# Pro Formula Mazda 2004

Motec M400 Engine Management Seminar

Mid-Ohio Raceway, June 2004

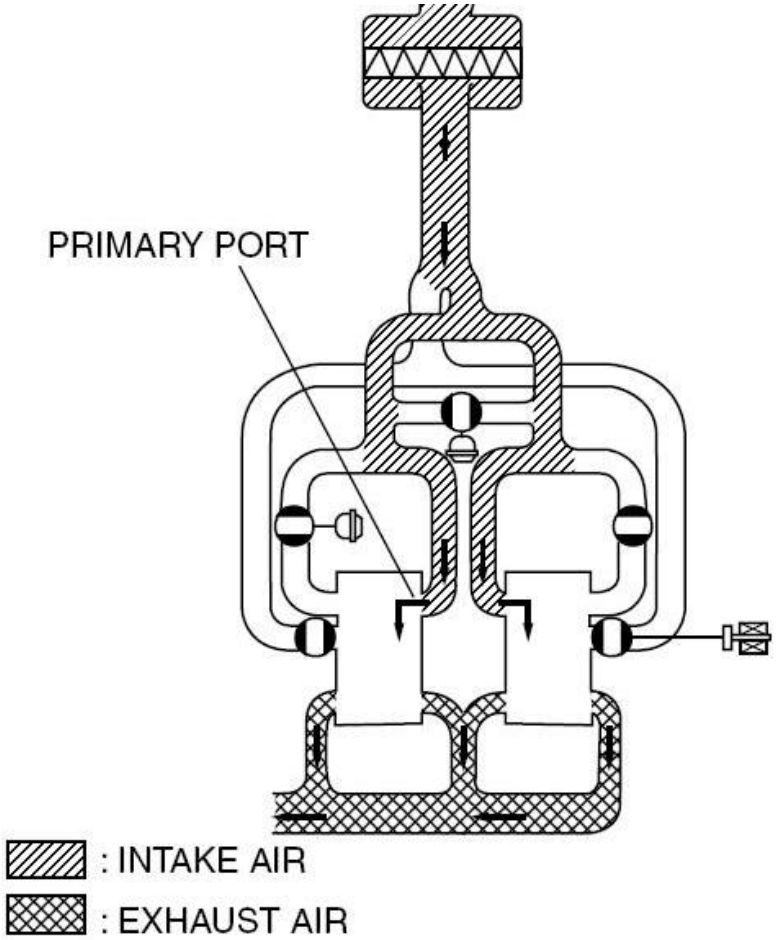
Presented by Motec Systems USA

# Renesis Engine Technology

- Intake system design and layout
- Fuel injection design and layout
- Ignition system design and layout
- Engine synchronization

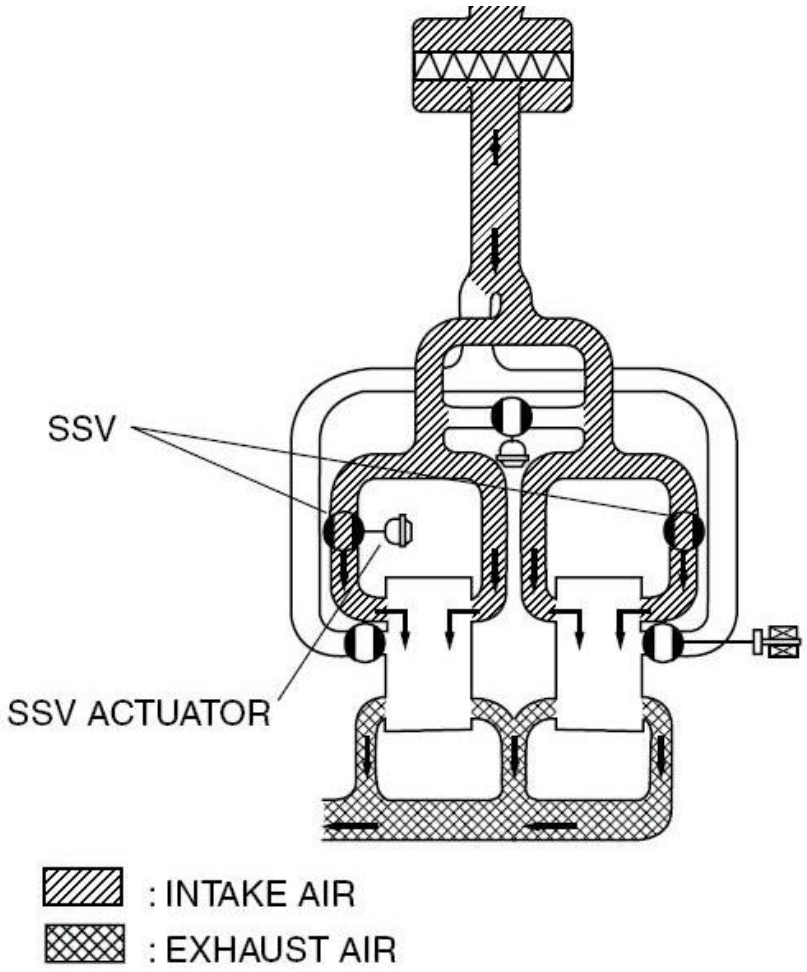
# Intake System

- Intake system has three different modes to improve intake system efficiency
- These modes are selected by three independent valve systems
- All valves are controlled by the Motec M400



