), which can be anywhere between a less-than-expected braking deceleration all the way up to a positive vehicle acceleration as the brakes are applied, depending on the magnitudes of the two accelerations. Either of these cases is interpreted by the driver as a lack of braking effectiveness, which explains the driver's testimonies in all these cases. In more everyday English some drivers may state that the brakes "didn't work". But the brakes did work. Their braking effectiveness just got diminished by the increased output torque of the engine as the engine RPM's decreased while the idle stabilizer valve remained completely open.

After an Audi 5000 sudden acceleration incident, the brakes always continue to operate and pass all tests with normal brake operation. The explanation above explains not only why Audi 5000 drivers perceived that the brakes lacked effectiveness, but also proves that the drivers were actually pressing on the brake pedal and not on the accelerator pedal. This is because the brake load torque must be involved in order to reduce the engine RPM while the idle stabilizer continues to provide air to the engine. And if the driver's foot was pressing on the brake pedal, it couldn't be pressing on the accelerator pedal. This is why NHTSA's conclusion of "pedal confusion" is wrong. Pedal confusion isn't needed to explain the lack of braking effectiveness. Braking effectiveness is diminished by the increased output torque of the engine as the engine RPM's decrease. And pedal confusion is not a proven fact, but only an unproven hypothesis that contradicts the testimony of the drivers in the Audi incidents.

Let's consider the implications of the above explanation in a different way. The Pollard and Sussman report states in many places that "No plausible mechanism for temporary, self-correcting brake failure has been identified which has any relevance to SAI" and that "Chapter 6 of Appendix H ... concludes unequivocally that no SAI-related brake failure modes exist which leave no readily detectable evidence of their occurrence". These statements apply only to the vehicle's braking system without considering the effects of other vehicle systems. NHTSA's definition of SAI ^[2], on the other hand, is "unintended, unexpected, high-power accelerations from a stationary position or a very low initial speed accompanied by an apparent loss of braking effectiveness". Note that NHTSA's definition mentions "braking effectiveness" instead of "brake failure" because it is the stopping power of the brakes during an event of interest that is most important, and not just the integrity of the braking system or the stopping power of the brakes alone. And during an event of interest other vehicle systems can affect the stopping power of the brakes, like the engine output torque increasing as the brakes are being applied while the engine RPM's remains high. Therefore, "braking effectiveness" can be diminished during an event of interest while no "brake failure" is encountered, because the engine output

2. Pollard and Sussman report, "An Examination of Sudden Acceleration", page 1.

torque can increase as the brakes are being applied during an event, causing the “brake effectiveness” (i.e., the stopping power of the brakes) to be reduced, as explained above.

The result is that an event like applying the brakes while the idle stabilizer is fully open during an Audi 5000 event clearly meets NHTSA’s definition of SAI because it is: 1) an “unintended, unexpected, high-power acceleration^[3] from a stationary position or a very low initial speed” accompanied by 2) an “apparent loss of braking effectiveness”. And this does not contradict NHTSA’s statements that “no plausible mechanism for temporary, self-correcting brake failure has been identified which has any relevance to SAI”. Given that Audi 5000 idle stabilizer events truly satisfy NHTSA’s definition of a sudden acceleration incident (SAI), the explanation given above that the engine output torque increases as the brakes are being applied while the idle stabilizer valve remains fully open constitutes a valid explanation of this SAI event. There is no need to assume that the drivers were pressing on the accelerator pedal instead of the brake pedal. This is why NHTSA’s conclusion of “pedal confusion” is wrong. Pedal confusion isn’t needed to explain the lack of braking effectiveness. Braking effectiveness is diminished by the increased output torque of the engine as the engine RPM’s decrease. And pedal confusion is not a proven fact, but only an unproven hypothesis that contradicts the testimony of the drivers in the Audi incidents.

But pedal confusion does have one key advantage. It transfers the blame for Audi 5000 incidents from the vehicle manufacturer to the driver. This saves the vehicle manufacturer a lot of money for recalls and court cases if NHTSA cooperates by supporting this hypothesis. And it is easier for NHTSA to support this hypothesis than to find the true answer to Audi 5000 sudden acceleration while fighting the vehicle manufacturers.

Returning to the effects of the engine torque curve on braking effectiveness, if the engine is operating at a lower RPM in the positive slope region of the curve while the idle stabilizer valve remains fully open, then this lack of brake effectiveness does not happen. In this case, a decrease in the engine RPM caused by braking will cause the engine output torque to decrease. When this lower output engine torque is added to the load torque on the engine produced by braking, then the result is always a faster deceleration of the vehicle than when the brakes are applied normally. This is a good thing that is rarely encountered.

These two behaviors do not occur if the idle stabilizer valve is operating normally. This is because when the driver applies the brakes normally in either region, the engine torque decreases to zero because the accelerator pedal has been released. The idle stabilizer valve also returns to the idle position as the engine RPM decreases, which brings the engine RPM quickly back to the idle RPM of 800 to 900 RPM. Therefore, the only torque that remains is the braking load torque, which produces a normal vehicle deceleration.

II. Braking Effectiveness During Sudden Acceleration in Other ICE vehicles and Electric Vehicles

3. Page 8-1 of the Pollard and Sussman report states that “Tests by both VWOA and TSC have indicated that the idle-stabilizer system alone can accelerate the Audi 5000 at 0.3 g reaching speeds of 20 to 25 mph in approximately 10 seconds, eventually reaching speeds of 40 to 50 mph in drive”. Page 2-1 says “This vehicle acceleration may alarm the driver”. Page D-13 states that “a fully open valve caused this Audi to reach speeds of 45 mph in drive and 25 mph in reverse within 30 to 40 seconds. When the valve was opened at 60 mph the vehicle speed increased quickly to 65 mph and felt as if the cruise control had engaged”. Although this acceleration and vehicle speed are not that of a wide open throttle, they are high enough to “cause alarm by the driver” and difficulty with braking as the report verifies.

The same lack of braking effectiveness that occurred during idle stabilizer incidents in Audi 5000 vehicles can occur during sudden acceleration in all ICE vehicles and electric vehicles. The only difference is what causes engine RPM's to rise to a high value without the driver applying the accelerator pedal. The explanation that engine torque can increase while braking in the high RPM region eliminates the need for "pedal confusion" to explain the lack of braking effectiveness in these vehicles. The explanation is similar for both ICE vehicles and electric vehicles, but it differs slightly in one detail for the two types of vehicles. We will start by explaining sudden acceleration in ICE vehicles.

ICE Vehicles

In all ICE vehicles, both gasoline-powered and diesel-powered, engine torque varies with engine RPM as shown in Figure 3. Normal engine operation is shown in green. Normally, the driver starts from a stop by shifting the transmission into DRIVE and then pressing on the accelerator pedal to increase the throttle opening. This causes the engine RPM to increase and the engine torque to rise. The vehicle transmission starts out in the lowest forward gear, which produces the greatest torque to the drive wheels. The engine RPM's increase slowly because of the load placed on the engine by the drive train. As the engine RPM's slowly increase, the vehicle velocity increases, and the transmission shifts from the lowest gear into the next higher gear to keep the engine RPM's low while continuing to apply torque without going past the RPM at which the maximum torque occurs. This constrains operation along the green path shown in Figure 3, with the engine RPM's never exceeding the RPM at which the maximum torque occurs.

