

ECUs for Race Cars

2/3/2019 © Richard Gray Moorpark CA 0



- Elan NP01 Mazda 2.3l AEM ECU 240hp 1700lb w/driver (Richard Gray) 1.75 G's 150 mph max



ECUs for Race Cars





WHAT IS AN ECU?

- **Engine Control Unit**
- **A COMPUTER SYSTEM THAT RECEIVES DRIVER INPUT,**
- **AND MEASURES THE STATE OF THE ENGINE,**
- **AND SENDS APPROPRIATE SIGNALS TO THE ENGINE CONTROLS**
- **TO IMPLEMENT THE DRIVER'S COMMANDS**
- **(THROTTLE, FUEL MAP, ANTI-SLIP, ETC.)**

AEM ECU – INFINITY MODEL 516



INSTALLATION IN ELAN RACE CAR

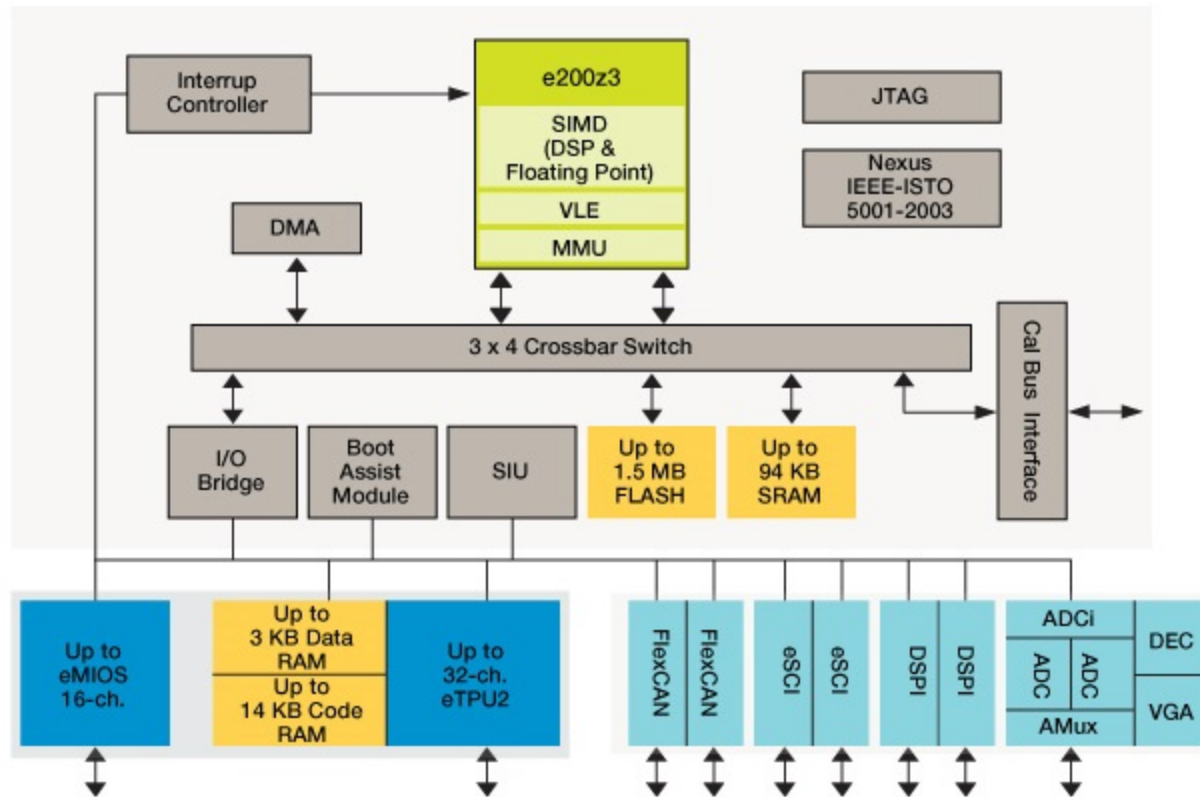




ECU Design Parameters

- **Automotive Environment : Heat, Vibration, Moisture, Oil, Voltage, EMI**
- **Signal Speed: 10,000 RPM = millisecond cycle time with microsecond response**
- **Multiple In – Multiple Out**
- **Mixed Signal I/O**
- **Real Time Processing**
- **Cost**

