Hack your car for Boost and Power

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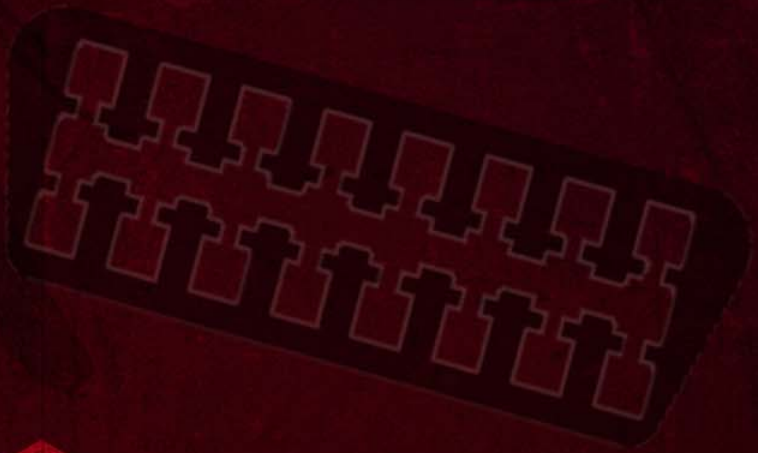
- Video clips



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Who Am I?

- ASE certified mechanic? – Nope
- CISSP – Not anymore, I spent my dues on something useful, car parts.
- I'm just a geek who loves technology, cars, and hacks
- I hacked my own car using google, Internet forums, open source software, sweat, and bloody knuckles
- Thanks to Intrepidus Group

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What is this talk NOT about…

- How to maintain your cars warranty in good standing.
- Staying “green”? Fuel economy? No way
- Installing a computer in your car to play MP3s and WoW? Nope.
- Wardriving? That’s so 2002.

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What this talk IS about…

- Owning your car, to make it *Faster*
- Introduction to modern computer controlled engine management
  - Tools for ECU programming
    - Commercial and Open source
  - Car protocols
  - The role of difference sensors for electronic fuel injection
  - Performance tuning theory

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Continued: What this talk IS about…

- What's a dyno and how to get data without one
- Analyzing logs and making changes
- Turbochargers and supercharges
- Fuel octane, ignition timing
- Removing pesky emissions equipment

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Continued: What this talk IS about…

- Computer controlled alcohol or methanol to cope with high boost and low quality fuel
- Other ECU data and privacy concerns
- ECU firmware piracy
- Bypassing RFID chips in car keys
- Car modification laws
- ODBII emissions testing

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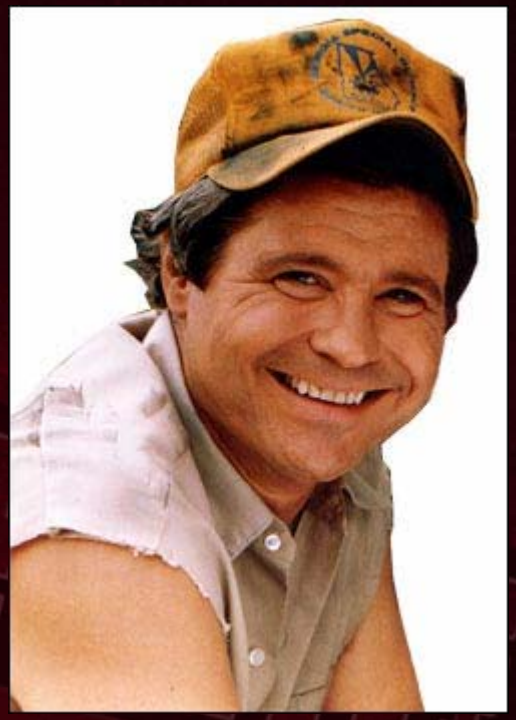
Car hackers



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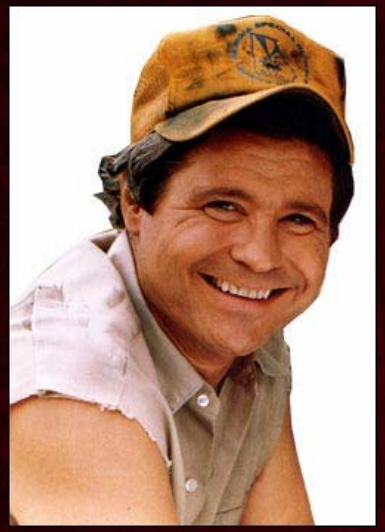
How these guys did it…



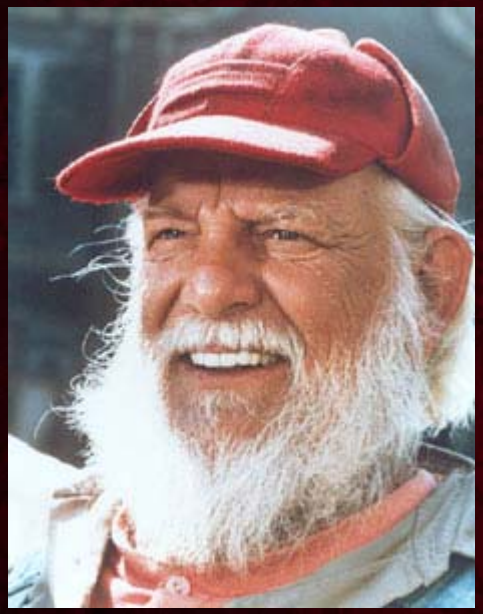
Their power making tools:

- American iron
- Carburetor
- Ignition advance
- Dirt and grime

And their secret weapon…

Uncle Jesse's moonshine…

- Yeeeeeeehaw!



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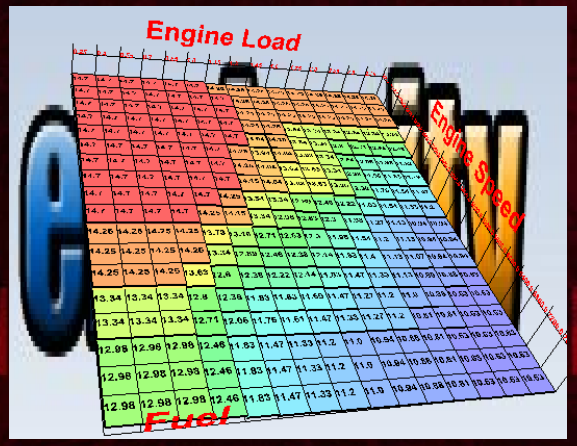
Today's car hackers…

Today's power making tools:



- ~~Carburetor~~
- Electronic Fuel Injection (EFI)
- Laptops
- ECU Re-flashing
- Less dirt on my delicate computer fingers ☺

Some things remain the same…

Then…

And now…

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Moonshine , alcohol, methanol

Dukes method…

- Pour moonshine in the general lee's gas tank.
- Result:

Today's method

*Picture from aquamist.co.uk

There’s no replacement for displacement?

454 ci 8 cylinder big block 500hp

- 7.44 liters

152 ci 4 cylinder 300hp

- 2.5 liters

Actually compressing air and fuel…

Turbo size envy…

Tools of the trade

ECU - Engine Control Unit

- The brain – just another computer
- Controls Fuel Injection
- Controls Ignition timing
- Programmable

Methods of altering the code

- Replacement ECUs
- EPROM chips
- Piggy Back ECUs
- ECU re-flashing

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Replacement ECUs

- Standalone units completely replace the factory ECU
- Upside
  - Enhanced features
  - Quick edits
- Downside
  - No ODBII
  - Costly

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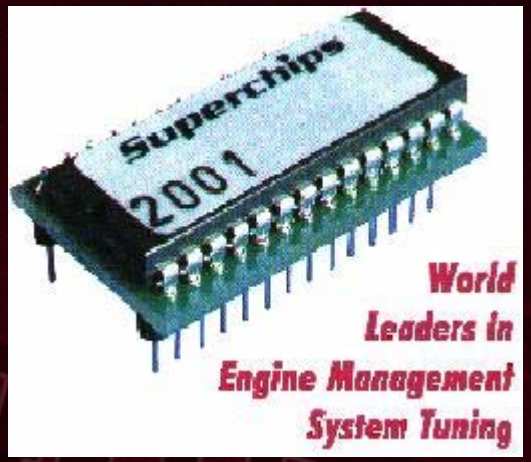
EPROM Chips

- Early “Chip” tuning was exactly that
- Upside
  - Can alter the operation of older ECUs
- Downside
  - Slower
  - Set-and-forget, soldering, etc..



