

ProECU Subaru Diesel



Tuning Guide 2008-onward Model Year

v1.4

Contents

Diesel Tuning Info	3
General Diesel Tuning Information	3
Diesel AFR targets.....	3
EGR (Exhaust Gas Recirculation)	3
Subaru Diesel Map Descriptions	4
Fuel Rail Pressure (MPa).....	4
Desired Torque and Maximum Allowed Torque Limit	4
Max Injection Quantity	5
Injector Opening Time.....	6
Smoke Limit	6
Torque Reduction maps.....	7
Boost Control	7
EGR Control	7
MAF Sensor scaling.....	7
Limiters for Injection Quantity and Fuel pressure.....	7
Additional Maps.....	7
Diesel Tuning Info	8
General Diesel Tuning Information	8
Airflow	8
Diesel AFR targets.....	8
Tuning Tips.....	10
Quick Safe Tune	10
Which maps to change and by how much	10
Data Logging with DeltaDash	11
Which ROM File to choose	11
Auto Gearbox Gear change issues	11
CTRL+ ALT+F and CTRL +ALT+ M for big maps.....	11
ECU Learning	12
GENERAL DIESEL INFORMATION	13
System Block Diagram	14
Common Rail.....	15
Supply Pump	16
Construction description	16
Pump Learning.....	17
Fuel Temperature Sensor.....	17
Suction Control Valve.....	18
Control System.....	22
Fuel Injection Control	23
Fuel Injection Amount Control.....	24
Learning Pre-Injection Amount	24
Fuel Injection Timing Control	25
Fuel Pressure Control	26
Exhaust Gas Recirculation (EGR) System	26
System Configuration Diagram	26
EGR Valve Position Sensor.....	27
EGR Valve (DC Motor)	27
Glossary.....	28

Diesel Tuning Info

General Diesel Tuning Information

Diesel AFR targets

Turbo Diesel Engines running without a Throttle Butterfly restricting the air intake from the turbocharger will run a minimum of 100KPA (1 Bar) Absolute even at Idle. It is rare to see vacuum in the Inlet Manifold unless in certain conditions where the throttle butterfly is closed by the ECU to create a manifold depression for either EGR control or maybe Brake Servo assistance.

As soon as Engine RPM increases and Turbo speed increases the AFR can be anything up to Lambda 2.0 or even higher. Expect to see a Lambda of around 1.6 to 1.9 on normal part throttle driving and down to a Lambda of 1.3 on full load conditions.

Anything below Lambda 1.1 and you will start to see the dreaded Black Smoke.

On models without Electronic Boost Control it is possible to increase the boost manually by shortening the Wastegate actuator rod or by using a bleed off between the Compressor feed pipe and the Wastegate actuator.

Increasing the boost by 0.2 to 0.3 Bar is normally sufficient to raise the Lambda value and reduce the Black Smoke. Don't forget to increase the Boost Limit proportionally with the higher boost pressure.

EGT should ideally be measured pre-turbo as with petrol cars, as diesel cars can suffer from high EGT if too much fuel is added. Take care and make modest increases if you are not measuring EGT. DeltaDash provides many EGT and DPF related parameters that should be logged.

EGR (Exhaust Gas Recirculation)

EGR is used to reduce NOx emissions at light load conditions. Basically EGR allow spent exhaust gas back into the Intake to 'dilute' the incoming fresh charge of oxygen. This reduces cylinder pressure which reduces cylinder combustion temperatures which in turn means lower NOx output, but this polluted Intake charge mixed with spent exhaust gas will reduce power output and therefore increase fuel consumption.

From ProECU Live Data feature you will see EGR working at Idle and Light Load conditions. Reducing the EGR reduction amount should improve power and more importantly improve fuel consumption.

For a given RPM and throttle angle or torque output there is a target Mass Airflow value in Milligrams of Air from the AFM.

The ECU will then use the EGR valve to try and reach its target EGR Dilution level whilst trying to maintain the Target Intake Airflow in Milligram by monitoring the AFM reading.

Subaru Diesel Map Descriptions

Fuel Rail Pressure (MPa)

New Common Rail Diesel Engines use very high fuel pressure. Maximum Rail Pressure used is 180 MPa. There is a Mechanical Pressure relief valve on fuel rail used for safety, which is usually around 200MPa and will bleed fuel back to the tank should Fuel Pressure Increase above this. So do not demand over 200MPa or the Fuel Pump will be working very hard only for the fuel to be wasted back to the tank. Try to avoid increasing Fuel Pressure over the stock 180MPa. It is possible to achieve very good power and torque increases throughout the RPM range without having to change the Fuel Pressure maps.

Should you Increase the Target Fuel Pressure values below 180MPa, ensure these changes are applied to ALL Fuel Pressure Target tables.

A higher Fuel Pressure is a good and proven way of increasing power/torque output across the RPM range and Fuel Atomisation should (in theory) also be improved.

Desired Torque and Maximum Allowed Torque Limit

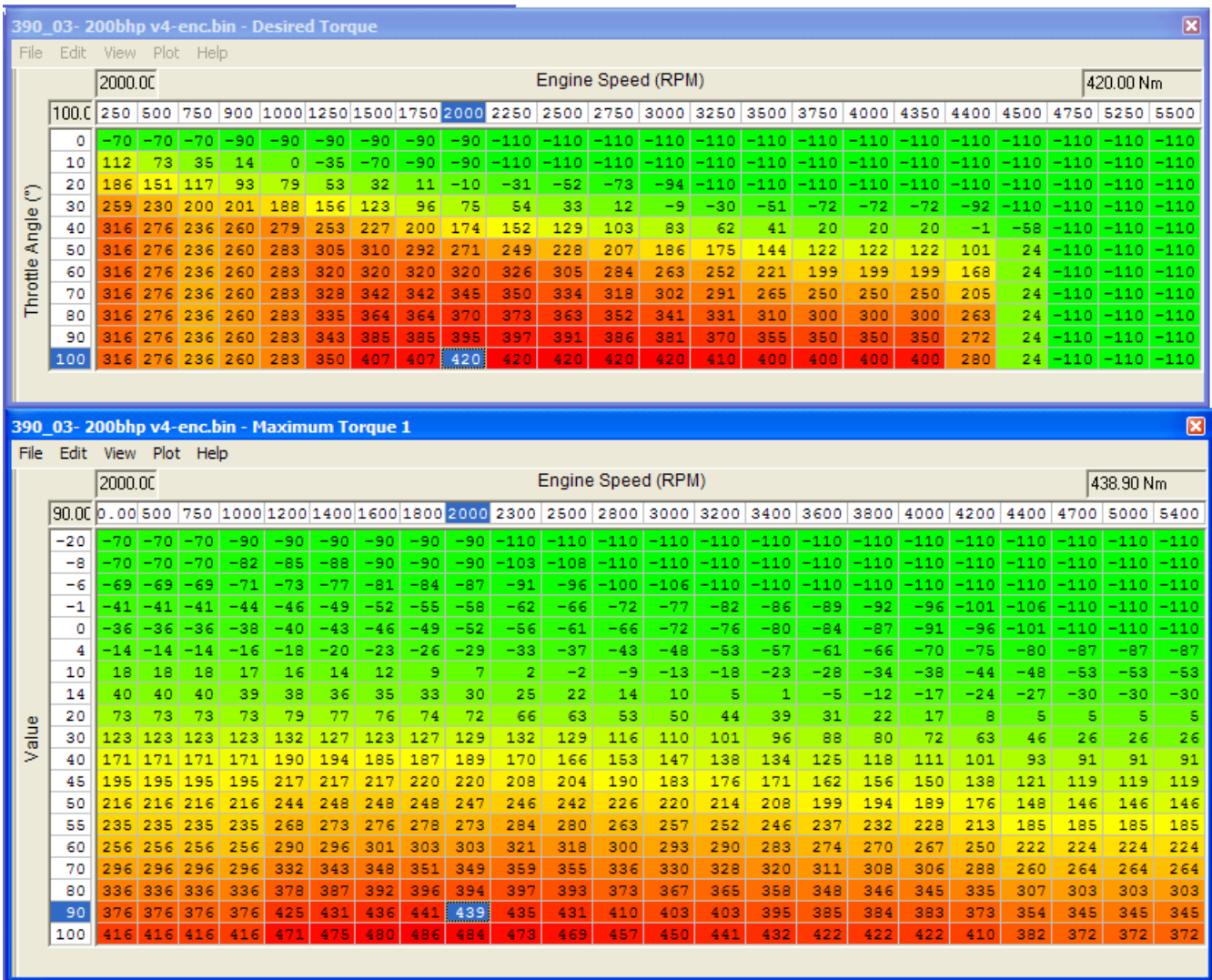
Desired Torque table can be used to increased torque output on part throttle.

If you Increase the torque value in the Desired Torque table then you may not actually achieve that higher Desired Torque Value due to the MAXIMUM TORQUE limit maps.

There are several MAXIMUM TORQUE maps, the ECU does swap between them for different vehicle speeds and conditions, so be sure to alter all MAXIMUM TORQUE maps by the same amount.

NOTE: Just because you desire 420NM does not necessarily mean the Maximum Torque Y-axis Input will be 100% of the Desired 420NM , many other factors like vehicle speed, Coolant Temp , Air Temp , Atmospheric Pressure and any learning or Torque Reduction tables may reduce the Desired Torque value proportionally.

