FTF | FREESCALE TECHNOLOGY FORUM
POWERING INNOVATION

An Open Source, Off-the-Shelf Powertrain Reference Design

FTF-AUT-F0018

Mike Garrard
Freescale Powertrain Systems
Bill Lucas for Bruce Bowling, Megasquirt
Al Grippo, Megasquirt
Phil Tobin, EFI Analytics

June 2012

Introduction

This session will introduce the Megasquirt Qorivva Engine Control Unit (ECU)

This session is for you if you are involved in powertrain controls and want to know more about and/or have access to the design materials used to create the ECU, including

- Hardware design: schematics, Bill of Materials
- Software: low level drivers and application code
- Tools: software, debug and calibration

This ECU has been developed by Freescale in conjunction with Megasquirt and EFI Analytics. You will meet:

- Mike Garrard: Senior Powertrain Systems Engineer, Freescale
- Al Grippo: Co-Owner and designers of Megasquirt products
- Bill Lucas: Megasquirt design engineer
- Phil Tobin: Author of Tuner Studio Calibration Application

Session Objectives

After completing this session you will know:

- The origin, purpose and capability of a Megasquirt Qorivva ECU
- Where to access existing material
- What tools make up the development environment and how to obtain them
- The plans for open source code and further ECU release

Agenda

- Background and motivation
- Freescale in powertrain
- Megasquirt overview and products
- MSQorivva hardware description
- Software structure
- Calibration tool
- Online resources
- Work products and timelines
- Summary and Q&A

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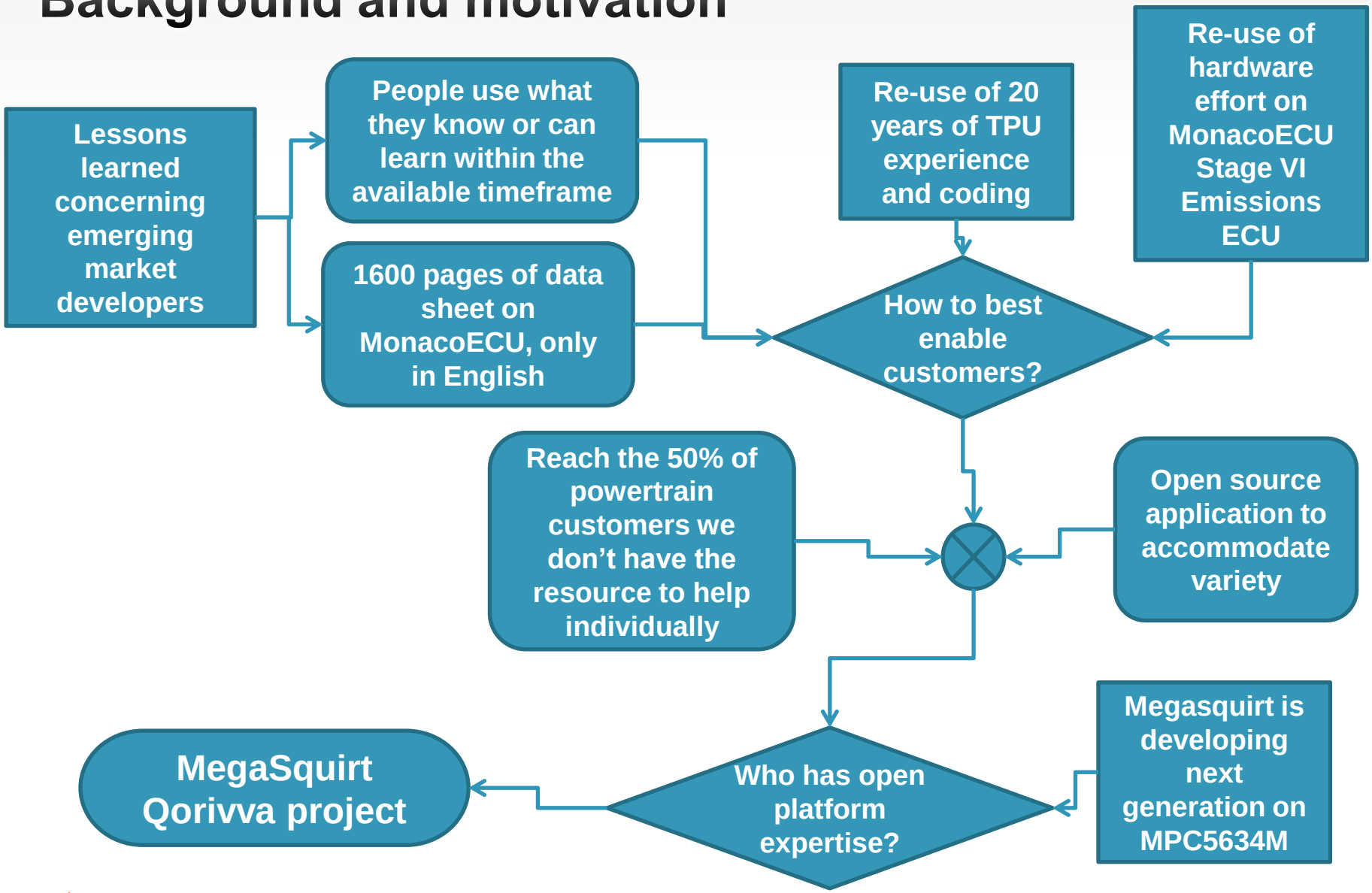
Background and motivation



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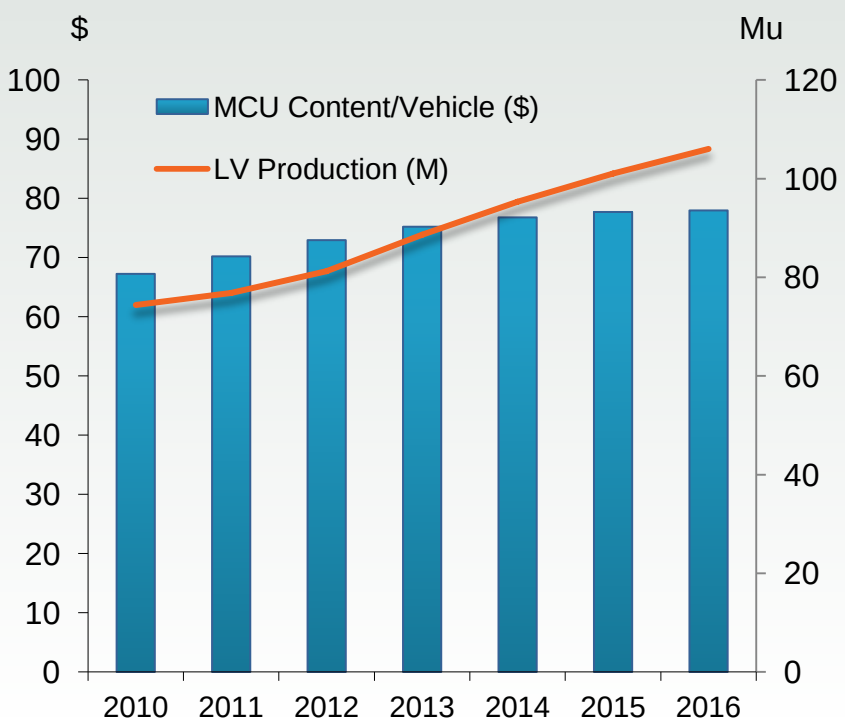
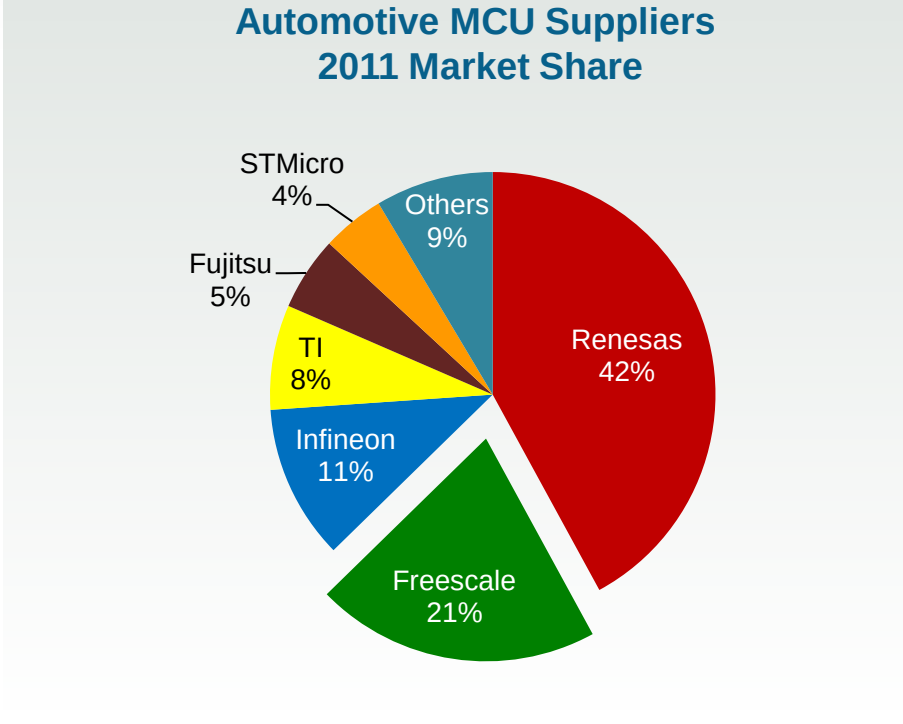
Automotive Microcontroller Share