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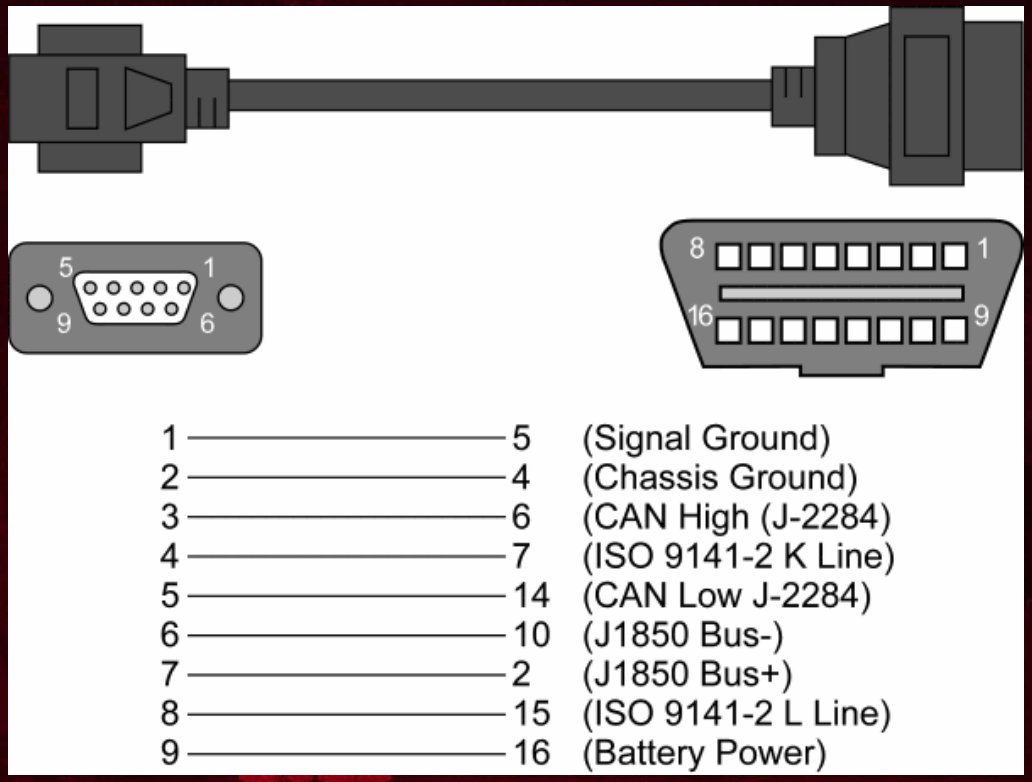
Piggy Back ECUs

- Think Man-In-The-Middle attack
- Upside
  - Fast to market
  - Extra features
  - Quick Edits
- Downside
  - Costly
  - Increased complexity

ECU Re-flashing

- Thank you ODBII
  - Every car, 1996 and up
  - Primarily for data acquisition and troubleshooting
  - Also used for "firmware" updates



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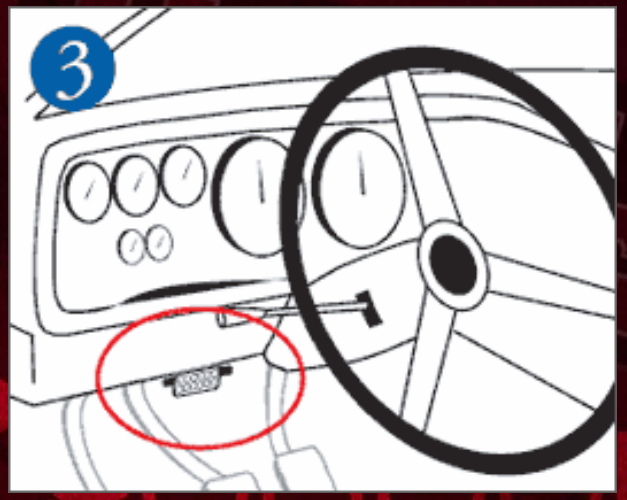
Continued: ECU Re-flashing

- The ECU is a computer loaded with software
  - ECUs occasionally have bugs
  - nhtsa.dot.gov TSBs
  - Auto manufacturers fix these with a re-flash, often times through the ODBII port



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Continued: ECU Re-flashing

- The auto manufactures don't publish their re-flashing protocols.
- They don't publish ECU code
- $$$ Big business for reverse engineers
  - Would you pay $1000 dollars for a PSP firmware update?

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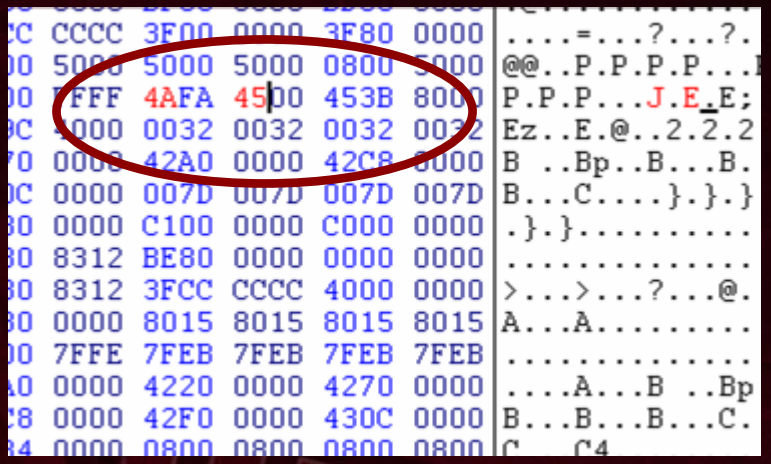
Continued: ECU Re-flashing

- Overview of how it's done
  - Step one, crack the re-flashing protocol
  - Step two download the ECU code
  - Step three map out ECU
  - Step four edit and re-flash
  - Step five pray you didn't brick your ECU

    (or do something that will blow up you car…)



- ^ Will that make your car faster?
- Or will your air bags deploy when you honk the horn?

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Continued: ECU Re-flashing

- $$$ Big Business
  - A lot of R&D is required
  - Expensive equipment
  - Anti-Piracy methods
    - Special code – DRM?
    - Hardware tokens etc..
    - Lawyers

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Continued: ECU Re-flashing

- Then: take you car to a "tuner" who licensed the software
  - They charge you for the license and tuning fees

New ECUTek Customer
ECUTek reflash / license - $650.00 + $32.50 tax = $682.50
Custom dyno tuning min. 2hours @ $200.00/hr = $400.00
Total = $1,082.50

- Now: The industry is moving to more DIY applications
  - Portable re-flashers
  - Laptop and PDA based

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Continued: ECU Re-flashing

- Portable tuners
  - Usually have preset settings or “stages”
- Increase performance
- Change shift points
- Account for larger wheels
- Security features to tie the device to only one vehicle
- Pricing $400-$1000

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Continued: ECU Re-flashing

- Laptop based tuners
  - Usually have preset settings or “stages”
  - Typically give the end user more control
- Increase performance
- Also have anti-copy features $$$

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Continued: ECU Re-flashing

- Laptop based tuners
  - More control
  - Performance “Stages”
  - Highly customizable

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Continued: ECU Re-flashing

- Open Source re-flashing
  - More on this later…

  - http://www.osecuroms.org
  - http://www.enginuity.org
  - http://www.openecu.org

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So what can you do with complete control over your ECU?

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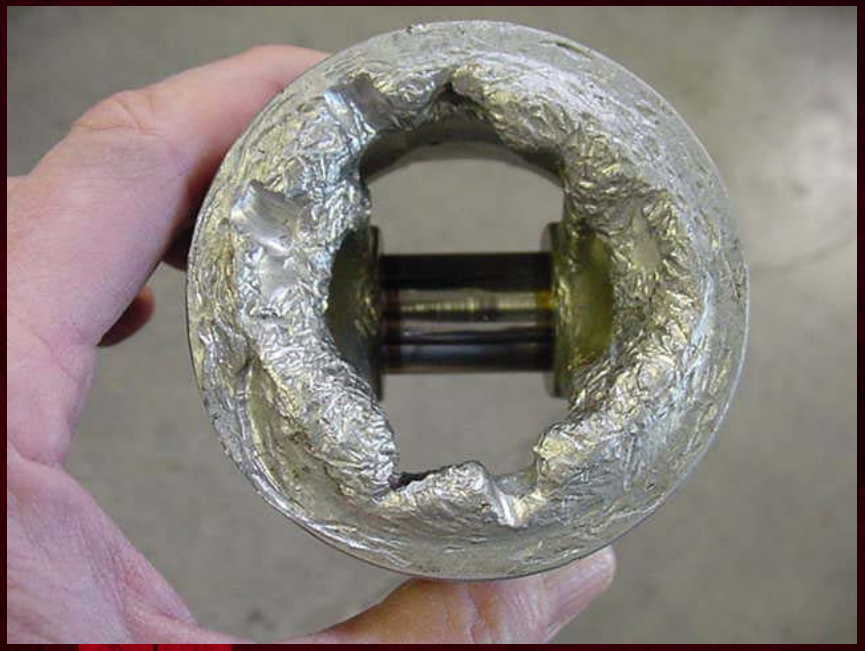
You can do a lot… of DAMAGE

Piston Before:

Piston After bad tune:



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Connecting rod before:

Connecting rod after:

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But you can also make PowAH!