GUTS OF ECU – NXP CHIP



 Freescale Technology

32 BIT 80 Mhz 80 GPIO AD/DA CAN FLASH SYSTEM ON CHIP
1181 PAGE REFERENCE MANUAL 4 CYLINDER VERSION



ECU SIGNALS – I/O

- Data – CAN UART
- Driver – High - Low side P vs N SiC MOSFET
- **Digital:**
- **Analog:** Sensor current or voltage
- AD levels and bits and speeds
- **Protections:** Short, over voltage, EMI



ECU INPUTS

- **Driver:**
Throttle Gear Brake Steering Settings
- **Engine:**
Temperatures Pressures RPM Positions
- **Chassis:**
Pressures Positions RPMs GPS

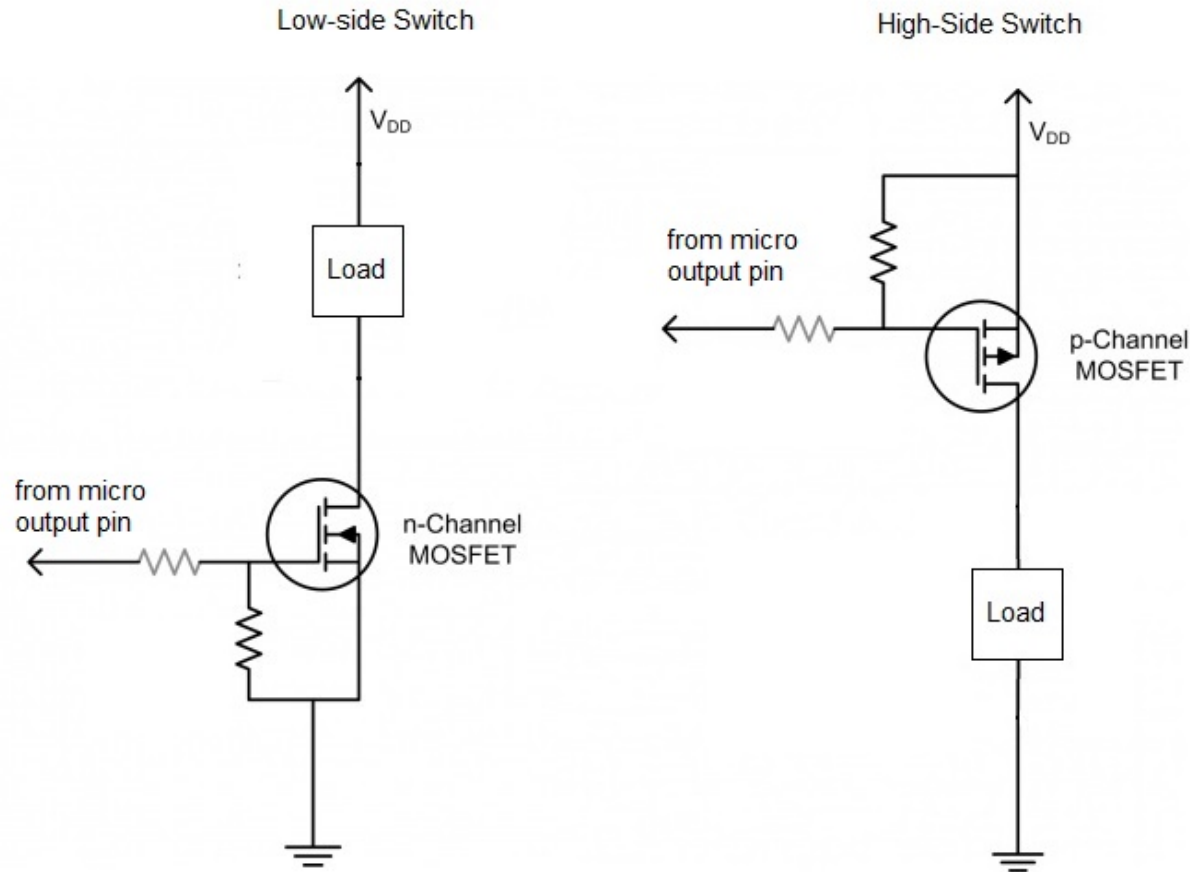


ECU OUTPUTS

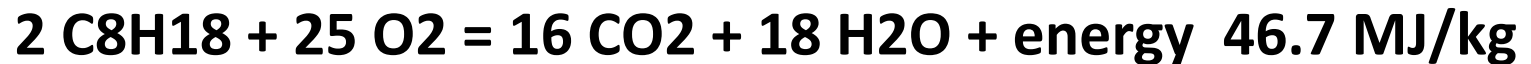
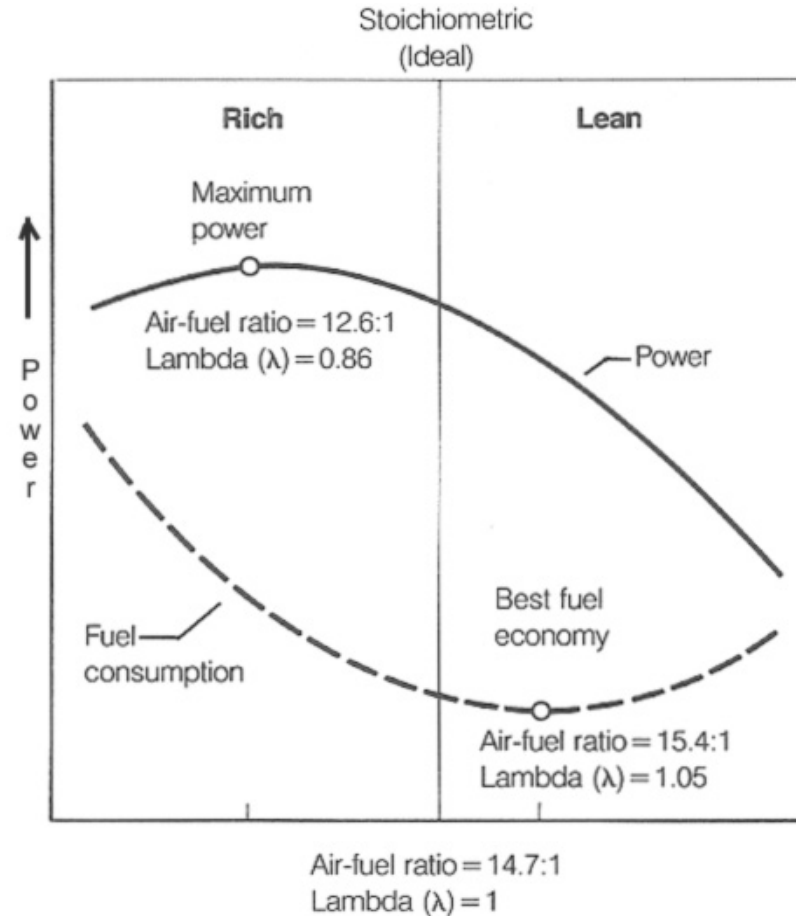
- **Engine:** Triggers & Data
Ignition, Throttle, Fuel Injection, Fans,
Pumps
- **Driver:** Data
Dash Display, Data Logs