Source: Strategy Analytics, January 2012



Source: IHS iSuppli, March 2012

Freescale Shipped **360M** auto MCUs (> 4/car) in ’11

We are in **Approx 50 million** new vehicles / year

freescale™

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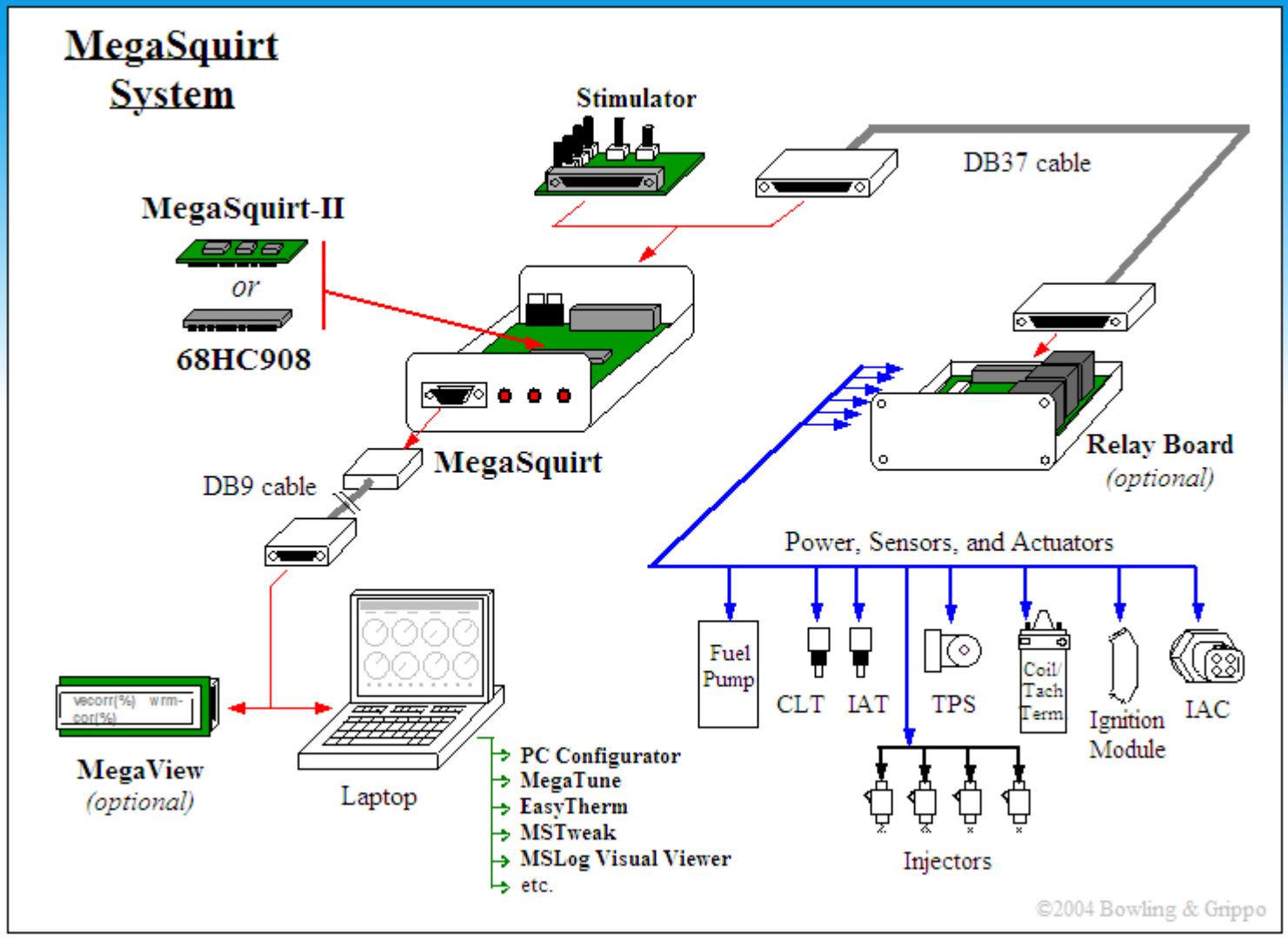
Do-it-Yourself Engine Controls

- MegaSquirt was created in 2001 as a simple aftermarket fuel injection controller for internal-combustion engines
- Project details were first published in Circuit Cellar Magazine in January 2002 as a do-it-yourself fuel controller
- MegaSquirt has evolved into a fully-featured engine management system, controlling fuel delivery requirements, ignition control, and auxiliary function management (boost, nitrous, traction, etc)
- Megasquirt successfully controls thousands of internal combustion engines worldwide, from chainsaws to land-speed record vehicles!

MegaSquirt

- Many different versions of MegaSquirt hardware exist today, each addressing different engine applications:
  - Do-it-yourself assembly kits and modules (MS1/MS2/MS3)
  - Plug-and-Play OEM-replacement ECUs (MS-PnP)
  - Small-engine ECUs (MicroSquirt)
  - Aftermarket High-end Engine Management Systems (EMS)
  - Spin-off hardware for transmission and data acquisition (MS-GPIO)
- Source code availability to end-users presents opportunity for custom modifications and functional additions (MS-Extra)

MegaSquirt DIY: System Block Diagram



MegaSquirt – Hardware Processor Evolution

- MegaSquirt has evolved in processor technology use over the years, improving performance with each step:
  - MS1 – MC68HC08GP32 8-bit microcontroller
  - MS2 – MC9S12C128 16-bit microcontroller
  - MS3 – MC9S12XEP100 16-bit microcontroller + XGATE
- MS-Qorivva is the next step in CPU performance and capability, providing the following enhancements:
  - E200z3 Power Architecture 32-bit CPU core
  - 1.5MB flash, 94KB RAM
  - eTPU2 for engine crankshaft position tracking and real-time hardware-based fuel and ignition events
  - DMA - performs peripheral data movement without CPU intervention