Stock 2006 Corvette

- 6 liter V8
- 320 whp
- 330 ft/lbs torque
- Brochure says 400 hp
- ~23% drive train loss

- Wheel horse power
- Drive train loss
- Every dyno is different

What's a Dyno? (dynamometer)

- A tool to place load on the engine to measure power

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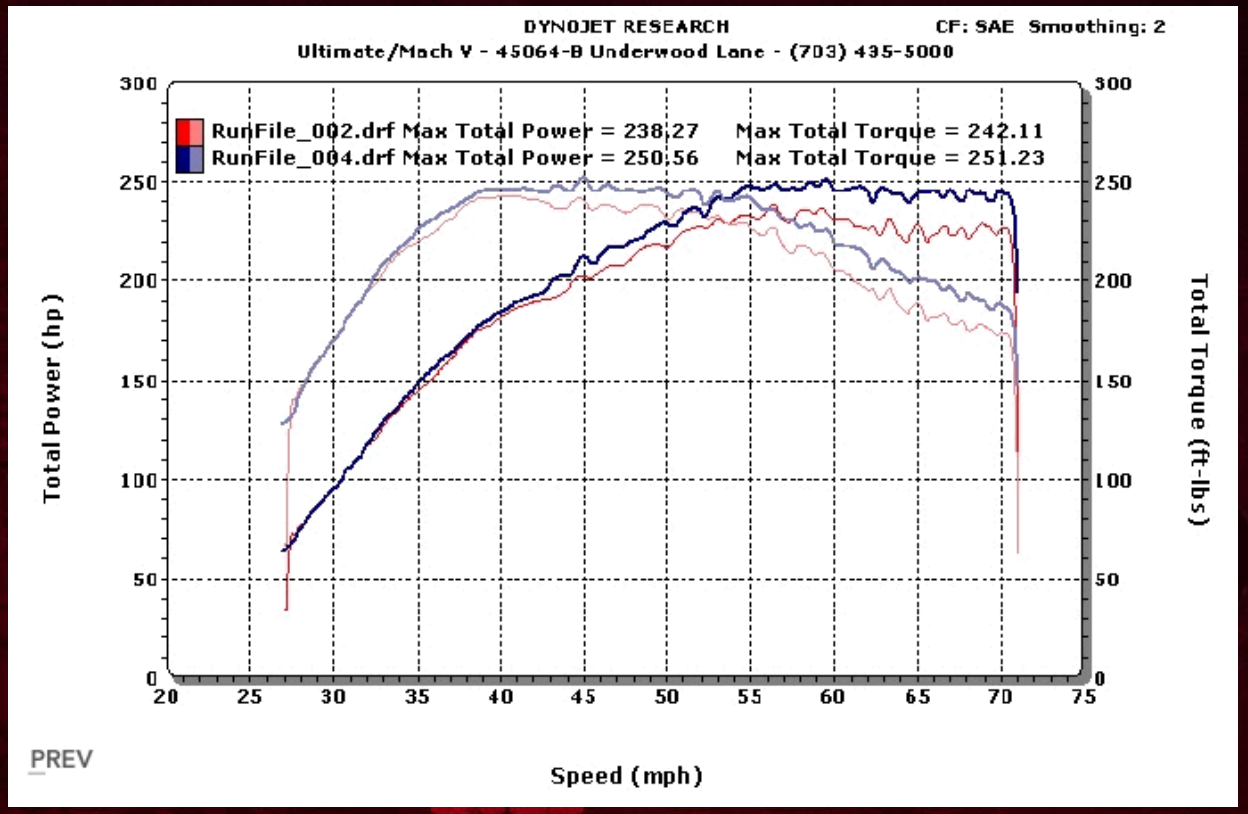
Before ECU tuning

- 2.5 liter
- 238 awhp
- 242 ft/lbs torque

- Brochure says 300 hp
- ~25% drive train loss



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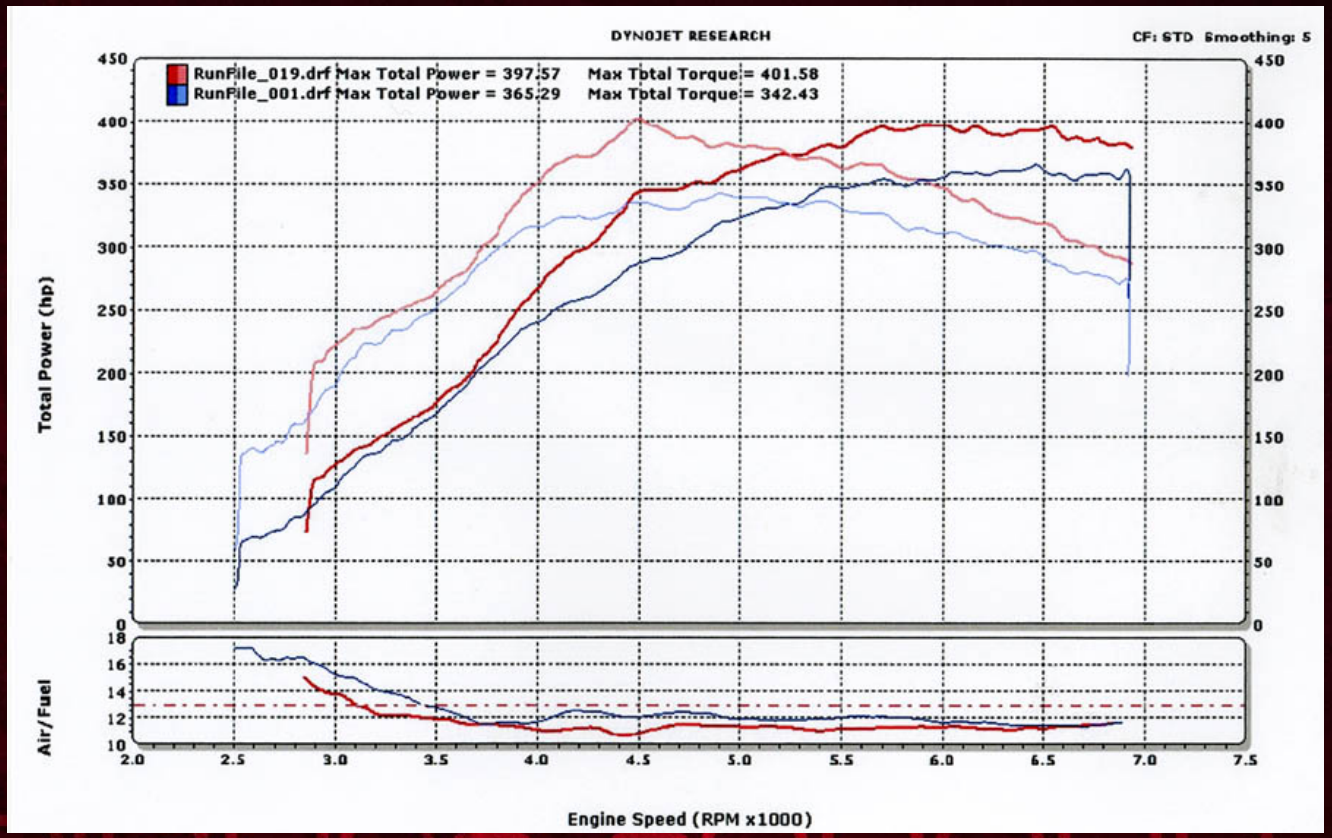
After ECU tuning

- …and some parts
- 397 awhp
- 401 ft/lbs torque
- X 25% driveline loss ==~500 hp



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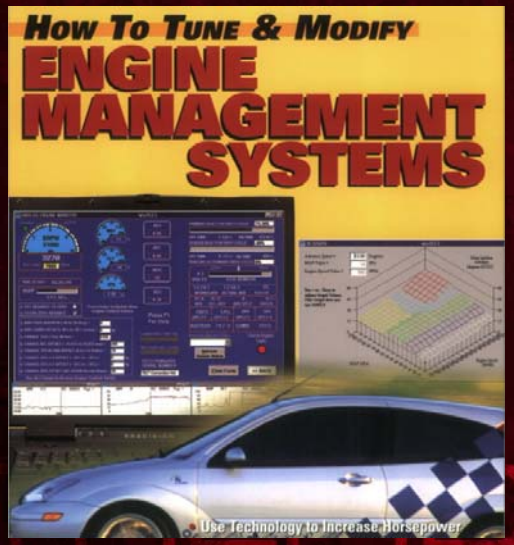
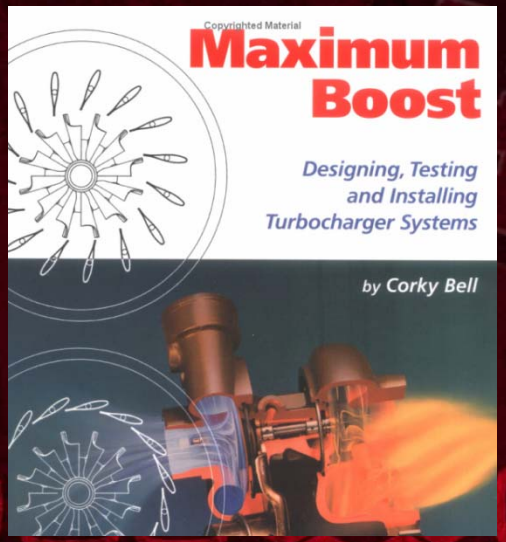
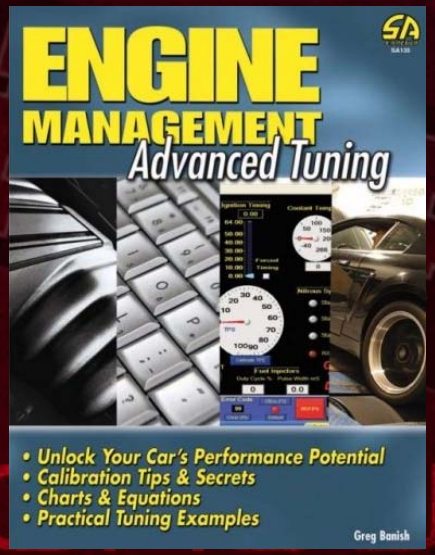
Introduction to performance tuning

- We cant be experts in 75 minutes, but we can cover the fundamentals….