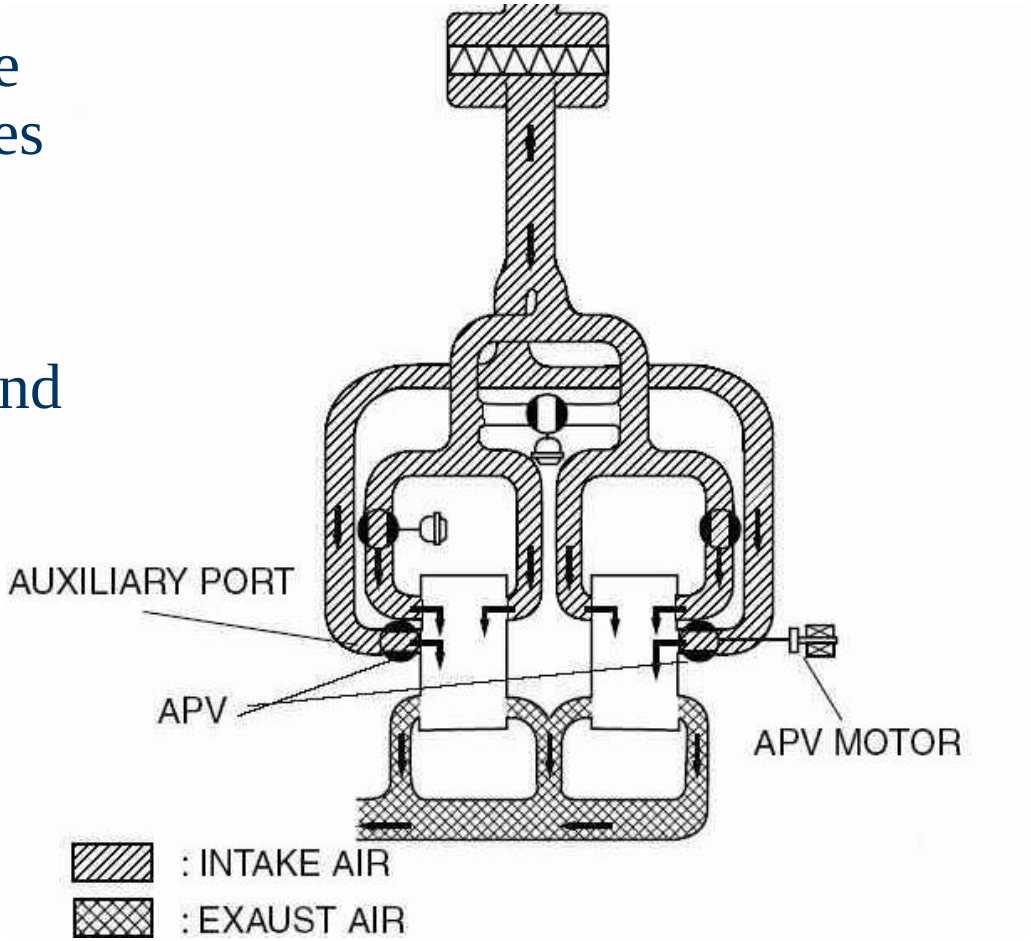
# Sequential Shutter Valve

- Provides larger airflow path as engine speed and load increase
- A.K.A “SSV” Valve
- Opens based on RPM and throttle position, but always open above 5500RPM
- Controlled by AUX3
- Harness Label “Valve B”



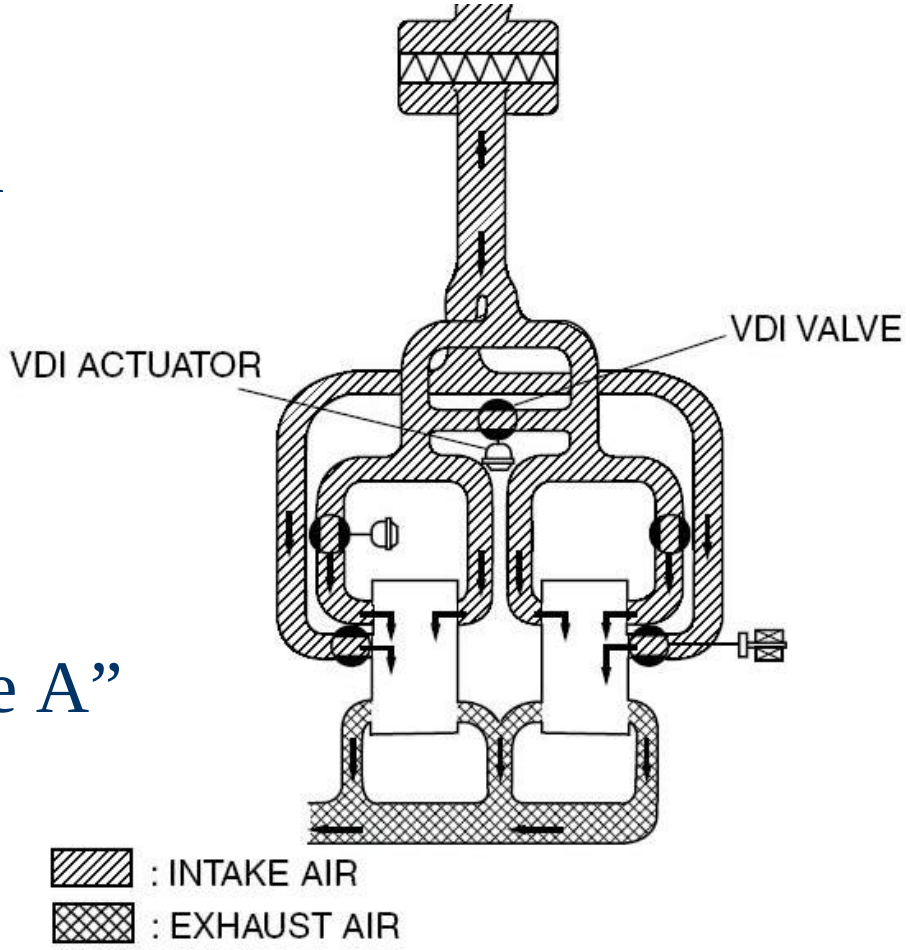
# Auxiliary Port Valve

- Final expansion of intake manifold flow capabilities
- A.K.A. “APV” Valve
- Opens at 6300RPM
- DC Servo driven ‘rack and pinion’ controlled by AUX7 and AUX8
- Incorporated position switch for monitoring action of valve

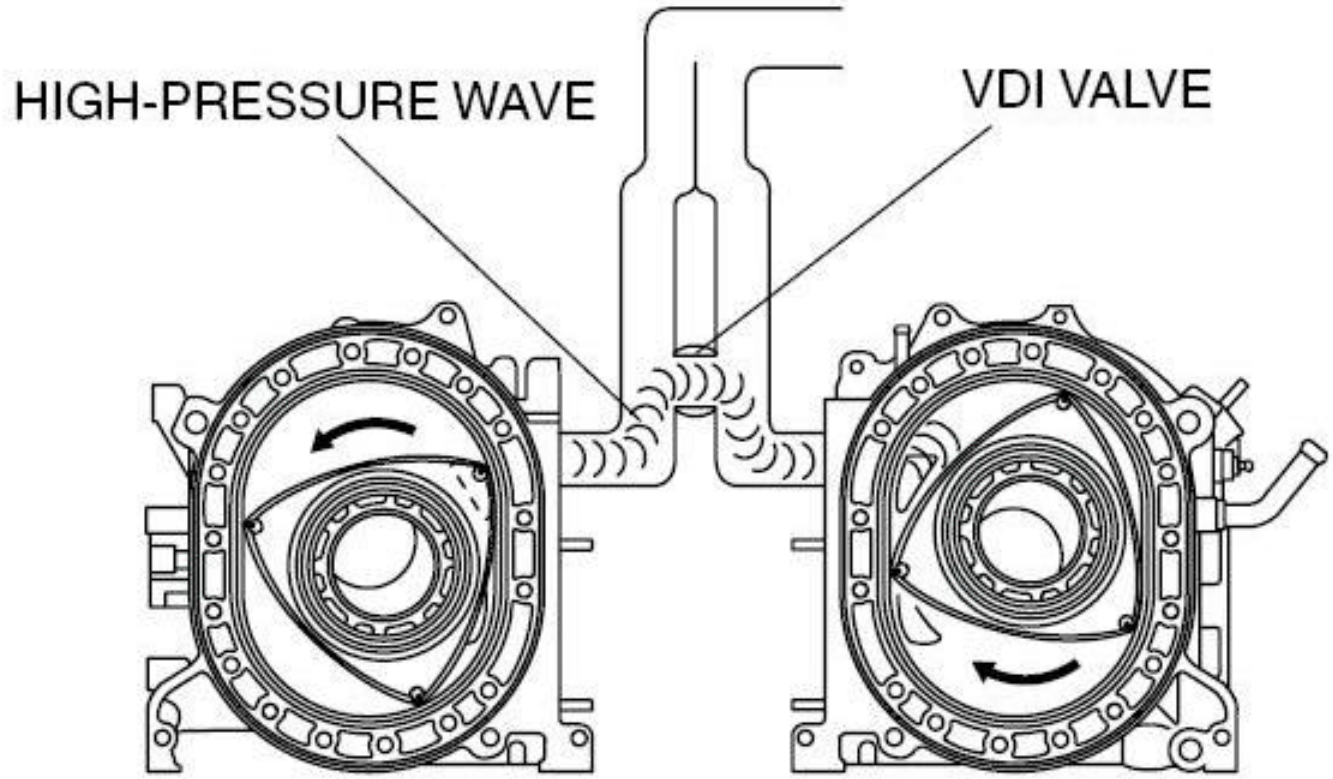


# Variable Dynamic Intake Valve

- Provides intake supercharging at high engine speeds
- A.K.A “VDI” valve
- Opens at 7600RPM
- Controlled by AUX2
- Harness Label “Valve A”