When the driver wants to slow down, he releases the accelerator pedal, which causes the throttle opening to decrease and the engine torque to decrease to its idle value. With the accelerator pedal released, the driver can then apply the brake pedal to slow the vehicle down even faster. When the brakes are applied, the brakes increase the load torque on the engine, which opposes the torque produced by the engine. This higher load torque causes the engine RPMs to decrease faster than if no brakes were applied, causing the torque produced by the engine to decrease faster. The driver perceives that applying the brakes causes the vehicle to slow down faster than with no brakes applied because the engine torque decreases in response to the brake torque being applied.

During sudden acceleration the engine RPM's increase suddenly without the driver stepping on the accelerator pedal. While the vehicle remains stationary, the engine RPM's increase rapidly from the idle value of 800 RPM along the red curve A to B to C as determined by the throttle opening.^[4] The engine RPM's rise rapidly because there is no load on the engine due to delayed engagement of the transmission gears, which leaves the gears temporarily in NEUTRAL.^[5] About 1 to 3 seconds after the RPM's have started to rise, the engine operation reaches point C, at which the transmission gears finally engage into the lowest gear in DRIVE or REVERSE. The transmission drops into the lowest gear because the vehicle is usually not moving at the start of the sudden acceleration, or is moving only very slowly. This lowest gear puts a sudden load on the engine, causing the vehicle to lurch forward or backward. The vehicle continues to move forward or backward because the throttle remains open and not under the driver's control.

4. The throttle opening during sudden acceleration is determined by the defect mechanism that causes the sudden acceleration. In most cases of sudden acceleration the throttle opening is 100%. But in the case of Audi 5000 vehicles between 1982 and 1987, the throttle appears to have remained closed during the sudden acceleration, with the idle air control valve suddenly opening to 100%. This would have corresponded to a throttle opening of about 20%.

5. For a discussion of delayed engagement and how it operates in various transmissions, see the author's paper entitled "Delayed Engagement as a Contributor to SUA" found at <https://www.autosafety.org/donald-a-belts-sudden-acceleration-papers/>. The frequency of sudden acceleration incidents seems to be higher in vehicles that have delayed engagement problems.

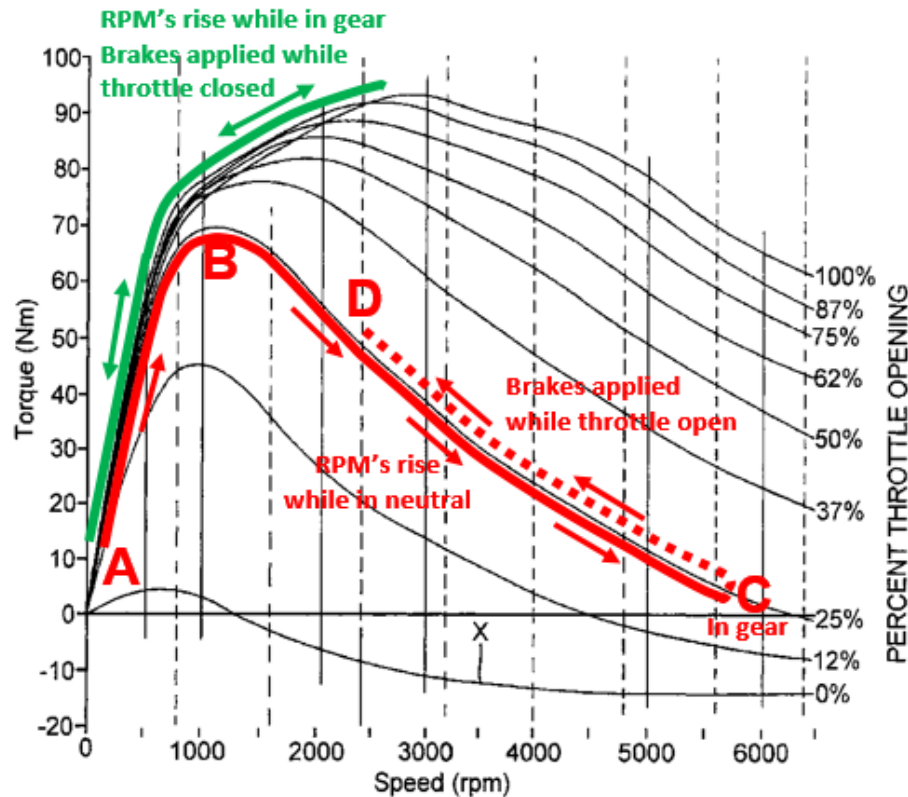


Figure 3. Engine torque versus engine speed for an ICE vehicle. During normal operation the engine follows the green curve to the left of the maximum points in the throttle opening curves. The engine torque increases as the engine RPM's increase and decreases as the engine RPM's decrease while braking with the accelerator pedal released and the throttle closed. During sudden acceleration, the engine RPM's increase rapidly following the red curve while the transmission remains in neutral due to delayed engagement. At point C the transmission drops into the lowest gear to begin vehicle motion. When the brakes are applied during sudden acceleration, the engine torque increases as the engine RPM's decrease because of the increased load on the engine produced by the brakes as a result of the engine operating to the right of the maximum torque position while the throttle remains open. The resulting increase in engine torque counters the braking torque, giving the driver the impression that the brakes are failing. In vehicles with engines that produce a lot of torque the driver may even perceive that the vehicle speeds up as the driver presses on the brake pedal during sudden acceleration.

When the driver applies the brakes to try to stop the sudden acceleration, the load on the engine increases further, causing the engine RPM's to decrease. But as the engine RPM's decrease, the engine torque increases as a result of operating between points C and D to the right of the curve maximum where the curve slopes upward with decreasing engine RPM's. If the increase in the engine torque is low, then the increase in engine torque opposes or neutralizes the applied braking torque, causing the driver to perceive that the brakes are less effective or have failed completely. If the increase in the engine torque is higher than the applied braking torque because of a powerful engine, then the increase in engine torque causes the vehicle to accelerate as the driver applies the brakes. This is the reason many drivers involved in sudden acceleration incidents say that the brakes have failed or that pressing on the brake pedal caused the vehicle to accelerate. It is the perception of the driver-- resulting from the vehicle acceleration-- that the brakes are failing, and not the actual failing of the brakes. This perception of brake failure is

correct because while the engine is operating to the right of the maximum RPM value, the engine torque increases as the engine RPM's decrease when the brakes are applied. This increase in engine torque counters the applied braking torque, making the driver perceive that the brakes are ineffective. The harder one presses on the brake pedal, the faster the engine RPM's decrease and the faster the engine torque increases to oppose the brake torque or to cause the vehicle to accelerate.

Electric Vehicles

In vehicles powered by electric drive motors, the motor torque varies with motor RPM as shown in Figure 4. The torque in the base region varies with the battery current as controlled by the driver pressing on the accelerator pedal, and remains constant as the motor RPM's increase up to the base speed of around 2000 RPM. At motor RPM's higher than the base speed the drive motor torque decreases with increasing motor RPM's.