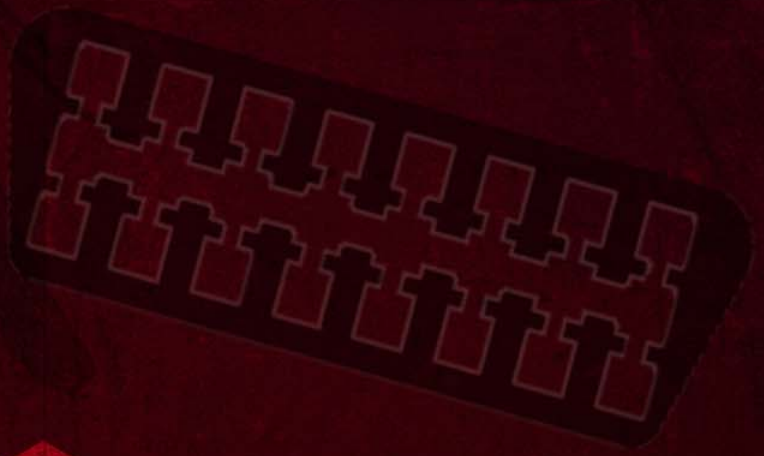






Electronic Fuel Injection

- Topics for performance tuning
  - Protocols
  - Important EFI sensors
  - **Fuel, Spark, and Air**
  - **Boost**
  - **Data Acquisition**



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EFI Performance tuning
Important sensors

- Oxygen sensors (O2 sensors)
- Mass Air Flow (MAF)
- Manifold Absolute Pressure (MAP)
- Intake Air Temperature (IAT)
- Throttle position sensor (TPS)
- Coolant temperature
- **Knock** sensor

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EFI Performance tuning: Fuel

- The ECU has to cope with different grades and quality of fuel
- It processes data from the different sensors
- Based on information it gets from MAF, MAP, and O2 sensors, it determines an injector duty cycle needed to reach a desired air fuel ratio (AFR)

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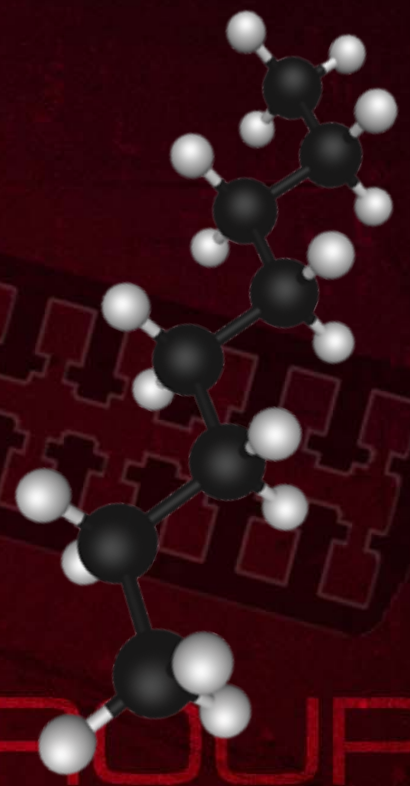
EFI Performance tuning: Fuel

- A perfectly mixed batch of fuel and air for total combustion is ~14.7 parts air to 1 part fuel
- This is called stoichiometric
  - Apologies to the lambda folks
  - 14.7:1 ARF is also known as 1 *lambda*
- Most engines makes the best power running AFRs between 12.2:1 and 12.8:1
- More on octane later…



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EFI Performance tuning: Fuel

- An air fuel mixture is ignited
- Exhaust gases are measured for oxygen
- The ECU makes adjustments to reach its programmed AFR values

Low Detonation Fuel B

Engine Load (g/rev)

Engine Speed (RPM)	0.25	0.40	0.55	0.70	0.85	1.00	1.15	1.30	1.45	1.60	1.75	2.00	2.25	2.50	2.75
800	14.70	14.70	14.70	14.70	14.70	14.70	14.25	14.25	14.25	14.25	14.25	14.25	14.25	14.25	14.25
1200	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.25	14.25	14.25	14.25	14.25	14.25	14.25	14.25
1600	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.25	14.25	14.25	14.25	14.25	14.25	14.25	14.25
2000	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.25	14.25	13.54	13.34	13.34	13.34	13.34	13.34
2400	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.04	14.15	13.54	13.34	12.80	12.71	12.54	12.46
2800	14.70	14.70	14.70	14.70	14.70	14.70	14.25	13.94	14.04	13.63	13.34	12.54	12.06	11.98	11.83
3200	14.70	14.70	14.70	14.70	14.70	14.70	14.25	14.04	13.63	13.63	13.34	12.38	11.98	11.83	11.76
3600	14.70	14.70	14.70	14.70	14.70	14.70	14.15	14.04	13.63	13.63	13.25	12.38	11.76	11.54	11.47
4000	14.70	14.70	14.70	14.70	14.70	14.25	13.54	13.34	12.89	12.46	12.22	11.83	11.54	11.33	11.20
4400	14.70	14.70	14.70	14.70	14.25	14.15	13.34	12.98	12.63	12.30	11.98	11.27	11.13	10.94	10.94
4800	14.25	14.25	14.25	14.25	13.73	13.16	12.71	12.63	12.30	11.98	11.54	11.20	11.13	10.94	10.94
5200	14.25	14.25	14.25	14.25	13.34	12.89	12.46	12.38	12.14	11.83	11.40	11.13	11.07	10.94	10.94
5600	14.25	14.25	14.25	13.63	12.80	12.38	12.22	12.14	11.83	11.47	11.33	11.13	10.88	10.88	10.63
6000	13.34	13.34	13.34	12.80	12.38	11.83	11.83	11.69	11.47	11.27	11.20	11.00	10.88	10.63	10.63
6400	13.34	13.34	13.34	12.71	12.06	11.76	11.61	11.47	11.33	11.27	11.20	10.81	10.81	10.63	10.63
6800	12.98	12.98	12.98	12.46	11.83	11.47	11.33	11.20	11.00	10.94	10.88	10.81	10.63	10.63	10.63
7200	12.98	12.98	12.98	12.46	11.83	11.47	11.33	11.20	11.00	10.94	10.88	10.81	10.63	10.63	10.63
7600	12.98	12.98	12.98	12.46	11.83	11.47	11.33	11.20	11.00	10.94	10.88	10.81	10.63	10.63	10.63

Air/Fuel Ratio

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EFI Performance tuning: Fuel

- Auto manufactures have many factors to cope with when programming the desired air fuel ratios for:
  - Safety and engine longevity
  - Fuel economy
  - Emissions control
  - Altitude and fuel octane ratings
    - Different parts of the world have different grades of fuel
    - For instance premium octane in California is only 91 octane
- Because the AFRs account for a wide variety of conditions they are not optimized for max horsepower

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EFI Performance tuning: Spark

- The right mix of fuel needs to be ignited at the right time
- TDC – Top Dead Center
  - The highest point a piston can reach
- Spark Advance
  - Adjusting the timing to fire the spark plug before TDC is reached. (while the piston is traveling up)
  - Measured in degrees
- Spark retard

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EFI Performance tuning: Spark

- Advancing timing
- Benefits:
  - Increased pressure, more powerful explosion == more power
- The drawbacks:
  - Too much advance:
    - No additional power
    - Too much cylinder pressure
    - More prone to pre-ignition
    - AKA detonation, aka knock
- Remember this picture:

Continued on next page…

EFI Performance tuning: Air

- We will talk about knock more later
- Measuring air is necessary to calculate the correct fuel mix
  - Increased pressure, more powerful explosion == more power
- Measuring air and manifold pressure also helps the ECU figure out how much load it's under

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EFI Performance tuning: Air

- Superchargers and Turbochargers
  - Create “boost”
  - Increase cylinder pressure
  - Increase heat
- Boost is a volume knob
  - Huge Garrett GT4202 →
  - 800+ whp

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EFI Performance tuning: Air

- More boost More problems
  - Boost pressurizes more air in the cylinders. The ECU needs to toss more fuel into the mixture.
  - Fuel injectors, fuel pumps, and motors all have physical limitations
- More vigilant maintenance
  - Most car owners aren't responsible enough to care for boosted motors

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EFI Performance tuning: KNOCK

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EFI Performance tuning: KNOCK

- More boost More problems…
- Knock is when the air fuel mixture ignites without the ECU firing the spark plug
  - Knock occurs when temperature and cylinder pressures are too high causing the mix to ignite without spark
  - AKA “ping” “detonation”

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EFI Performance tuning: KNOCK

- Your motors is a precise orchestra of explosions turning a crankshaft
- Imagine what happens when one of these cylinders fires out of sequence

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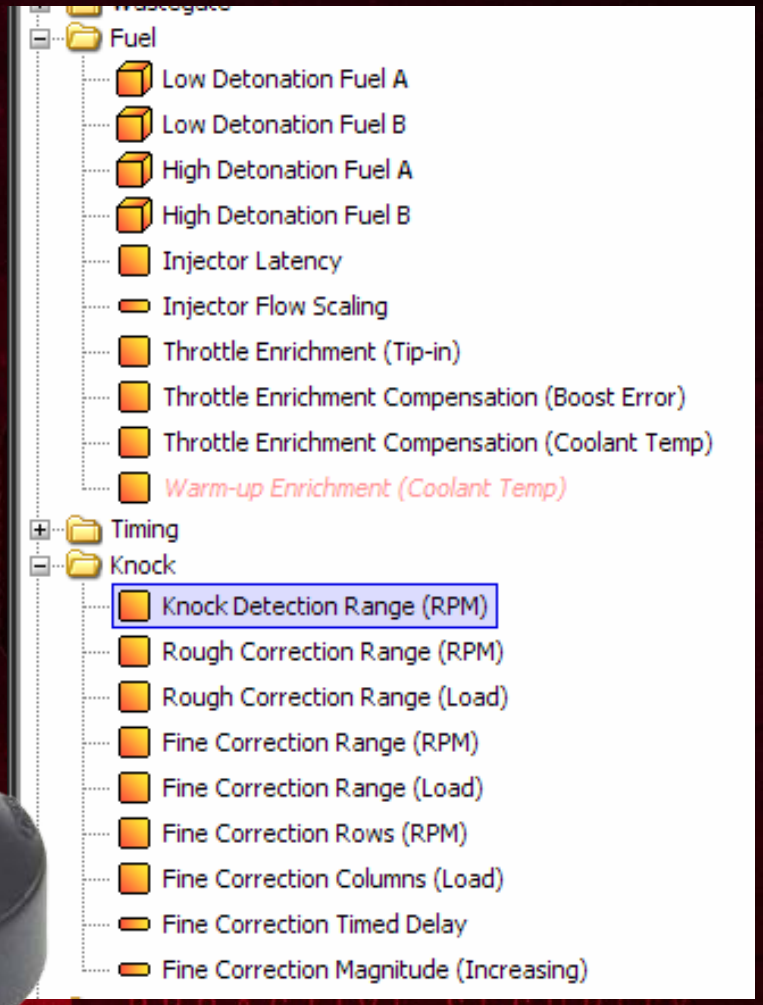
EFI Performance tuning: KNOCK

