

Hybrid, Help!

This article is a true description of an AECS technical help desk problem and how it was solved.

Vehicle:

2001 NHW11 Toyota Prius Hybrid 1NZFXE.

Problem presented to the help desk

This Hybrid was presented to a workshop with all sorts of warning lights on and low on power. The Master warning light in the dashboard was on, and on the centre TV display, all sorts of warnings and messages in Japanese scrolled along the screen.

The workshop where the car was first presented to, scanned the car for fault codes. This revealed that pretty much all control units on board listed the same fault code P3101. The code description is "engine system malfunction".

In the engine control unit, it had code P3191 with the description "engine does not start".

As a result of these codes the workshop decided to replace the 12V battery (??!).

I do not see how they came to this conclusion as the engine gets started as a result of the residual torque balance between Motor Generator (MG) 1&2. Both these MG's are running on the 300V battery. The only relationship the 12V battery has to the engine system is that it is powering up the ECU and the actuators of the engine.

The codes were cleared and the customer sent on its way. No need to say that the problem reoccurred and that the car went back to the same garage again.

After several weeks of diagnostic time, the customer was advised in writing that it could be the engine ECU, the injectors, the fuel pump, the filter or the pressure regulator. The customer was asked which of these items he first would like to have replaced....

I find this incomprehensible. There is no better

Seasons Greetings

Dear AECS Customer,

A tumultuous year ends for us all in the industry.

We all need a bit of family time to recover and refocus on what we are good at.

"It is what we are good at, that we need to reinforce and nurture to get ahead in life."

AECS wishes you all a Merry Christmas and Happy New Year.

AECS Ltd



way to show your customer that you do not know what you are doing! This will chase work away to for example dealers or specialists.

Car removed

It was no surprise that the car was removed from the workshop without any payment for the vast amount of diagnostic time spent.

Will that customer ever come back with any of his other vehicles? Will they tell their friends?

Hybrid Help

The workshop where the car was transported to on a trailer (as these cars can NOT be towed!) had attended one of the AECS diagnostic Hybrid courses and owned a LaunchX431 and an ATS 5004d scope. This place was ultimately equipped to handle this problem effectively.

Very few workshops in NZ are comfortable with the Hybrid high voltage technology yet, so it is fair



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to say that this workshop is certainly part of the avant-garde.

The lack of knowledge out there creates some unbelievable situations like cars towed (!) to the wreckers because the 12V battery is flat, or another one: brake fluid not changed every 24 months because it is not broken yet.....

AECS training

The AECS Hybrid training seminars deal with all aspects of the hybrid vehicles commonly on the road in NZ; how does it work, how to stay safe, how to diagnose and how to maintain these vehicles. Believe me!, the first time you get one of these in the shop you will see that even the simplest jobs 'feels funny', even driving the car feels strange.

Dreaming

The shop where the car ended up, realised and experienced this at an early stage, and got in to the technology. Their stance was "if we believe that the hybrids are going away, just like what we thought a number of years ago about EFI, we are dreaming".

Almost all car brands produce hybrids cars now.

Where do the expert starts

So where do we start?

The shop used the scan tool and confirmed the fault codes reported by the previous garage. To them it was likely (based on the codes) that the

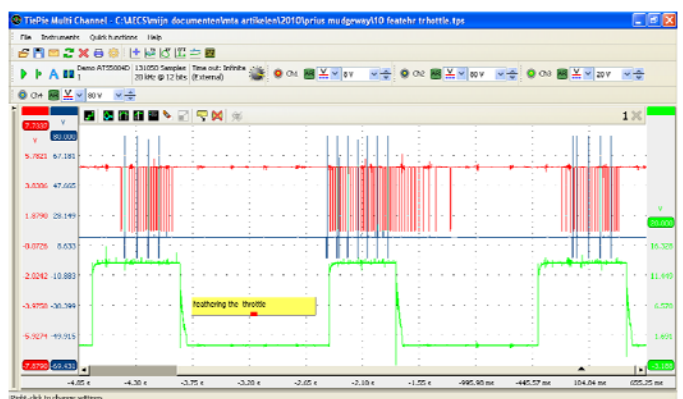
intermittent fault was in the petrol engine system. In addition, the customer reported that when the warning lights came on the engine sound was gone while the car kept (slowly) driving.