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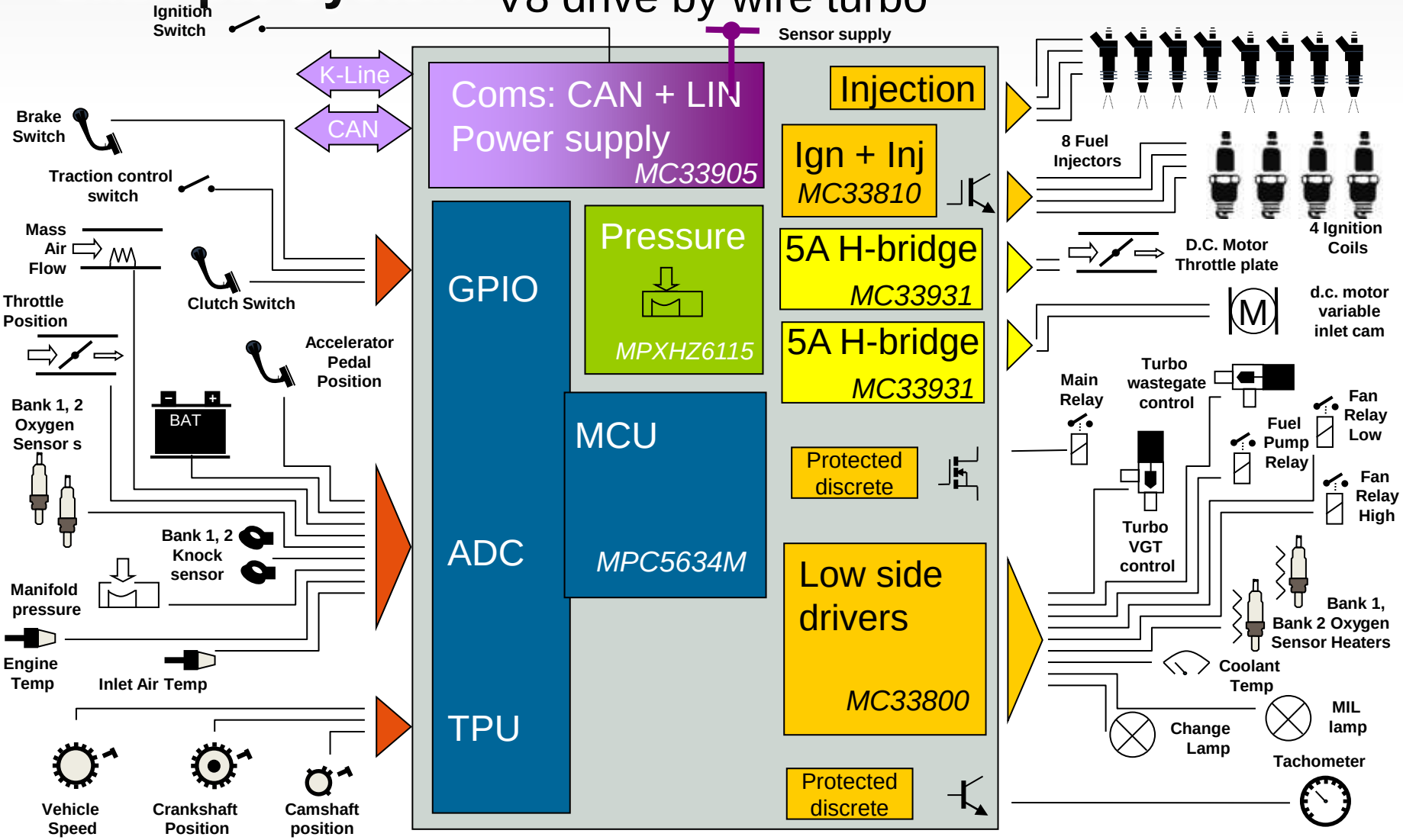
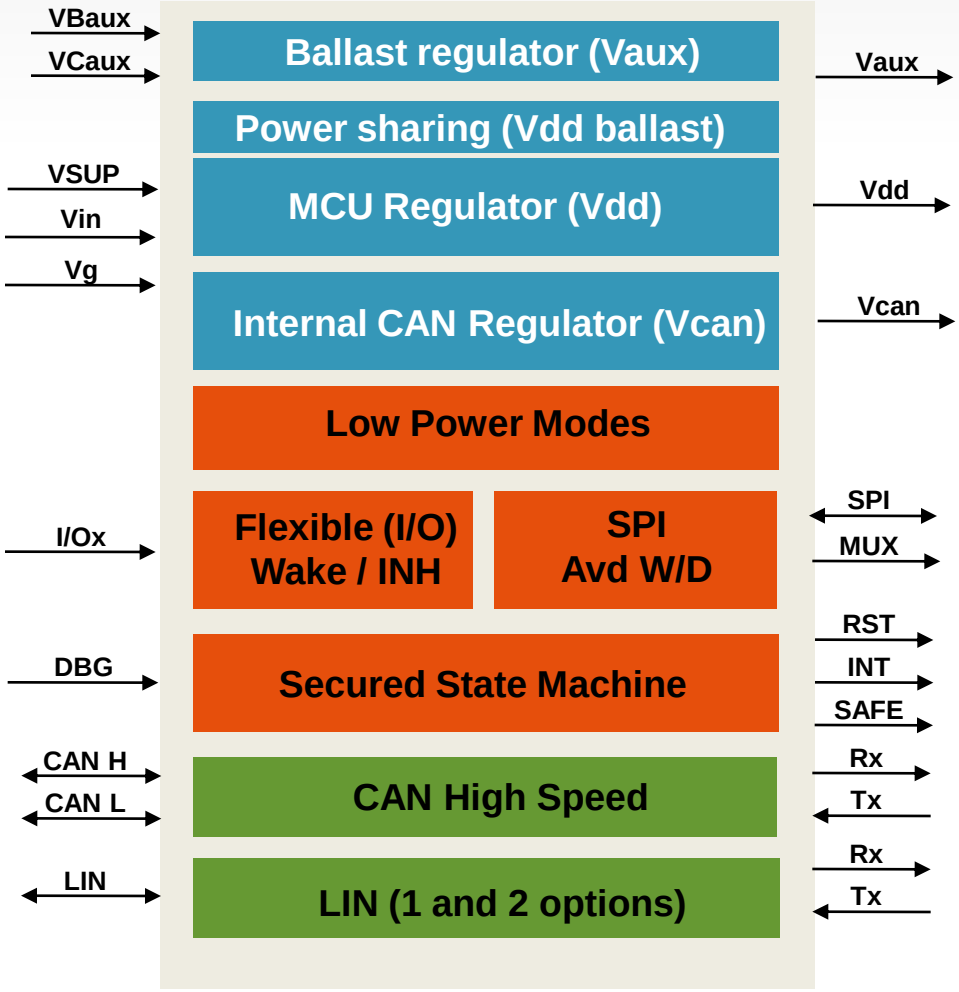
Megasquirt Qorivva Example System

V8 drive by wire turbo



MC33905 System Bases Chip

- **Scalability :**
  - Low drop out split regulators for adaptable application power and configuration
  - Power sharing to lower thermal effects
- **Safety :**
  - Failsafe State Machine accessible by SAFE pin
  - Secured SPI with Watchdog Capabilities
  - High protection on outputs
- **Diagnostics :**
  - Feedback on feature health
  - Multiple Analog monitoring to MUX output
  - High Precision VSupply Voltage Monitoring via SENSE pin



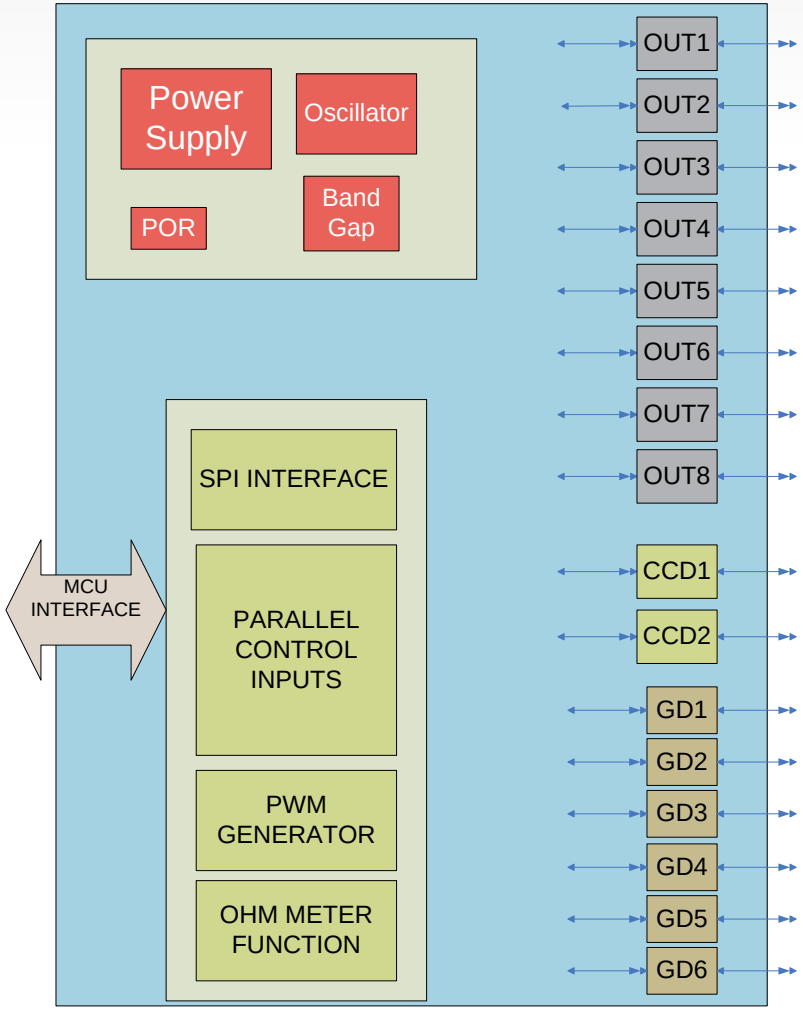
QFNeP / SOICeP

MCZ33800 Multi-Function Driver

- Mops up all miscellaneous ECU outputs
  - OR
- Drives a whole transmission!