- An ECU listens to knock sensors attached to the engine
- If it detects knock, it will switch to different settings
  - Ex. Richer fuel, less timing advance



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EFI Performance tuning: KNOCK

- Because auto manufactures play it safe, the ECU can be remapped to make more power
  - Especially if you help the engine in other ways ward off knock
- This also helps take full advantage of aftermarket parts because factory ECU parts will only up the performance to a certain point
  - Ex. A larger exhaust

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Downloading and Re-flashing

- Protocols
  - CANOBD2
  - ODB-II
  - ISO9141-2 K Line
  - ISO9141-2 L Line
  - VW/Audi CAN BUS ISO 11898/11519
  - Subaru Select Monitor (SSM)

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Re-flashing: Hardware

- This is a USB to ODBII cable from tactrix.com
- What is it?

"The OpenPort 1.3U is an USB device that interfaces between your PC and car engine computers (ECUs) that use a ISO 9141-2 compatible OBDII interface. It also contains special hardware and connectors to allow it reprogram (reflash) most modern (1996+) Mitsubishi ECUs and 2002+ Subaru ECUs. "

- "What cars use ISO 9141-2?

Most all post-1996 Chrysler, European, and Asian vehicles."

Cost: ~$90

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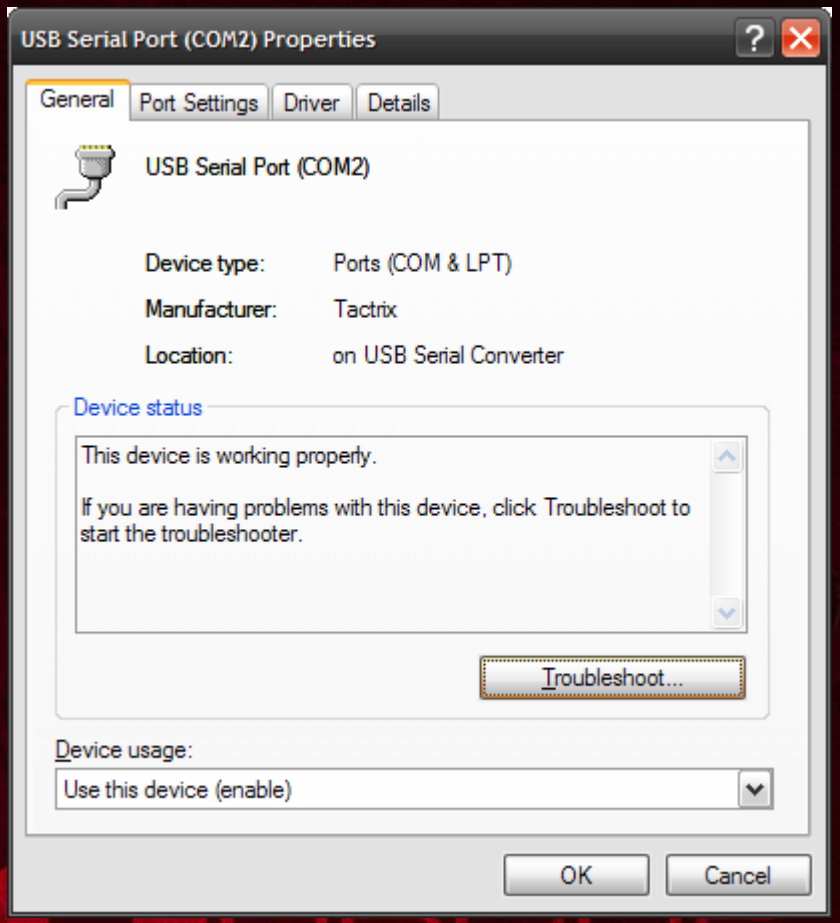
Re-flashing: Hardware

- It has been used in Windows, Linux, OSX
- The openport cable is recognized as a serial COM port similar to a USB -> Serial adapter
- OpenECU.org's ECUFlash comes with a driver



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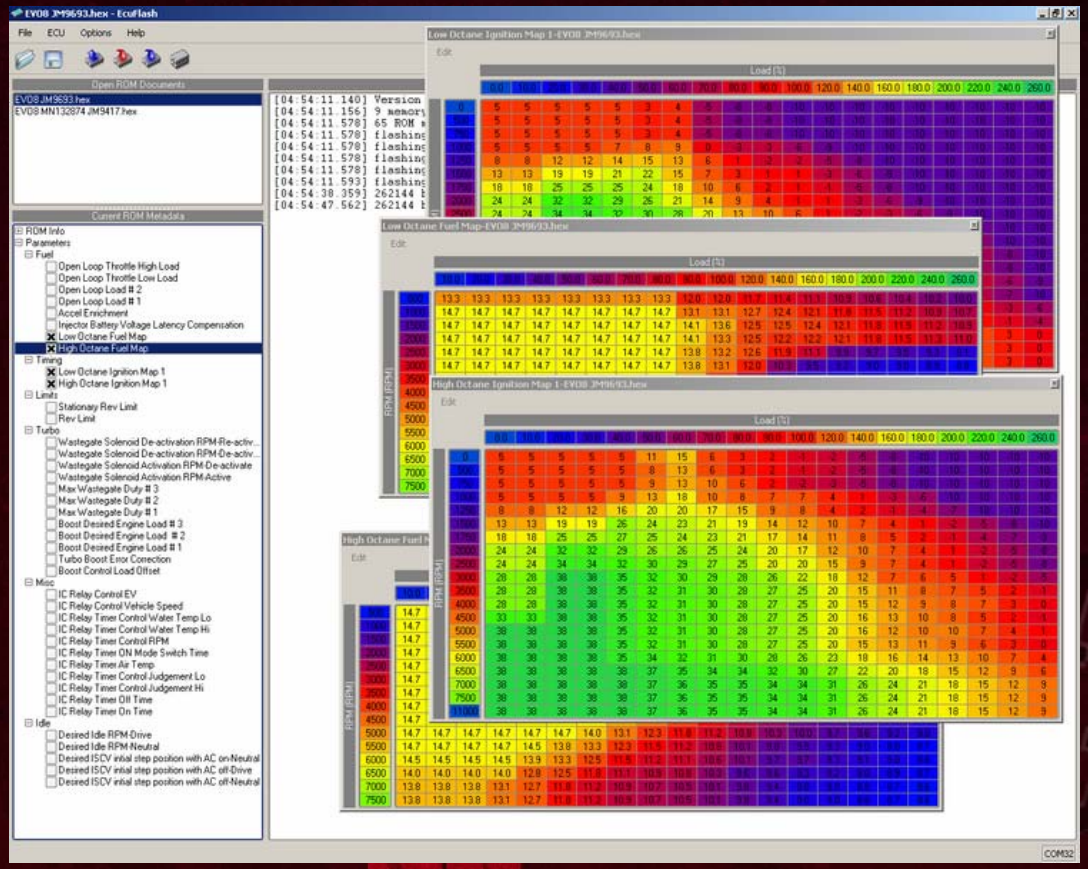
Re-flashing: Software