In our experience the ECU normally uses around 90 to 95% of the Desired Torque assuming the engine is up to temperature and Air temperature is not too high.



Desired Torque vs. Maximum Allowed Torque

Max Injection Quantity

The output torque value from the MAXIMUM TORQUE limit maps is used in the Desired Torque value on the Y-axis of the MAX INJECTION QUANTITY map.

Be sure that you rescale the Y-axis to match nearer to your Desired Torque value.

Example: You can DESIRE 420NM but if the Y-axis on MAX INJECTION QUANTITY map is only scaled to 360NM then you will not have any more fuel quantity injected between 360NM and 420NM. By extending the Desired Torque values on the MAX INJECTION QUANTITY map's Y-axis we will now inject more Fuel Quantity between 360NM and 400NM (in the example shown below).

NOTE: We suggest that you simply increase the Max Injection Quantity map by percentage.

Very good, easy and simple results can be achieved by adding 20% to actual Injection amount from 1200rpm to 5000rpm over 20NM of Torque Input. This simple modification will produce a good increase without altering any Torque maps at all.

L200-Thai 4wd 165ps 390_03-Tuned Example-enc.bin - Desired Torque

		Engine Speed (RPM)																						
		250	500	750	900	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4350	4400	4500	4750	5250	5500
Throttle Angle (°)	0	-70	-70	-70	-90	-90	-90	-90	-90	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110
	10	112	73	35	14	0	-35	-70	-90	-90	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110
	20	186	151	117	93	79	53	32	11	-10	-31	-52	-73	-94	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110
	30	259	230	200	201	188	156	123	96	75	54	33	12	-9	-30	-51	-72	-72	-72	-92	-110	-110	-110	-110
	40	316	276	236	260	279	253	227	200	174	152	129	103	83	62	41	20	20	20	-1	-58	-110	-110	-110
	50	316	276	236	260	283	305	310	292	271	249	228	207	186	175	144	122	122	122	101	24	-110	-110	-110
	60	316	276	236	260	283	320	320	320	320	326	305	284	263	252	221	199	199	199	168	24	-110	-110	-110
	70	316	276	236	260	283	328	342	342	345	350	334	318	302	291	265	250	250	250	205	24	-110	-110	-110
	80	316	276	236	260	283	335	364	364	370	373	363	352	341	331	310	300	300	300	263	24	-110	-110	-110
	90	316	276	236	260	283	343	385	385	395	397	391	386	381	370	355	350	350	350	272	24	-110	-110	-110
	100	316	276	236	260	283	350	407	407	420	420	420	420	420	410	400	400	400	400	280	24	-110	-110	-110

Old Value = 366
New Value = 420

L200-Thai 4wd 165ps 390_03-Tuned Example-enc.bin - Max Injection Quantity 1

		Engine Speed (RPM)																				-20.00 mm ³		
		0.00	500	750	1000	1200	1400	1600	1800	2000	2300	2500.0	2800	3000	3200	3400	3600	3800	4000	4200	4400	4700	5000	5400
Desired Torque (Nm)	-110	-20	-20	-20	-20	-20	-20	-20	-20	-20.0	-20.00	-20.0	-20.0	-20	-20	-20	-20.0	-20.0	-20	-20	-20	-20	-20	-20
	-90	-20	-20	-20	-20	-20	-20	-20	-20	-5.8	-5.02	-4.2	-3.2	-2	-2	-1	-0.6	0.2	1	2	3	3	3	3
	-70	-20	-20	-20	-6	-5	-5	-4	-4	-3	-2.4	-1.62	-0.7	0.3	1	2	2	3.2	4.0	5	6	7	7	7
	-60	-4	-4	-4	-4	-3	-2	-2	-1	-0.6	0.09	1.0	2.0	3	3	4	5.0	5.8	7	8	9	9	9	9
	0	7	7	7	7	9	9	10	10	11	11.6	12.36	13.8	14.7	16	17	18	19.5	20.6	22	23	23	23	23
	10	8	8	8	9	11	11	12	12	13	13.7	14.40	15.9	16.8	18	19	20	21.8	22.9	25	26	26	26	26
	20	10	10	11	12	13	13	14	14	15	15.7	16.44	18.0	18.8	20	21	22	24.0	25.2	27	29	29	29	29
	40	14	14	15	16	17	18	18	18	19	19.9	20.53	22.2	23.0	24	25	27	28.4	30.0	32	34	34	34	34
	60	18	18	19	20	22	22	22	22	23	24.0	24.61	26.4	27.6	29	30	31	33.0	34.7	37	38	38	38	38
	80	22	22	24	24	26	27	27	27	28.0	28.68	30.6	32.0	33	34	36	37.8	39.2	41	43	43	43	43	43
	100	26	26	28	28	31	32	33	32	32	32.0	32.66	34.8	36.0	38	39	41	42.5	43.8	46	47	47	47	47
	120	30	32	32	32	36	37	38	37	37	36.0	36.69	39.0	40.7	42	44	45	46.9	48.5	50	52	52	52	52
	160	38	41	41	41	45	45	46	46	46	45.2	45.78	48.0	49.8	51	53	55	56.0	57.6	60	62	62	62	62
	200	46	51	51	51	55	55	54	54	54	54.6	55.20	57.4	59.5	61	63	64	65.5	67.4	70	73	73	73	73
	220	51	56	56	56	60	59	59	59	59	59.5	60.00	62.6	65.1	67	68	70	70.9	73.2	76	79	79	79	79
	240	56	62	62	62	65	64	63	63	64	64.8	65.00	67.9	69.9	72	74	76	77.1	79.5	82	85	85	85	85
260	61	67	67	67	71	69	68	68	69	70.2	70.68	73.6	75.1	77	79	81	83.4	86.0	87	88	88	88	88	
280	66	73	73	73	77	75	74	73	73	75.7	76.48	79.1	80.7	83	85	86	87.5	89.5	90	91	91	91	91	
320	71	78	78	78	83	81	79	79	79	81.2	82.26	84.7	86.7	89	90	91	91.7	93.0	93	94	94	94	94	
360	79	86	86	86	92	89	88	87	88	90.0	91.20	94.7	96.7	94	95	95	95.8	96.5	97	97	97	97	97	
400	86	95	95	95	101	98	97	96	97	98.0	99.20	99.8	100.0	100	100	100	100.0	100.0	100	100	100	100	100	

Desired Torque vs. Injection Quantity

Injector Opening Time

This map is a favourite map for most diesel tuners. The ECU calculates how much Fuel Quantity in mm³ is required and for a given Fuel Pressure how long to keep the Injector open (Injector Open Time in m/s) to delivery that Quantity of fuel in mm³. Simply Increasing the Opening Time in m/s by a percentage can work reasonably well. One downside (depending on your sales tactics) is any Fuel Consumption meter can become inaccurate due to the ECU not actually Injecting the Quantity of Fuel it actually calculated it injected! The fuel meter will show improved fuel consumption, though this would not actually be true.

Any DPF calculations for regeneration time periods could also be incorrect if based against actual Injection Quantity though this is unlikely to cause a problem as the pressure sensors in the exhaust should trigger a premature regen cycle anyway.

We suggest that you apply a percentage increase to the MAX INJECTION QUANTITY maps instead.

Smoke Limit

Smoke Limit table will limit the Maximum Injection Quantity amount during transient throttle conditions where the Lambda value will drop and cause Black Smoke. This happens particularly during turbo spool (Turbo Lag), so the Injection Quantity is restrained by the Smoke Limit tables against Boost Pressure or sometimes against Airflow (mg/cyl). The Smoke Limit Tables do not always limit Injection Quantity once the turbo has spooled and is on full boost pressure.

Torque Reduction maps

There are various Torque reduction maps for air temp, coolant temp and vehicle speed (or Per Gear). Reduction from high coolant temp can stop the engine overheating whilst pulling a heavy load up a long steep hill. Per Gear maps are useful to reduce engine torque output in a low gear or in 4WD LOW where Engine Torque Output is multiplied to enormous values at the wheels, which could easily break gearboxes or differentials. Per Gear Torque reduction maps can also be used as a Vehicle Max Speed Limiter.

Boost Control

Desired Boost is the target against RPM and current Injection Quantity. The Subaru Diesel is fitted with a very small variable vane turbo that runs on the limit so take care.

Initial and Max wastegate duty is used to control the wastegate actuator.

EGR Control

EGR (Exhaust Gas Recirculation) only works at low and light throttle conditions. EGR can be easily seen active in DeltaDash when driving around 30 to 100 kph at steady state. The EGR control valve basically allows spent exhaust gas back into the Intake system. This will pollute the fresh incoming charge which will reduce engine power output, peak cylinder combustion temperatures and therefore reduce the NOx amount emitted.

By reducing the amount of EGR allowed at light throttle it is possible to increase engine efficiency and therefore improve fuel consumption but this will be at the expense of NOx emissions. Take care adjusting these maps, make small adjustments and make sure you log with DeltaDash before and after so you can see what changed.

MAF Sensor scaling

This 2D map only needs adjusting if the Air Intake Tube, that contains the MAF sensor, is replaced for a larger housing. There is no need to adjust this otherwise.

Limiters for Injection Quantity and Fuel pressure

These 2D maps limits the maximum amount of Injection Quantity allowed in mm³ or maximum allowed Fuel pressure in MPa.

Additional Maps

Additional maps, with relevant help files, will be added to new versions as further testing and development is carried out.

