STAR MAZDA CHAMPIONSHIP

mazda

PRESENTED BY GOODYEAR

Renesis Engine Tutorial

2.August.2012

Pro Formula Mazda Capacities

Engine Oil

- 8 quarts with external regulator
- 10-30wt
- Changed every 2 hours of run time, 500 miles or each event weekend
- Should be 6.5 inches from bottom of the tank

Water

- 2 gallons
- Dual pass and single pass radiators are legal
- 20-25 psi cap

Engine Vitals: Limits and Suggested Warning Light Values

Oil Temperature:

Operating Range = 190F – 230F Target Temp 200F

Terminal Temp = 250F

Warning light suggestion = High: ~~250F~~ 220F,

Low: ~~150F~~ 160F

Temp is measured on the Oil In side of the system, There is a 30° temperature rise within the engine therefore a max ECU reading of 220° is approx. 250° exiting the engine

Water Temperature:

Operating Range = 180F – 220F

Terminal Temp = 240F

*Map compensation starts at 212F

Warning light suggestion = High: 220F, Low: 160F

Battery Voltage:

Operating Range = 13v-14v

ECU will not fire coils at 8v. Plugs need 11.2 to fire.

Warning light suggestion = High: 14.5v, Low: 12.5V

Engine Vitals: Limits and suggested warning light values

Oil Pressure:

Operating Range = ~~100psi -110psi at 8600rpm~~

90psi – 105psi at 8600rpm

Target is 95psi at 8600 rpm

Terminal Pressure = High: 150psi, Low: ~~60 psi~~ 70 psi

Warning light suggestion = High: 140psi, Low: ~~75 psi~~ 80 psi

Setting Oil Pressure:

Completely warmed up oil and water

Monitor Oil Pressure in ECU View Live Sensors

Raise Engine RPM to 3000, monitor Oil Pressure increase

Make adjustments to regulator, retest or allow to cool then retest as necessary.

Fuel Pressure: Operating Range = 56 +/- 2%

Warning light suggestion = ~~40 psi~~ 50 psi

Engine Vitals: Lambda

Lambda is the measure of the amount of oxygen in the exhaust stream. The value expressed is a percentage of the stoichiometric air/fuel ratio 14.7:1.

Air/fuel ratio can be calculated by multiplying the lambda value monitored by data system by 14.7

(ex: .90 Lambda translates as (.9 x 14.7 =)13.23 Air/fuel ratio

Operating Range = .87 - .91, aim for ~~.90~~ .89

Overly rich (lower lambda) numbers will reduce economy and power

Overly lean (higher lambda) numbers will elevate temperatures, reduce power and possibly cause detonation

Lambda will read lean after a shift, traction control event, pit lane speed limit and valve immediate opening.

Engine Vitals: Lambda continued

There are two methods of lambda monitoring: ECU or ADL (the ADL reads approximately .2 higher)

Lambda bung location should be toward rear of pipe, 6” from muffler junction (be sure to accommodate for possible interference with the bellhousing)

The depth of the sensor in the pipe should be so that the tip is flush with the inner wall of the tube.

Lambda sensor precision:

- Sensor life
  - Sensors tend to wear out more quickly when closer to header. These are consumable parts much like the spark plugs and are manufactured similarly
- Monitor Channel Lambda ZP
  - monitors the time the heater has been on in basic terms and reflects the temperature of the sensor
  - Low numbers means too hot, High numbers means too cold – both produce corrupt readings
  - Calibrating Lambda per memo 23.Jan.2010

Engine Vitals: Exhaust Gas Temperatures

Exhaust Gas Temperatures (EGTs) are the second most important tuning and troubleshooting channel next to Lambda.

EGTs reflect on the injector balance between the front and rear rotor

Reflects misfires through high readings accompanied by normal lambda

Decline in engine performance can be evidenced by the rate of temperature acceleration between the rotors during a long pull – gapping

Emphasis needs put on the condition of the EGTs – low reading sensors are beginning to fail. In order to have an accurate assessment of the performance, EGT sensors must be replaced often.

Generally, one EGT sensor is used per rotor. One sensor bung should be welded on the each the outer exhaust pipes 3” from the header flange (the center pipe usually does not receive a sensor). The sensor depth should be enough to where the tip of the sensor is in the centerline of the exhaust flow.

Operational Range: Front Rotor: 1450F – 1600F,
Rear Rotor: 1400F – 1550F

Procedure: Start Up

These cars hate the cold!

Always use the jumper battery. The battery will need to be able to start the car twice without the battery to pass the tech inspection

Idle @ 1500 RPM until 120F Water Temperature

Raise RPM slowly, approx to 3000, until 180F Water Temperature.

Place fan in front of left side pod to reduce Engine Temp. Hold Rpm at 3000 until 180F Oil Temperature is reached.

Check and set the oil pressure per previous slide description

Systems: Intake

Throttle Body

The throttle body should have .020” gap between the butterfly and the housing. The gap translates to 0-3% in the ECU and Dash.