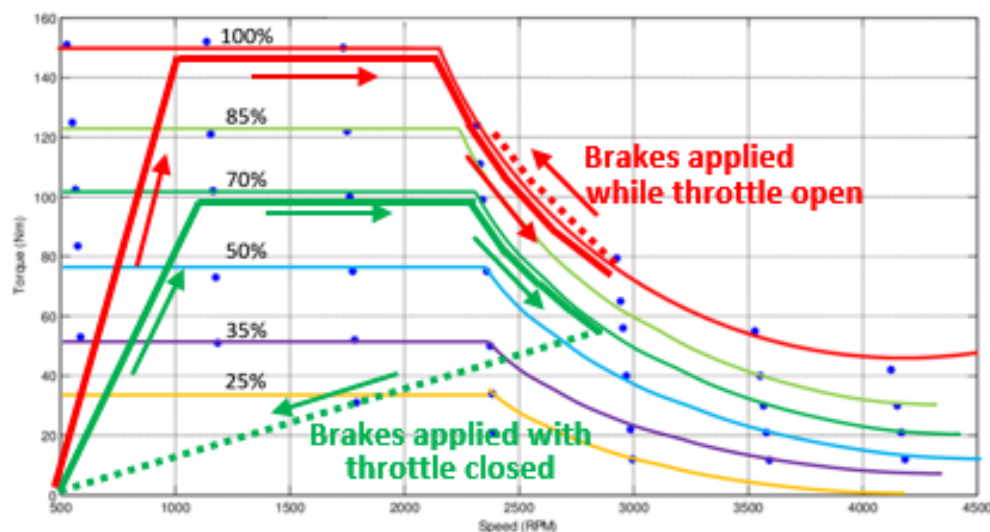


Figure 4. Motor torque versus motor speed for the drive motor of an electric vehicle. During normal operation the drive motor follows the green curve, causing the motor torque to decrease as the motor RPM's decrease while braking with the accelerator pedal released and no current applied to the motor. During sudden acceleration the motor follows the red curve, causing the motor torque to increase as the motor RPM's decrease while braking as current continues to be applied to the motor.^[6] The increased motor torque counters the braking torque, giving the driver the impression that the brakes are failing.

6. This is the case when sudden acceleration is caused by a temporary voltage dip in the 5V supply to the accelerator pedal sensor, which causes the digitized accelerator pedal sensor reading to increase while the analog accelerator pedal sensor output remains at 0% because the accelerator pedal is released. This is explained further in the paper entitled "*A Cause of SUA Common to All Vehicles with Electronic Throttles – 7/20/24*" by this author, available at <https://www.autosafety.org/dr-ronald-a-belts-sudden-acceleration-papers/>. Sudden acceleration can also be caused by a temporary voltage dip in the 12V supply to the high voltage sensor, which changes the operating point of the control system for the drive motor, causing the control system to operate in the field weakening region instead of the base region. In this case, the voltage dip causes motor operation in Figure 2 to jump suddenly from a point on the red curve in the base region near zero torque to a point on the red curve in the field weakening region at the same torque without increasing the torque to 100%. This is explained further in the paper entitled "*A Cause of Sudden Acceleration in Battery Powered Electric Vehicles*" by this author, available at <https://www.autosafety.org/dr-ronald-a-belts-sudden-acceleration-papers/>.

In some electric vehicles the drive wheels are directly connected to the drive motor without a geared transmission. In these vehicles, the vehicle speed is directly proportional the motor RPM as shown in Figure 4. This difference in drive train design causes the following differences between ICE vehicles and electric vehicles during sudden acceleration:

- 1) Increase in engine RPM's during sudden acceleration. In ICE vehicles, during sudden acceleration the engine RPM's increase while the transmission remains in neutral as a result of delayed engagement. This causes the engine RPM's to increase suddenly within less than 1-3 seconds because there is no load torque on the engine as the RPM's increase. In electric vehicles with direct drive there is no delayed engagement of the transmission gears. Instead, during sudden acceleration the motor RPM's increase while the drive train remains connected to the drive motor. This causes the motor RPM's to increase more slowly because the load torque from the drive train is applied to the drive motor as the RPM's increase. The vehicle speed in some electric vehicles can still increase quite rapidly as a result of the high battery currents produced.
- 2) Braking during sudden acceleration. In ICE vehicles, during sudden acceleration when the brakes are applied, the engine RPM's decrease because of the increased brake load on the engine being applied. But the effect on the vehicle speed depends on the total torque being applied to the drive wheels, which depends on the engine torque minus the braking torque. If the engine torque increases faster than the braking torque while the engine RPM's decrease during braking, then the vehicle speed may increase during braking instead of decreasing. In electric vehicles that have a direct connection of the drive motor to the drive wheels, the vehicle speed is always directly proportional to the drive motor speed. During sudden acceleration, when the brakes are applied to this type of vehicle, the motor torque will increase when the vehicle speed exceeds the base speed of approximately 70 to 90 km/hr (45 to 55 mi/hr). This increase in motor torque will cause the vehicle speed to decrease more slowly while braking during sudden acceleration, but will never result in the vehicle speed increasing while braking during sudden acceleration.

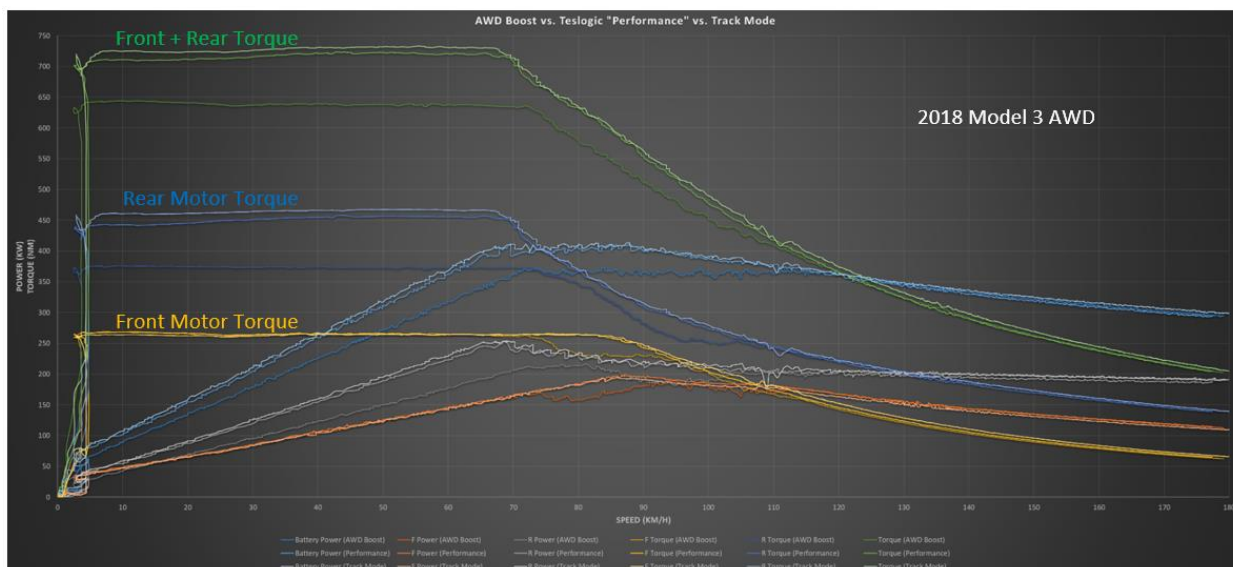


Figure 5. Motor torque versus vehicle speed for the two drive motors of a 2018 Model 3 Tesla with AWD. Only the maximum torques (100% throttle) are shown. Lower torques are

obtained by using lower accelerator pedal settings that apply proportionally lower currents to the motors.