Please use the EcuTek Update regularly to receive new software versions with the updates help files.

Diesel Tuning Info

General Diesel Tuning Information

Airflow

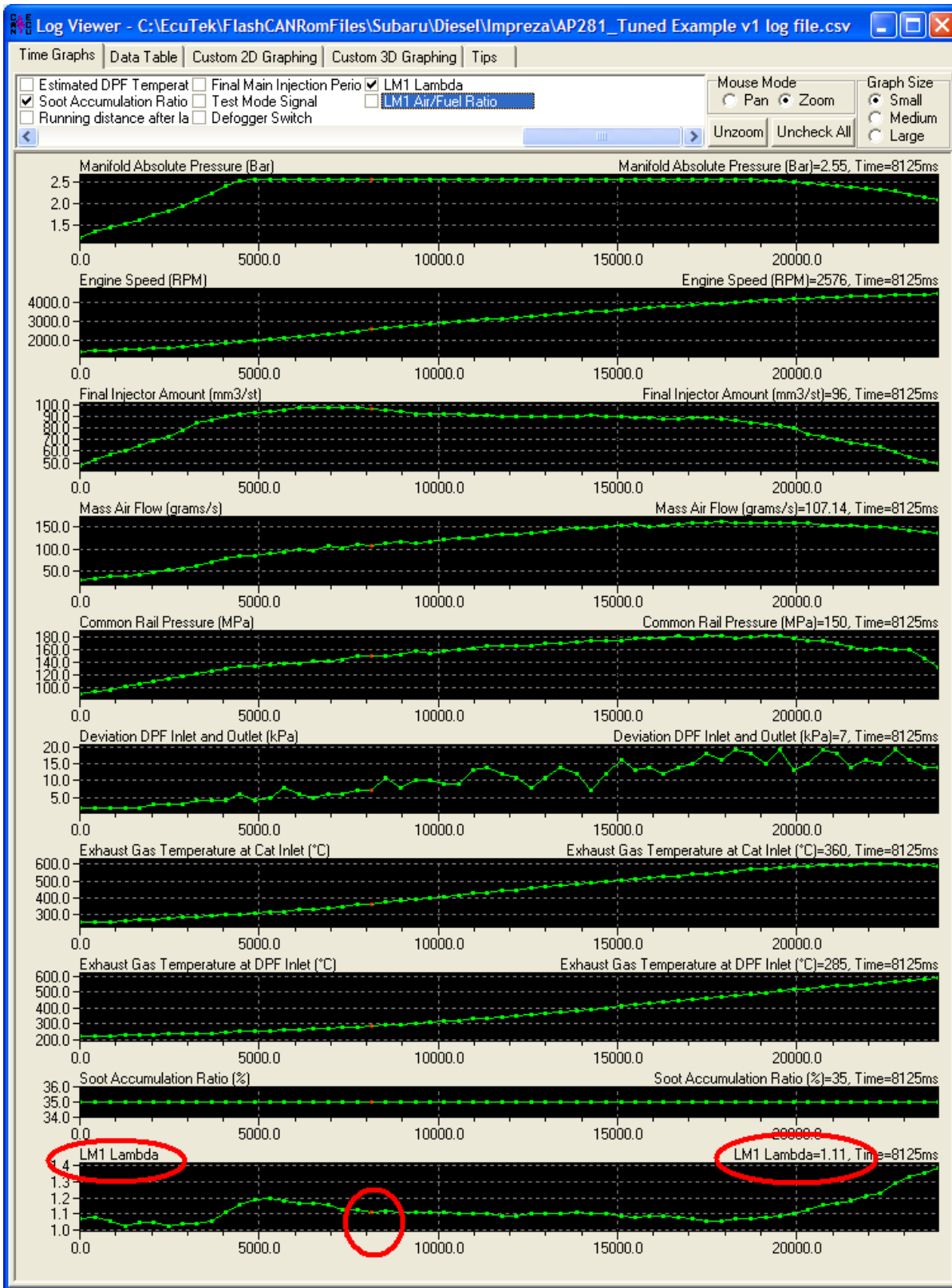
Increasing Power and Torque output with more fuel (Injection Quantity mm³) does not actually increase airflow, as seen with petrol engines where airflow can be related to power output. Diesel engines run continuously with a large excess air ratio.

Diesel AFR targets

Wideband Lambda sensors should be used for measuring Air Fuel Ratio in the exhaust pipe, similar to petrol cars.

The Lambda and AFR readings shown below were measured using the Innovate LM1 (or LC1). The Innovate sensors can be imported into ProECU in order to view and log the true AFR or Lambda readings. The logged readings can then be viewed in DeltaDash.

Exhaust Gas Analysis, in our opinion, is easier to comprehend as a Lambda value than as an AFR value. For example: 1.3 or 1.8 Lambda is easier to understand than 19:1 AFR or 26:1 AFR.



On the 4th gear road pull shown above Lambda is around 1.1 (16:1 AFR), this is the absolute minimum recommended value before visible Black smoke will appear. TAKE CARE with models fitted with DPF as Black Smoke will not be shown but the DPF will become blocked very quickly. Always log the Soot Accumulation parameter in DeltaDash to avoid a blocked DPF. We suggest Lambda 1.15 to 1.2 should be the lowest value seen. If Lambda is lower than 1 then reduce the Injection Ratio Quantity Amount.

Tuning Tips

Quick Safe Tune

We suggest that you simply increase the Max Injection Quantity maps by percentage.

Very good, easy and simple results can be achieved by adding 15% to actual Injection amount from 1200rpm to 5000rpm over 20Nm of Torque Input. This simple modification will produce a good increase without altering any other maps at all. Further improvement can be made by holding the desired peak torque and extending the desired torque value up to 4500rpm.

Watch your Lambda readings though, as the standard turbo cannot supply enough air past 3400rpm to keep the black smoke from appearing or blocking the DPF!!

Which maps to change and by how much

We suggest that you start with our example maps that can be found here :

C:\EcuTek\ProECURomFiles\Subaru\Diesel\Example ROMs

If an Example ROM is not available for your exact model, then you can Copy and Paste the maps from another similar Example ROM into your original ROM.

Typical maps to change and why:

Maximum Torque Limit: Raise values to allow a higher Engine Torque for an Injection Quantity amount

Torque Reduction - Coolant Temp: Reduce Engine Torque over 102 Deg C.

Smoke Limit for Airflow #1: Raise to allow a slightly higher Injection Quantity.

Smoke Limit for Airflow #1: Raise to allow a slightly higher Injection Quantity.

Max Injection Quantity #1: Raise Injection Quantity values for a Desired Engine Torque.

Desired Torque: Increase values to hold 400NM to maximum RPM on full throttle. Torque values can also be raised at lower throttle openings to make the engine more aggressive at part throttle.

Fuel Pressure #1 to #6: Increase values to allow more Fuel Quantity to be injected for the same opening time period.

Injection Quantity Limit #1 and #2: Increased to allow a higher Injection Quantity

Fuel pressure Limit #1 and #2: Increased to allow a higher fuel pressure

Data Logging with DeltaDash

We cannot stress how important it is to make good log files.

Using DeltaDash it possible to see exactly how the engine is performing.

DeltaDash has extensive diagnostic parameters available for live display and more important data logging. EcuTeK can support you and any questions you may have if you can provide good quality log files. Certain key parameters should always be logged, see the '[Logging and Viewing Live Data using DeltaDash](#)' section for more information.

Using the 'DeltaDash Road Dyno' feature when a 4wd chassis dyno is not available, can also prove a valuable addition to support your power increase claims.

Which ROM File to choose

When in Utility Mode you are shown what exact ROM is currently in the ECU. You are also shown a list of compatible ROM files, as shown below:

AP280_9471

AP281_0000

AP281_9473

Choose the latest revision available, they are normally sequential.

In the case shown above, the latest revision is AP281_9473.

Auto Gearbox Gear change issues

If during tuning an Auto Gearbox model you find the Engine does not change gear quick enough and sits around the maximum engine revs for too long before changing gear, then you will need to change the DESIRED TORQUE or MAXIMUM TORQUE maps at higher RPM especially.

The Engine ECU supplies a current ENGINE TORQUE figure to the gearbox ECU in Nm.

The gearbox ECU uses this current Engine Torque figure to change gear at the correct time.

If you have increased the Injection Quantity mm³ by 20% then this ENGINE TORQUE value will actually be incorrect.

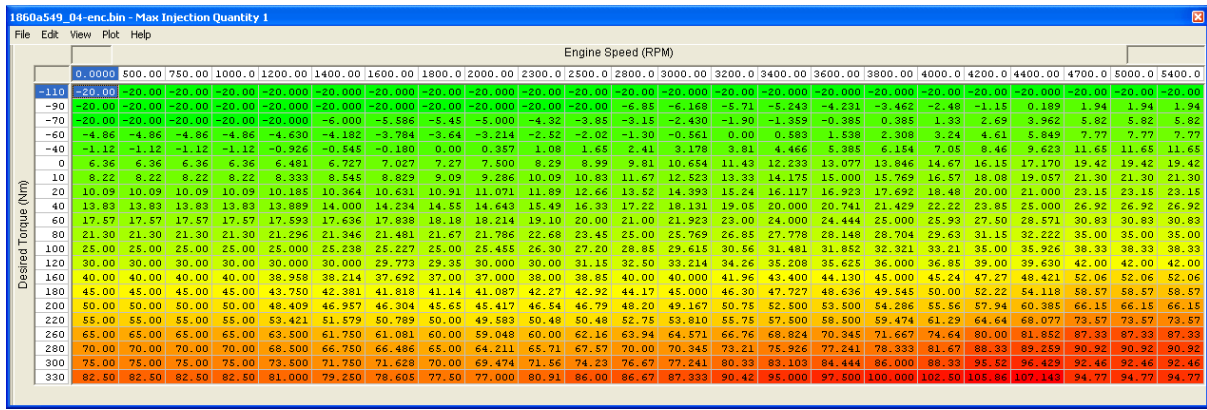
The gearbox will receive a Torque Value of say 300Nm, but actual Torque Output maybe 360Nm. This can cause the Torque Converter to excessively slip between gear changes and lock up.