- ECUflash from open ECU.org



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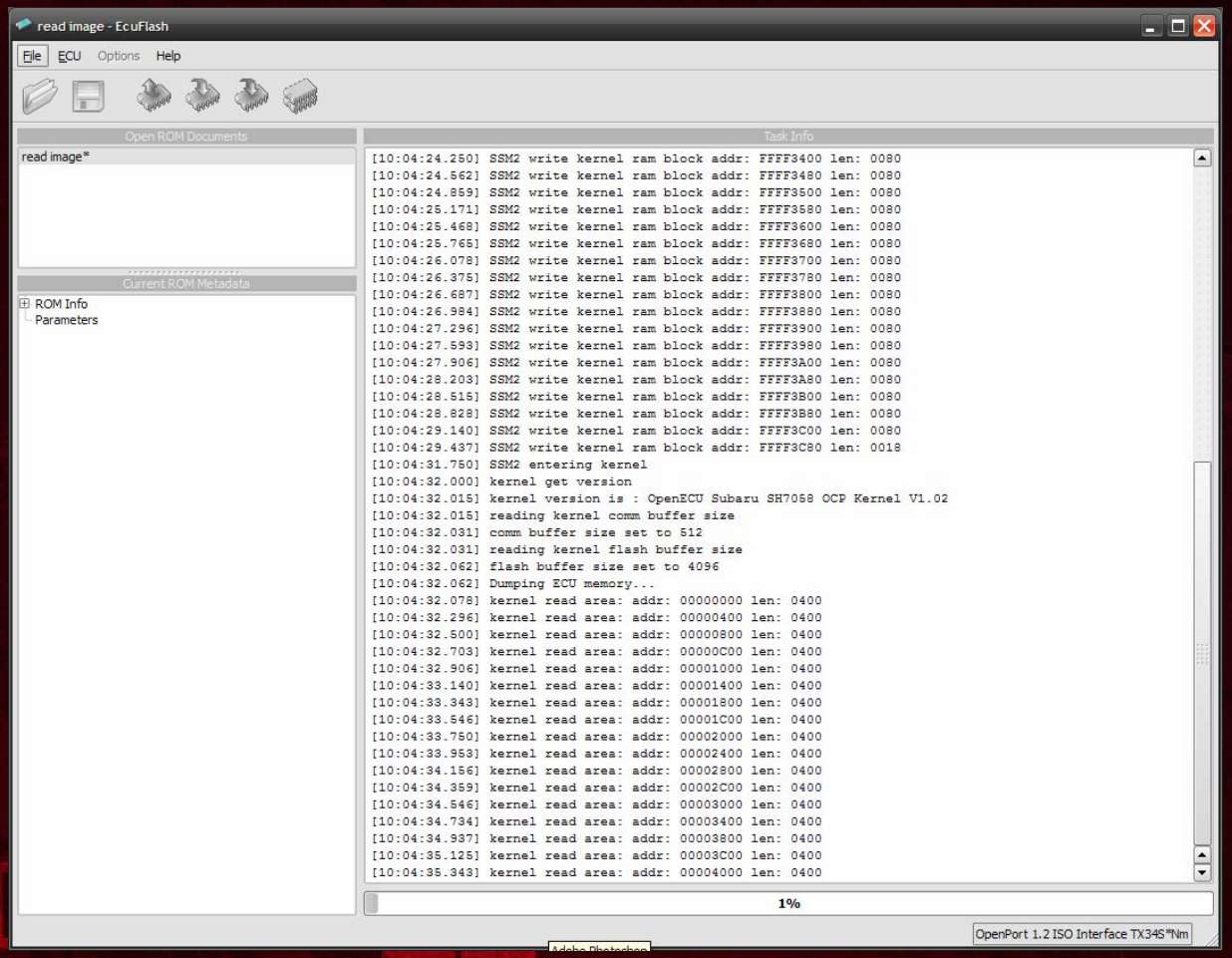
Re-flashing: Software

- Connect the openport cable
- Connect the re-flash jumper cable
- Turn ignition to ON
- Takes 3-4 minutes



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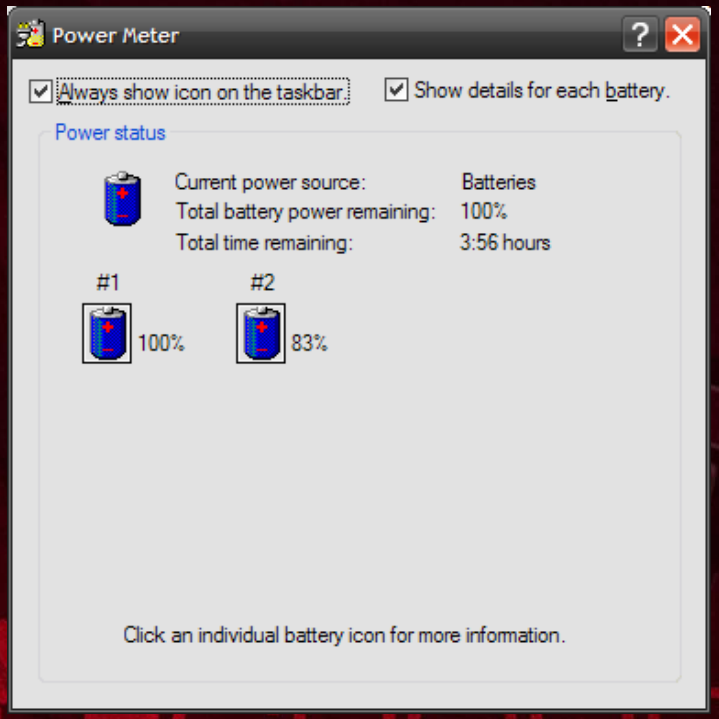
Re-flashing: Software

- Some helpful tips
  - Secure the openport cable
- Make sure your laptop has a full charge
  - (better to just plug it in)
- Sit still during the re-flash ☺



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Data logging …

RPM	MAP psia	MAF V	TPS %	Load Site	Knock Count	Mod AFR	Mod Ign#1 deg	Mod Inj#1 duty	Mod Ign deg	WB AFR	Fuel (CL) %	Boost	MAF V	AFR
3013	+5.1	3.1	104	30	00	13.3	+32.6	22.3	+21.7	-2.4	230.00	2.9	13.78	
3129	+6.4	3.2	104	30	00	12.2	+31.4	24.7	+20.2	-2.4	230.00	3.0	12.61	
3220	+8.2	3.3	104	40	00	12.0	+31.5	26.9	+18.9	-2.4	230.00	3.1	11.62	
3418	+9.6	3.4	104	50	00	rich	+29.7	29.7	+18.1	-2.2	230.00	3.2	11.55	
3599	+11.5	3.5	104	50	00	rich	+28.2	33.0	+17.6	-1.6	230.00	3.4	10.93	
3741	+13.7	3.6	104	60	00	rich	+25.3	40.3	+16.0	-2.2	230.00	3.6	10.93	
3916	+16.8	3.9	104	80	00	rich	+22.1	47.5	+16.7	-2.2	230.00	3.7	10.84	
4105	+19.8	4.0	104	90	00	rich	+17.4	59.7	+17.2	-1.4	230.00	4.0	10.86	
4312	+21.2	4.0	104	100	00	rich	+17.8	58.2	+18.3	-1.8	230.00	4.0	10.76	
4623	+22.1	4.1	104	100	00	rich	+20.1	63.1	+19.1	-3.0	230.00	3.9	10.81	
4823	+22.5	4.2	104	100	00	rich	+23.2	65.5	+19.5	-3.4	230.00	4.0	10.70	
5159	+21.5	4.3	104	100	00	rich	+21.7	71.[illegible]	[illegible]	[illegible]3	230.00	4.0	10.74	
5376	+21.7	4.4	104	100	00	rich	+21.5	74.[illegible]	[illegible]	[illegible]	[illegible]	4.1	10.82	
5500	+21.7	4.4	103	100	00	rich	+21.5	78.[illegible]	[illegible]	[illegible]	[illegible]	4.1	10.86	
5737	+21.7	4.4	104	100	00	rich	+21.8	80.[illegible]	[illegible]	[illegible]	[illegible]	4.1	10.78	
5878	+21.7	4.5	104	100	00	rich	+23.4	79.[illegible]	[illegible]	[illegible]	[illegible]	4.2	10.78	
6161	+21.7	4.5	104	100	00	rich	+24.9	80.[illegible]	[illegible]	[illegible]	[illegible]	4.2	10.87	
6385	+21.5	4.5	103	100	00	rich	+26.0	81.[illegible]	[illegible]	[illegible]	[illegible]	4.2	10.93	

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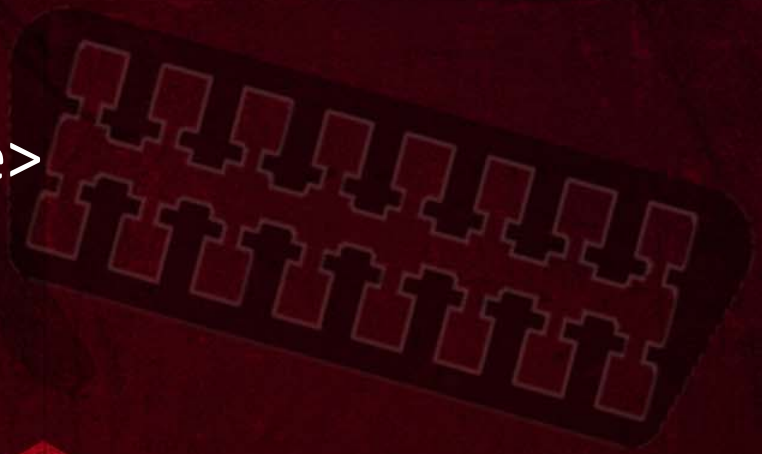
Data logging: Creating your own dyno

- Long straight road
- Low RPM
- Mash the pedal to redline

<Video clip here>



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Data logging: Creating your own dyno

- You may want to purchase an Intrusion Detection System for your simulated dyno road pulls ☺

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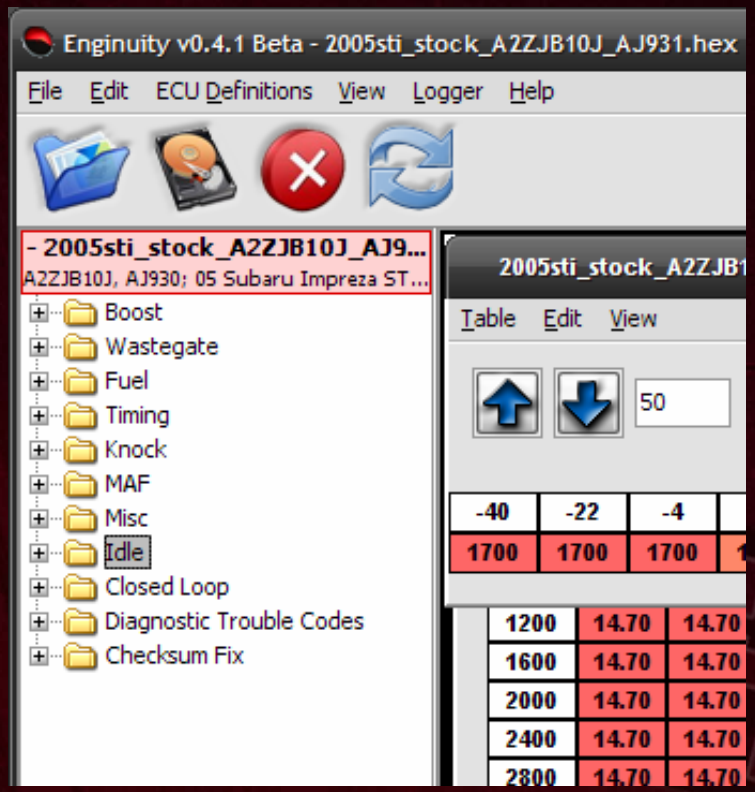
Re-flashing: ECU Editing Software