Valve System

The rotary uses a 6 port intake system (3 ports per rotor)

To maximize efficiency each port is opened via independent valve systems by the M400 based on Engine RPM

The three valves are:

Sequential Shutter Valve (a.k.a. SSV)

Auxiliary Port Valve (a.k.a. APV)

Variable Dynamic Intake Valve (a.k.a. VDI)

Valve opening is most obviously seen in the data through the lambda trace: The lambda will go rich during the valves operation, lean on immediate opening

Systems: Intake Sequential Shutter Valve (SSV)

Controlled by Aux 3 where open time is described as 100%

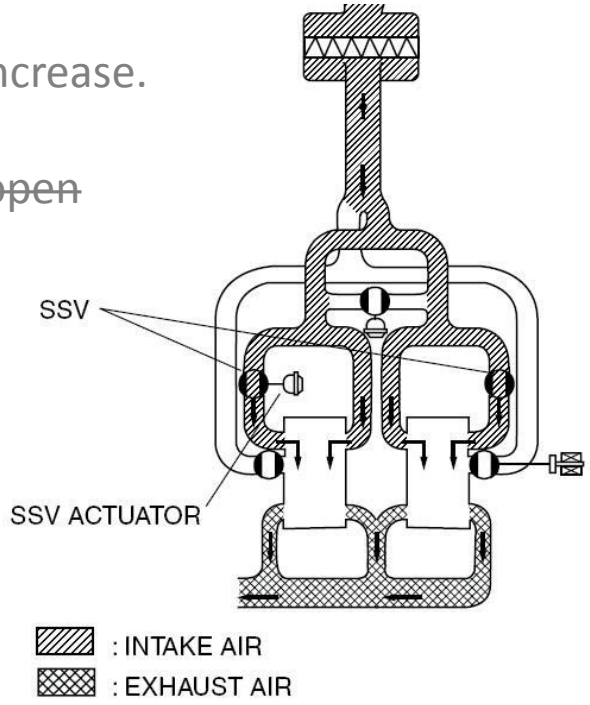
Harness label " Valve B ".

This valve is located in the middle of the engine.

Opens up the secondary (outer) ports at ~~3500~~ 3150 rpm.

Provides larger airflow path as engine speed and load increase.

~~Opens based on rpm and throttle position, but always open above 5500 rpm.~~



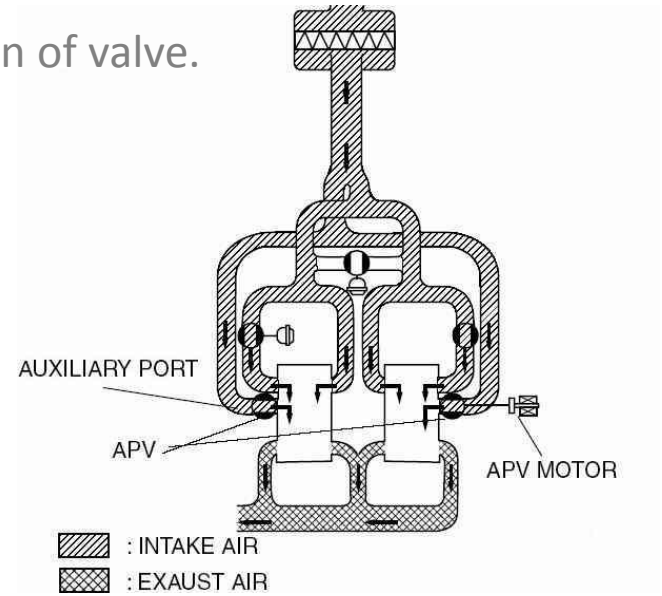
Systems: Intake Auxiliary Port Valve (APV)

Controlled by Aux 7 and Aux 8 through a motor driven rack and pinion where open time is described as 0% and closed time is described as 100%

Opens the 5th & 6th port at 6300 rpm.
Closes at 5900 rpm.

Final expansion of intake manifold flow capabilities.

A position switch is incorporated for monitoring action of valve.



Systems: Intake Variable Dynamic Intake Valve (VDI)

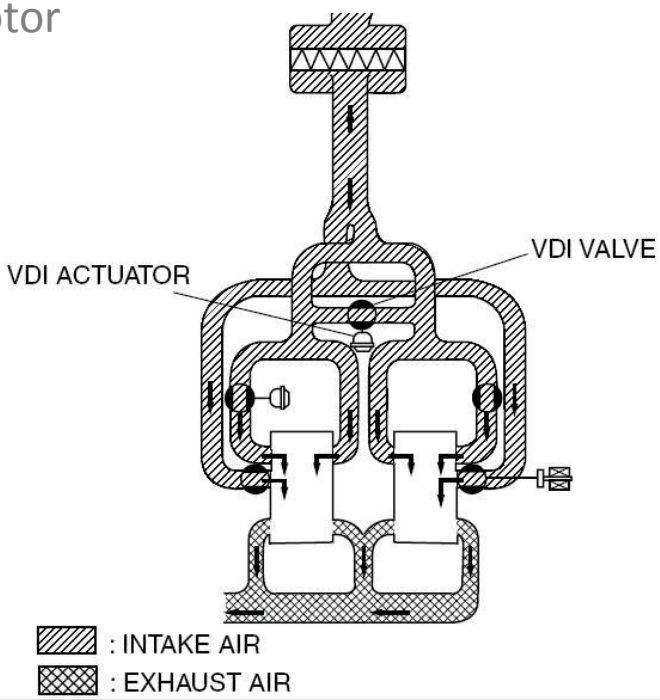
Controlled by Aux 2 where open time is defined at 100%

Harness label "Valve A".