If on hard acceleration the Engine RPM holds at 4000RPM for too long then try increasing the actual Desired Torque and Torque Limit Values so they are nearer the actual torque output of the Engine. The Gearbox will then see a more realistic ENGINE TORQUE OUTPUT and gearbox control will be tighter and more positive on gear change.

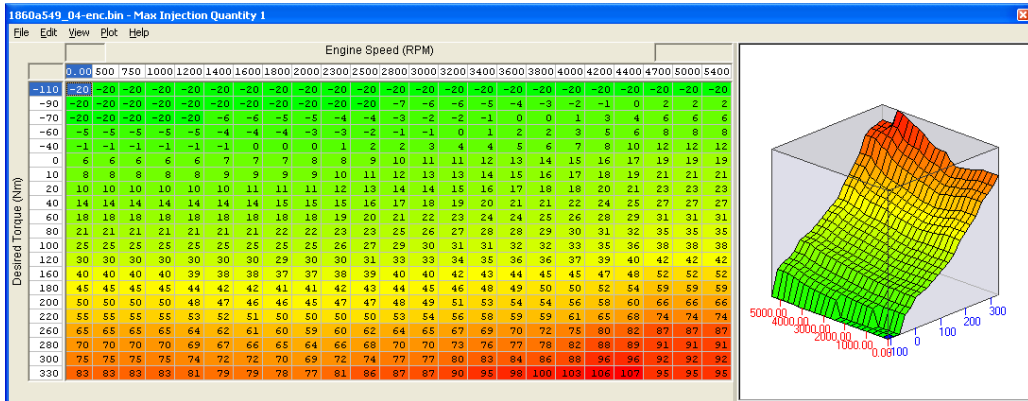
CTRL+ ALT+F and CTRL +ALT+ M for big maps

Lots of the Diesel maps are quite big, you really need a high res screen to see them.

But don't forget you can use the CTRL + ALT + F to make the values in the maps fewer (smaller) and you can make the map values bigger again by using the CTRL + ALT + M function. These shortcut keys are shown in the View menu under each map.



3D Map with More significant figures



3D Map with Fewer significant figures

ECU Learning

The DENSO High Pressure injection system can and will learn the amount of injection quantity required for each cylinder through cylinder balance testing.

This can sometimes be experienced at Idle by a varying engine sound and changing Idle speed. Each Cylinder can have a different amount of Injection Quantity at different Fuel Pressures and RPM zones. These learnt values are shown in DeltaDash as Small Injection Quantity Pressures 1 to 5.

ROM Data Protection When programming the Subaru Diesel ECU with an Example or any modified ROM the ECU data will be protected from over-programming or reflashing by any other non EcuTeK product. This includes the Subaru Select Monitor 3. The Subaru Select Monitor will function completely as normal in every other respect though. Diagnostic procedure will NOT be effected in any way and the SSM3 will not be able to tell the ECU has been reprogrammed (other than the fact that it cannot actually reflash the ECU).

If you wish to allow the SSM3 to be able to reprogram or reflash the ECU then using EcuTeK ProECU just reprogram the original ROM file back into the ECU , this will then allow the SSM3 to reflash the ECU again.

This feature also provides security from any other products ability to Read or Write to the ECU. This security feature does not prevent other EcuTeK dealers from programming the ECU though. Other EcuTeK dealers will only be able to program the ECU, they will NOT be able to READ the ECU.

If you suspect the ECU has been previously programmed with another product then you can choose the READ ROM function shown in the Utility Window. You can then Open, Edit and ROM COMPARE the ROM file currently in the customer's ECU.

GENERAL DIESEL INFORMATION

NOTE: Subaru use the DENSO Common Rail System:

The information contained below is from the Mitsubishi DENSO Common Rail system, but all principles apply to the Subaru DENSO Common Rail system as well.

The common rail engine control system is adopted for the fuel injection system. The common rail engine control system consists of sensors that detect the conditions of the engine and the actuators that operate under the control of the engine-ECU, which calculates and determines the engine control contents based on the signals provided by the sensors. The engine-ECU effects the fuel injection control, boost pressure control and exhaust gas recirculation (EGR) control. In addition, the engine-ECU contains a self-diagnosis system to facilitate the diagnosis of malfunctions in the major sensors and actuators.

The DENSO common rail system employs five injections. That is five distinct injections during each combustion stroke, each with a predetermined and metered fuel quantity.

The multiple injections are designated as the pilot, pre, main, after and post injections.

The “pilot” injection, occurring well before ignition, provides time for fuel and air to mix.

The “pre” injection, shortens the ignition delay during the main injection and, as a result, reduces the

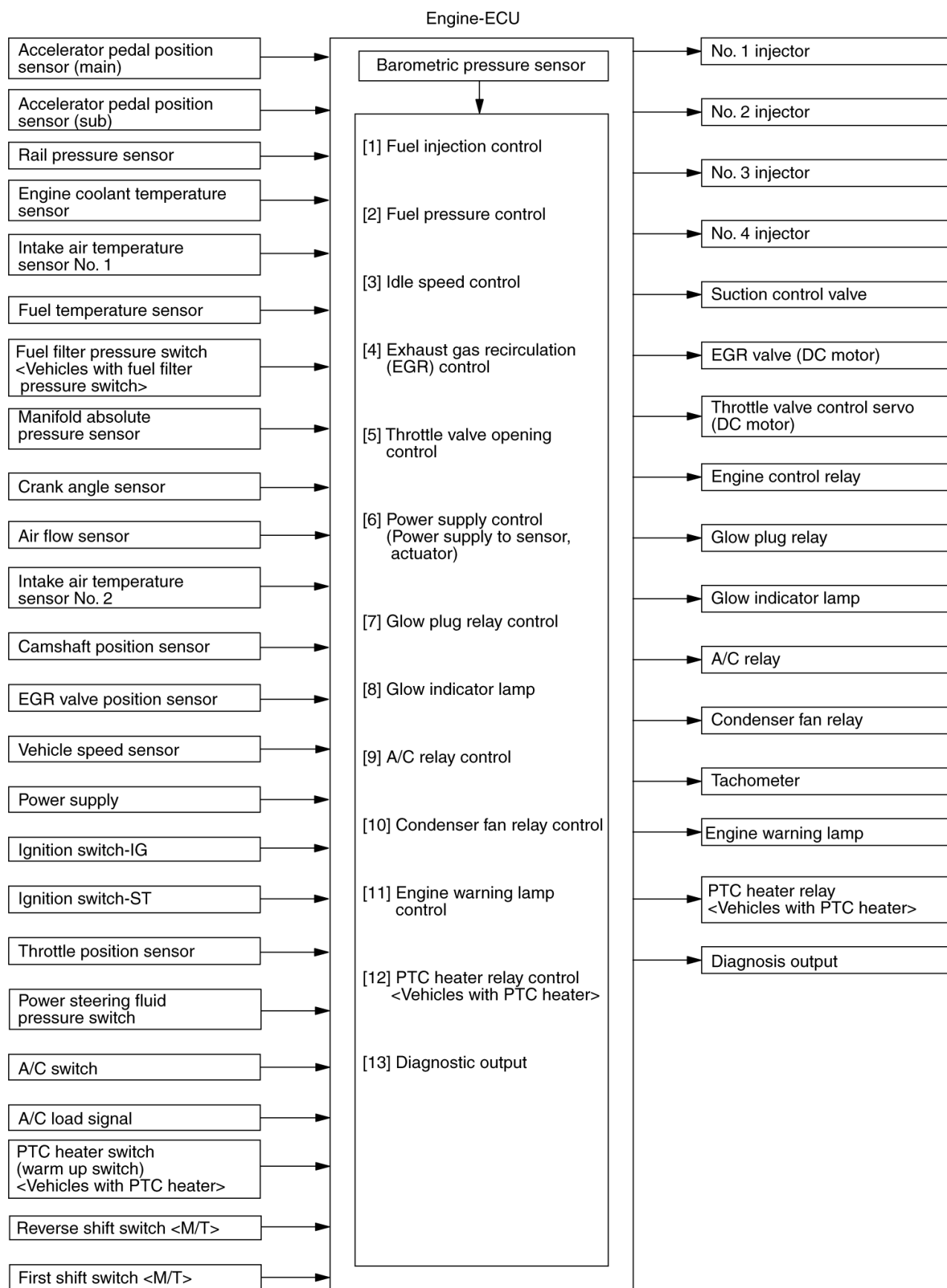
generation of nitrogen oxide, noise and engine vibration.