N vs P Channel MOSFET

High Side vs Low Side Drivers



POWER VS AIR-FUEL RATIO

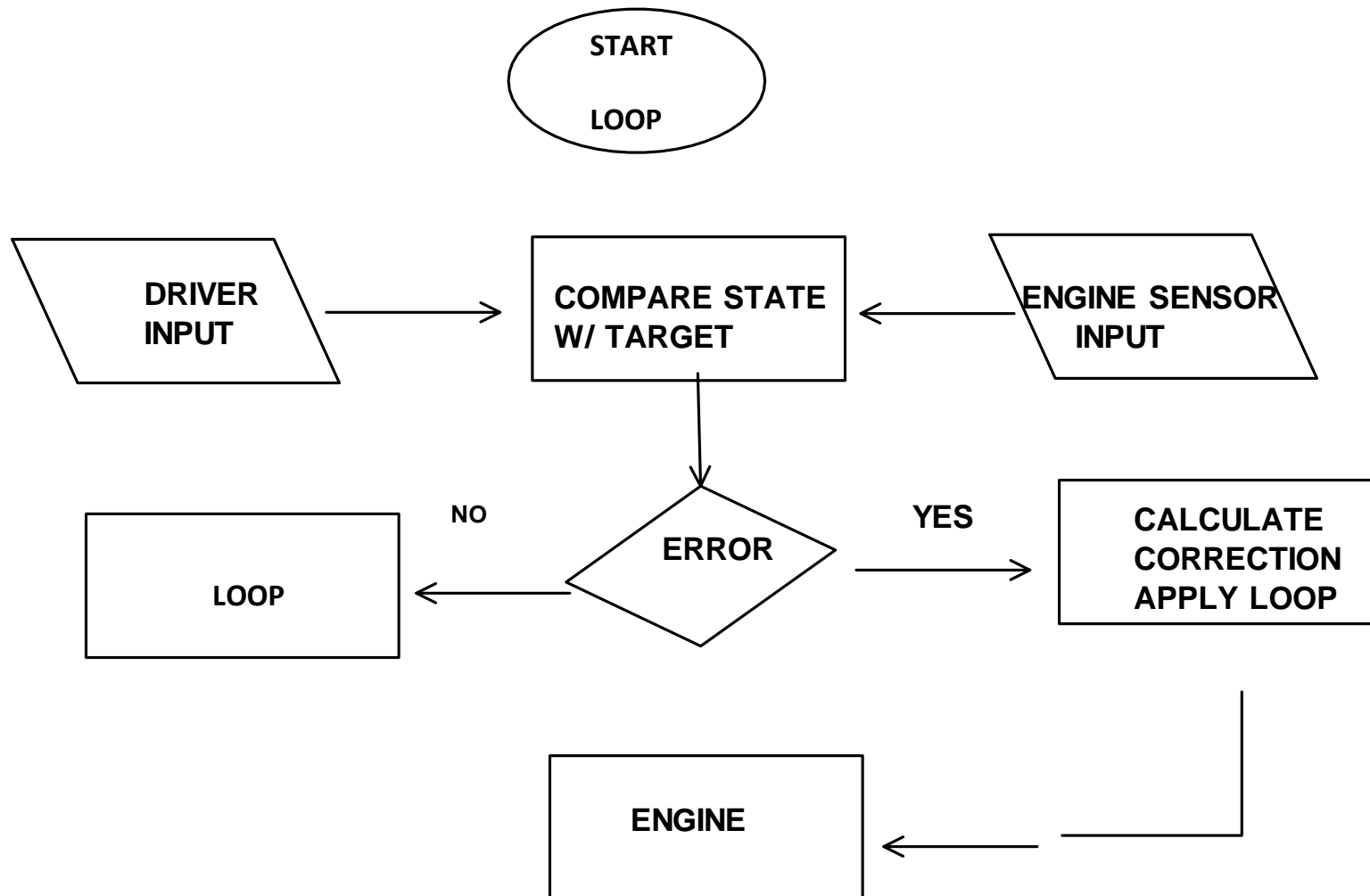




CONTROL

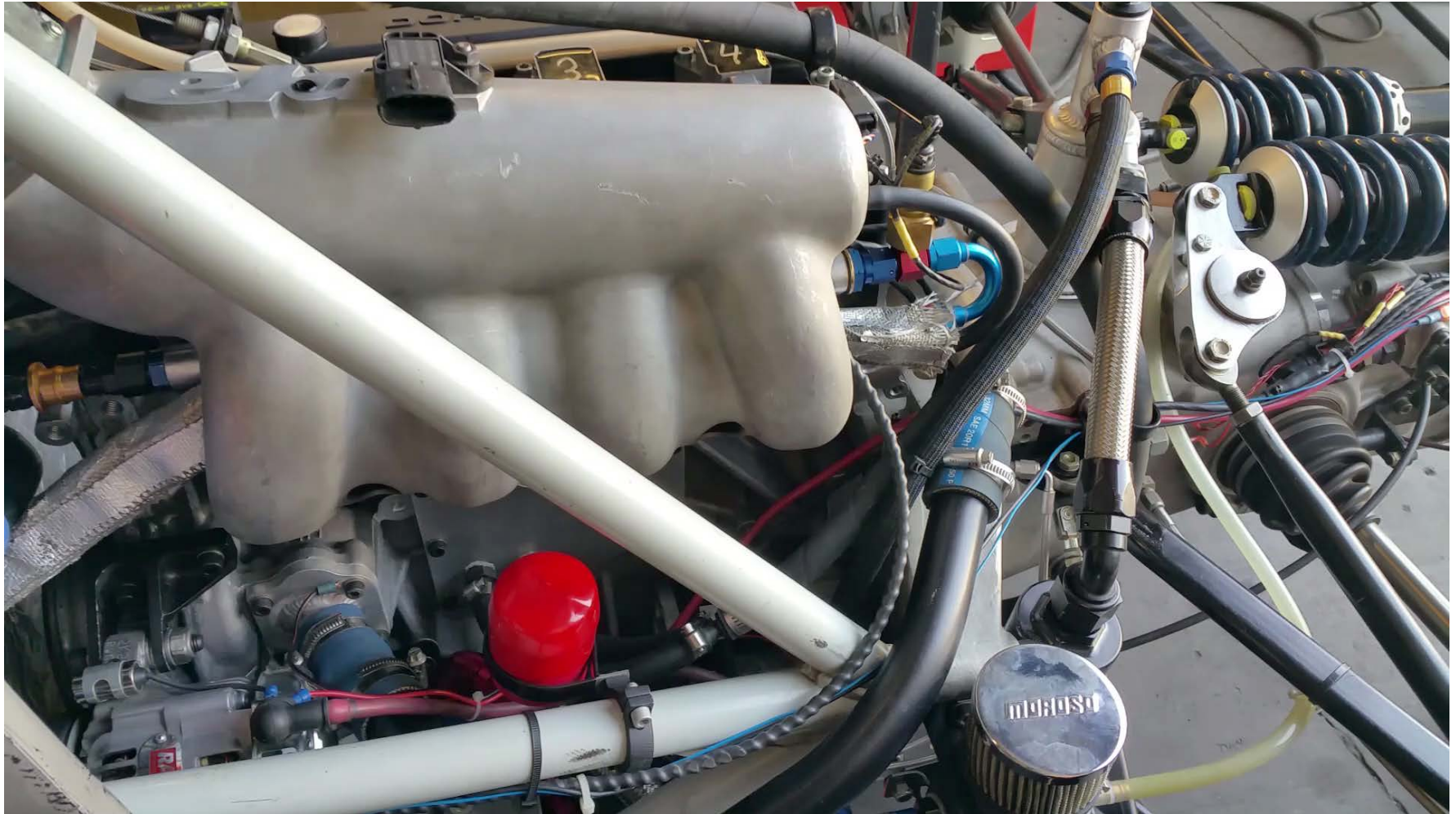
- **What is Control? Providing signals to engine to obtain desired performance.**
- **Optimization target (power) is found on dyno**
- **Servo control theory requires some closed loop feedback (O2 sensor for Air/Fuel ratio)**
- **Dynamic adaptation allowed by new powerful chips**
- **Stability in AEM is from bounded adaption**
- **Primary design parameter is volumetric efficiency at each throttle position or manifold pressure vs rpm**