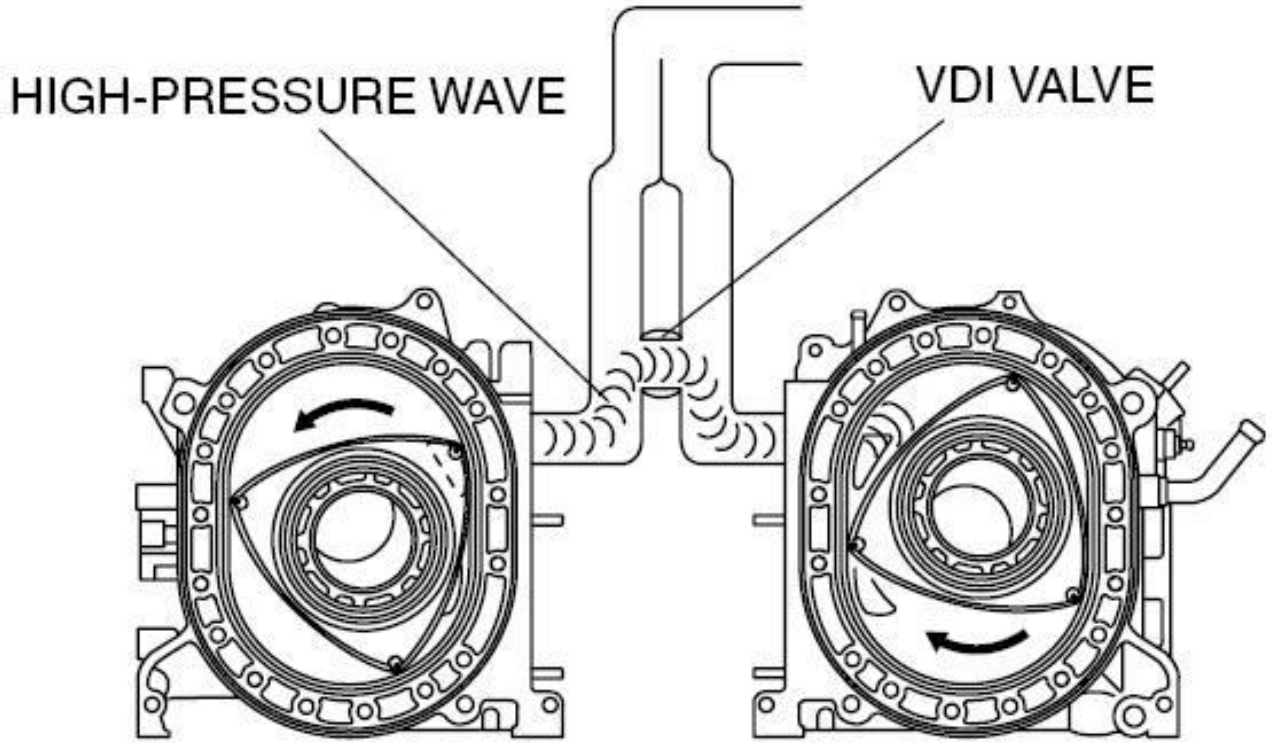
Opens the top intake valve at 7600 rpm and closes at 7500 rpm

This valve connects the two intake tracts between both rotors.

When one rotor is closed, it pushes air into the other rotor providing intake supercharging at high engine rpm.



Systems: Intake Variable Dynamic Intake Valve Diagram



Systems: Vacuum

The VDI and SSV valves are vacuum actuated via an electric solenoid and therefore requires both an electric and pneumatic signal to operate.

A black vacuum box is connected to the Upper Intake Manifold and pulls vacuum through the green and white check valve

The vacuum solenoid rack is run off the vacuum accumulated in the box

The solenoids then connect the vacuum to the diaphragms in the VDI and SSV actuators.

The actuators then turn the valves when the solenoids are electrically activated.

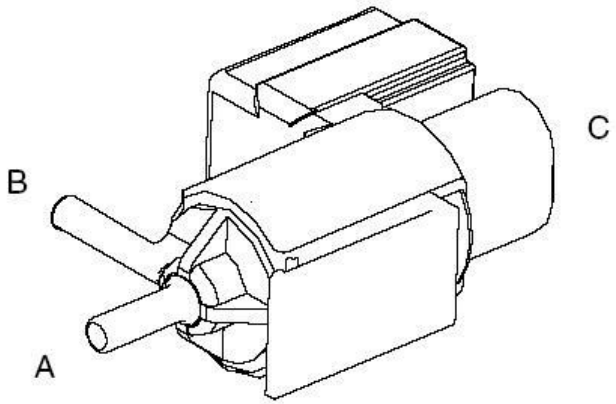
Systems: Vacuum

The solenoids that activate the valves have three ports:

A is connected to the vacuum box

B is connected to the actuator

C is vented to atmosphere



When the valve is OFF, A is closed off the actuator B is vented to atmosphere C

When the valve is ON, the solenoid connects the actuator B to the vacuum box A

System: Ignition

The ignition system is composed of four individually controlled and internally transistorized coil packs.