The “main” injection is, well, the main injection, providing the fuel for combustion and power.

The “after” injection occurs a split-second after the main injection and re-burns any remaining PM.

The “post” injection helps manage the temperature of the exhaust gases, which makes the exhaust processing in the engine’s after-treatment cycle more effective.

System Block Diagram

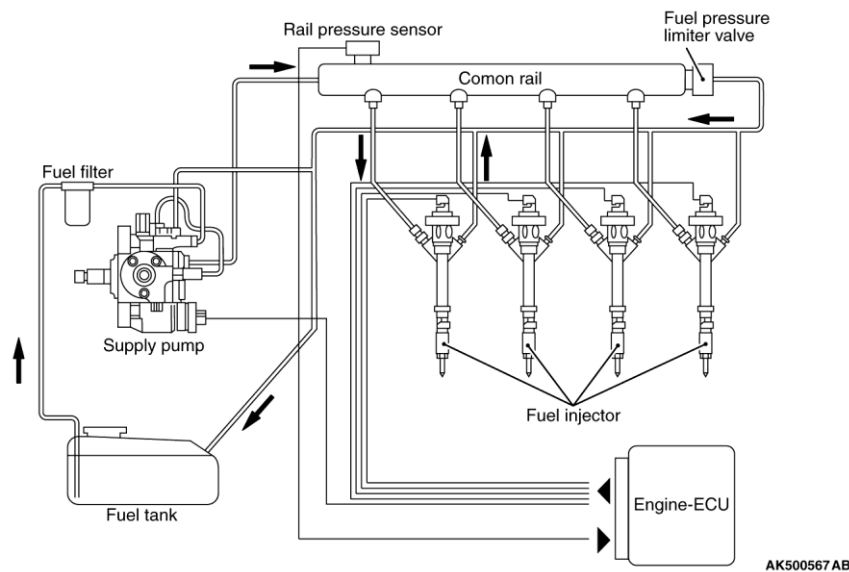


AK603942AB

Common Rail

In the common rail type fuel injection system, the pressurized fuel is supplied by the supply pump, stored in the common rail, and injected through the solenoid type injectors.

Construction Diagram



The engine-ECU transmits signals to the solenoid valves in the injectors in order to control the fuel injection timing and injection amount.

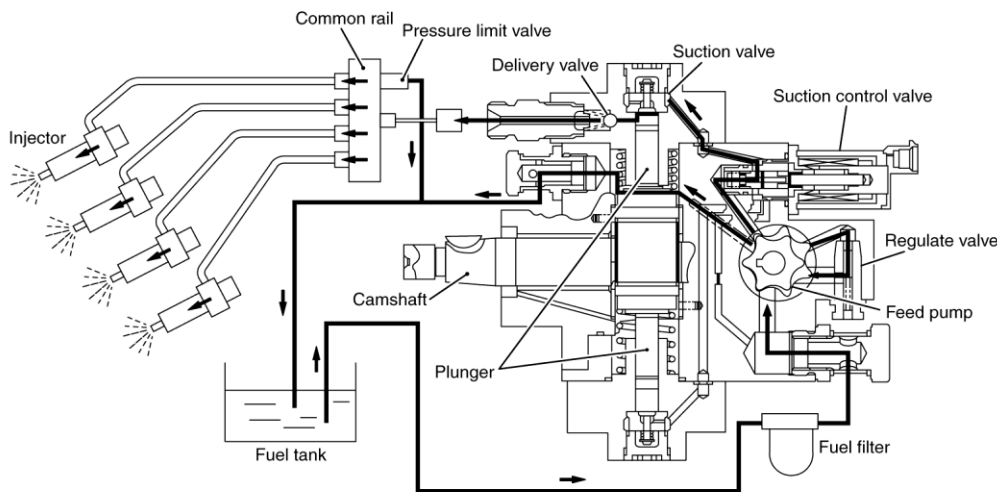
In the common rail type fuel injection system, the pressurized fuel (approximately 180 MPa max.) supplied by the supply pump is stored in the common rail. Thus, the system ensures a stable injection pressure at all times, even at low speeds, without being affected by engine speed or load. The engine-ECU monitors the internal pressure of the common rail by way of the rail pressure sensor, and actuates the suction control valve to deliver fuel, thus enabling the fuel in the common rail to attain the target pressure. Furthermore, the system uses a limiter valve in the common rail to prevent the fuel pressure in the common rail from rising excessively. The engine-ECU sends signals to the solenoid type injectors, which use solenoid valves to open and close the fuel passages. Because these solenoid type injectors can precisely control the fuel injection amount and injection timing, they can suppress the generation of black smoke, which is unique to diesel engines.

Furthermore, the system divides the injection of fuel in two stages, consisting of pilot injection followed by main injection. This allows the combustion to start gently during main injection, effectively reducing vibration and noise.

Supply Pump

The supply pump draws fuel from the fuel tank, pressurizes it (to approximately 180 MPa max.), and delivers it to the common rail.

Construction Diagram



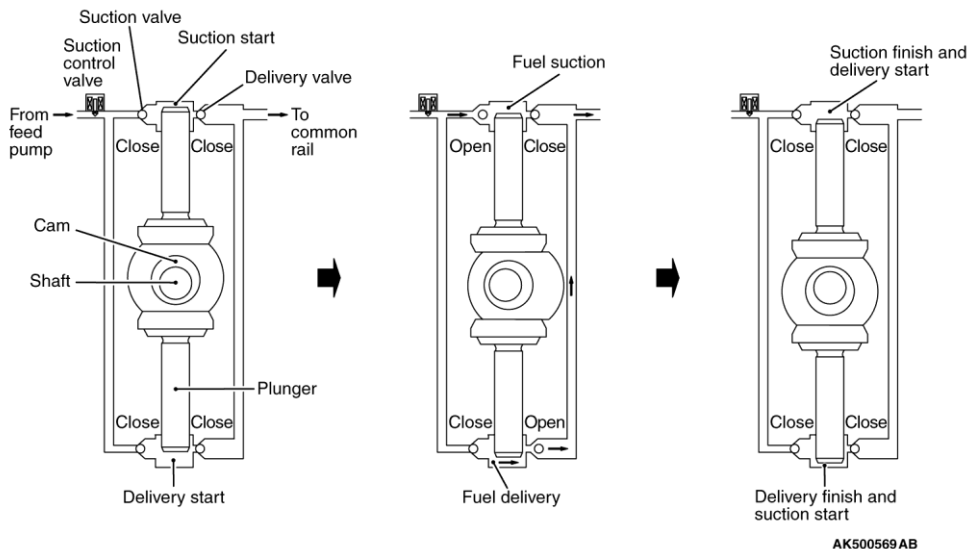
- Feed pump: Draws fuel from the fuel tank, into the supply pump.
- Regulator valve: Returns the fuel to the fuel tank when the fuel pressure between the feed pump and the suction control valve becomes higher than a predetermined value.
- Suction control valve: Regulates the amount of fuel that is delivered to the common rail.
- Plunger: Moves constantly at full stroke in order to pressurize the fuel in the high-pressure chamber.
- Delivery valve: Stops the fuel back flow from the delivery side when the fuel is suctioned into the high-pressure chamber.
- Suction valve: Prevents the fuel, which is pressurized in the high-pressure chamber, from flowing back.

Construction description

The supply pump camshaft rotation in correspondence with the crankshaft is converted into the two movements: One is the operation of the feed pump, which draws fuel from the fuel tank up into the supply pump, and another one is the reciprocal movements of two opposing plungers alternately by the cam on the shaft.

The electronically controlled suction control valve, which is located between the feed pump and the high-pressure chamber, regulates the amount of fuel that is supplied to the high-pressure chamber in accordance with the signals received from the engine-ECU.

Operation Diagram



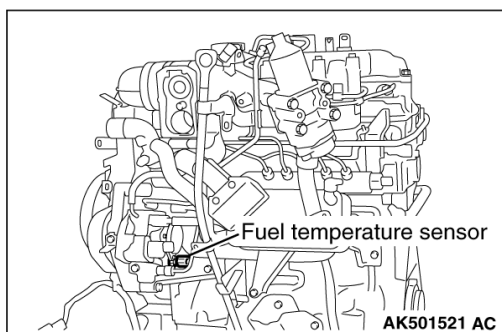
The two plungers move reciprocally to alternate the following functions: draws fuel past the suction control valve into the high-pressure chamber, and pressurizes the fuel and supplies it to the common rail. In other words, when one high-pressure chamber is performing a fuel suction stroke, the other is performing a fuel compression stroke. These movements enable the supply pump to perform two fuel pumping motions while the injectors injection fuel twice during each revolution of the engine, thus maintaining a constant fuel pressure in the common rail. Furthermore, the system enhances accuracy by using the signals, which are output by the rail pressure sensor located in the common rail, for feedback control.

Pump Learning

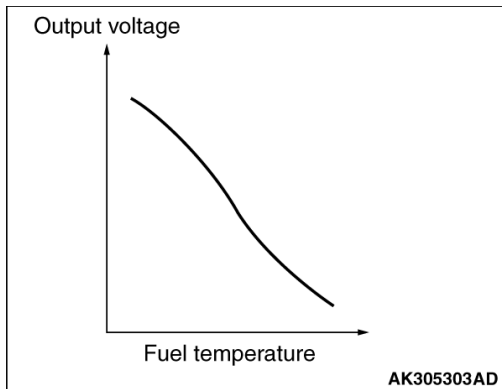
The engine-ECU checks the relationship between the amperage of the linear solenoid of the suction control valve and the pump delivery amount. Then, the engine-ECU corrects the pump delivery amount in relation to the amperage, based on the map values of the fuel pressure and amperage.