# Variable Dynamic Intake Supercharging Effect



# Ignition System

- Renesis Ignition system composed of four individually controlled and internally transistorized coil packs.
- Each coil is directly controlled by the Motec M400 with thee-dimensional dwell and advance point maps
- Each coil fires once per cycle (every 360°)
- Traditional Rotary ‘Split’ still used and varies with load and engine speed

# Engine Synchronization

- The M400 requires a precise understanding of the engine's rotational position at all times
- The eccentric shaft **REF**erence sensor provides both engine speed and cycle **SYNC**hronization related information via a 36 tooth wheel that has two missing teeth in a strategic location

# Motec Engine Management

- Motec M400 System
- Motec M400 System Security
- Understanding Lambda
- Environmental Adaptation
- The Fuel System vs. The ‘Tune-up’
- The Fuel Trim Knob
- Engine Speed Limiting
- Traction Control Fundamentals
- Gear Change Ignition cut Fundamentals
- Pit Lane Speed Limiting

# Motec M400 System

- Controls all aspects of the engine with multi-dimensional maps and detailed programming of engine specific parameters
- Has an internal operating system we call ‘HEX’ which is revised periodically to improve or add functions
- All engine specific programming is stored in ‘Configuration’ files stored in non-volatile memory
- Communicates via Controller Area Network (CAN) with your PC or other devices like the Motec ADL

# Motec M400 System Security

- For the Pro Formula Mazda Series these M400 ECUs are ‘locked’ to ensure all competitors have the same programming.
- Programming updates are delivered via encrypted files specific to each ECU and can be loaded by the end user or a series official
- Only series officials can ‘unlock’ an ECU to inspect programming or perform advanced diagnostics

# Understanding Lambda

- Lambda is a measure of the exhaust streams oxygen content with respect to the stoichiometric value of the fuel used
- For the series fuel, lambda 1.00 is equivalent to 14.7:1 Air-Fuel ratio. Therefore one can multiply any displayed lambda number by 14.7 to determine the current air/fuel ratio
- The PFM series engines should display 0.91 ~ 0.95 lambda at W.O.T. under steady state.
- Richer mixtures (lower lambda) will reduce economy and at extremes will result in power loss
- Leaner mixtures (higher lambda) will elevate engine operational temperatures (EGT, oil, and water), dramatically reduce power, and in extreme cases result in detonation
- Lambda numbers will read excessively lean after a shift, traction control event, while pit lane speed limiting is active, or on deceleration

# Environmental Adaptation

- The Motec M400 monitors environmental parameters and changes the fuel mixture ‘on-the-fly’ to meet these conditions.
- The engine temperature sensor enriches the mixture when the water temperature is cold to help with cold start
- The intake air temperature sensor partially adjusts for air density based on the intake air temperature
- The air box pressure sensor completes the density compensation and accounts for any ‘ram-air’ effects found at high speed

# The Fuel System vs. The ‘Tune-Up’

- Fuel pressure and fuel supply are critical to maintain the proper air/fuel mixtures in an electronic fuel injection system
- Fuel pressure has an exponential relationship to fuel flow through an injector resulting in large errors if it is out of specification
- The current PFM control maps were generated based on a fuel rail pressure of 40psi
- Current PFM control maps will correct for moderate fuel pressure discrepancies if a fuel pressure sensor is installed in your car.

# The Fuel Trim Knob

- This control input will allow the driver to add fuel to the engine in increments of 2, 4, or 6% * in real time as the car is operated on the track
- This input should be used for diagnostic purposes only as it will generally only result in increased fuel consumption and a slight reduction in engine power output
- The amount of enrichment is reported under “Fuel Comp 1” which is also seen as F(FC1)%

* In previous PFM control maps prior to 061604 this was a 4,8,12% enrichment

# Engine Speed Limiting

- The maximum permissible engine speed is 8300RPM
- Between 8300RPM and 8600RPM the engine is progressively ‘cut’ to prevent over-rev.
- Both fuel and ignition events are halted simultaneously on a randomly selected rotor face to accomplish the reduction in power
- This same method of cut is used in other engine power output control sub-systems like pit speed limiting, gear change ignition cut, and traction control

# Traction Control Fundamentals

- The traction control system looks for a difference between the fastest rolling wheel and slowest driven wheel to determine the current amount of slip
- All four wheel speeds are directly connected to the Motec M400 for this very purpose.
- The engine's power output is then limited by a table based on throttle position as well as several other factors
- The traction control can be defeated by the driver at any time with the cockpit mounted switch

# Gear Change Ignition Cut Fundamentals

- Gear change ignition cut is often referred to as ‘Shift Without Lift’ because it allows an up shift without clutch or throttle manipulation
- Gear change ignition cut has no effect on downshifts as this requires drive-line synchronization (throttle blipping).
- Gear change ignition cut is activated by a micro-switch on the shifter cable
- The amount of cut is based on the gear position and engine speed. No cut is permitted below 3000RPM.
- Instruct your drivers not to hang on to the gear selector as they will falsely trigger the gear change ignition cut system in doing so

# Pit Lane Speed Limiting

- Pit lane speed limiting is activated by a button on the steering wheel.
- When active the Motec M400 will not permit the vehicle to exceed 58kph (36mph) regardless of gear or throttle position
- The vehicle speed must be reduced to the pit lane speed limit by the driver applying the brakes. The M400 can not slow the chassis, it can only reduce the engine output.
- For smooth and accurate speed control, instruct your driver to use at least 50% throttle when pit lane speed is active

# Motec M400 Diagnostics and Troubleshooting

- Using ECU manager
- Active System Functional Test
- Passive Diagnostic Flags and Warnings
- Mechanical Tests of Components