- Enginuity - Open Source ECU Tuning
- http://www.enginuity.org
  - Datalogging and ROM editor



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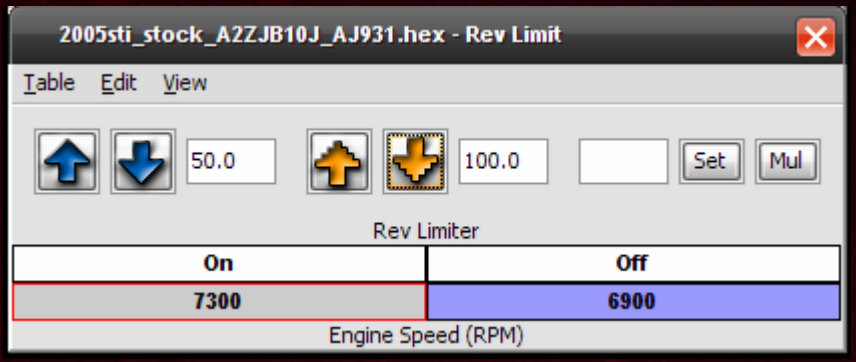
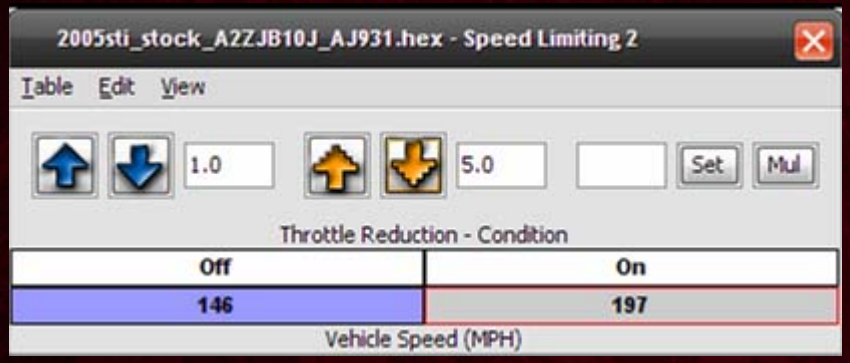
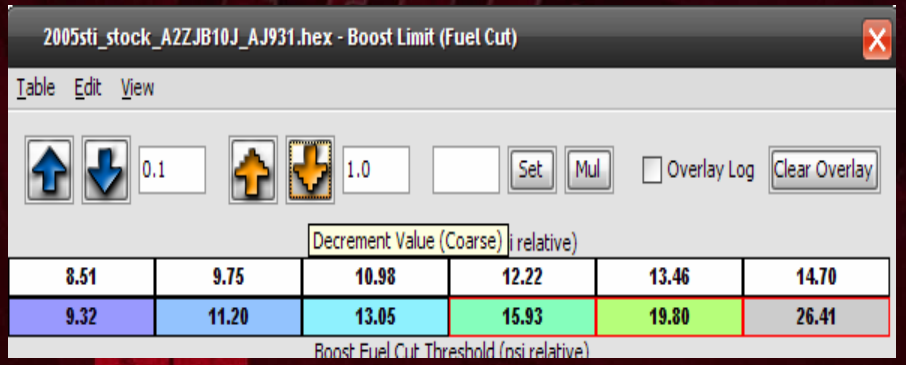
Re-flashing: ECU Editing Software

- Besides fuel, spark, and boost, what else?







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Re-flashing: ECU Editing Software

- Besides fuel, spark, and boost, what else can you do?

"The CAA also required that vehicle emissions inspection programs around the country begin inspection of the OBDII system. For several years, DEQ has been preparing to implement an OBDII inspection procedure. Effective July 1, 2005, the new OBDII inspection procedure became the official inspection process for most 1996 and newer motor vehicles."

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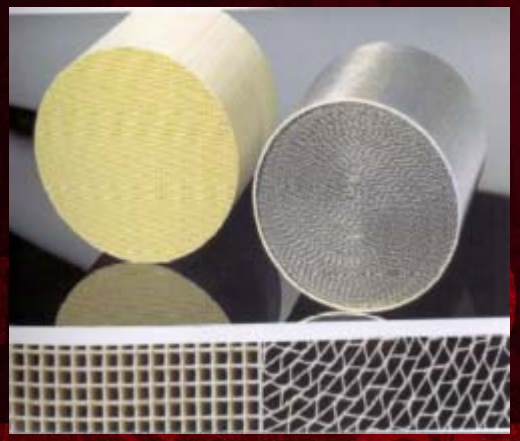
Re-flashing: ECU Editing Software

- Removing catalytic converters for “off-road use only”
- Some emissions equipment limits full power potential



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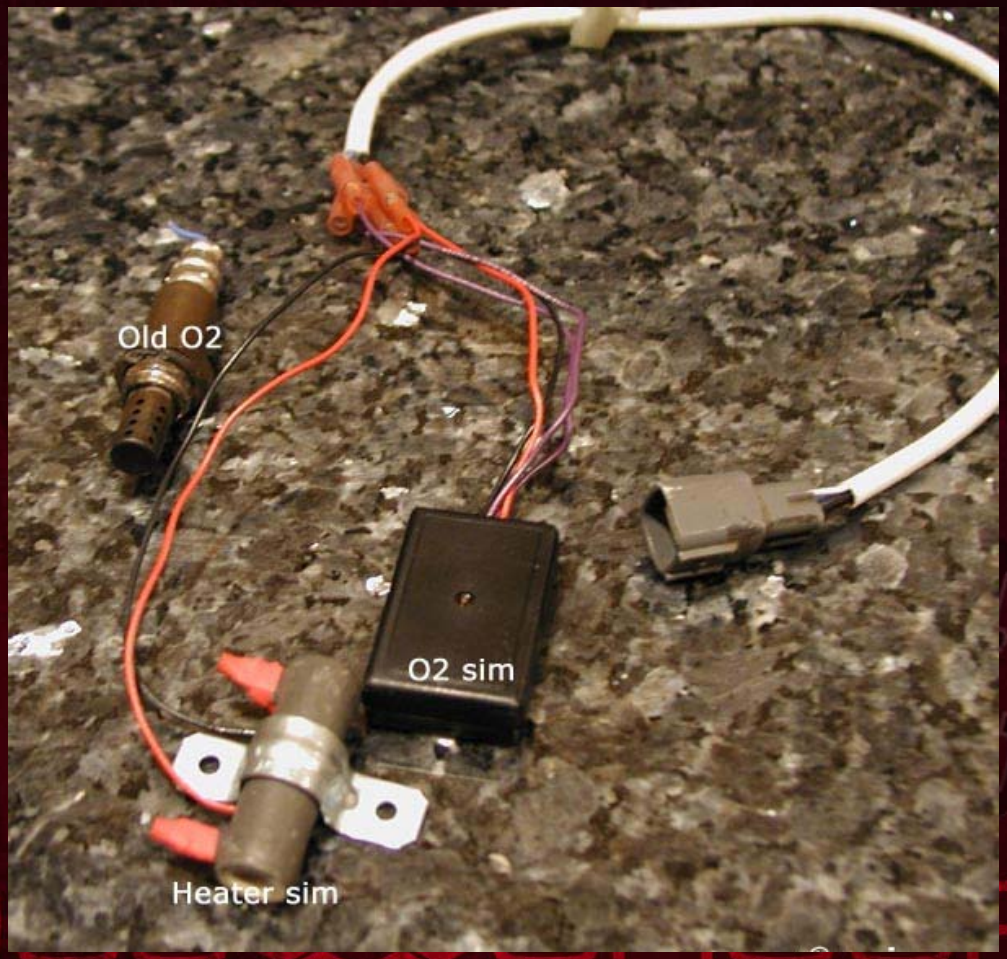
Re-flashing: ECU Editing Software