If the supply pump is replaced, it is necessary to use the M.U.T.-III tester to delete the previously learned value and acquire a new value. This learning process is performed for several seconds after the engine has been warmed up, and in a completely no-load state.

Fuel Temperature Sensor

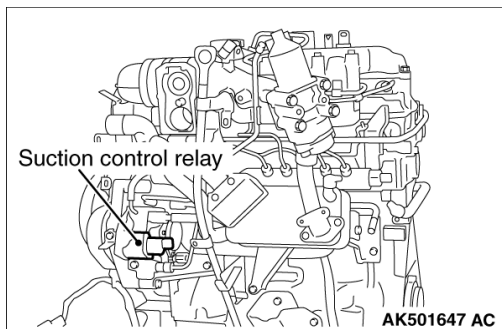


The fuel temperature sensor, which is mounted on the supply pump, detects the temperature of the fuel through the changes in the resistor of it's the thermistor.



The diagram describes the characteristics of this sensor.

Suction Control Valve

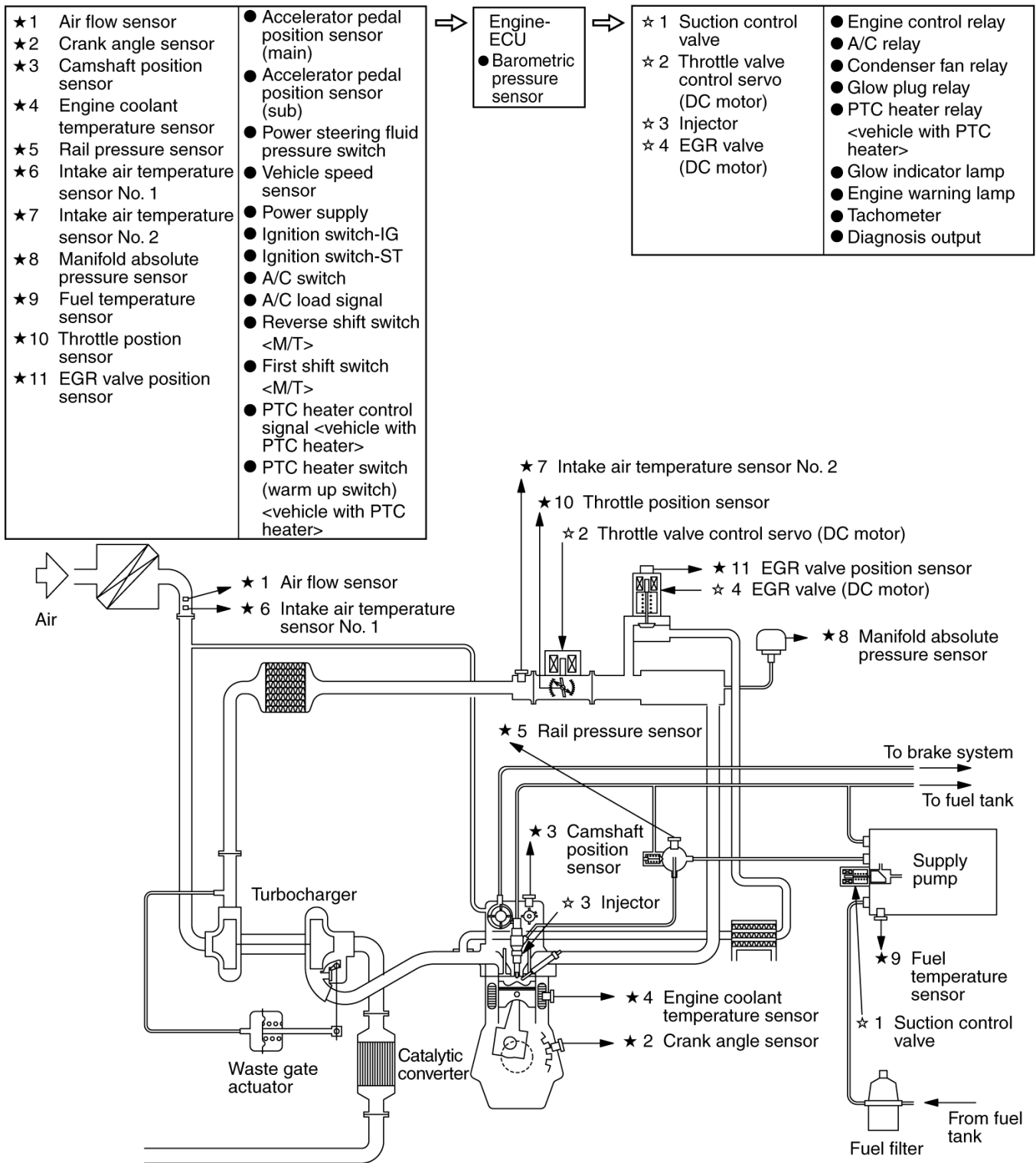


The suction control valve, which is a linear solenoid valve that operates under the duty-cycle rate, is mounted on the supply pump.

The suction control valve controls the amount of fuel that flows from the feed pump to the high-pressure chamber, based on the actuation signals that are output by the engine-ECU.

When the ON duty cycle ratio is lower, the valve opening increases. Then the amount of the fuel flowing into the common rail increases as well as the fuel pressure in the common rail.

When the ON duty cycle ratio is higher, the valve opening decreases. Then the amount of the fuel flowing into the common rail decreases as well as the fuel pressure in the common rail.



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List of Components and Functions

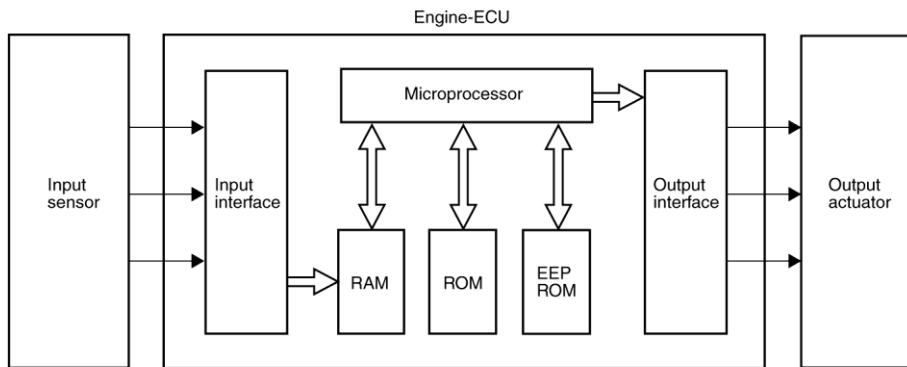
Name	Function
ECU	Engine-ECU
	Effects control to actuate the actuators in accordance with the driving conditions, based on the signals input by the sensors.
Sensors	Ignition switch-IG
	Detects the ignition switch-IG ON/OFF signals. The engine-ECU turns the engine control relay ON/OFF in accordance with these signals.
	Ignition switch-ST
	Detects that the engine is cranking. Based on this signal, the

		engine-ECU effects fuel injection amount and fuel injection timing control that are suited for starting the engine.
Accelerator pedal position sensors (main and sub)		Detects the position of the accelerator pedal and input it into the engine-ECU. Based on the voltage output by these sensors, the engine-ECU controls fuel injection amount in accordance with the accelerator pedal position.
Rail pressure sensor		Detects the fuel pressure in the common rail and input it into the engine-ECU. The engine-ECU uses the voltage that is output by this sensor to regulate the fuel pressure in the common rail.
Engine coolant temperature sensor		Contains a thermistor to detect the engine coolant temperature. The engine-ECU determines the warm-up condition of the engine based on the signals output by this sensor, and controls the pre-glow time and fuel injection amount.
Intake air temperature sensor No. 2		Contains a thermistor to detect the boost air temperature. Based on the voltage that is output by this sensor, the engine-ECU corrects the amount of the exhaust gas recirculate rate.
Fuel temperature sensor		Contains a thermistor to detect the fuel temperature. Based on the voltage that is output by this sensor, the engine-ECU corrects the fuel injection amount to suit the fuel temperature.
Crank angle sensor		Detects the engine speed and crankshaft position. Based on this signal, the engine-ECU controls the fuel injection amount and fuel injection timing.
Air flow sensor		Measures the current air mass. The engine-ECU calculates the exhaust gas recirculation rate based on this output signal.
Intake air temperature sensor No. 1		Contains a thermistor to detect the intake air temperature. Based on the voltage that is output by this sensor, the engine-ECU corrects the amount of the exhaust gas recirculation rate.
Throttle position sensor		Detects the position of the throttle valve and converts it into the output voltage. Based on the voltage output by this sensor, the engine-ECU effects feedback control for the throttle valve position.
Camshaft position sensor		Detects the No. 1 cylinder compression top dead center position by means of a magnetic resistance element.
EGR valve position sensor		Detects the position of the EGR valve and converts it into the output voltage. Based on the voltage output by this sensor, the engine-ECU effects feedback control for the EGR valve position.
Manifold absolute pressure sensor		Detects the absolute pressure in the inlet manifold. The engine-ECU uses the voltage that is output by this sensor to control the fuel injection amount.
Vehicle speed sensor		Detects the vehicle speed and converts it into the signal voltage. Based on the signal voltage output by this sensor, the engine-ECU controls the fuel injection amount.
Barometric pressure sensor		Detects the barometric pressure. The engine-ECU corrects the fuel injection amount and fuel injection timing to suit the barometric pressure.
A/C switch		Detects the ON/OFF condition of the air conditioner and inputs