The ECU uses three-dimensional dwell and advance point maps to control each coil.

The coil is a stock RX-8 street legal part and the life of the coils has been significantly improved with the additions of new maps over the years.

Coils can be tested using a KV tester but the user should make a point to note the battery voltage and ambient temperature when testing – will not generate precise output measurement but will create an accurate reference.

Coil failure is usually attributed to the switching transistor and is evidenced by a blister above the primary wire connector

System: Fuel Injectors

4 injector engine uses 2 green primary injectors and 2 brown secondary injectors

When injectors fail the part will usually either leak externally (easily evidenced) or internally.

Internal leaking will be evidenced in a misfire at low RPM, low lambda numbers, low EGT numbers at idle.

Injector cleaning and flowing is recommended so sets can be more evenly matched to produce the most efficient Lambda values.

When EGTs vary more than 50 F (20C), inspect injectors and match

Systems: Engine Control Unit

ECU Characteristics:

M400 Motec ECU Maps are ‘locked’ to ensure equal programming by an encryption know only by Star Race Cars.

Program updates are delivered from Star Race Cars as encrypted files and can be uploaded by either Star Race Cars or the end user.

The M400 control all aspects of the engine through multi-dimensional maps and detailed programming that has been optimized through out the years.

Communication is delivered from the ECU via CAN (Controller Area Network) to the user’s PC or ADL Motec System Dash

ECU Includes the following features:

Environmental Adaptation
Fuel Trim
Traction Control
Pit Lane Speed Limiting
Shift without Lift

Systems: Engine Control Unit

Engine Synchronization:

M400 requires a precise understanding of the engine's rotational position at all time

The position is monitored through the **REFerence** sensor which is mounted on the front of the engine and picks up engine speed and cycle **SYCNhronization** from a 36 toothed wheel

The REF and SYNC are signals that can be seen in the Motec i2 analysis and are commonly used to diagnose engine problems.

Environmental Adaptation:

The M400 is able to make 'on-the-fly' fuel mixture changes based on the environment

The ECU will richen the mixture when the water temperature is cold to help with cold start

The ECU will adjust for air density using the air temperature sensor as a reference

Air density compensation is finalized by the barometric pressure sensor

Systems: Engine Control Unit

Fuel Trim:

Fuel pressure and fuel supply are critical to maintaining the proper air/fuel mixtures. Our map corrects for variations in fuel pressure seen through the FP sensor and the driver can make adjustments through the Trim switch

The M400 map allows the driver to make real time adjustments to add fuel to the engine through a Fuel Trim Knob.

The 2010 map controls Fuel Trim through an optional 11-position knob that increases the adjustment range from:

-2 to +8 in 1% increments

The older 4-position switch can still be used with the 2010 map but will be limited in range:

P1 = 0%, P2 =+2%, P3 = +4%, P4 = +6%

Systems: Engine Control Unit

Engine Speed Limiting:

The M400 will limit the RPM under the following conditions:

Over Rev, Traction Control, Gear Change, Pit Lane Speed Limit, Cold Start Map

The M400 simultaneously halts fuel and ignition events on a randomly selected rotor face to accomplish the power reduction.

Over Rev: 8600 RPM and above

Over revs of 8600-8800 are of little concern , this area is limited by the rev limiter.

Extensive over revs between 8800 and 9000 on downshifts over a long period can cause slow engine damage.

Any over rev past 9000 RPM will cause damage to the engine.

The ECU cuts spark above 8600 rpm, but it also cuts fuel at zero throttle input. Therefore the engine is being starved of the lubricating oil in the fuel at high rpm for long periods of time when running above 8600 rpm t zero throttle

Systems: Engine Control Unit

Driver Controlled Traction Control:

Measures difference between fastest rolling wheel and slowest driven wheel to determine the current slip amount.

Power is limited by a table based on throttle position and other factors. Traction control is controlled using an 11-position switch in the cockpit

All four wheel speed sensors are directed to the ECU for traction control

Engine speed limiting continued:

Pit lane speed limit:

Activated through a button on the Steering Wheel

The ECU cuts the ignition to slow the engine down (slowing the chassis down is up to the driver!) regardless of gear or throttle position

The maximum speed the ECU will permit the vehicle to travel in with the switch activated is 36 mph (58kph)

Systems: Engine Control Unit

Engine Speed Limiting continued:

Gear Change Ignition Cut:

‘Shift without lift’ allows for drivers to upshift without the clutch or the need to back off the throttle

Down-shifting is not controlled using the ECU but by the driver through throttle blipping

The ignition cut is activated through a switch located near the shift cable mount in the cockpit.