- Before ECU edits



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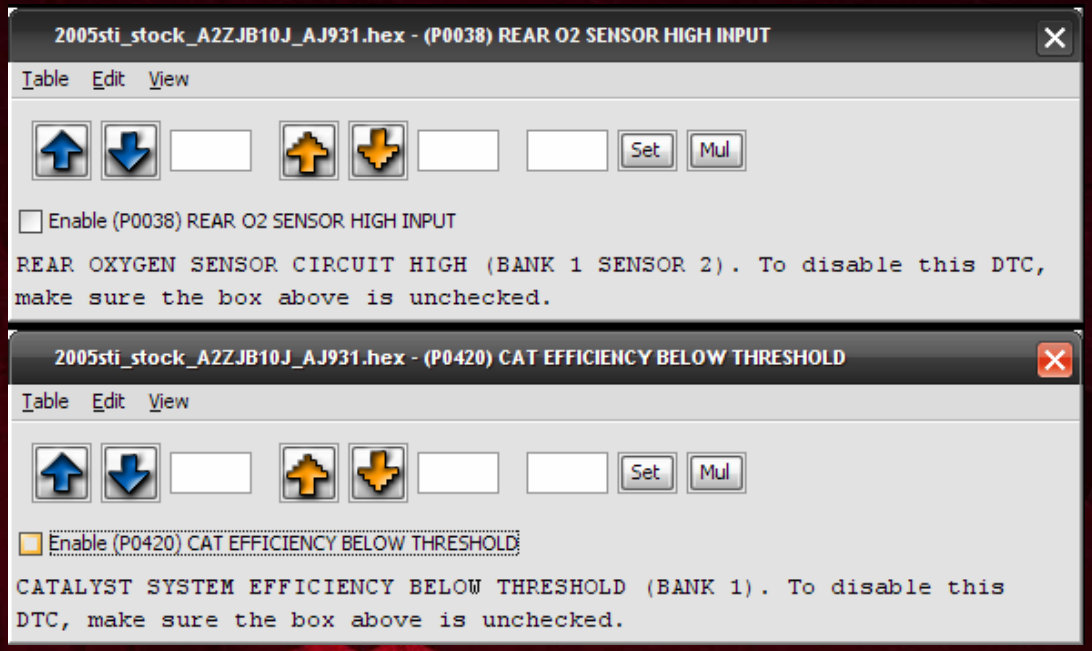
Re-flashing: ECU Editing Software

- With ECU edits, it's a two click effort

- Does this work?

"I passed with the external dump tube, they didn't even do a visual....Just plugged it into the OBD II and passed the car within 5 minutes."



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Re-flashing: ECU Re-Flash Software

- Remember these things?
- $400-$1000 ?
- Companies spend thousands on research and equipment

Continued on next page…

Re-flashing: ECU Re-Flash Software

- Free open source tools can download and re-flash?
- (It turns out we are not the only ones thinking about this…)

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Re-flashing: ECU Re-Flash Software

- Here is one of the first posts to the openecu.org forums:
- (This was also sent as a private message to several forum members)

David-EcuTeK writes:

EcuTeK LLP wishes it to be known that it owns copyright in EcuTeK software and its supporting documents and that it will act to protect these rights.

If you are concerned that you might have infringed our copyright or other intellectual property rights, or that you might do so in the future, we would be happy to discuss ways that a reasonable and amicable solution might be found.

David Power

**********EcuTeK
7 Union Buildings
Wallingford Road
…
<snip>

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Knock is the power limiter

- Dealing with knock
- Remember this?

Octane and other tricks for coping with knock…

Continued on next page…

Fixing knock with octane

- Octane and other tricks for coping with knock
  - Reduce cylinder temperatures
    - A richer AFR can cool the cylinder charge
    - Cool boosted air
      - Intercoolers
  - Decrease cylinder pressure
    - Less ignition advance
  - Increase fuel octane

A direct quote from Stone (p. 80): "The attraction of high octane fuels is that they enable high compression ratios to be used. Higher compression ratios give increased power output and improved economy [assuming the same power of engine] ... The octane number requirements for a given compression ratio vary widely, but typically a compression ratio of 7.5 requires 85 octane fuel, while a compression ratio of 10.0 requires 100 octane fuel.

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Fixing knock with octane

- This is why most re-flashed cars and trucks require premium grade fuels
- The higher compression ratio is also why turbocharged and supercharged motors require premium octane
  - Higher octane fuels lets you get away with running more boost and more ignition advance making more power

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Super Duper Hi-Tech stuff

- What if you live in one of unfortunate states that passes off 91 octane as premium fuel?
- Mix in some E85
  - 100 octane
- Water injection
  - WWII Fighter planes
  - Cools combustion
  - 50/50 Methanol H20

Continued on next page…

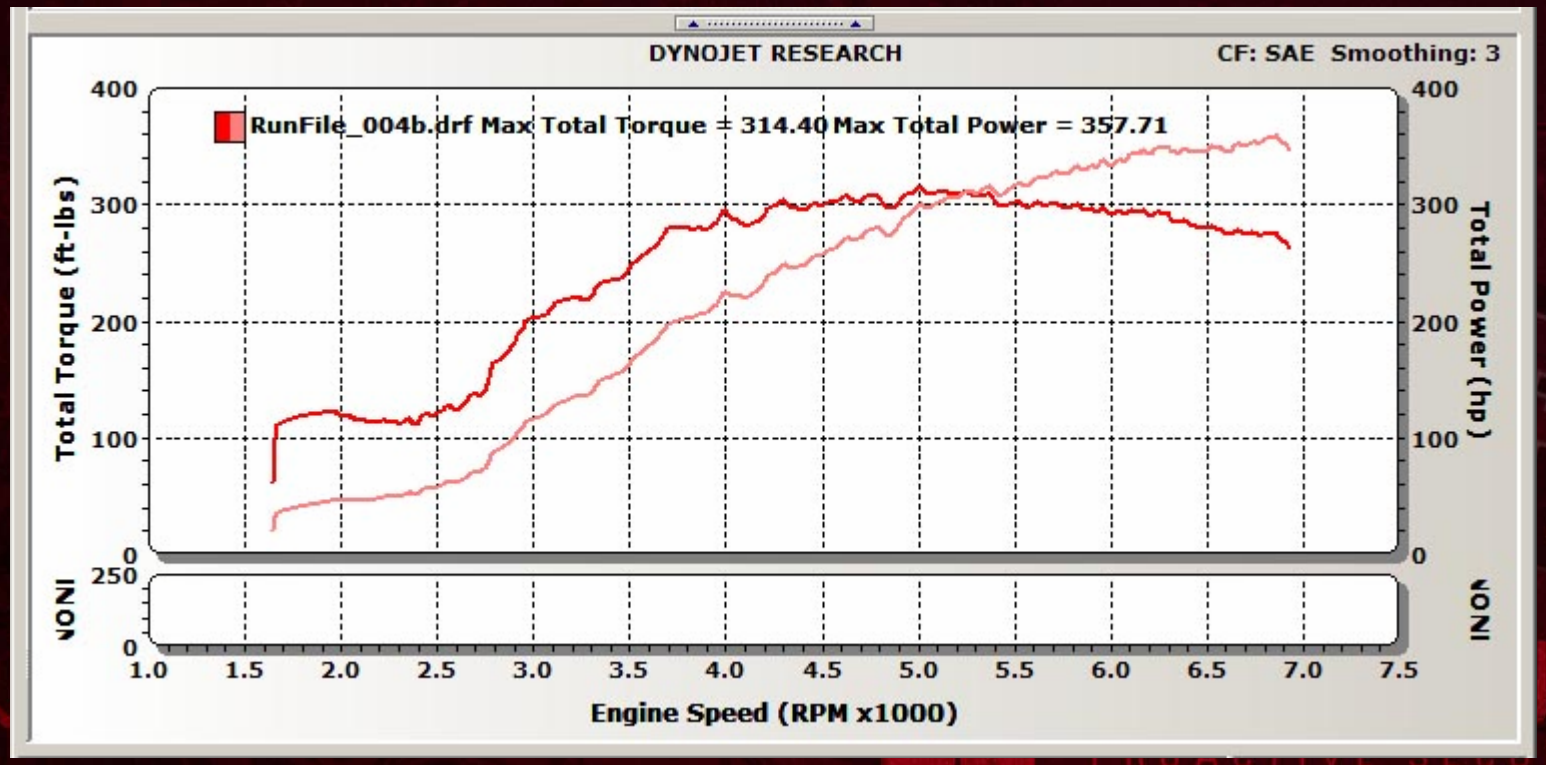
Super Duper Hi-Tech stuff

- The advantage of modern electronics is that precise amounts can be injected at optimal times

Continued on next page…

Super Duper Hi-Tech stuff

- Results… Before 50/50 methanol injection…
- Knocking past 21psi of boost (1.45 BAR)



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Super Duper Hi-Tech stuff

- Results…
- After 50/50 methanol injection…
  - Can run 25psi of boost (1.72 BAR)
  - Increase of +40whp (11%) +87ft/lbs (28%)
- http://coolingmist.com/
- http://www.alcohol-injection.com/
- http://www.snowperformance.net/
- http://www.aquamist.co.uk/

Stealing high end cars with re-flashes or standalone ECUs?

- Car RFID Security System Cracked
  - "The NY Times reports that the security chip in new auto keys has been cracked."
- "The dealership told her it will cost another $1000 labor to remove her car's computer, send it to Lexus' computer repair center to have it programmed for the new key, and then re-install it."

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Is your car spying on you?

- Motor Vehicle Event Data Recorders
- It's supposed to help analyze crash data
- "*AutoWeek* reported that OnStar collects data on near-collisions and collisions and retains this data for as long as 18 months."
- *Under the Hood, with Big Brother*: http://www.autoweek.com/apps/pbcs.dll/article?AID=/20041108/FREE/411080714

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Some final thoughts

- The green movement
- Fuel economy legislation
  - Don't forget about those of us who enjoy driving
- The ECU will play a big role in enforcing fuel economy
- How about a law that forces everybody to drive 40 MPH to conserve fuel?

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Questions?

- Thanks and Greetz:

ride5000 nhluhr hotrod hippy Slorice
TheMadScientist mick_the_ginge Freon
Cdvma Jon [in CT] cboles Tgui crazymike TurbojonLS
Wolfplayer Richard L x cntrk75 HighWayDrifter
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