Adjust View Tools Layout Utilities Help

Serial Number

ECU Enables

e M400
Ignition Cut
Injection
ng 512k
un Boost
on Control

Enabled
options List

Connected ECU Serial Number

# ECU Manager Start Page


Connection &
Error Status

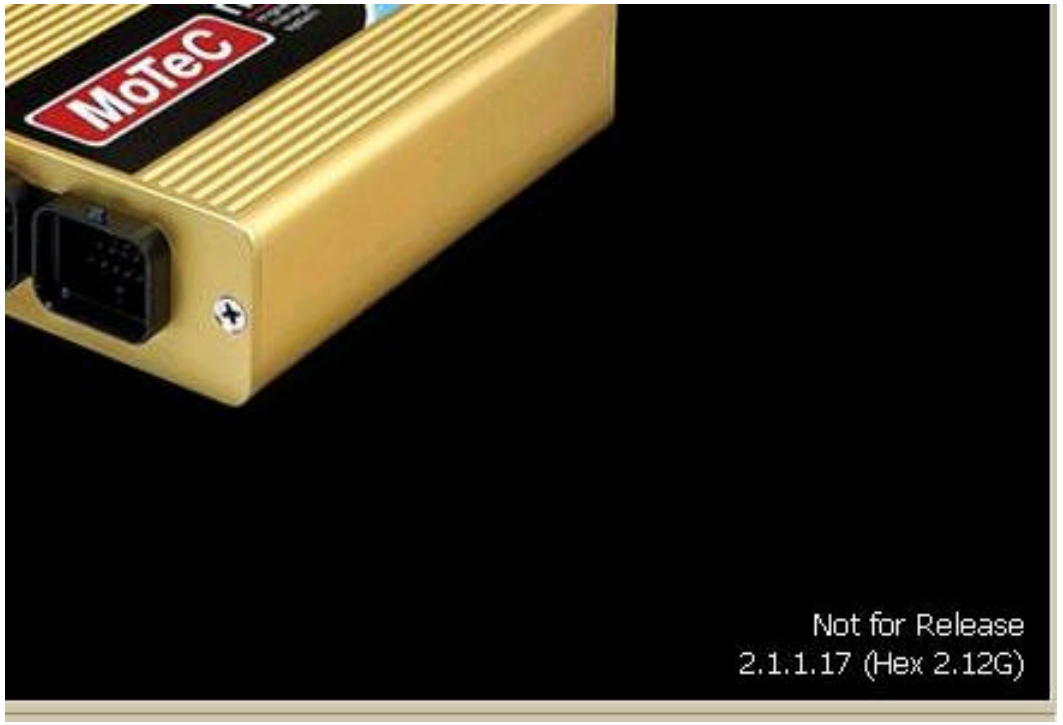
Software & HEX
Revision Level

Not for Rele
2.1.1.17 (Hex 2.1

Connected V2.12G Diagnostic Errors: 3

# Motec ECU Manager Software Versions

- PFM uses ECU manager version 2.1.1.17 or newer
- PFM uses ECU HEX version 2.12G or newer
- Motec employees will refer to software by it's HEX version



# ECU Manager and M400 Communications

- The M400 communicates via CAN with the laptop using the same cable and download port as your Motec ADL
- ADL software must NOT be open during ECU communications as the laptop can only ‘talk’ with one device at a time
- The ECU manager software will report the status of it’s connection in the lower left-hand corner of the screen:

# Communications Errors

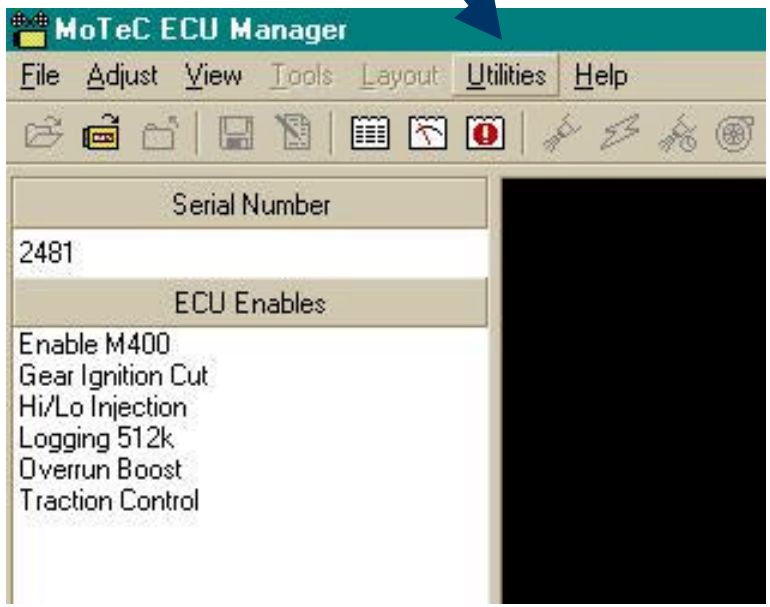
- The ECU manager will report errors if it is unable to connect.
- Typical errors are:
  - "The CAN interface cable has no power"
    - 0v or 8v not present at download connector
  - "Excessive number of CAN bus errors"
    - CAN HI and LO wires reversed or shorted in harness
  - "Communication Timeout: Device not connected"
    - CAN cable powered but can not find ECU, CAN HI or LO broken

# Active System Function Tests

- ECU manager can be used to test the following systems:
  - Ignition coils: Spark Test
  - Fuel injectors: Pulse Test
  - VDI valve: Open/Close
  - SSV valve: Open/Close
  - APV valve: Open/Close
- Your laptop must be connected and the engine must be OFF (not running) to enter test mode
- Test mode is entered by selecting ‘Test Outputs’ on the Utilities pull-down menu and then selecting the specific tab of the system you wish to test

# The Utilities Menu

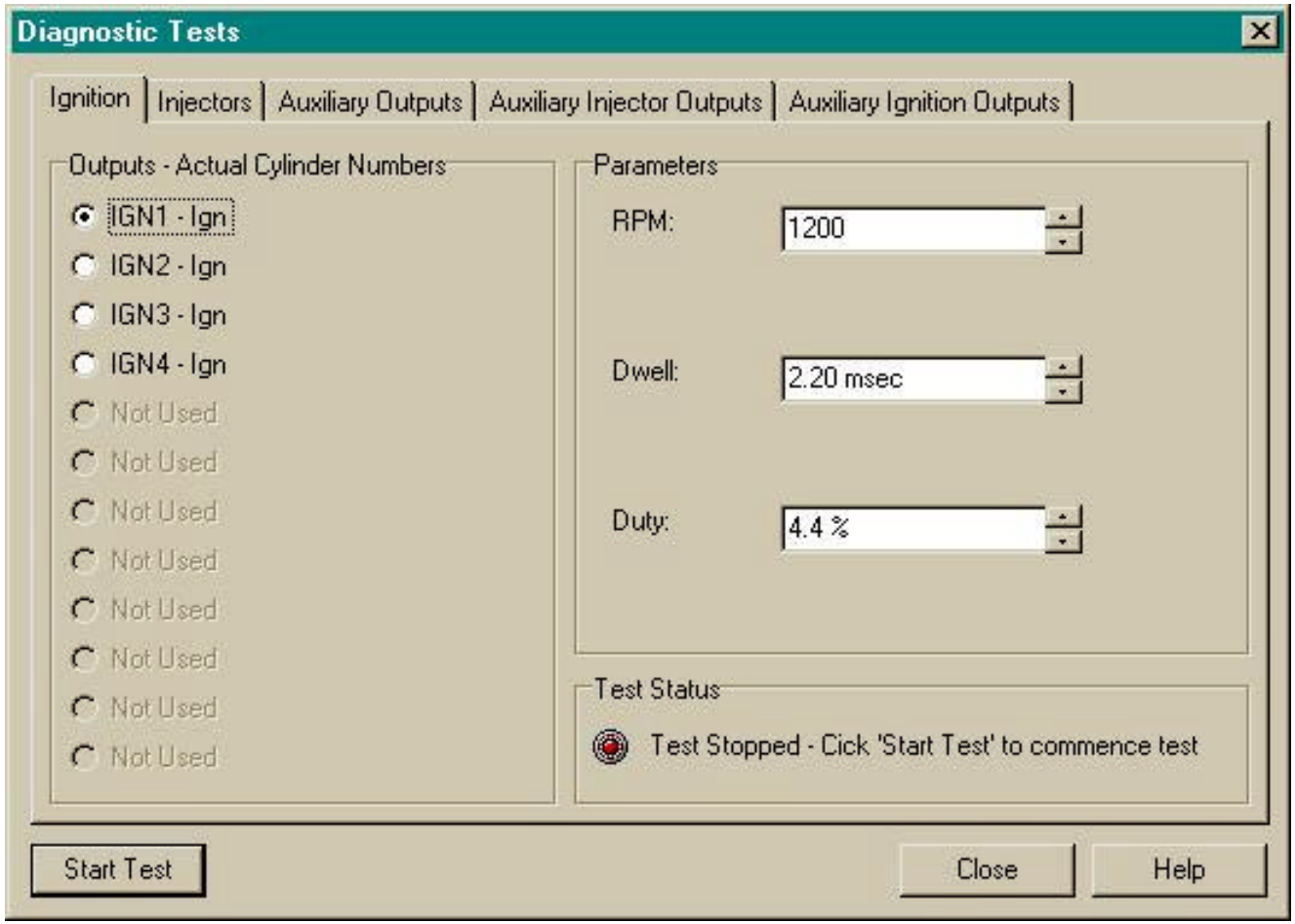
- Select the ‘Utilities’ menu and then choose the ‘Test Outputs’ found in the drop-down menu