Hook up

The ATS 4 channel recording differential scope (ATS 5004d) was connected to the major out puts of the engine ECU, an injector, the IGF (ignition feedback) to check the operation of all coils and the fuel pump power supply.

Sounds simple, but a lot of thought went into this. He needed to determine if the ECU 'wanted' the engine to stop, or if the ECU 'tried to keep the engine going'. There is a major difference in diagnostic approach with both cases.

It needs to be said that the problem was very intermittent, in the first days of driving everything worked fine. While waiting for the fault to appear, measurements of patterns were taken to establish what the normal patterns look like.



ATS 5004 recoding of Injection, IGF and fuel pump supply at around 25 km/h while feathering the throttle.

For remote inspection of inaccessible areas.



VO scope

Video Inspection Endoscope

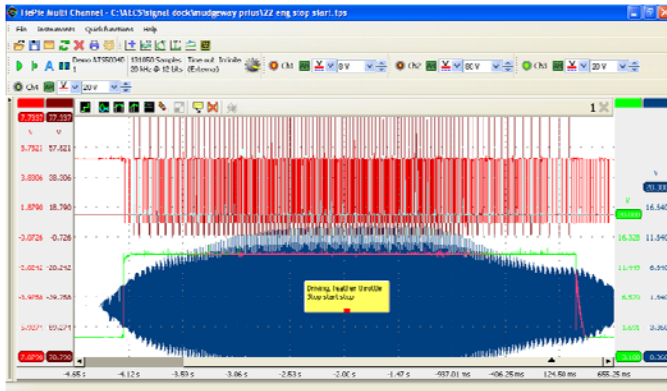
Made in the USA

- Colour screen (320x240)
- LED light
- 6mm shaft
- RCA out for image&video capture
- Carry case

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This recording revealed that every time when the engine is supposed to stall, the injection stops, and a little while later the ignition and fuel pump cut out.

During the next few days, it was decided that it would be a good idea to also have the crankshaft sensor signal recorded, just in case.

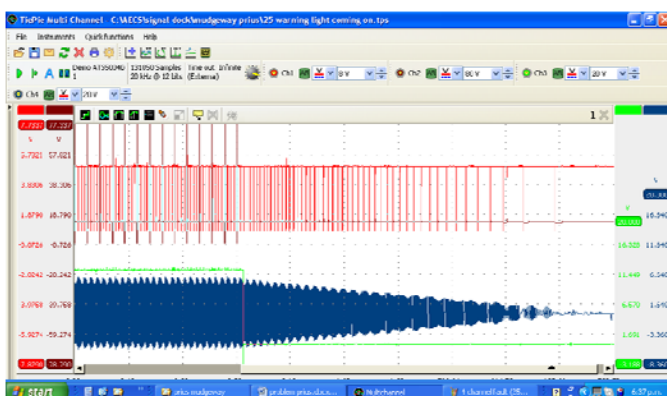


Everything looked still perfect, even zooming in to the minutest detail revealed nothing out of the ordinary.

The days went by without the problem presenting itself. The car was used by the technician to drive to work and back. Until the fault occurred!

Bingo!

The ATS scope recording was stopped and saved for review in the workshop. The fault code was reset after which the car drove normally again.



ATS scope recording when the engine stalled un-intentionally

This pattern had to reveal what went wrong as we did not get many chances.

It could clearly be seen that the engine slowly wound down after the fuel pump stopped. Was the engine slowing down as a result of the pump being switched off, or did the engine wind down with as result that the fuel pump got switched off? Realise that the MG's can easily hold the petrol engine at a constant speed of say 1000 rpm.