		it to the engine-ECU.
	A/C load signal	Air conditioner inputs the drive state of the compressor to the engine-ECU. The engine-ECU controls to air conditioner idle-up engine speed using this signal.
	Power steering fluid pressure switch	Detects the ON/OFF condition of the power steering load and inputs it to the engine-ECU.
	First shift switch	Detects the first shift of the transmission. The engine-ECU confines the engine speed at the start by using this switch signal.
	Reverse shift switch	Detects the reverse shift of the transmission. The engine-ECU confines the engine speed by using this switch signal.
	Fuel filter pressure switch <Vehicles with fuel filter pressure switch>	A switch using contact switch for monitoring fuel pressure state between fuel filter and supply pump and for converting finding into voltage signal, which is output to engine-ECU. This allows engine-ECU to detect clogged fuel filter.
	PTC heater switch (warm up switch) <Vehicles with PTC heater>	A switch using contact switch for detecting on/off state of PTC heater switch and for converting finding into voltage signal, which is output to engine-ECU. Engine-ECU controls PTC heater, based on this signal.
Actuators	Injectors	Inject fuel in accordance with the actuation signals provided by the engine-ECU.
	Suction control valve	Adjusts the fuel flow into the common rail in accordance with the signals provided by the engine-ECU. This allows controlling the fuel pressure in the common rail.
	Engine control relay	In accordance with the signals provided by the engine-ECU, this relay controls the power supply for the engine-ECU, sensors and actuators.
	Throttle valve control servo	Controls the actuator of the throttle valve in accordance with the signals provided by the engine-ECU.
	EGR valve (stepper motor)	Controls the EGR flow rate in accordance with the signals received from the engine-ECU.
	Glow indicator lamp	Informs the driver with illuminating lamp during the preparedness in the engine start.
	Glow plug relay	Controls the actuation of the glow plugs in accordance with the signals provided by the engine-ECU.
	Condenser fan relay	Controls the actuation of the condenser fan in accordance with the signals provided by the engine-ECU.
	A/C relay	Controls the actuation of the A/C compressor in accordance with the signals provided by the engine-ECU.
	Engine warning lamp	Informs the driver with illuminating lamp when the malfunction of the engine is detected by using various sensors.
	PTC heater relay (warm up switch) <Vehicles with PTC heater>	A relay using signal from engine-ECU for turning on/off electrical supply switch for PTC heater.

Control System

Engine-ECU



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In accordance with the data input by the sensors, the engine-ECU determines (calculates) optimal control and actuates the output actuators to suit the constantly changing driving conditions.

The engine-ECU consists of a 32-bit microprocessor, random access memory (RAM), read only memory (ROM), and input-output (I/O interface).

It has adopted a rewritable flash-memory ROM in which the control data can be changed or corrected through the use of a special tool. In addition, it has adopted an electrically erasable programmable read only memory (EEP ROM) so that the learned correction data will not be deleted even if the battery is disconnected.

ECU Connector Input / Output Pin Arrangement

Engine-ECU Connector

C-105

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81

C-103

91	92	93	94	95	96	97	98	99	100	101
102	103	104	105	106	107	108	109		110	111
112	113	114	115	116	117	118	119			
120	121	122	123	124	125	126	127	128	129	130

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1	No. 1, 4 injector battery	61	Ground
2	No. 2, 3 injector battery	65	Intake air temperature sensor 2
3	No. 3 injector	70	Intake air temperature sensor 1 ground
4	No. 3 injector	71	Air flow sensor ground
5	No. 2 injector	72	EGR position sensor ground
6	No. 2 injector	73	Manifold absolute pressure sensor ground
11	Engine check lamp	74	Engine coolant temperature sensor ground
13	A/C load signal	75	Sensor ground
14	PTC heater switch (warm up switch) <vehicle with PTC heater>	76	Rail pressure sensor ground
15	A/C switch	78	Camshaft position sensor ground
17	Suction control valve (positive)	79	Crank angle sensor ground
19	EGR motor (positive)	80	Sensor source
20	EGR motor (negative)	81	Rail pressure sensor power supply
22	Ground	91	Tachometer
23	No. 1 injector	92	Ignition switch - IG
24	No. 1 injector	96	Power steering switch

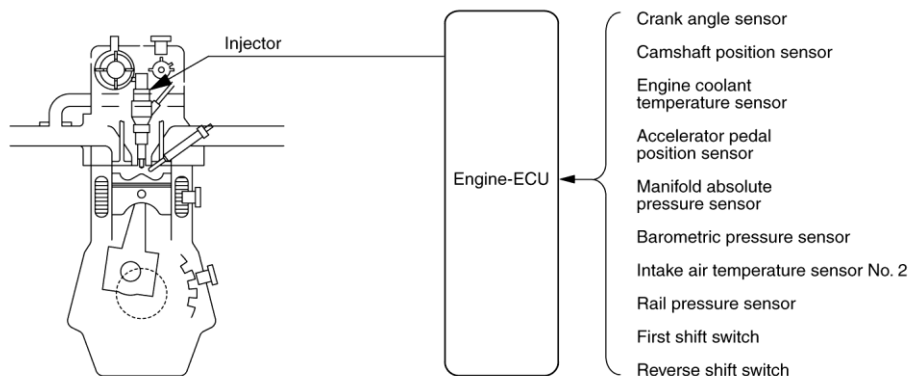
25	No. 4 injector	99	Battery
26	No. 4 injector	100	Battery
28	Glow lamp	101	Battery (backup with monitor)
29	Glow plug relay	102	Fuel filter pressure switch <vehicles with fuel filter pressure switch>
35	PTC heater control signal <vehicles with PTC heater>	103	Ignition switch - ST
37	Suction control valve (negative)	104	First shift switch
38	PTC heater relay 2 <vehicles with PTC heater>	105	Reverse shift switch
39	Condenser fan relay	109	Engine control relay
40	A/C relay	111	Throttle valve control servo (-)
41	PTC heater relay 1 <vehicles with PTC heater>	112	Accelerator pedal position sensor (sub) power supply
49	Intake air temperature sensor 1	113	Accelerator pedal position sensor (sub)
50	Air flow sensor	114	Accelerator pedal position sensor (sub) ground
51	EGR position sensor	117	CAN interface (high)
52	Manifold absolute pressure sensor	119	Vehicle speed sensor
53	Engine coolant temperature sensor	120	Accelerator pedal position sensor (main) power supply
54	Fuel temperature sensor	121	Accelerator pedal position sensor (main)
55	Rail pressure sensor backup	122	Accelerator pedal position sensor (main) ground
56	Rail pressure sensor	124	Throttle position sensor
57	Camshaft position sensor	125	CAN interface (low)
58	Crank angle sensor	128	Ground
59	Camshaft position sensor power supply	130	Throttle valve control servo (+)
60	Crank angle sensor power supply		

Fuel Injection Control

Fuel Injection Amount Control

Based on the signals provided by various sensors, the engine-ECU calculates the optimal fuel injection amount that suits the operating conditions. Then, it controls the fuel injection amount by actuating the solenoid valves of the injectors located at the cylinders.

System Configuration Diagram



AK500546AE

The engine-ECU compares the basic fuel injection amount against the maximum fuel injection amount. Then, it uses the lower injection amount to calculate the intended injection amount, which is achieved by controlling the actuation time of the solenoid valves in the injectors. The longer the actuation time of the solenoid valves, the greater will be the injection amount. Conversely, the shorter the actuation time of the solenoid valves, the lesser will be the injection amount.

Basic fuel injection amount:

Calculated based on the signals provided by the accelerator pedal position sensor and the crank angle sensor.

Maximum fuel injection amount:

Calculated by applying corrections based on various sensors to the basic fuel injection amount.

Drive Train System Protection Control

This control protects the drive train from extreme loads at the start by controlling the engine speed under the predetermined speed of 3,000 r/min.

The engine-ECU controls the fuel injection amount at the following conditions.

1. The transmission shift: first or reverse
2. The vehicle speed: 5 km/h or lower

Learning Pre-Injection Amount

The engine-ECU determines the variances in the fuel injection amount by monitoring the engine speed. Based on the changes in engine speed, the engine-ECU regulates the actual injection amount for each cylinder by correcting their fuel injection amount command values. The engine-ECU stores the correction values in its memory in the form of learning values.

The engine-ECU keeps the learning values stored in its memory until it is updated with subsequent learning values.

The system learns the injection amount with a higher injection pressure than normal.

Although the sound of the engine changes while the system is learning the injection amount, this is normal.