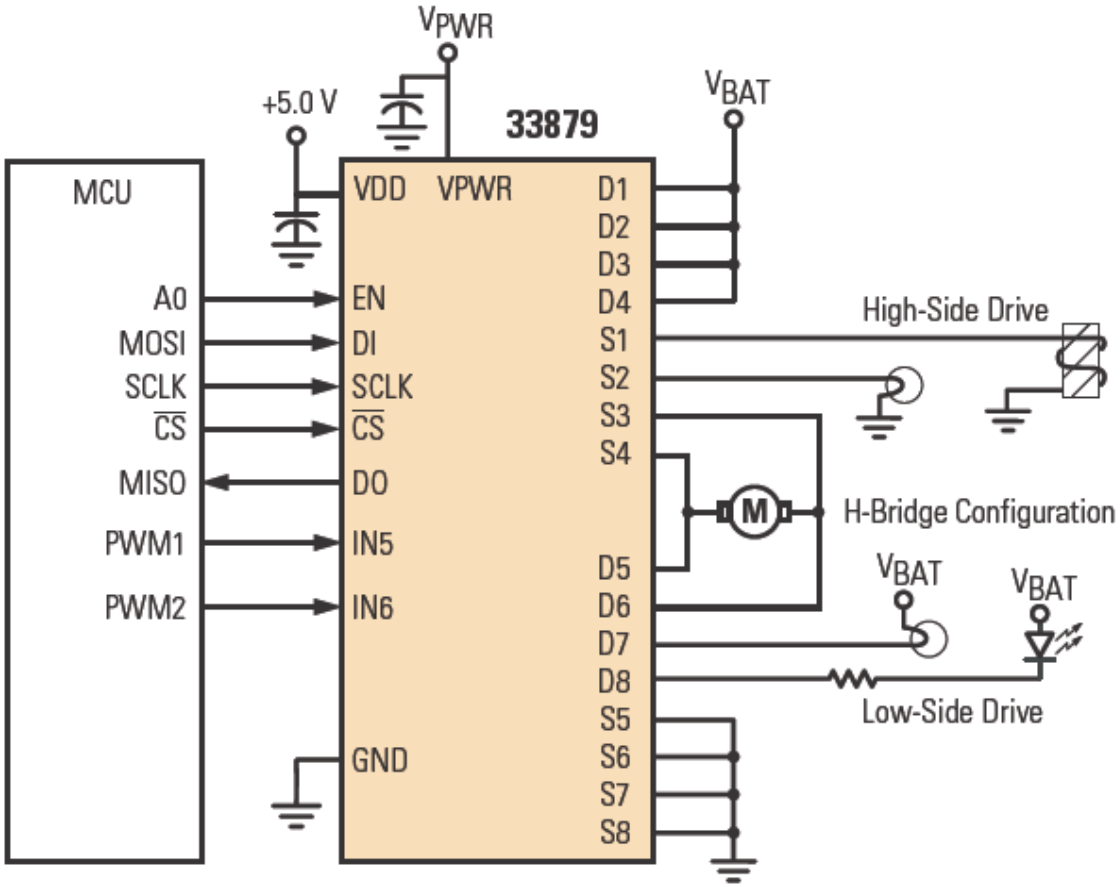
Automotive Applications

- Air Bypass Solenoid
- EGR vacuum control
- Temperature gauge
- Tacho
- HEGO heaters
- Purge control
- Fuel economy gauge
- Relays
- MIL etc.

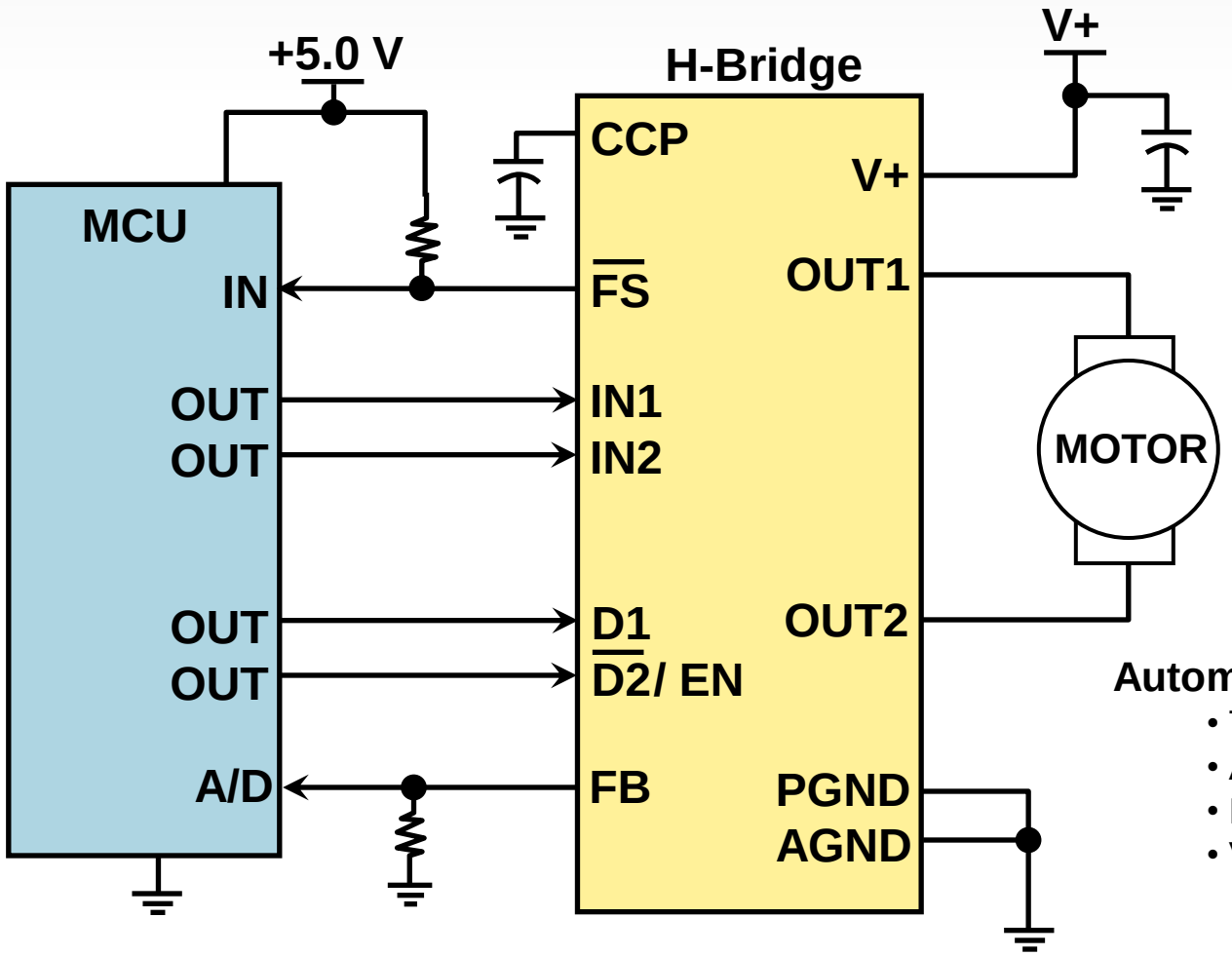


MC33879 Configurable Low/High Side Driver

- Eight floating MOSFETS
- Configure as high side or low side
- Combine to increase current
- Pair up for bridge driver
- Protection
- Diagnostics