All the diagnostic tools you need in your workshop.....

58 car brands



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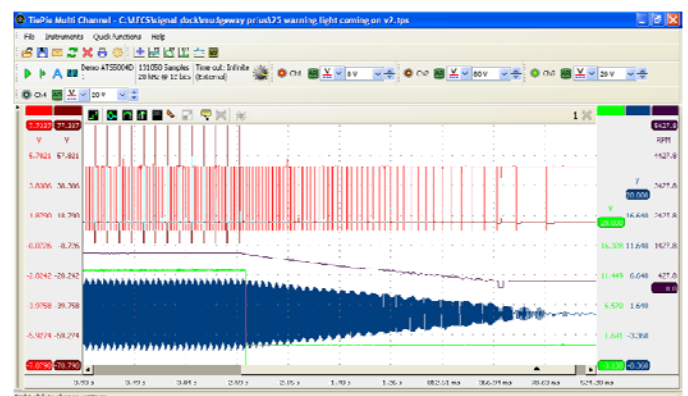


ATIS5004 4 Channel Scope

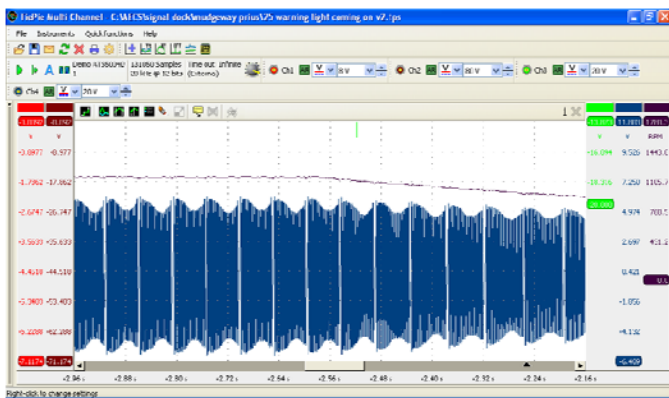


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Time to utilise some of the countless capabilities of the ATS scope's software. We decided to add an analogue RPM signal in the scope screen. The added trace is purely a calculation on the crankshaft signal and shows very accurately the engine speed variations in each position of the crankshaft.

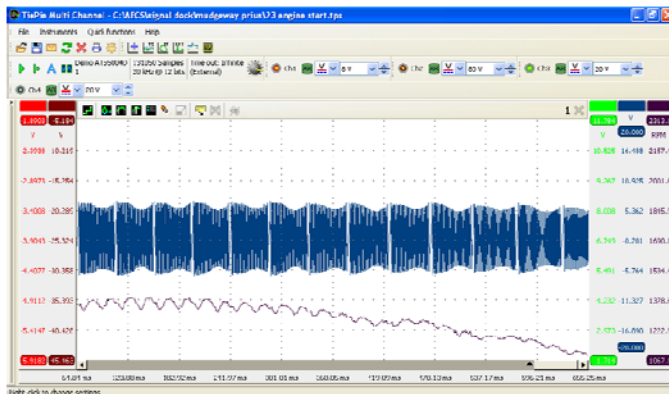


Best is to zoom in and focus on the moment where the fuel pump got switched off.



The picture is zoomed in on the crankshaft sensor signal and RPM calculation when the fuel pump is being switched off.

There is something strange about this picture as the RPM is not fluctuating as a result of compression and ignition. I suspected that the RPM should increase and decrease 2 x in one revolution. Better look at a pattern where the engine is running and add the RPM calculation to that pattern.



Zoomed in pattern where the engine gets stopped as a result of 'no more power requested'.

The recording is zoomed in on a section where the engine is just about being shut down as a result of 'no power' request (regenerative braking). It is clear to see that in each crankshaft revolution the engine speeds up twice and slows down twice (bulges in RPM signal), except towards the lower RPM when the engine produces no more power.