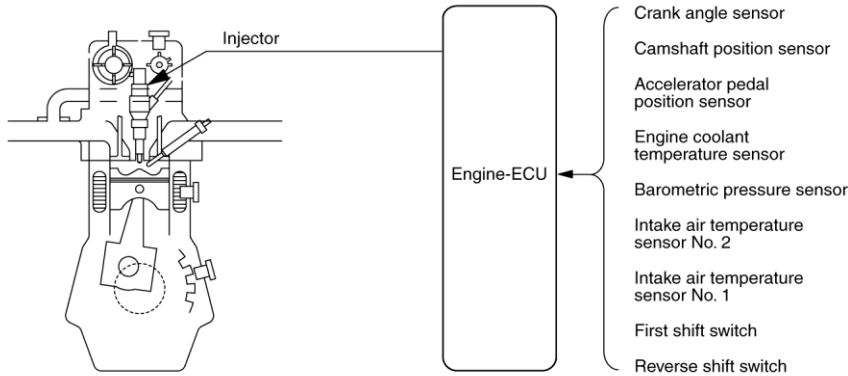
The system learns the injection amount automatically, or can be forced to learn through the use of an M.U.T.-III.

Fuel Injection Timing Control

Based on the signals provided by various sensors, the engine-ECU calculates the optimal fuel injection timing that suits the operating conditions. Then, it controls the fuel injection timing by actuating the injectors.

In addition, the engine-ECU performs pilot injection, which injects fuel preceding the main injection, for the purpose of reducing the generation of combustion sound and NOx emissions.

System Configuration Diagram



AK500546AF

Based on the signals input by various sensors, the engine-ECU calculates the fuel injection timing by applying corrections to a predetermined basic target fuel injection timing. Thus, it controls the injection timing by controlling the actuation timing of the injectors.

Basic target fuel injection timing:

Calculated based on the crank angle sensor signal and the fuel injection amount.

The system advances the actuation timing of the injectors to advance the injection timing, and retards the actuation timing of the injectors to retard the injection timing.

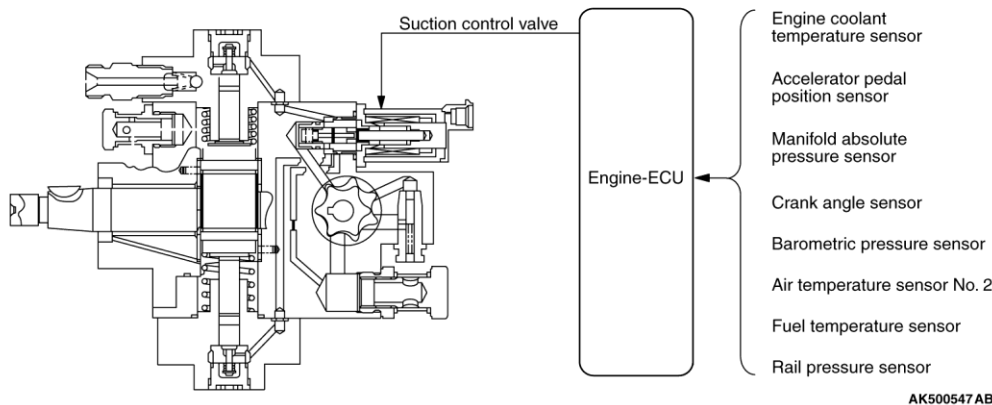
The ignition becomes retarded only during the main injection, thus increasing the amount of fuel that is injected from the start of injection until the fuel is ignited. For this reason, the combustion of the fuel occurs suddenly at a high temperature and pressure. This increases the combustion sound and the amount of NOx that is emitted.

With the combination of pilot injection and main injection, the pilot injection that injects a small amount of fuel preceding the main injection makes the combustion constant, thus reducing the combustion sound and the amount of NOx that is emitted.

Fuel Pressure Control

Based on the signals provided by various sensors, the engine-ECU calculates the optimal fuel injection pressure that suits the operating conditions. Then, it actuates the suction control valve to control the fuel injection pressure.

System Configuration Diagram



Based on the signal input by the crank angle sensor and the fuel injection amount, the engine-ECU calculates the fuel injection pressure. Then, it actuates the suction control valve to control the fuel injection pressure.

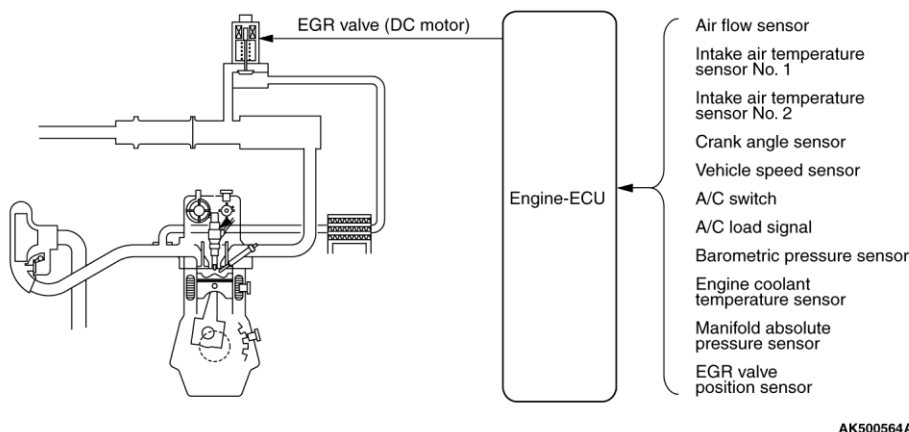
In order to appropriately control the fuel injection pressure, the engine-ECU effects feedback control of the fuel injection pressure by using the signals provided by the rail pressure sensor located on the common rail.

Because this system can maintain a high fuel injection pressure without being affected by the engine speed, it can reduce the amount of PM (particulate matter) and NOx that are emitted at low engine speeds.

Exhaust Gas Recirculation (EGR) System

Based on the signals received from various sensors, the engine-ECU actuates the EGR valve to control the exhaust gas recirculation volume, in order to reduce the amount of NOx (nitric oxide) exhaust.

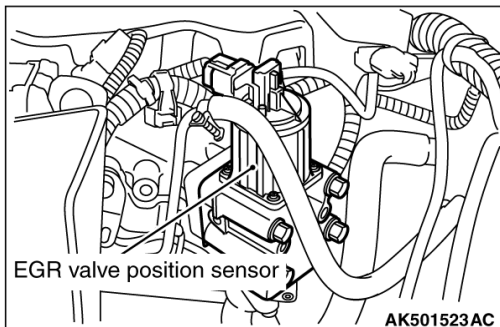
System Configuration Diagram



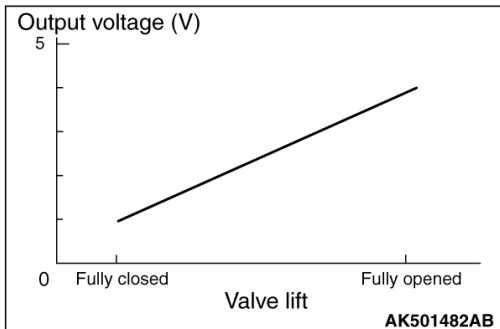
The amount of NO_x (nitric oxide) increases when the combustion gas temperature increases. To reduce the volume of NO_x exhaust, the engine-ECU actuates the EGR valve in accordance with the operating conditions of the engine. Thus, the engine-ECU regulates the oxygen concentration level in the intake air in order to attain an optimal combustion temperature. To enhance accuracy, the engine-ECU utilizes the signals output by the EGR valve position sensor in order to effect feedback control on the EGR valve.

When the EGR valve opens, the exhaust gas mixes with the intake air. This reduces the ratio of oxygen in the air that is drawn into the combustion chamber. As a result, the combustion speed decreases, which lowers the combustion temperature and reduces the amount of NO_x exhaust. Furthermore, an EGR cooler, which significantly lowers the temperature of the exhaust gas that mixes with intake air, has been provided in order to increase the recirculation efficiency of the exhaust gas.

EGR Valve Position Sensor

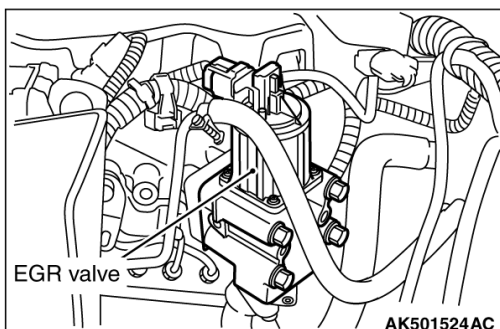


The EGR valve position sensor, which is mounted on the EGR valve, converts the position of the EGR valve into the electrical signals and inputs it into the engine-ECU. Based on the voltage that is output by this sensor, the engine-ECU effects the EGR valve feedback control.



The diagram describes the characteristics of this sensor.

EGR Valve (DC Motor)



The EGR valve is located in the middle of the bypass that recirculates the exhaust gas from the exhaust manifold into the intake manifold. It is a type of DC motor that controls the opening and closing of the valve in accordance with the changes in the direction of the electrical current.

Glossary

AFM

Air Flow Meter

AFR

Air Fuel Ratio

FMIC

Front Mounted Intercooler

ISS

Intercooler Spray System

MAF

Mass Air Flow (sensor)

MAP

Manifold Absolute Pressure (sensor)

MRP

Manifold Relative Pressure or boost pressure.

O2 Sensor

Lambda Sensor (oxygen sensor)

Calculated Air Flow

The air flow sensor voltage is not linearly related to the amount of air flow. The ECU uses a scaling map to translate the air flow sensor voltage into an air flow rate value i.e. calculated air flow.

Calculated Engine Load

The ECU calculates engine load based on calculated air flow divided by engine RPM. It is effectively how much air enters the engine on each revolution.