MC33931 Five Ampere H-Bridge



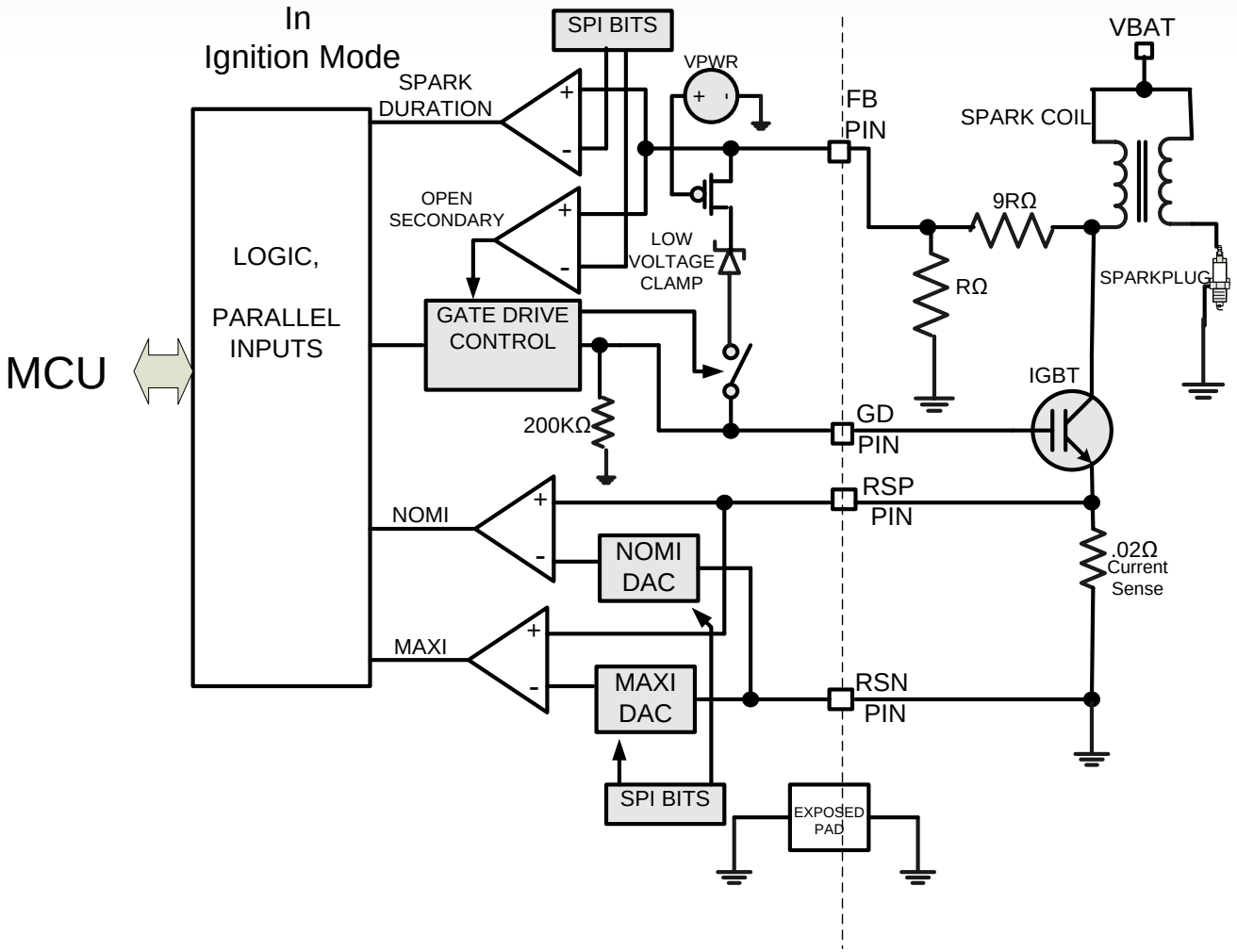
MC33931

Automotive Applications

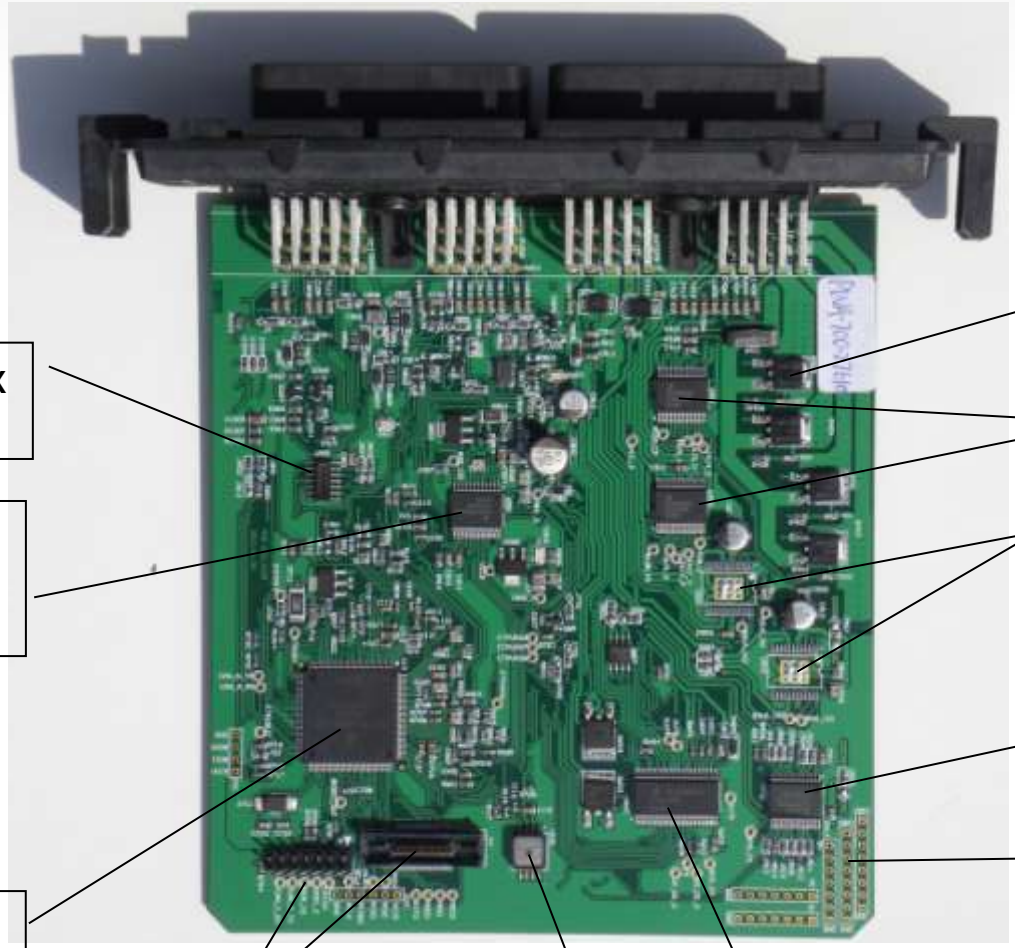
- Throttle Control
- Air Bypass Control
- EGR
- VCT

MC33810: Ignition Pre-Driver Mode

- **4 Ignition Pre-Drivers**
- Parallel Input only
- Low Voltage Clamp
- Coil Current Detection
  - NOMI – Nominal I
  - MAXI – Maximum I
- Max Dwell Timer
- Overlapping Dwell
- Spark Duration
- Open Secondary Detect
- Only one Sense resistor needed per bank
- Can be individually selected to be GPGD pre-drivers via SPI



Topside Component Layout



ADC external MUX buffer

MC33905 Power supplies + CAN +LIN

MPC5634M 32b MCU 1.5Mb flash 80MHz

Debug connector JTAG + Nexus

Pressure sensor

MC33800 5 low side + 4 FET predrivers

Small prototyping area

MC33879 Configurable 4W high/low side driver

2x MC33931 5A H-Bridges

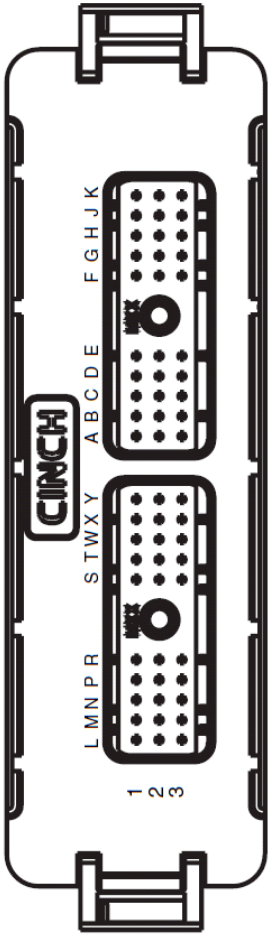
2x MC33810 Eight Injector drivers

Four Ignition IGBTs

Underside Component Layout

- Acknowledgement: a quality job from Shanghai office

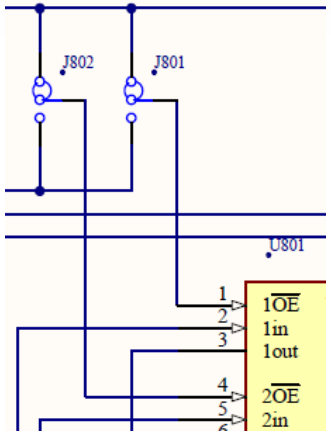
Configuration Options



Ign2	Ign1	Ign4	IGBT	IGBT	IGBT	Ign2	Ign1	Ign4
Inj2	GndIgn	Ign3	2A LS	Gnd	IGBT	Inj2	GndIgn	Ign3
Inj1	Inj3	Inj4	2A LS	2A LS	2A LS	Inj1	Inj3	Inj4
5A HS or LS	5A HS or LS	GndLR	5A half-bridge	5A half-bridge	Gnd	ETC1M	ETC1P	GndLR
Inj8	Inj7	Inj6	2A LS	2A LS	2A LS	Inj8	Inj7	Inj6
1A HS or LS	1A HS or LS	Inj5	1A half-bridge	1A half-bridge	2A LS	StepB	StepA	Inj5
4A FET	4A FET	Vbat	1A half-bridge	1A half-bridge	Vbat	StepD	StepC	Vbat
5A half-bridge	5A half-bridge	Tacho	1A Const	1A LS	10mA LS	IACV	MIL	Tach
GndSY	FP_Rly	UpHeat	Gnd	3A LS	9A FET	GndSY	FP_Rly	UpHeat
Vign	FanRly	DnHeat	Wake	3A LS	9A FET	Vign	FanRly	DnHeat
Vspeed	ADC common	GPIO	GPIO	1A LS	Comms	Vspeed	Purge	CAN_C_H
20mA HS	ADC common	GPIO	GPIO	1A LS	Comms	BrakeSw	TempOut	CAN_C_L
GndAE	GPIO	PwrRly	Gnd	Comms	1A LS	GndAE	K_Line	PwrRly
ADC	CAN_A_H	50mA 5V	GPIO	Comms	GPIO	FPdiag	CAN_A_H	PAS_Sw
TPS_A	CAN_A_L	50mA ADCmux	ADC	Comms	ADC	TPS_A	CAN_A_L	IAT
MAP	50mA ADCmux	VCC5_Sns	ADC	ADC	VCC5	MAP	ECT	VCC5_Sns
GndSns	CPSP	Knock 2P	Gnd	VR+	ADC	GndSns	CPSP	TPS_B
50mA ADCmux	CPSN	Knock 2M	ADC	VR-	ADC	UpO2	CPSN	PedalB
VR CamExM	VR CamInM	KnockP	ADC	ADC	diff. ADCP	PedalA	DnO2	KnockP
VR CamExP	VR CamInP	KnockN	Hall I/P	Hall I/P	diff. ADCM	CamEx	CamIn	KnockN