Dead before it died

In the faulty pattern it now becomes clear that the engine had already stopped producing power before the fuel pump relay was switched off. The moment the warning lights came on the fuel pump got switched off and the MG's stopped driving the engine to preserve battery energy. Subsequently the vehicle ran only on Battery power (EV mode) which slowed it down considerably.

Ignition/injection

It should also be noted that the injection was pre-

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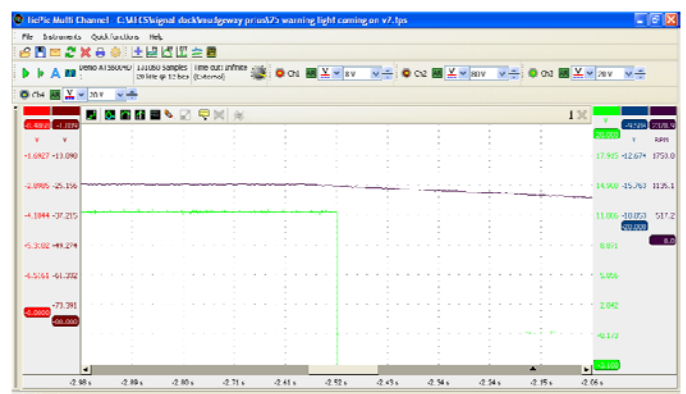
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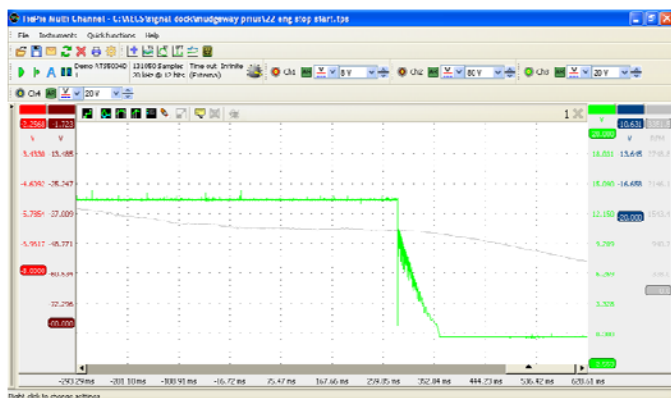
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sent until the fuel pump got switched off and that the ignition feedback shows that the ignition system worked to the ECU's satisfaction.



Calculated RPM signal vs fuel pump voltage when the pump is switched off after the warning light comes on.

Let's compare this to a pattern where the engine runs good.



Clear difference!

In the pattern where the fault occurs is the voltage of the pump (green line) switched off directly and square, in the good pattern is the signal slowly coming down as a result of the pump's spinning armature acting as a generator.

Pump not rotating

This was clear now, we nailed it! The pump was not spinning when the fault occurred.

Opening up the pump revealed that the armature had an intermittent short with the pump shaft, we tested this by feeding a high voltage with a megger into the armature of the pump testing its insulation



Pump armature being tested on the bench, the windings' insulation broke down at 32V.

Repair

A new pump was fitted which fixed the fault.

I agree totally that this repair required a little more than average scope skills, but what do you think, will things really become easier out there? We were dealing with an almost ten year old vehicle, of which there are plenty on the road. How likely is it that you will get one on your yard, perhaps with a faulty fuel pump?

Get skilled up with **AECS!**

Conclusion:

I can only say: Get decent equipment and skill up!

The equipment used for the diagnosis and repair: ATS 5004d scope, a Launch X431 GX3 and a Mega ohm resistance measuring device (megger).

Invest in your skills and in the best equipment available (AECS) with great back up from AECS! It is the combination of these key elements, which made this, job a success.

Herbert

For **AECS Ltd:**
H.P. Leijen
(trainer/research)

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DMS1-3

Diesel Management Systems 1 – 3

(Denso common rail system is covered in great detail)

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