BASIC PROGRAM OF ECU



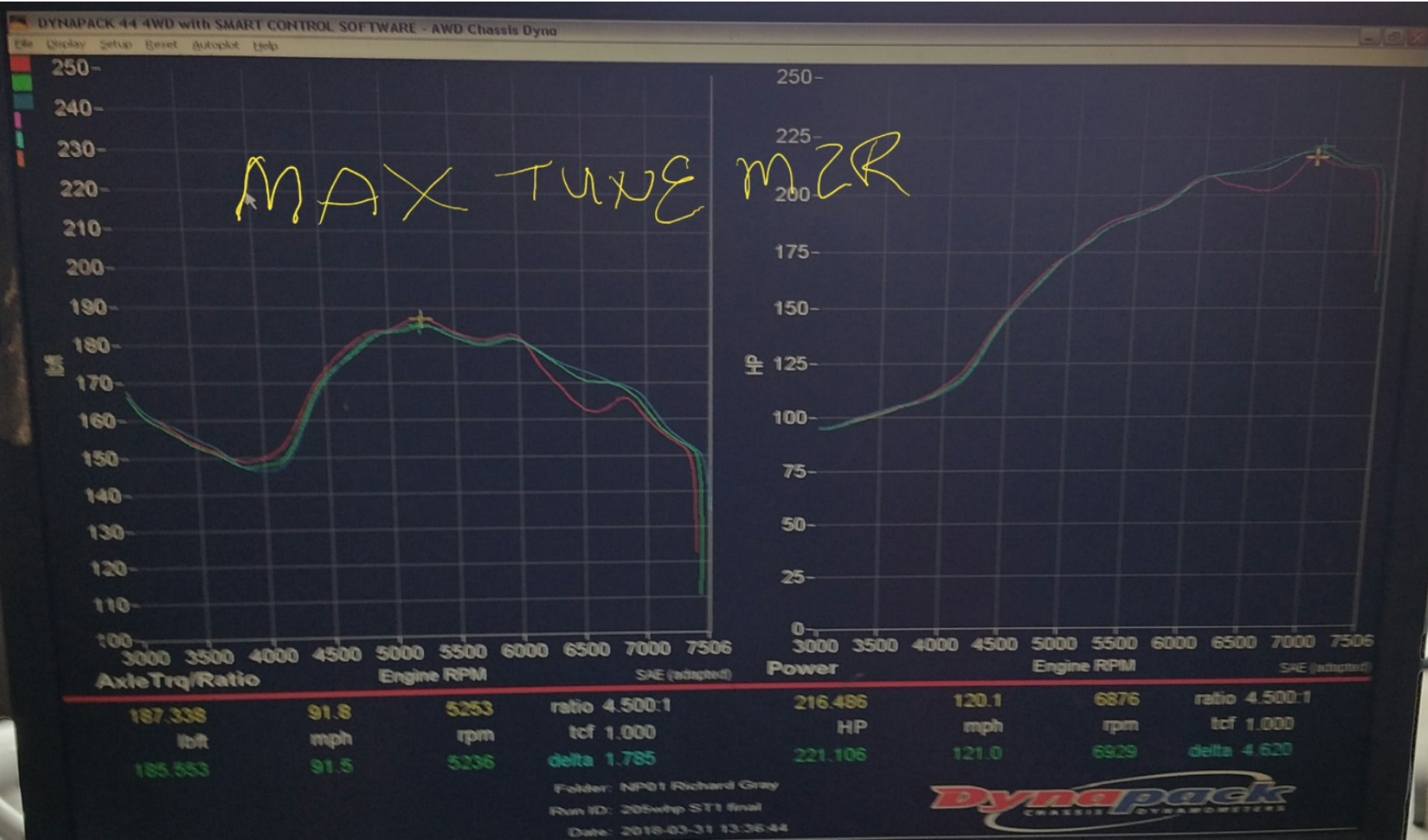
- $u(t) = k_p e(t) + k_i \int_0^t e(\tau) d\tau + k_d \frac{de}{dt}$
- PROPORTIONAL INTEGRAL DERIVATIVE