The ECU uses gear position and engine speed to determine the length of the cut. No cut is permitted below 3000 RPM

Drivers have been know to falsely trigger ignition cuts by keeping their hand on the lever too long or by bumping into the lever. Star Race Cars supplies a housing for the switch that mounts directly onto the shift lever.

ECU Trouble Shooting

Importance of ECU Data: Everything that is recorded in the ECU data is not always recorded in the dash regardless if you are running a Motec Dash. Many of the indicators and signals for error and engine performance are recorded it the ECU data. ECU data is where to go first for trouble shooting problems. Be sure to download your ECU data after every session!

Common Problems:

Communication analysis between ECU and PC

Active System Tests through the ECU

Diagnostic Flags and Warning

Mechanical Tests

ECU Trouble Shooting: Communication

The ECU connects to the computer through the CAN port located on the roll hoop.

The Motec ADL Dash connects through the same port, however, because the CAN port can only communicate to one system at a time, the ECU communication will always preside over the dash communication.

The status of the CAN connection is reported in the left lower corner of the screen.

-"CAN interface cable has no power"

-*Translation:* 0-8volts not present at download connector

-"Excessive number of CAN bus errors"

-*Translation:* CAN HI and LO wires are reversed or shorted in the harness

-"Communication Timeout: Device not connected"

-*Translation:* CAN Power cannot find ECU, usually occurs with the wrong edition of software

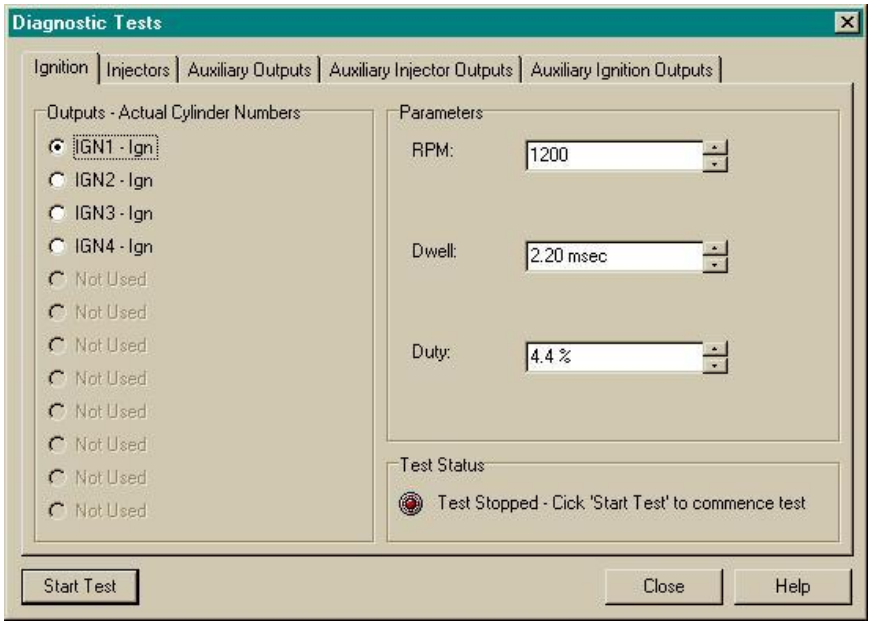
ECU Trouble Shooting: Active Systems ECU Test

The ECU can test the following sub systems:

- Ignition coils
- Fuel injector
- Intake Valves

In order to perform the tests, the engine must be off and your laptop must be connected.

Begin the test by selecting ‘Utilities – Test Outputs” in ECU Manager



ECU Trouble Shooting: Active Systems ECU Test - Coils

After you select 'Utilities – Test Outputs' select the Ignition page from the Diagnostic Test window

Either a KV tester can be used (or a device of similar nature), an inline spark light or the spark plug can be removed from the engine, remain connected to the coil and must be grounded to the engine block

Ignition must be ON for this test, unplug Fuel Pump

On the Ignition page, select the output and hit start.

IGN1 = Front Rotor Leading

IGN2 = Rear Rotor Leading

IGN3 = Front Rotor Trailing

IGN4 = Rear Rotor Trailing

You will be looking for spark to start with then compare the intensity across the coils.

Remember accuracy vs. precision!

ECU Trouble Shooting: Active Systems ECU Test - Injectors

After you select 'Utilities – Test Outputs' select the Injectors page from the Diagnostic Test window

It is advised to have the spark plugs out for this test and to turn the engine over a few time to relieve any injected fuel from the test

The injectors could also be removed from their mounting places and tested, but be prepared for a mess!

The fuel pump must remain OFF for this test – Since the ECU supplies power, unplug the pump

On the Injector page, select the output and hit start.