Second options for pin function

Primary pin function coloured by type



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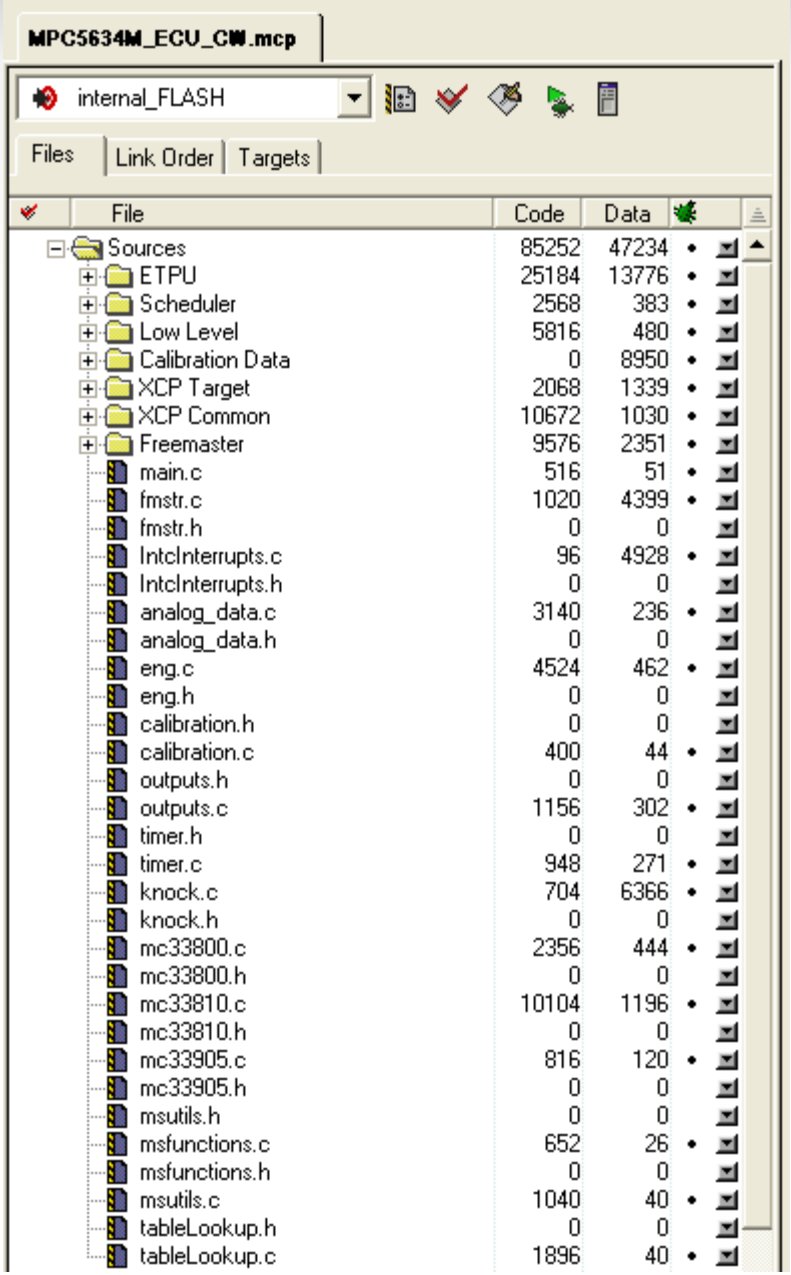
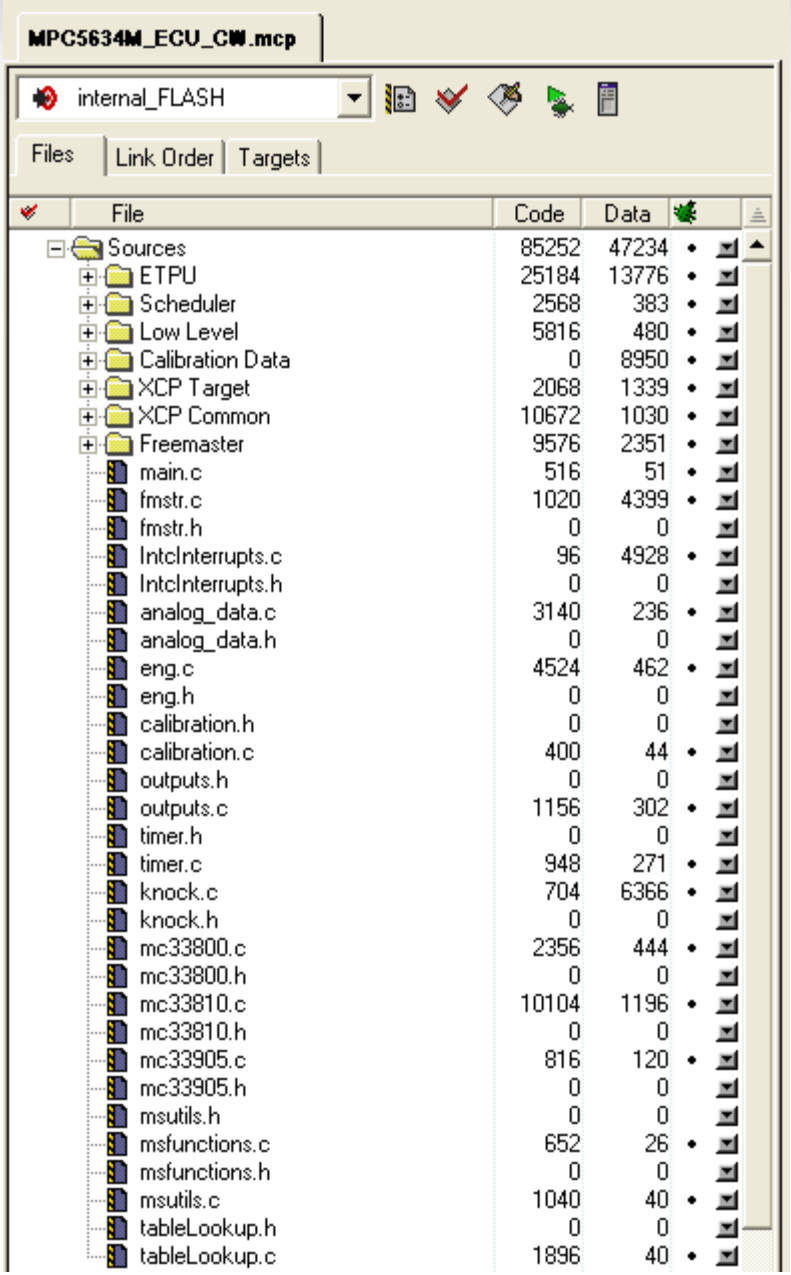
Curret codebase folders

- ETPU functions from GCT
- Scheduler folder: CocoOS files
- Low Level folder: MCU peripheral files eg: siu.c, dma.c
  - Initial configuration
- Calibration data
  - Engine specific calibration
- XCP: ETAS INCA (restricted)
- Freemaster
  - Knock demonstration
- Chip specific files eg: MC33800.c, MC33905.c
  - Register definitions
  - SPI configuration and quizzing