DYNO TUNING (DYNAPACK)



- HUB DYNO REAL TIME EDITING OF ECU TABLES

DYNO CURVE



• TORQUE

HORSEPOWER

TARGET LOOKUP TABLE

IgnMap [degBTDC]

6.00	2.00	2.75	3.50	4.25	5.00	6.50	7.25	8.00	8.00	6.75	5.75	5.25	5.75	6.25	6.75	7.00	7.75	8.25	9.25
5.50	2.50	3.25	3.75	4.50	6.00	7.50	8.75	9.50	9.25	7.75	6.50	5.75	6.25	7.00	7.25	7.75	8.25	9.00	9.75
5.00	2.75	3.50	4.75	6.00	7.50	9.25	10.75	11.50	11.00	9.25	7.50	6.75	7.25	8.00	8.50	9.00	9.25	10.00	10.75
4.50	3.25	4.00	6.00	7.25	9.25	11.50	13.25	14.00	13.00	10.75	8.75	7.75	8.25	9.00	10.00	10.50	10.75	11.25	12.00
4.00	3.75	4.50	7.00	8.75	11.25	13.75	15.50	16.25	15.00	12.50	10.00	9.00	9.25	10.00	11.25	11.75	12.00	12.75	13.50
3.50	4.25	5.00	7.75	10.00	13.00	15.75	17.75	18.00	16.75	14.00	11.50	10.25	10.50	11.25	12.50	13.25	13.50	14.25	14.75
3.25	4.50	5.75	8.75	11.50	14.50	17.50	19.25	19.25	18.25	15.50	13.00	11.50	11.75	12.50	13.75	14.50	15.00	15.50	16.00
3.00	5.00	6.50	10.00	12.75	16.00	19.00	20.75	20.50	19.50	16.75	14.50	13.00	13.00	13.75	15.00	16.00	16.25	17.00	17.50
2.75	5.50	6.75	9.75	14.00	17.50	19.75	21.75	21.50	20.75	18.25	16.00	14.50	14.50	15.00	16.25	17.25	17.75	18.25	18.75
2.50	5.75	7.25	10.25	15.00	18.75	20.75	22.50	22.75	22.00	19.75	17.50	15.75	15.75	16.50	17.75	18.50	19.00	19.50	19.75
2.25	6.25	7.75	11.25	16.00	19.75	21.50	23.50	23.75	23.25	21.25	18.75	17.25	17.25	17.75	19.00	19.75	20.25	20.50	21.00
2.00	6.75	8.25	11.75	17.00	20.75	22.25	24.50	25.00	24.25	22.50	20.25	18.75	18.75	19.25	20.25	20.75	21.25	21.50	22.00
1.75	7.25	8.50	12.00	17.25	21.25	23.00	25.50	26.00	25.50	24.00	21.50	20.25	20.25	20.75	21.50	22.00	22.25	22.50	22.75
1.50	7.50	8.75	12.00	16.75	21.00	24.00	26.25	27.25	26.75	25.50	23.50	22.25	22.00	22.50	23.00	23.50	23.75	24.00	24.25
1.25	8.00	8.75	11.50	15.75	20.50	24.75	27.25	28.25	28.00	27.00	25.75	24.75	24.50	24.75	25.25	25.75	26.00	26.00	26.25
1.00	8.00	8.50	11.00	15.00	20.50	26.00	29.25	30.50	30.25	29.25	28.25	27.25	27.00	27.25	27.50	27.75	27.75	28.00	28.00
0.75	8.00	8.25	10.50	14.75	21.25	28.00	31.25	32.25	32.25	31.50	31.00	30.25	30.00	30.00	30.25	30.25	30.25	30.50	30.50
0.50	8.00	8.00	9.75	14.00	21.75	32.25	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00
0.25	8.00	8.00	10.00	14.25	23.00	35.50	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00
0.00	8.00	8.00	10.00	14.25	24.00	37.50	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00