III. Testing the Brakes During a Simulated Sudden Acceleration.

NHTSA's 1989 report by Pollard and Sussman entitled "An Examination of Sudden Acceleration" (aka, the "Silver Book") contains a section E on testing the brakes of two Audi 5000 vehicles and several other vehicles during a simulated sudden acceleration. Brakes were tested under the following conditions:

- 1) Test Series 4 (With the vehicle stopped, shift to DRIVE then open throttle wide open. Apply brakes as soon as one can with throttle remaining wide open until stopped at 60, 100, and 150 lbs force and measure the time to stop and the total distance travelled with each force).
- 2) Test Series 5 (Same as Series 4 but throttle closed during the stop),.
- 3) Test Series 6 (With the vehicle stopped, shift to DRIVE then simulate a vacuum pump/dump valve C/C failure. After the simulated C/C failure is applied, apply the brakes as soon as one can until stopped at 60, 100, and 150 lbs force and measure the time to stop and the total distance travelled with each force).
- 4) Test Series 7 (With the vehicle stopped, actuate RESUME set at 65 mph in DRIVE to simulate a minimum speed circuit fault. Approximately 1 and 2 seconds after the RESUME has been applied, apply the brakes with pedal forces of approximately 60, 100, and 150 lb for each series and measure the time to stop and the total distance travelled with each force).
- 5) Test Series 8 (With the vehicle stopped, start the cruise control pump by shorting it to ground with the dump valve plugged. Then measure the minimum the brake pedal force (needed to shift out of Park and then maintained after shifting to Drive) to prevent the cruise control from causing the vehicle to move).
- 6) Test Series 9 (Measure the stopping distance and the pedal force needed to stop from 30 mph with the throttle closed during the stop). Test in both Drive and Reverse.
- 7) Test Series 10 (Measure the stopping distance and the pedal force needed to stop from 30 mph with the throttle wide open during the stop). Test in both Drive and Reverse.
- 8) Test Series 11A (Measure the stopping distance and the pedal force needed to stop from 30 mph with the throttle closed (normal) and with a 0.33 g (10.7 ft/sec/sec) deceleration). Test in both Drive and Reverse.
- 9) Test Series 11B (Measure the stopping distance and the pedal force needed to stop from 30 mph with the throttle held wide open and with a 0.33 g (10.7 ft/sec/sec) deceleration). Test in both Drive and Reverse.
- 10) Test Series 11C. (Measure the stopping distance and the pedal force needed to stop from 30 mph with the throttle wide open and the same braking force as applied in the original normal stop). Test in both Drive and Reverse.

Note that all of these tests on ICE vehicles were done while the engine was operating in the green region of Figure 3 where the engine torque decreases with decreasing engine RPM. Therefore, they did not simulate the case when the vehicle is operating in the red region of Figure 3, which is where the engine torque increases with decreasing engine RPM. The red region is the region where engine torque increases as the brakes are being applied while stopping during sudden acceleration with the transmission in the lowest gear. This is the case that causes the drivers to perceive that the brakes are failing because the engine torque increases in response to the brake torque being applied, which does not happen in the green region. Therefore, these tests failed to reproduce how the Audi 5000 vehicles really behaved during the original sudden acceleration incidents and what the drivers of these vehicles perceived as a result.

As a result of these incorrect tests, NHTSA concluded that when Audi drivers stated that the brakes seemed to fail during their sudden acceleration incidents, or even that the vehicle seemed to speed up in response to stepping on the accelerator pedal, that the drivers were mistaken about the position of their foot during the incidents. Therefore, based on test results showing that the brakes remained operable after the incidents, NHTSA concluded that the drivers had unknowingly stepped on the accelerator pedal instead of the brake pedal to cause the sudden acceleration incidents. And in all subsequent petitions for investigations of vehicles in sudden acceleration incidents over the past thirty years, NHTSA has continued to deny the petitions based on these same incorrect test results.

The brake test that should have been done is to first operate the engine in the red region of Figure 3 where the engine torque increases with decreasing engine RPM by raising the engine speed above the RPM at which the maximum torque is produced while the transmission remains in the lowest gear in DRIVE. This can be done by raising the engine RPM's while in NEUTRAL to some RPM above the RPM at which the maximum torque occurs, after which the transmission is shifted into LOW gear. Then, while the throttle continues to be applied, the brakes should be applied and the brake pedal force measured. In this case, one will find that the engine torque increases as the brake pedal force is applied to stop the vehicle, which reduces the effectiveness of the brakes in stopping the vehicle. This is the cause of the perceived brake failure reported by many drivers during the Audi 5000 idle stabilizer incidents.

This reduced effectiveness of the brakes in stopping the vehicle (or an increase in the brake pedal force needed to stop the vehicle) as the engine RPM decreases constitutes direct evidence that the driver was applying force to the brake pedal during the Audi 5000 sudden acceleration incidents because the brake load torque must be involved in order to reduce the engine RPM. Therefore, this provides direct evidence that the Audi drivers had their foot on the brake pedal during their sudden acceleration incidents (as they steadfastly maintained), and refutes NHTSA's conclusion that the drivers unknowingly stepped on the accelerator pedal instead of the brake pedal to cause the Audi sudden acceleration incidents. This is why NHTSA's conclusion of "pedal confusion" is wrong. There is no need to assume without proof that the drivers were pressing on the accelerator pedal instead of the brake pedal. This same explanation applies to nearly all subsequent petitions to NHTSA for investigations of vehicles in sudden acceleration incidents over the past thirty years, which NHTSA has continued to deny based on their conclusion in the Audi investigation that the drivers stepped on the accelerator pedal instead of the brake pedal to cause the sudden acceleration incidents.

IV. Conclusion

NHTSA's 1989 report by Pollard and Sussman entitled "An Examination of Sudden Acceleration" (aka, the "Silver Book") concluded that "no plausible mechanisms could be identified for temporary, self-correcting brake failure which are relevant to SAI". This paper, on the other hand, explains how drivers can perceive that the brakes failed during a sudden acceleration incident and yet remained operable after the incident. Therefore, this paper explains how NHTSA's conclusion regarding brake failure in their 1989 report is incorrect. It further explains how the brake tests described in NHTSA's 1989 report failed to simulate properly the engine torque produced during a sudden acceleration incident in an Audi 5000 vehicle, and describes a brake test that should have been done that would have found a mechanism for a "temporary, self-correcting brake failure which is relevant to SAI".