# Ignition Testing

- Coils MUST remain connected to spark plugs during this test! Either remove the current plugs from the engine or have a second set of known good plugs available for the test
- The spark plugs MUST be grounded to the engine block during the test
- The ignition switch MUST be on so that the coils are powered during the test
- Simply select the radio button next to the channel you wish to test and click the start test button. The coil will output until you stop the test again. The channels are assigned as follows:
  - IGN1 = Front Rotor Leading
  - IGN2 = Rear Rotor Leading
  - IGN3 = Front Rotor Trailing
  - IGN4 = Rear Rotor Trailing

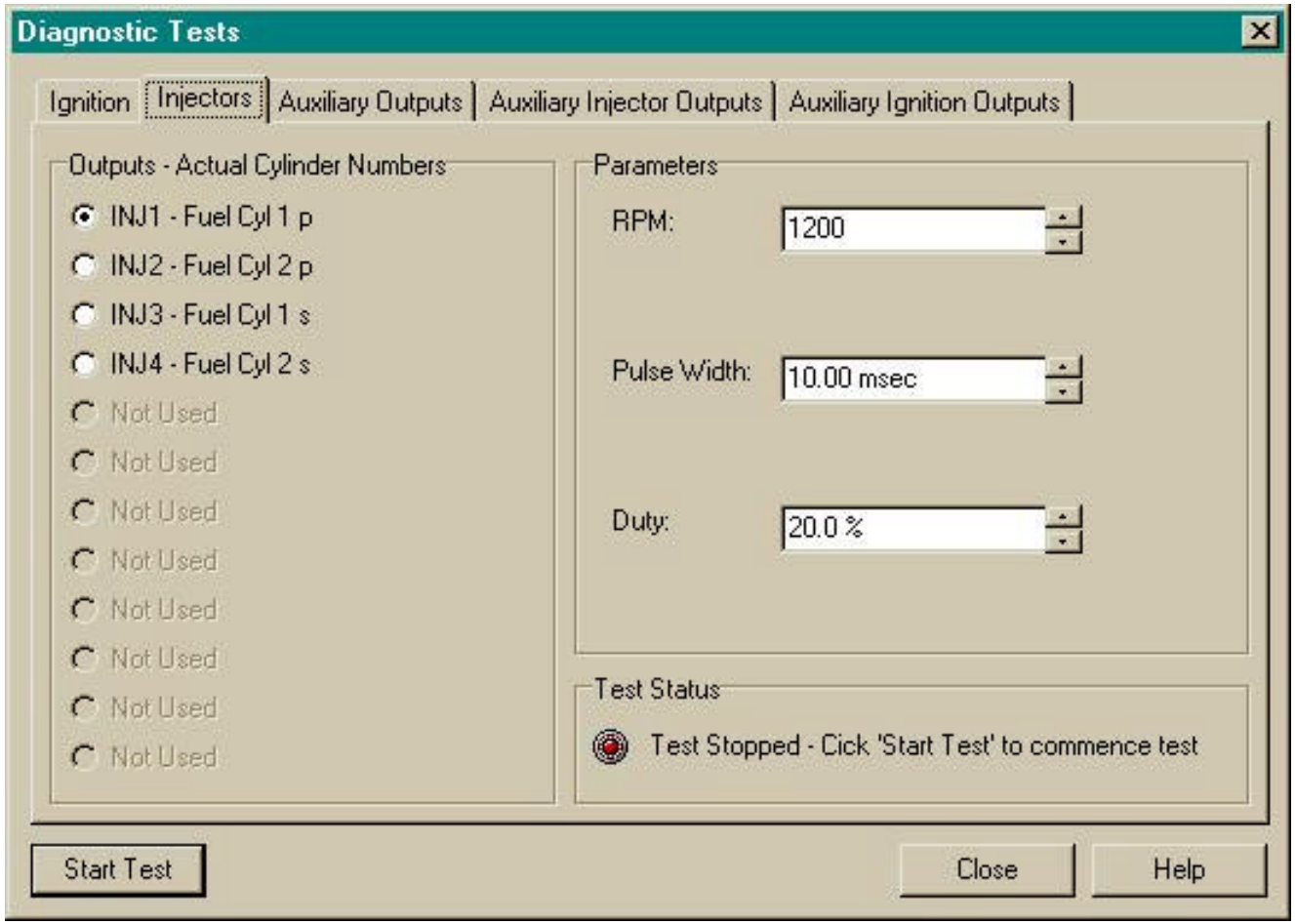
# Ignition Test Screen



# Fuel Injector Testing

- The fuel pump MUST remain off during this test!
- It is advisable to have the spark plugs out during this test and that the engine is turned over for a few seconds after testing is completed to exhaust any ingested fuel from the test
- Simply select the radio button next to the channel you wish to test and click the start test button. The injector will output until you stop the test again. The channels are assigned as follows:
  - INJ1 = Front Rotor Primary (RED) injector
  - INJ2 = Rear Rotor Primary (RED) injector
  - INJ3 = Front Rotor Secondary Inner & Outer (YELLOW) injectors
  - INJ4 = Rear Rotor Secondary Inner & Outer (YELLOW) injectors