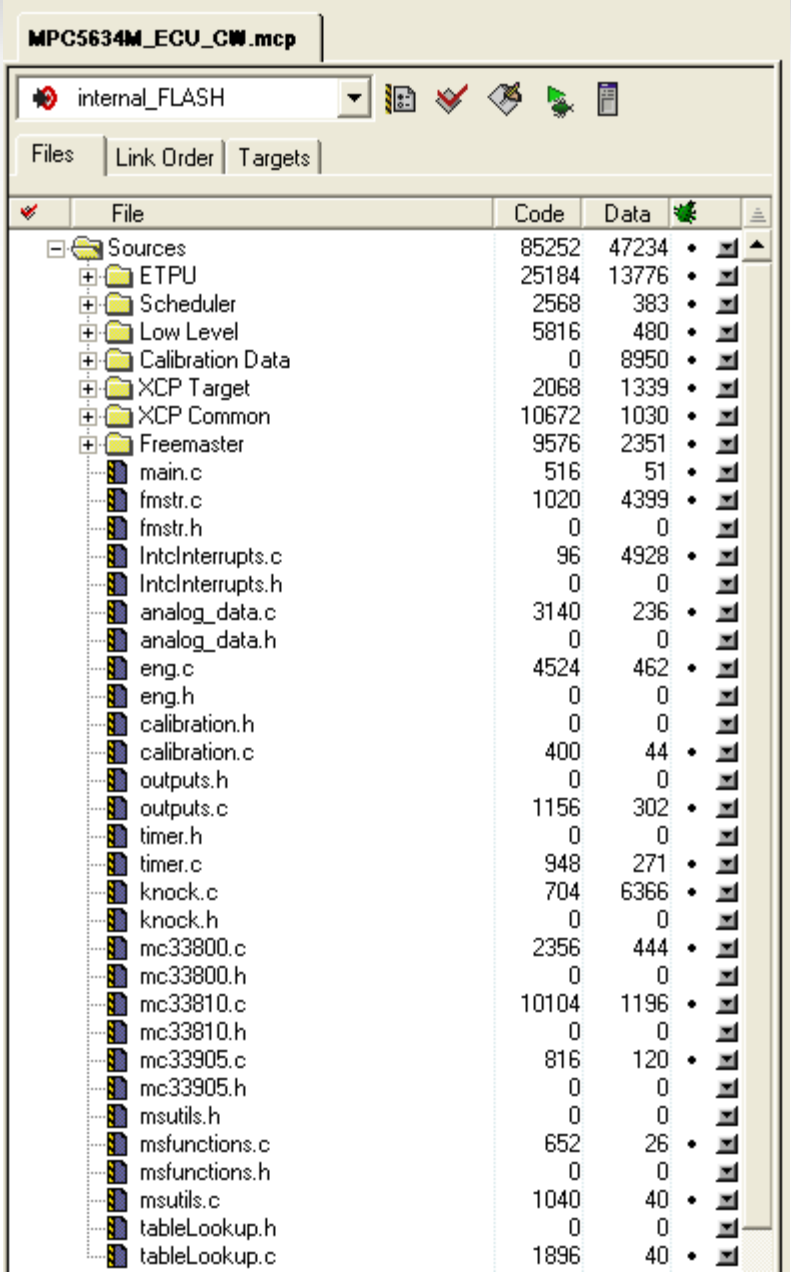
Curret codebase files

- Fmstr = Freemaster
- IntcInterrupts
  - Routes and manages interrupts
- Analog_data
  - Reads queue and scales vars
- Eng
  - Main engine operations
  - Read sensors and set actuators
- Knock
  - Get old window and set up new
- Outputs
  - Functions to set pins or modules



Curret codebase files

- Timers
  - Operates a timebase for sensors and actuators
- Chip specific files eg: MC33800.c, MC33905.c
  - Register definitions
  - SPI configuration and quizzing
- Msfunctions
  - Warm up enrichment
- Msutils
  - 1D interpolation lookup
- Tablelookup
  - 2D interpolation lookup



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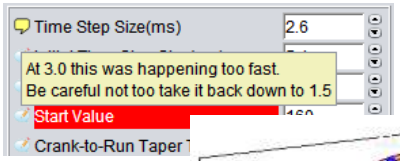
TunerStudio MS 2.0

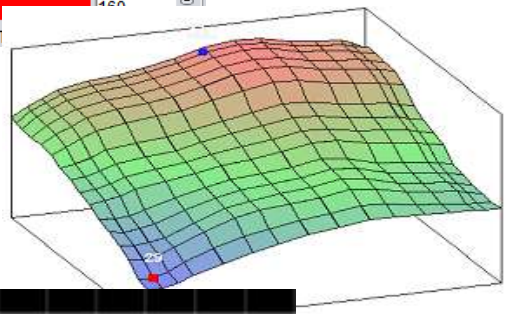
TunerStudio

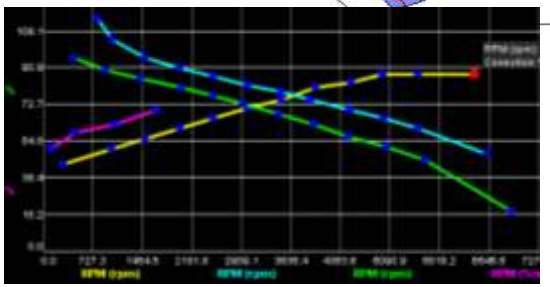
- Calibration and Configuration application used by MegaSquirt
- MS Edition Primarily targeted toward tuning shops and retail customers, providing for
  - Quick, simplified end user setup
  - Powerful & independent configuration for firmware developers
  - Low Cost Licensing for retail users
  - Refined user centric feature set focusing on needs of hobbyist and serious installer & tuners

Features

- Large selection of Dashboards & Dashboard designer to create and customize your own.
- Flexible Configuration of data structures, Configuration tools, UI Menus & Dialog and Analytics
- Automatic UI Component rendering based on data type
- High speed Math Parser for Runtime values, enable conditions, Log transformations
- Broad set of available Configuration settings UI widgets
  - 2D Tables
  - 3D Tables
  - Curve Graphs
  - Bit and scalar value
  - Logger Control
  - Real-time Clock calibration
  - Command buttons
- Graphical Difference Reports
- Automatic Restore Points - Tune settings are automatically saved on key events.
- Offline / Online tuning with synchronization
- Configuration Settings easily restored to new firmware versions
- Internet integration - Automatic configuration file look up, Translation services, remote connectivity
- Contextual Help Support
- Tuners Notes Log, Free form notes at the Tune and Setting level
- Multi-Language Support. - Currently contains translations for 19 Languages
- VE Analyze – Fuel Table Auto Tuning
- Plug-in Support
- Refined UI features for a rich, smooth user experience
- High speed memory loggers -Ignition Logger, MAP logger
- Multi-Controller and CAN Pass through support







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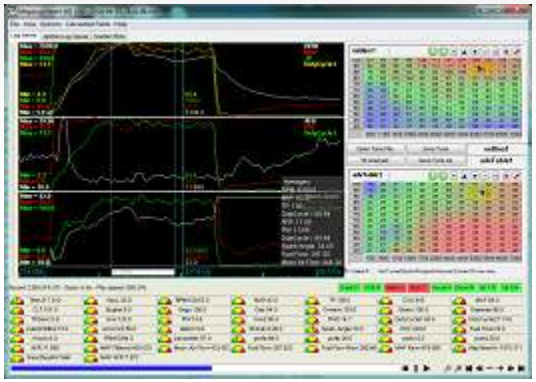
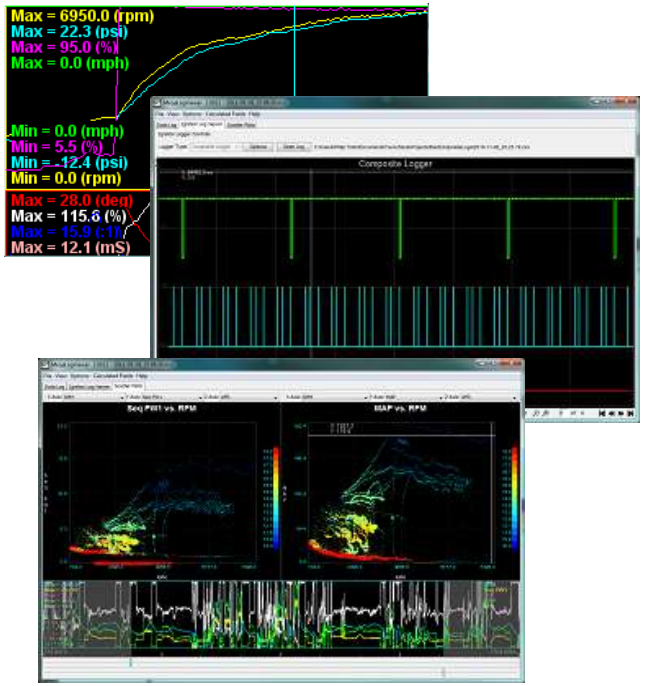
EFI ANALYTICS

MegaLogViewer



Datalog View and Analysis software tool
- Adopted by many aftermarket communities
- Broad user base

Features
- Fast navigation through large data sets
- Universal Delimited File loader
- Pluggable Binary file Loaders
- Standard viewer displays up to 16 fields by default
  - 4 groups of 4
- Scatter Plots rendered almost instantly with hundreds of thousands of records.
  - Define data range
  - Apply filters
- Ignition Wheel Log Viewer
- Custom Calculated fields based on your own Mathematical Expressions
  - Reference log data, current record or historical
  - Include transform functions using lookup table
- Built in Common Calculated Fields
  - Instant MPG, HP, Tq, Vacuum, Boost, RPM/Sec, etc.
  - AFR from O2, MAF, AFR to Lambda
- Field Name mapping to canonical
- Scale change, from 1/10 to 10x zoom
- Auto Scale or Defined ranges
- Playback from 1/8 speed to 8x speed
- Tune File Table Editing
- Fuel Table Auto Tuning
- Auto Update - check here for more info on Auto update
- Compare mode - Overlay second file values
- Wideband O2 - AFR calculations
- Save Graph to Jpeg for easy posting to web
- Customizable colors, gauges and UI features.
- User-friendly interface that saves all settings and enables navigation by keyboard, buttons and mouse.