The mechanism causing a loss of brake effectiveness as explained in this paper is not limited to Audi 5000 sudden acceleration incidents back in the late 1980's. It can occur in all vehicles with internal combustion engines when faulty engine operation causes the engine to operate continuously in the region of the torque-versus-engine RPM curve where the torque increases with decreasing engine RPM. And the engine RPM needs only to be above about 2000 RPM or

so for this to occur. Vehicle speed is not important for this mechanism to occur, and can be quite low when the brakes lose their effectiveness. Therefore, this mechanism could certainly have affected many Toyota vehicles during their sudden acceleration incidents back in 2010, as well as many other vehicles having electronic throttles from the year 2000 up to the present time. And it can also be present in electric vehicles during their sudden acceleration incidents, and could certainly have affected Tesla vehicles as well as other electric vehicles during their sudden acceleration incidents between 2015 and the present time. Therefore, NHTSA is urged to accept all petitions that are currently pending for the investigation of sudden acceleration in many vehicles, considering that the loss of braking effectiveness in these incidents could certainly have been caused by this mechanism and not by “unknowingly stepping on the accelerator pedal instead of the brake pedal”.

NHTSA’s failure to find this brake failure mechanism back in 1989 played a critical role in forming their conclusion that the only alternative for explaining Audi 5000 sudden acceleration incidents in which drivers claimed that the brakes appeared to fail was that the drivers unknowingly stepped on the accelerator pedal instead of the brake pedal to cause the sudden acceleration. This paper has shown conclusively that NHTSA’s conclusion of “pedal confusion” in these Audi incidents was wrong. And since NHTSA has continued to deny nearly all subsequent petitions for investigations of vehicles in sudden acceleration incidents over the past thirty years based on this conclusion in the Audi investigation, it implies that NHTSA’s denial of all these later petitions based on “pedal confusion” is also wrong. Therefore, NHTSA is urged not only to accept the petitions that are currently pending for the investigation of sudden acceleration in many vehicles, but also to review their denials of petitions for the investigation of sudden acceleration in many vehicles over the past thirty years if these denials cited “pedal confusion” as the cause of these sudden acceleration incidents.

Appendix 1. Audi 5000 Idle Stabilizer

Page 1-6 of the Pollard and Sussman report states: “TSC reached the following conclusions: The Audi 5000 has mechanical and electronic failure modes that can induce engine surging and produce unexpected increases in engine power. In particular, failures in the idle-stabilizer system used in 1984 to 1986 vehicles have been observed which produce surges typical of some SAIs and could potentially initiate such incidents. Because of their intermittent nature, these idle-stabilizer system failures would most likely not be detected during normal Audi-specified testing of the unit, or in post-accident NHTSA investigations”. These failure modes in the idle-stabilizer system occur in the control electronics and not in the idle stabilizer valve itself.

In the thirty-six years that have passed between this statement and the writing of this paper, more has been learned about the control electronics and its failure modes. This appendix summarizes some of this new information that can be found on the internet.

Figure A-1 shows the Audi 5000 idle stabilizer control electronics as found in Appendix H of the Pollard and Sussman report on page 3-12. This low resolution black and white photograph reveals little about the electronics.

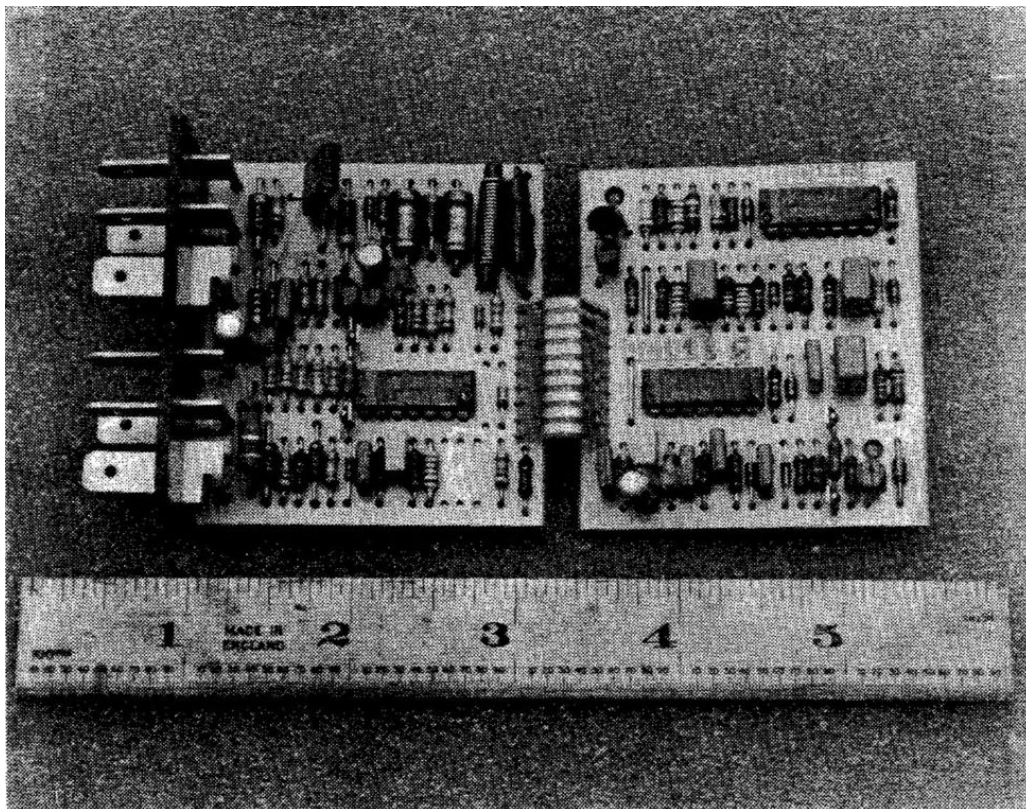


Figure A-1. Audi 5000 idle stabilizer control electronics as shown in Appendix H of the Pollard and Sussman report on page 3-12.

Figure A-2 shows a color photograph of the Audi idle stabilizer control electronics found on a slightly later Audi model. Although the number of pins has increased by two, the circuit design and components are believed to be essentially the same with only minor changes over time. Figure A-2 clearly shows a failed PNP drive transistor, failed diode, and two overheated resistors that caused a fully open idle stabilizer valve. The output current of this failed unit was 2.3 amps when the maximum current of a normally functioning unit was 1.3 amps. When the transistor and diode were replaced, complete functionality of the control electronics and idle stabilizer

valve was restored. This proves that the sudden opening of the idle stabilizer valve initiating the Audi 5000 SAI incidents was caused by the drive transistor and diode instantaneously losing their functionality by being overheated by a current higher than the normal 1.3 ampere current that fully opens the valve.