INJ1 = Front Rotor Primary green on 4 injector engine

INJ2 = Rear Rotor Primary

INJ3 = Front Rotor Secondary brown on 4 injector

INJ4 = Rear Rotor Secondary

ECU Trouble Shooting: Active Systems ECU Test – SSV and VDI

After you select 'Utilities – Test Outputs' select the Auxiliary Outputs page from the Diagnostic Test window

This window will be used to test the SSV (AUX 3) and the VDI valves (AUX 2)

Before beginning the test, increase the Duty Cycle to 100%

Click on the Duty Cycle box and hit Control + the Up arrow key. This will rapidly advance the number

Duty Cycle defaults to original setting after you have closed the test window – no need to reset

Select AUX 2 to test the VDI valve and hit start. (remember to hit STOP)

Select AUX 3 to test the SSV valve and hit start. (remember to hit STOP)

You will hear the valve 'clunk' open but it is also advised to watch it move as well so you can tell if anything is in its way!

Remember the valves are run on vacuum, intensity depends on the vacuum built up.

Running the valves is a good method to check for vacuum leaks as well

ECU Trouble Shooting: Active Systems ECU Test – APV

(The APV Test is not controlled by the ECU)

To test the APV Valve, with the Master Switch on open the throttle to 100%.

The motor controlling the rack and pinion will open the valve when the throttle gets to 90% and close the valve below 90%

You will be able to hear the motor turning

It is helpful to place your hand on the motor as well

The intensity of the motor sound helps determine the motor condition

This test is disabled when the engine is running.

ECU Trouble Shooting: ECU Manager Diagnostic Page

Diagnostic errors, raw voltage and sensors can be monitored using the ECU manager ‘View – View Sensors or View Diagnostics’

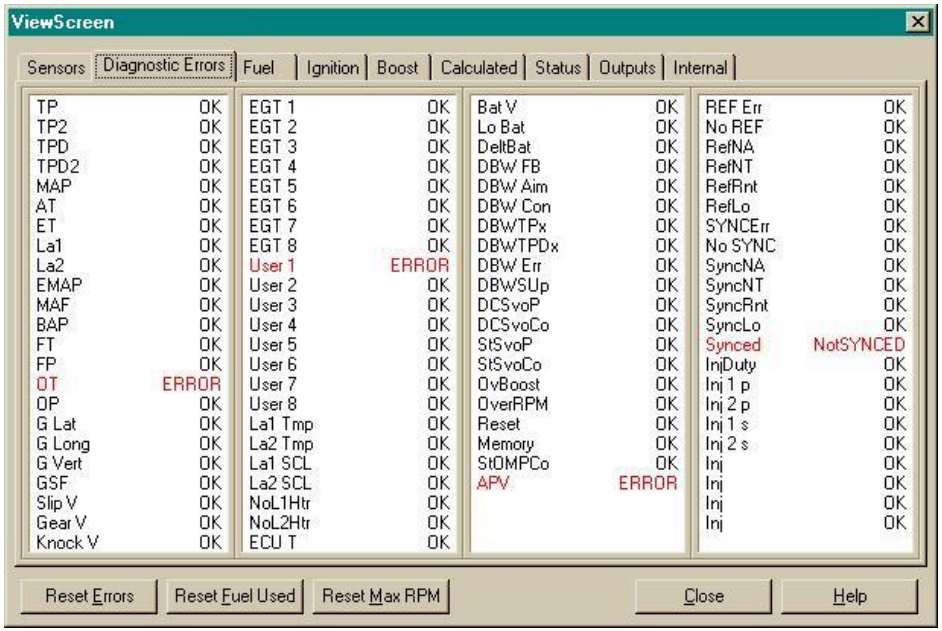
The ECU must be connected to your laptop in order to view this screen.

Diagnostic Errors are presented in RED text

The Reset Errors button will clear the errors unless there is a problem. If the error does not clear, further investigation is required EXCEPT for:

SYNC status will always be NotSYNCED with the engine is off

APV will always be ERROR and should be ignored



ECU Trouble Shooting: REF and SYNC

When the engine is running properly, the REF and SYNC errors can be cleared after cranking

When the engine is not running properly the REF and SYNC will not be cleared

If there are problems cranking the REF sensor needs to be inspected!

Recall that the REF or Crank Sensor surface is sensitive to the gap between the sensor and the toothed wheel

The gap should be between .030” and .050”

A common problem with the REF sensor is the two wires connected to the plug tend to break at the pin due to vibration – be sure to check when problems arise

Sensor Trouble Shooting: Diagnostic Error

The ‘View Diagnostic’ page uses the following abbreviations when problems arise:

TP = Throttle Position Sensor

AT = Air Temperature Sensor

ET = Engine Temperature Sensor

EMAP = Barometric Pressure

FP = Fuel Pressure Sensor

OT = Oil Temperature Sensor

OP = Oil Pressure Sensor

GSF = Gear Shift Sensor

Gear V = Gear Position Sensor

USER 1 = Fuel Trim Knob

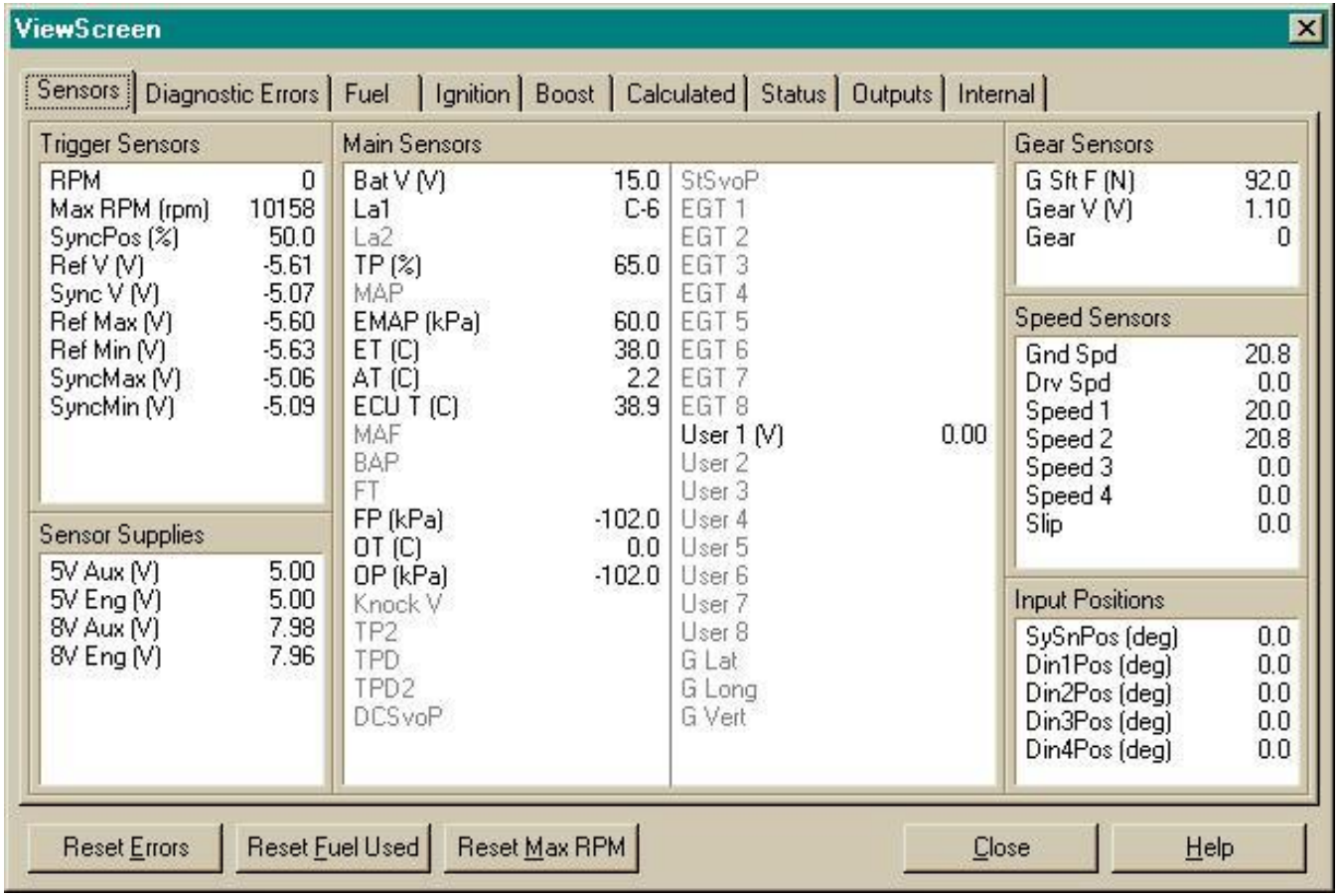
DeltBat = Rapid Power Loss

BAT Lo = Battery Voltage Too Low

Sensor Trouble Shooting: Sensor Error

Sensors that will report error on the View Sensors page are:

- Wheel Speeds
- Gear Position
- Actual Gear Volts
- Sensor Supplies



Sensor Trouble Shooting: Wheel Speed Testing

Wheel Speeds, expressed in KPH, can be viewed on the right hand side of the 'View Sensors' page

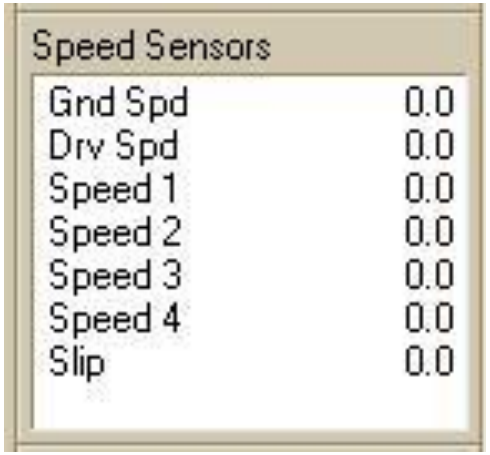
Roll the wheels in question and monitor that area:

Speed 1 = Front Left (rolling)

Speed 2 = Front Right (rolling)

Speed 3 = Rear Left (driven)

Speed 4 = Rear Right (driven)



The Wheel Speeds are powered by the 8V Aux Supply which can be monitored on the left hand side of 'View Sensors'. The supply needs to be at or around 8 volts to power the sensors.