# Fuel Injector Test Screen

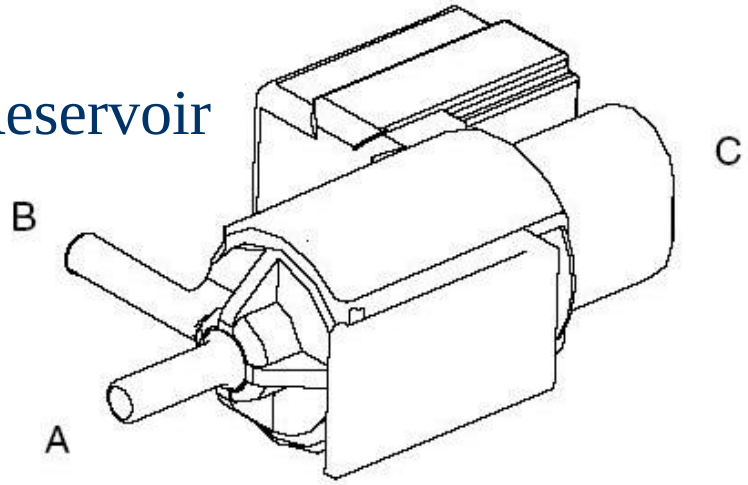


# Intake System VDI & SSV Valve Details

- The VDI and SSV valves are vacuum actuated via electronic solenoid control
- Therefore it requires both an electronic and pneumatic signal to move either the VDI or SSV valve.
- The black plastic vacuum reservoir chamber is connected to the intake system via a white and green check valve. In turn the reservoir is connected to the solenoid rack.
- The solenoids connect vacuum to the diaphragms of the VDI and SSV actuators which mechanically turn the valves when the solenoids are electrically activated

# Intake System Solenoid Testing

- The electrical solenoids for the VDI and SSV valves have three ports:
  - A = Connected to Vacuum Reservoir
  - B = Connected to Actuator
  - C = Vent to Atmosphere




- When ‘OFF’ A is blocked while B connects to C
- When ‘ON’ A is connected to B while C is blocked

# Testing SSV and VDI with ECU Manager

- Open the AUXILIARY OUTPUTS test tab
- You MUST set the parameter ‘Duty’ to 100% or else the test will not work correctly.
- Click on the up arrow to the right of the ‘duty’ field while holding the CNTRL key down on your keyboard to rapidly advance it to 100%
- AUX2 ‘Load/RPM’ will operate the VDI valve


- AUX3 ‘Aux Table’ will operate the SSV valve
- The ‘Start Test’ button will open the valve once
- The ‘Stop Test’ button will then close the valve
- The number of times the test can be performed electronically is limitless, but when the vacuum reservoir becomes empty the valve will no longer actuate, only the solenoid will click.

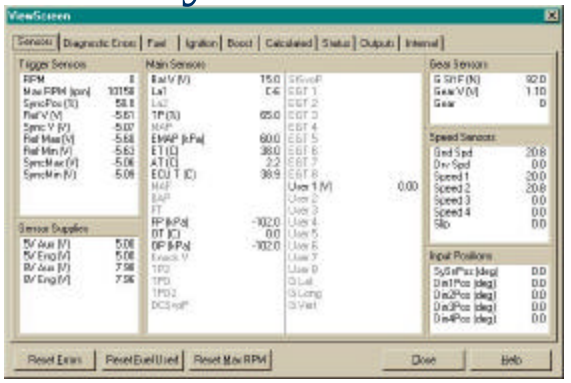
# Testing the APV Valve

- The APV valve is NOT tested with the output testing menu as it is a complex control system.
- To determine if the APV is working, simply open the throttle to 100% with the engine off and the valve will open*
- Lowering the throttle below 90% will make the APV close again
- This test is disabled when the engine is running

*This feature was implemented in ECU HEX 2.12D and higher

# ECU Manager Diagnostics & Information Window

- This window can be called a number of different ways and opens to the appropriate ‘tab’ based on the key used to access it:
  - ‘F3’ key = Diagnostic Errors Page
  - ‘S’ key = Live sensor data page
  - ‘V’ key = Last viewed data page



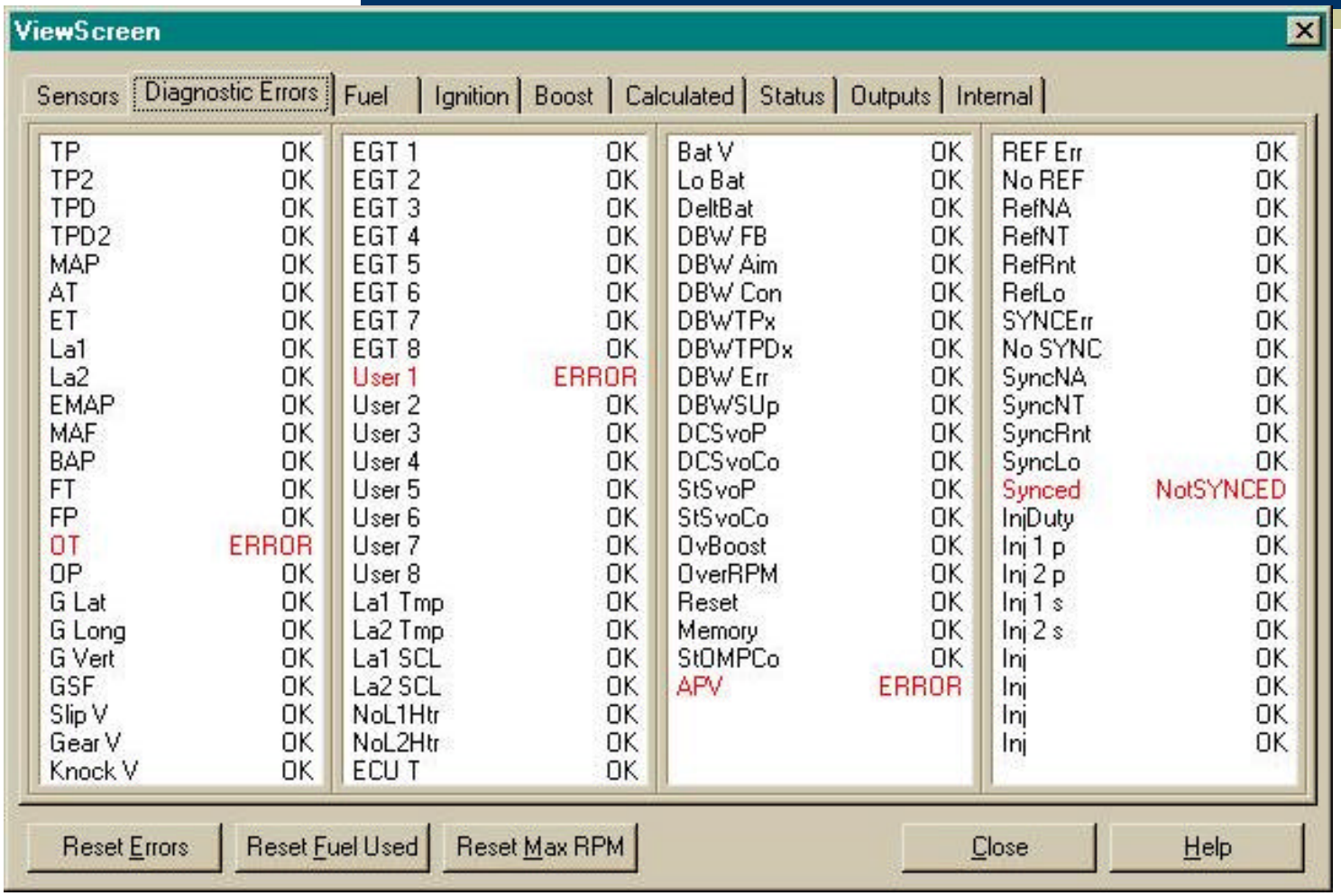

- Once opened the ‘TAB’ key can be used to cycle through any of the other displays:

  (Fuel/Ignition/Boost/Calculated/Status/Outputs/Internal)

# ECU Manager Diagnostic Errors

- Pressing the ‘F3’ key at any time while an ECU is connected to the PC will recall the diagnostic error page
- If an ECU is NOT connected to the PC then this page can not be accessed
- Diagnostic errors are always presented in RED text
- Errors are cleared with the ‘Enter’ key or by clicking the ‘Reset Errors’ button

# Typical Diagnostic Error Screen



# ‘Synced’ Status and APV error

- The SYNC status will always be red and report ‘NOT SYNCED’ when the engine is not running. Once the engine is started the text will turn black and will report ‘SYNCED’
- The APV ERROR should be ignored. Use the ‘APV Sw’ field on the status page to evaluate the APV system

# REF and SYNC Errors While Cranking

- As long as the engine starts properly and the reported errors during cranking can be cleared as soon as the engine has fired there is no cause for concern.
- The output of the eccentric shaft sensor is surface speed dependant and is adversely effected by gap.
- Errors during cranking on a car that will not start may be rectified by adjusting the sensor gap to be 0.030” ~ 0.050”

# Primary Sensor Faults & Their Associated Hardware

- TP = Throttle Position Sensor
- AT = Air Temperature Sensor
- ET = Engine Temperature Sensor
- EMAP = Air Box Pressure Sensor
- FP = Fuel Pressure Sensor
- OT = Oil Temperature Sensor
- OP = Oil Pressure Sensor
- GSF = Gear Shift Sensor
- Gear V = Gear Position Sensor
- USER1 = Fuel Trim Knob
- DeltBat = Rapid Power Loss
- BAT Lo = Battery Voltage Too Low

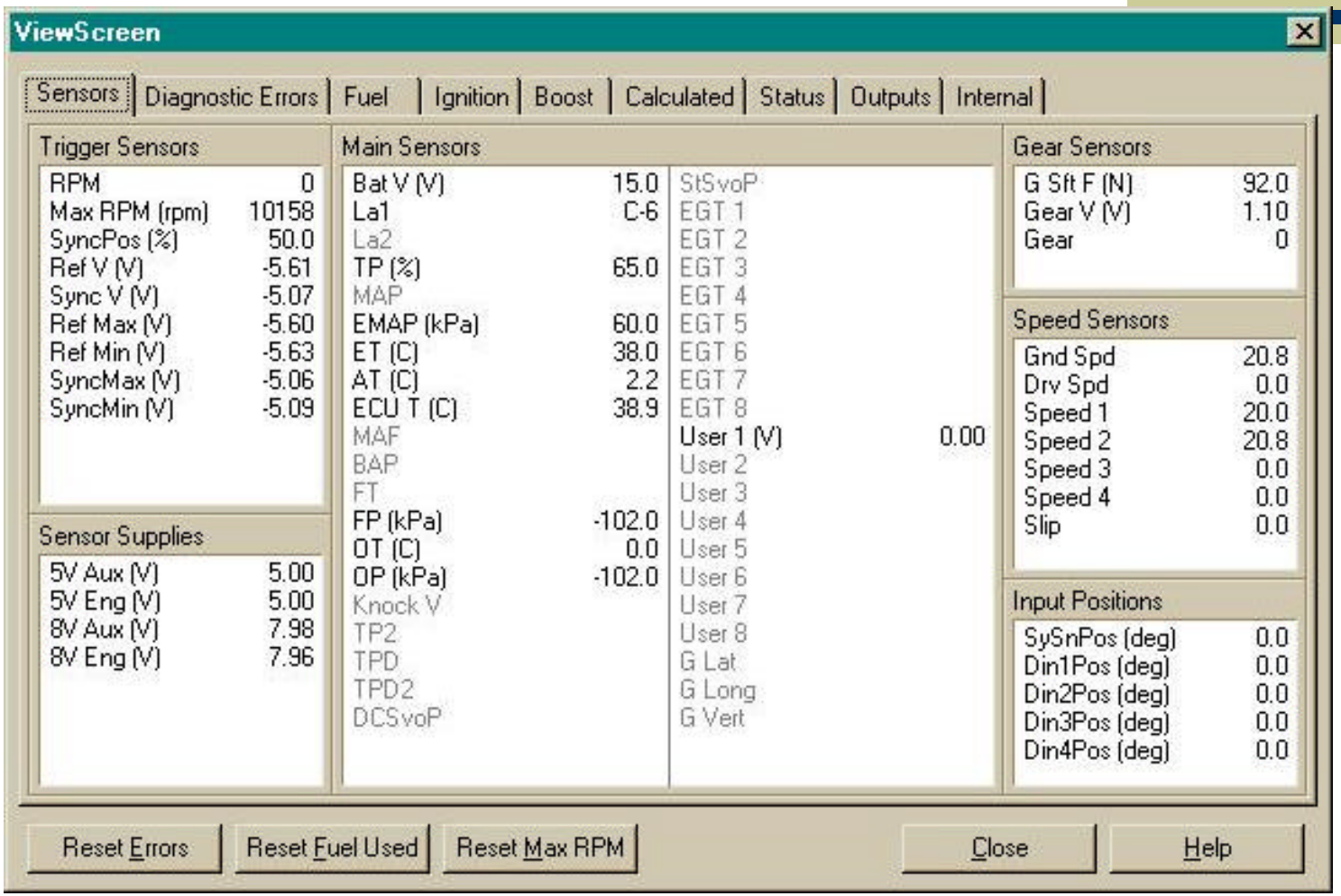
# What to do When There is a Primary Sensor Fault

- Find the reported sensor in the vehicle and disconnect the harness from the sensor.
- Look at the connector and inspect for signs of damage including:
  - Recessed pins
  - Broken wires / Bad crimps
  - Mechanical damage (Crushing/Melting)
- Reconnect the sensor and attempt to clear the error. If you are successful be sure to watch the sensor in subsequent data logs for repetitive failures.
- If the error will not clear, replace the sensor with a known good spare and try to clear the error again. If unsuccessful report a possible harness problem to a series official or track support representative

# Secondary Sensor Evaluation

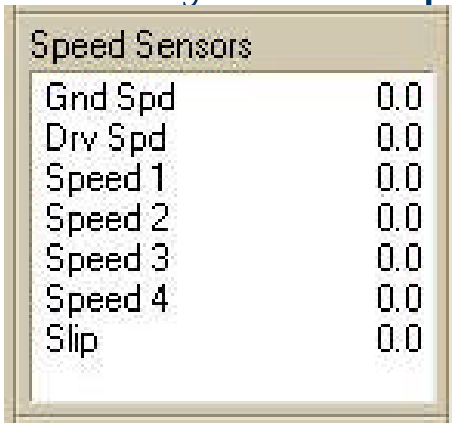
- The following sensors will require the use of the ‘Sensors’ tab on the View Screen.
  - Wheel Speeds
  - Gear Position
  - Actual Gear Volts
  - Sensor Supplies

# ECU Manager View Screen (Live Sensor Data Page)



# Wheel Speed Testing

- Speeds are displayed in KMH
- Simply Roll the wheel you wish to check by hand. Speed channels are assigned as:
  - Speed 1 = Front Left (Rolling)
  - Speed 2 = Front Right (Rolling)
  - Speed 3 = Rear Left (Driven)
  - Speed 4 = Rear Right (Driven)