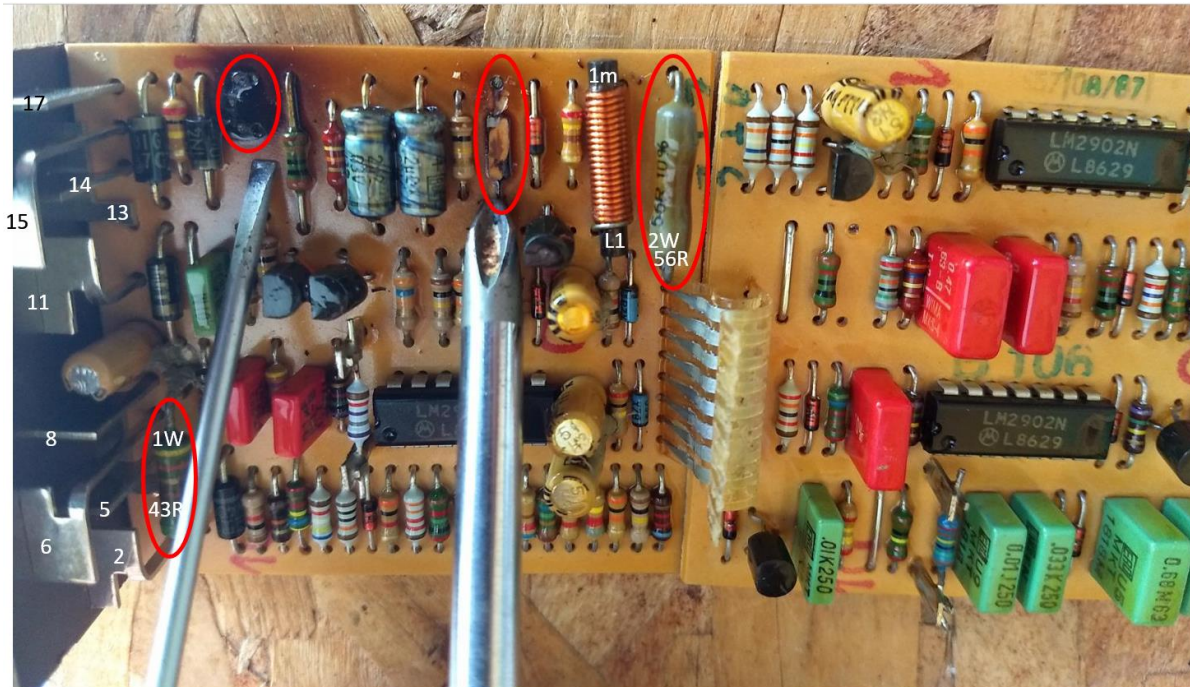


Figure A-2. Audi 5000 idle stabilizer control electronics taken from a slightly later Audi model, showing a failed transistor, failed diode, and two overheated resistors.

When the transistor and diode were replaced, full functionality was restored. ^[1]

Figure A-3 shows a different view of the same electronics that shows more clearly the heat stress accompanying the component failures. This figure also shows how the two boards get folded up before being put into a housing.

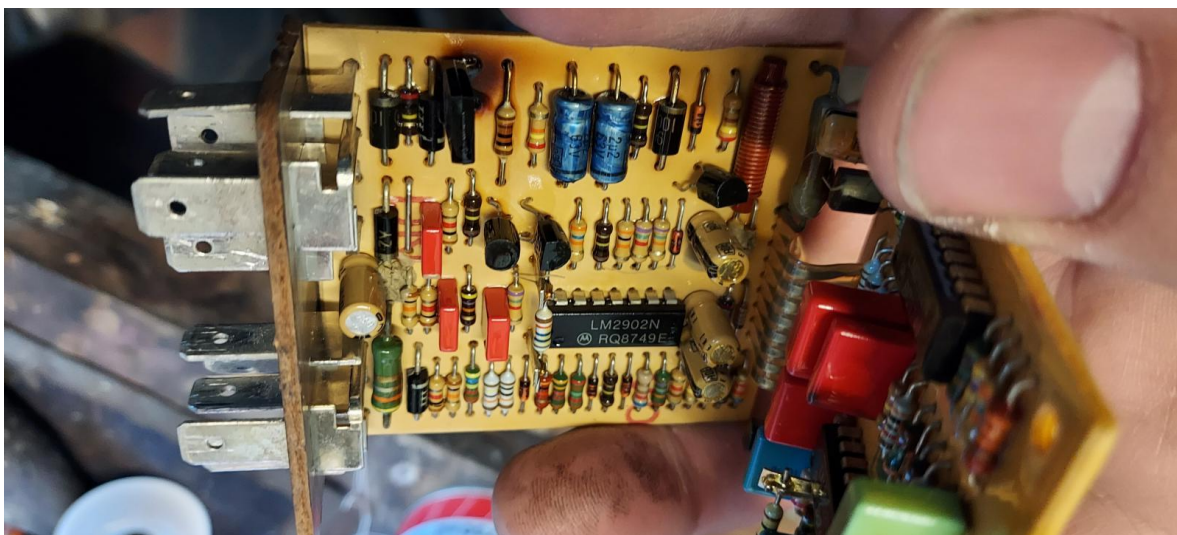


Figure A-3. Different view of the same electronics that shows more clearly the heat stress associated with the component failures. ^[2]

Finally, Figures A-4 and A-5 show how the folded boards are put into a small housing that fits under the driver side dashboard.