500 750 1000 1250 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500

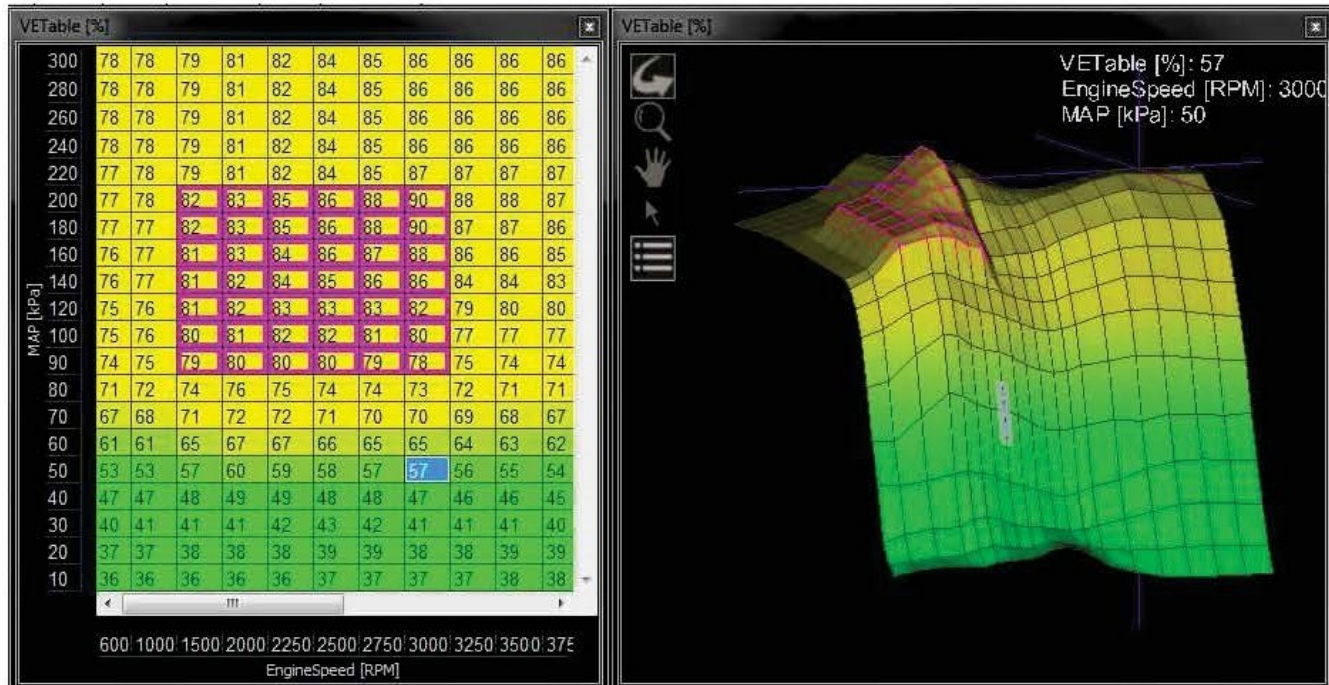
EngineSpeed [RPM]

- IGNITION TIMING FOR MASS AIR FLOW VS RPM

VOLUMETRIC EFFICIENCY TABLE

Infinity User Guide

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Right Click Editing

- VS RPM VE IS THEORETICAL PERCENT OF CYLINDER FILLING
- 0 AT CLOSED THROTTLE TO 300+ W/TURBO
- VE FOR MANIFOLD PRESSURE



ECU FUTURE

- End of era for internal combustion engine
- Electric motor control is already here
- EEG to ECU brain activity precedes motor activity. Faster reaction time
- Avatar racing.
- Autonomous race cars – VR racing
- More distributed processors. IOT for each component of car.

ECUs for Race Cars



THANK'S FOR YOUR INTEREST, AND THANK YOU IEEE FOR THIS FORUM