Sensor Trouble Shooting: ECU Sensor Supply

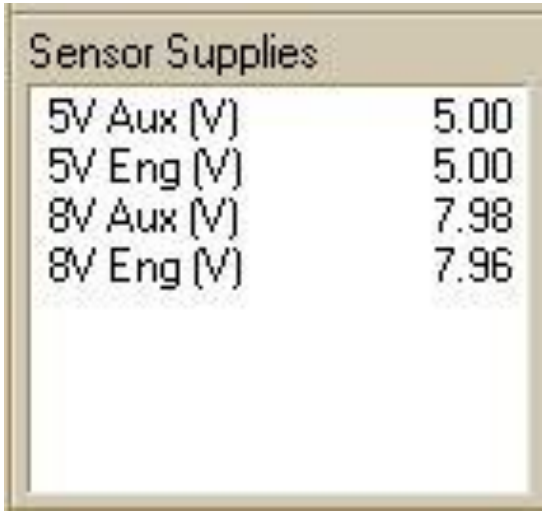
There are four regulated voltage supplies in the M400 which power communications and certain sensors. The voltages can be viewed in ECU Manager under the 'View Sensors' tab.

5V Eng supplies Throttle Position, Baro Pressure (EMAP), Fuel Pressure, Oil Pressure, Gear and Ignition Cut and APV

5v Aux supplies GPS and Fuel Trim Knob

8v Eng supplies power to the CAN cable

8V Aux supplies wheel speed sensors



Sensor Trouble Shooting: Gear Position and Force Sensor Test

The ECU identifies the gear number based on a signal seen from the micro-switch and voltage from the gear position sensor.

These signals can be view under ‘View – View Sensors’.

Gear Position is a rotary potentiometer located on the back of the gearbox and voltage should read around the following values:

Neutral = .85 v

1st = 1.47 v

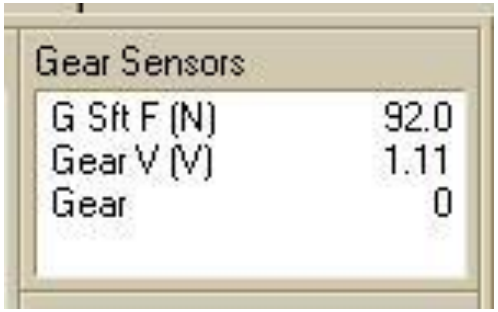
2nd = 2.08 v

3rd = 2.75 v

4th = 3.38 v

5th = 4.05 v

6th = 4.71 v



The Gear Position Sensor can be re-clocked to fix discrepancies

Gear Shift Force Sensor is the micro-switch mounted on the gear change cable used to indicate ignition cuts and should move approximately between 10 and 90 while up shifting when viewing the sensor.

Sensor Trouble Shooting: Status Page

ECU engine management software provides a status table where ON/OFF types of inputs can be monitored and tested

Select ‘View – View Diagnostics’, then tab over to Status

RED text means that the entry is ACTIVE while the BLACK text indicates the function is not requested or OFF

<u>Popular inputs to view:</u>

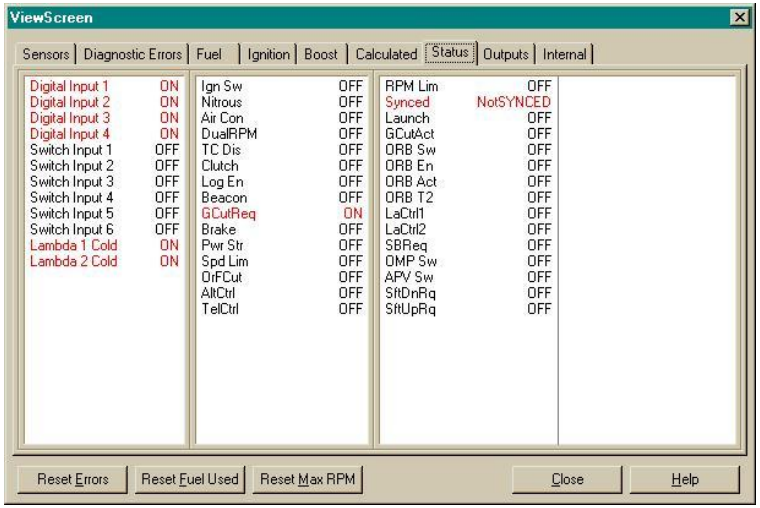
TC Dis = Traction Control disabled (switch closed)

GCutReq = Gear Change Ingition Cut REQUEST active (switch closed)

Spd Lim = Pit Lane Speed Limiting Active (switch closed)

GCutAct = Ignition Cut for Next Gear Active

APV SW = APV is OPEN when red



Sensor Trouble Shooting: Temperature Sensor

Air Temp Sensor: at 68F (20C) the sensor should read about 3300 Ohm when measuring resistance across the two terminal. This number will fall as the temperature rises

Engine Temp and Oil Temp Sensor: at 68F (20C) the sensor will read about 3000 Ohm when measuring resistance across the two terminals. This number will fall as the temperature rises.

Questions?