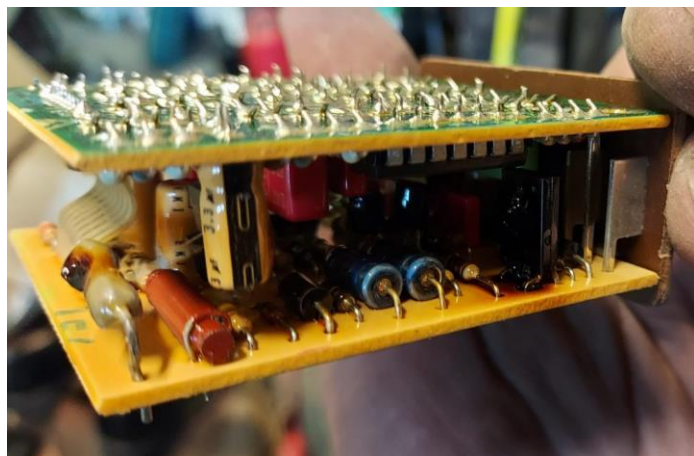
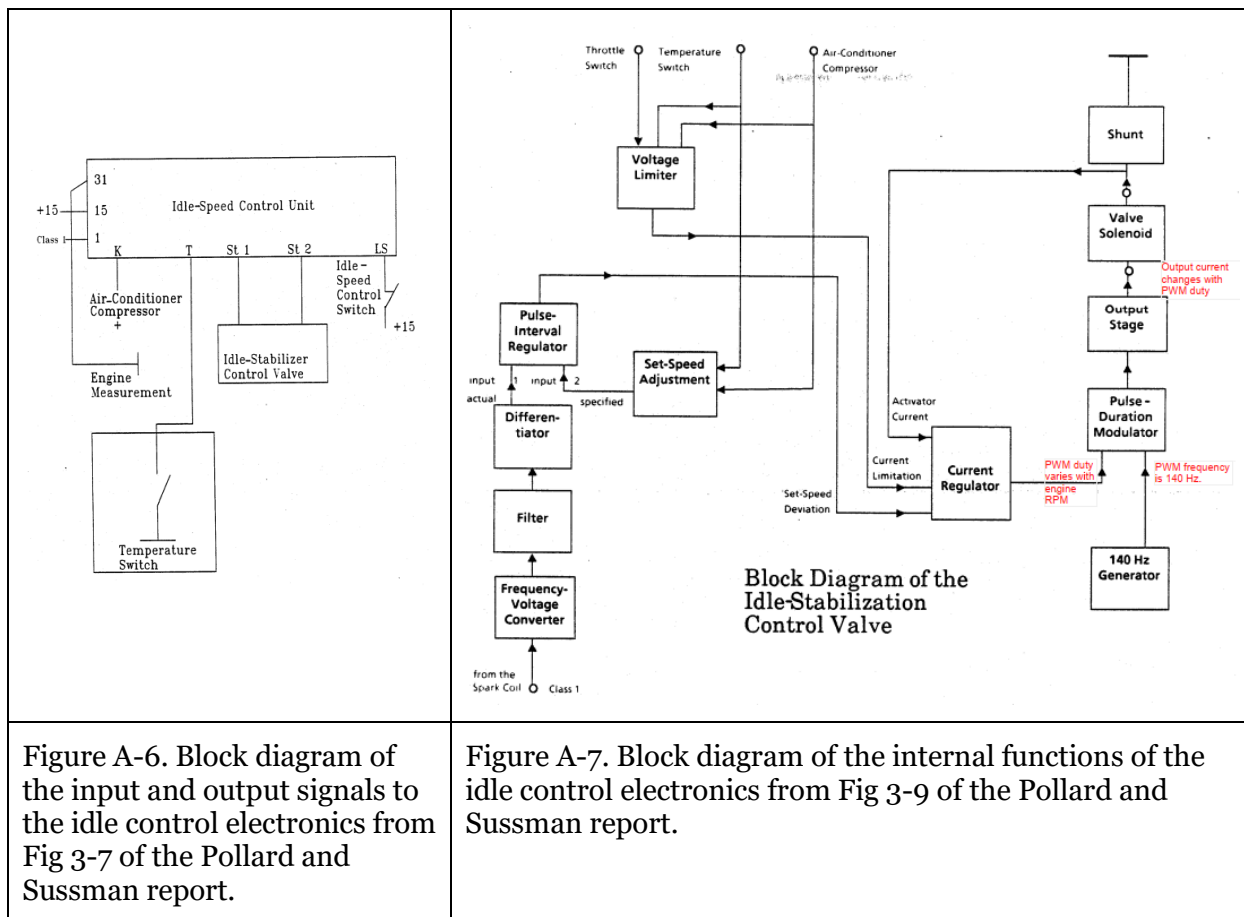


Figure A-4. Completely folded idle stabilizer electronics without housing.[3]



Figure A-5. Idle stabilizer electronics in its housing that fits under the driver side dashboard.

The Pollard and Sussman report give only a limited description of the operation of the idle stabilizer electronics as shown in Figures A-6 and A-7.



The Pollard and Sussman report contains a reference on page 3-13 to a Figure 3-11 that shows a circuit diagram for the idle stabilizer control electronics. But it does not include this circuit diagram in the report. However, in 2020 an Audi owner on the internet published such a circuit diagram for the idle stabilizer control electronics in his 1986 Audi with a 2.1L engine. This diagram is shown in Figures A-8 and A-9. It is believed that this is essentially the same as the circuit diagram omitted in the Pollard and Sussman report.

In Figure A-8 one can see that transistor QQ4, a PNP drive transistor with the part number NTE185, modulates the current between VCC and the ISC valve with a duty cycle that changes with engine RPM as provided by the saw tooth oscillator and the electronics in the lower left hand portion of the figure. When the ignition is ON, another 12V supply provides further current through diode DD10, with the part number NTE125. When the PNP drive transistor and diode fail, the output current to the ISC valve increases to cause a fully open idle control valve that does not close as the engine RPM changes. Replacing these two components with new components restores the idle control electronics to its normal operation. When the control electronics is inoperative, two resistors also become discolored due to the higher current through them. But these resistors do not need to be replaced to restore normal operation.

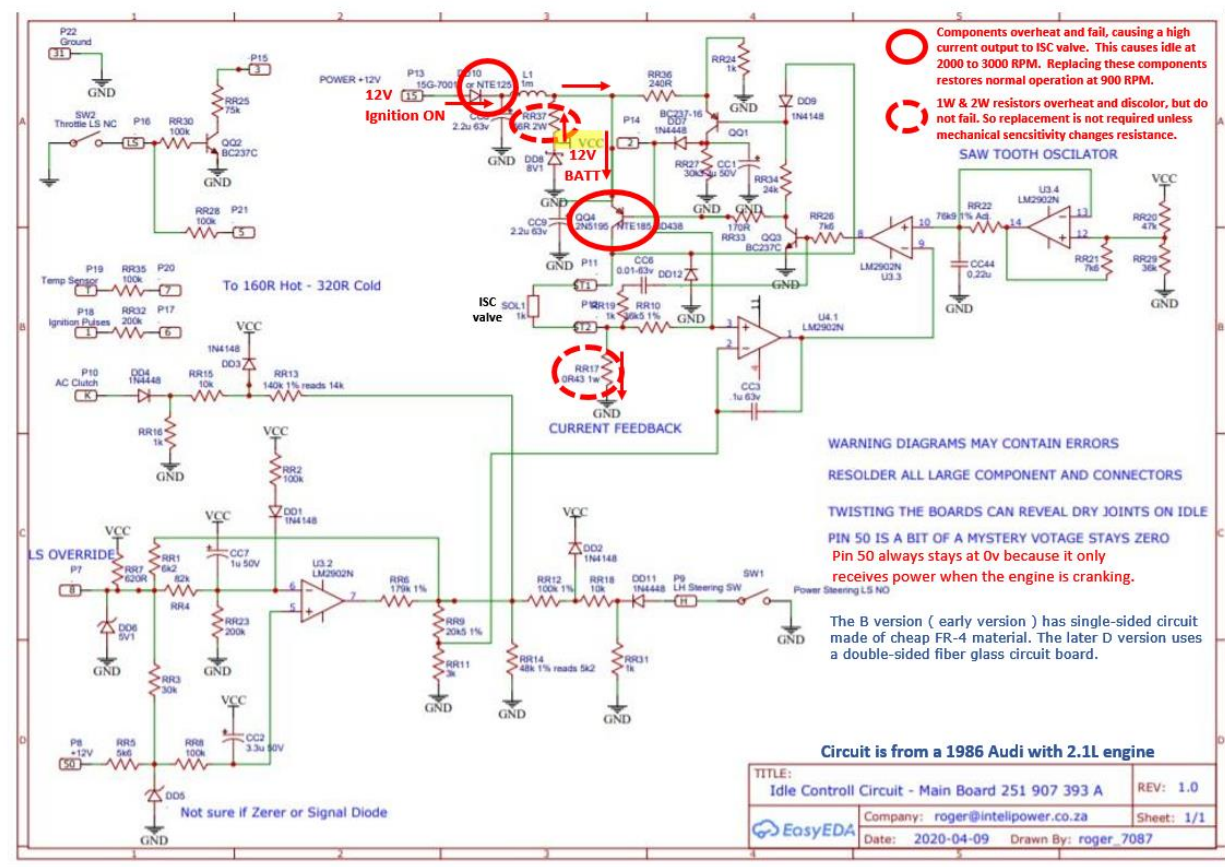


Figure A-8. Circuit diagram for the idle stabilizer control electronics of a 1986 Audi 2.7L engine on the PWB containing the I/O pins.^[4]