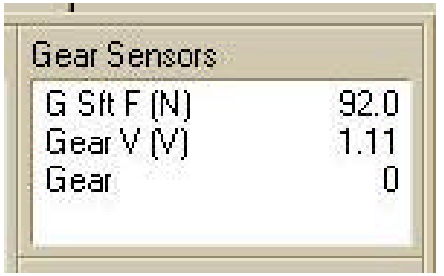



- Be sure to check that the 8v Aux Supply is at or very close to 8.00v as it powers the wheel speed sensors. If not there is a short circuit somewhere

# Gear Position & Force Sensor Testing

- The gear position sensor is a rotary potentiometer located on the tail of the transmission
- The gear shift force sensor is a micro-switch on the shifter cable just aft of the shift lever
- Gear volts should read near the values listed in the chart on the right
- The gear position sensor can be re-clocked to correct for small discrepancies
- The ECU should report the proper gear during testing
- Gear shift force should move approximately between 10 and 90 while you are up-shifting only

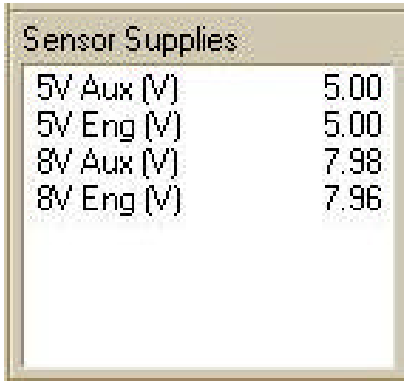
| | |
|---|---|
| Neutral | 0.87 v |
| 1st | 1.52 v |
| 2nd | 2.16 v |
| 3rd | 2.79 v |
| 4th | 3.42 v |
| 5th | 4.09v |
| 6th | 4.75 v |



# ECU Sensor Supply Evaluation

- There are four regulated supplies on the M400 which provide steady clean power for the sensor and communications equipment used on the engine and chassis
- The engine 5v supply powers the TP / EMAP / FP / OP / GCIC / and APV status sensor
- The auxiliary 5v supply powers Gear Position Sensor, Fuel Trim Knob, and is found at the TC disable switch connector
- The engine 8v supply powers the CAN cable
- The auxiliary 8v supply powers

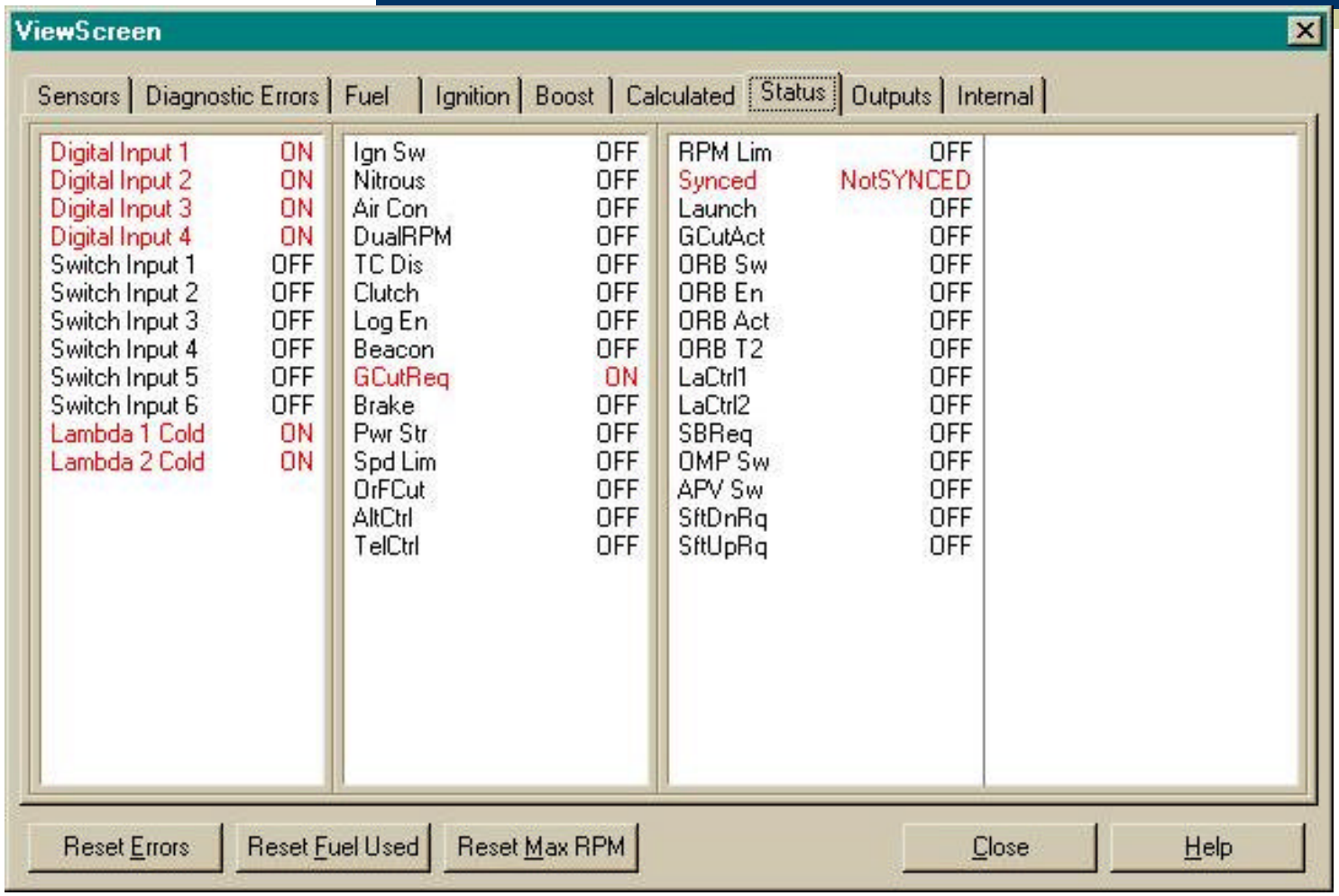
  all four wheels speeds



# ECU Status Page Tests

- There are features in the M400 that are ON/OFF types of inputs which can be monitored or tested on the ‘Status’ tab of the View Screen
- Any entry in the list that is RED is active while black text indicates the function is not requested (or off)
  - TC Dis = Traction Control Disabled (switch closed)
  - GCutReq = Gear Change Ignition Cut REQUEST active (switch closed)
  - Spd Lim = Pit Lane Speed Limiting active (switch closed)
  - OrFCut = Over-Run fuel cut active (off throttle above idle)
  - RPM Lim = Engine Speed Limiting active (max engine speed exceeded)
  - GCutAct = Ignition Cut for Next Gear Active (ignition cut to reduce power)
  - APV SW = APV is OPEN when red

# ECU Manager Status Screen



# Temperature Sensor Test Data

- At 20C (68F)  the AT sensor should read about 3300 ohms when measuring across it's two terminals with an ohm meter. This number will fall as the temperature rises
- At 20C (68F) the ET / OT sensors will read about 3000 ohms when measuring across it's two terminals with an ohm meter. This number will fall as the temperature rises

# Notes