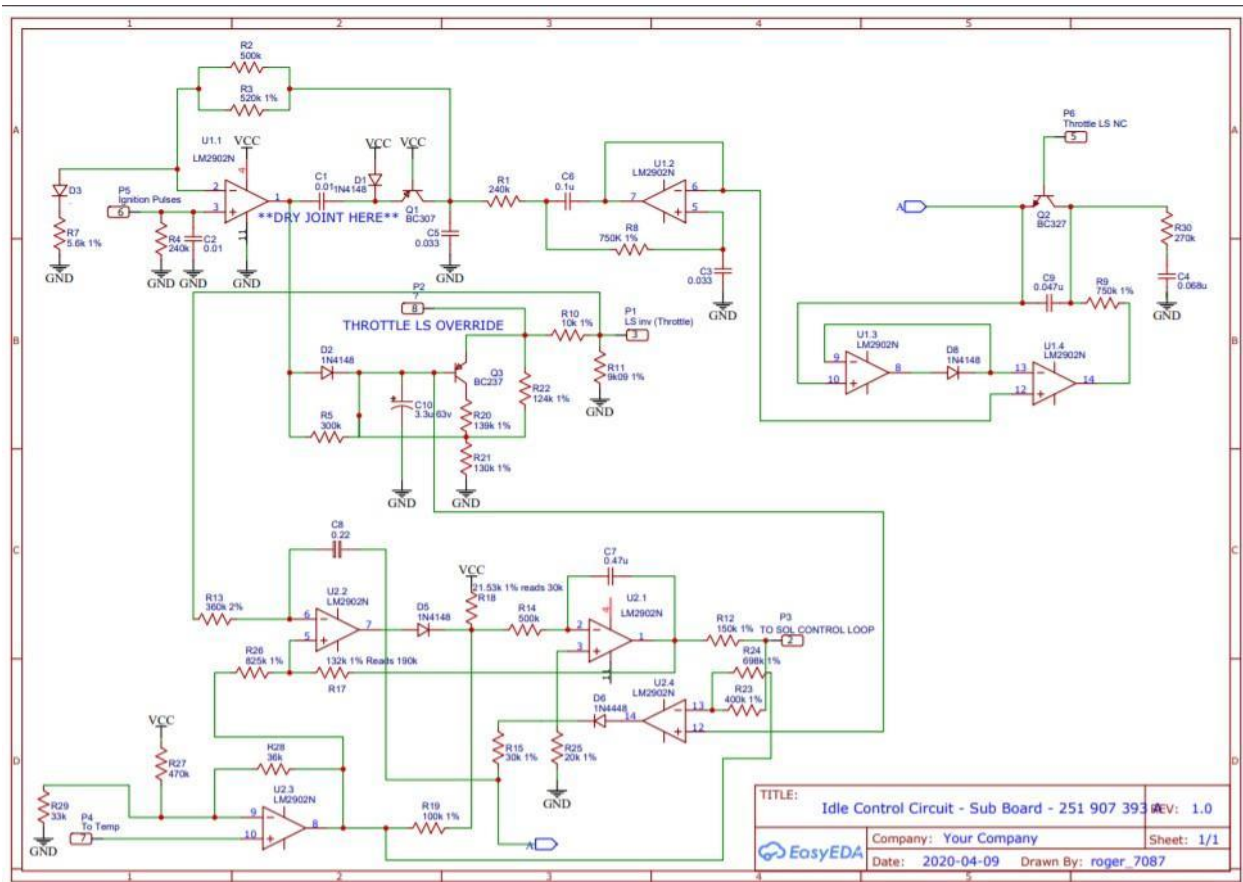


Figure A-8. Circuit diagram for the idle stabilizer control electronics of a 1986 Audi 2.7L engine on the PWB without the I/O pins. [5]

It is still not known whether the higher current during faulty operation was caused by an instantaneously higher supply voltage, by the electronics operating at a temperature higher than the component rating, or by some other phenomenon, like a faulty ISC valve. One can see that no heat sink is used for the PNP drive transistor while the 1 watt and 2 watt resistors get discolored by overheating of the conformal coating used on the board. And the cheap PWB material used does not provide a low thermal resistance to spread the heat out across the board. Finally, the folding of the electronics onto itself while being inserted into the smallest possible housing does not allow proper air flow for adequate cooling. This suggests that poor thermal control has caused the transistor and diode to exceed their rated temperature.

Page 3-13 of the Pollard and Sussman report provides some further insights into why these two components fail. It states that:

“Excessive temperatures in the ECU are the most likely cause of intermittent shorts in the output and driver transistors. TSC laboratory measurements of the case temperature of a driver transistor have shown it to be as much as 45° C above ambient. NHTSA field measurements on a hot sunny day indicate initial ambient temperatures inside the ECU box can easily exceed 50° C. Thus, these components may be commonly exposed to temperatures above 70° C, which is considered the desirable upper limit for most commercial-grade devices.”

“In a laboratory experiment, one ECU which had tested normally for 2 weeks of continuous operation was placed in an environmental chamber. It continued normally until the temperature was raised to 55° C. Thereafter, even when operating at room temperature, it intermittently exhibited either normal behavior or one of four distinct abnormal modes. One of

these abnormal states resulted in no output while another yielded about 25 percent of the normal current. The other two provided normal current but at greatly elevated pulse rates, 3.5 kHz and 7 kHz, respectively. Tapping or flexing the output transistor could cause the control to jump between fault states or back to normal. (Operation at normal current, but at a very high pulse rate of 28 kHz, was often exhibited by the ECU from the test car just prior to its intermittent jumps into the shorted, maximum-current fault mode. This observed high-frequency pulse was an indicator to a failure of high current.)”

Finally, if the ISC valve is shorted (e.g., zero ohms instead of 4 to 8 ohms) or if the internal actuator is stuck, then the PNP drive transistor will get hot trying to operate it, causing the transistor to eventually fail.^[6]

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1. dhaavers at <https://www.thesamba.com/vw/forum/viewtopic.php?t=115399&postdays=0&postorder=asc&start=20>
 2. dhaavers at <https://www.thesamba.com/vw/forum/viewtopic.php?t=115399&postdays=0&postorder=asc&start=20>
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 4. roger@intelipower.co.za at <https://www.thesamba.com/vw/forum/viewtopic.php?t=115399&postdays=0&postorder=asc&start=20>
 5. roger@intelipower.co.za at <https://www.thesamba.com/vw/forum/viewtopic.php?t=115399&postdays=0&postorder=asc&start=20>
 6. RawUmbert at <https://www.thesamba.com/vw/forum/viewtopic.php?t=115399&postdays=0&postorder=asc&start=40>