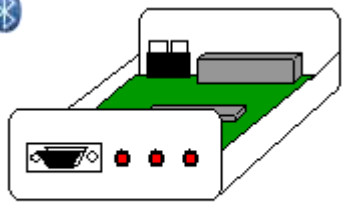


EFI Analytics Configuration Tools

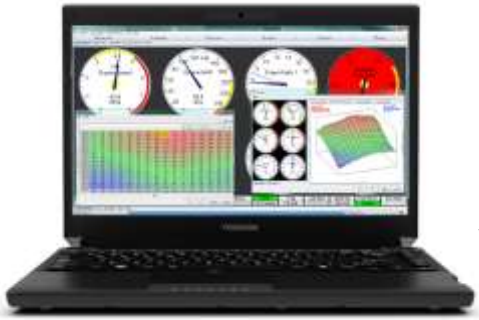
Mobile and Internet integration for simplified, integrated user experience
- Collaborative tuning
- Project synchronization
- Remote access
- Store and Forward where practical

Shadow Logger MS
- Android

Works independently or takes advantage of networked integration



ShadowTuner.com
- User portal
- Log file access
- Integration services
  - File synchronization
  - Project synchronization
- Application Services
  - Translation
  - Authentication
  - Entitlements



TunerStudio MS
- Windows
- Linux
- OS X

Works independently or take advantage of networked integration

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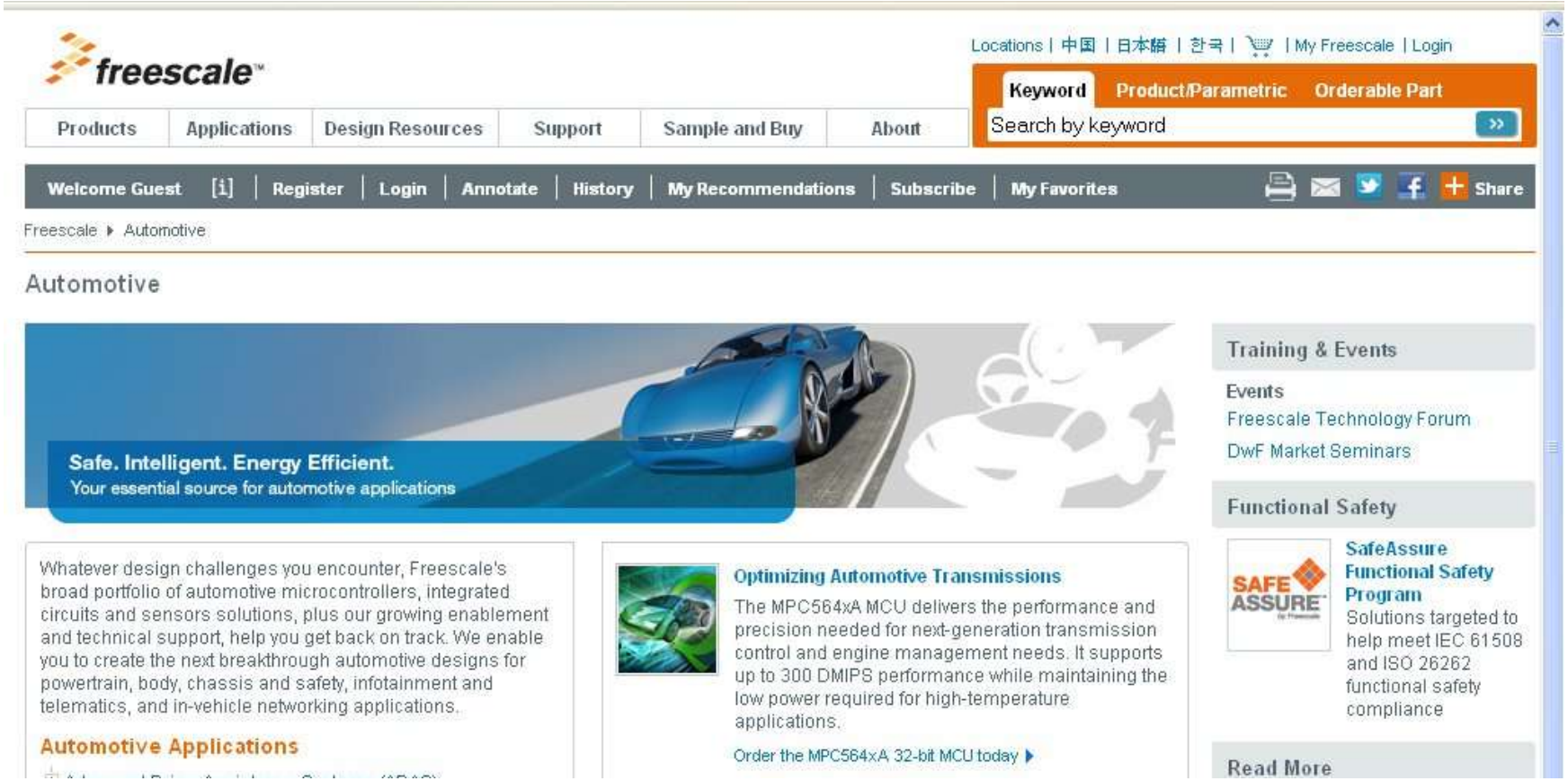
Freescale Megasquirt ECU launch page, available shortly, meanwhile…

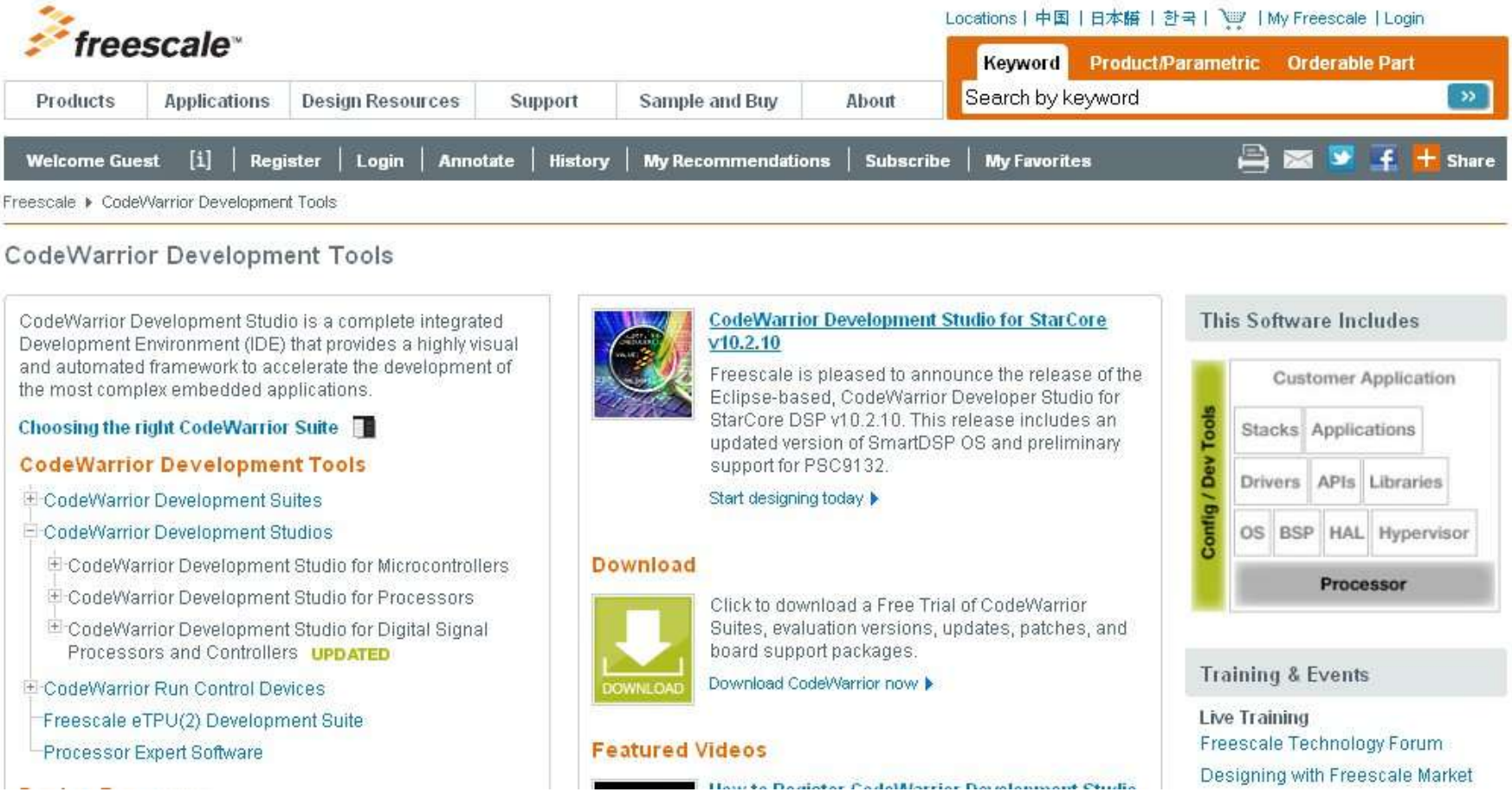
www.freescale.com/automotive

Search Product/Parametric using part number



CodeWarrior

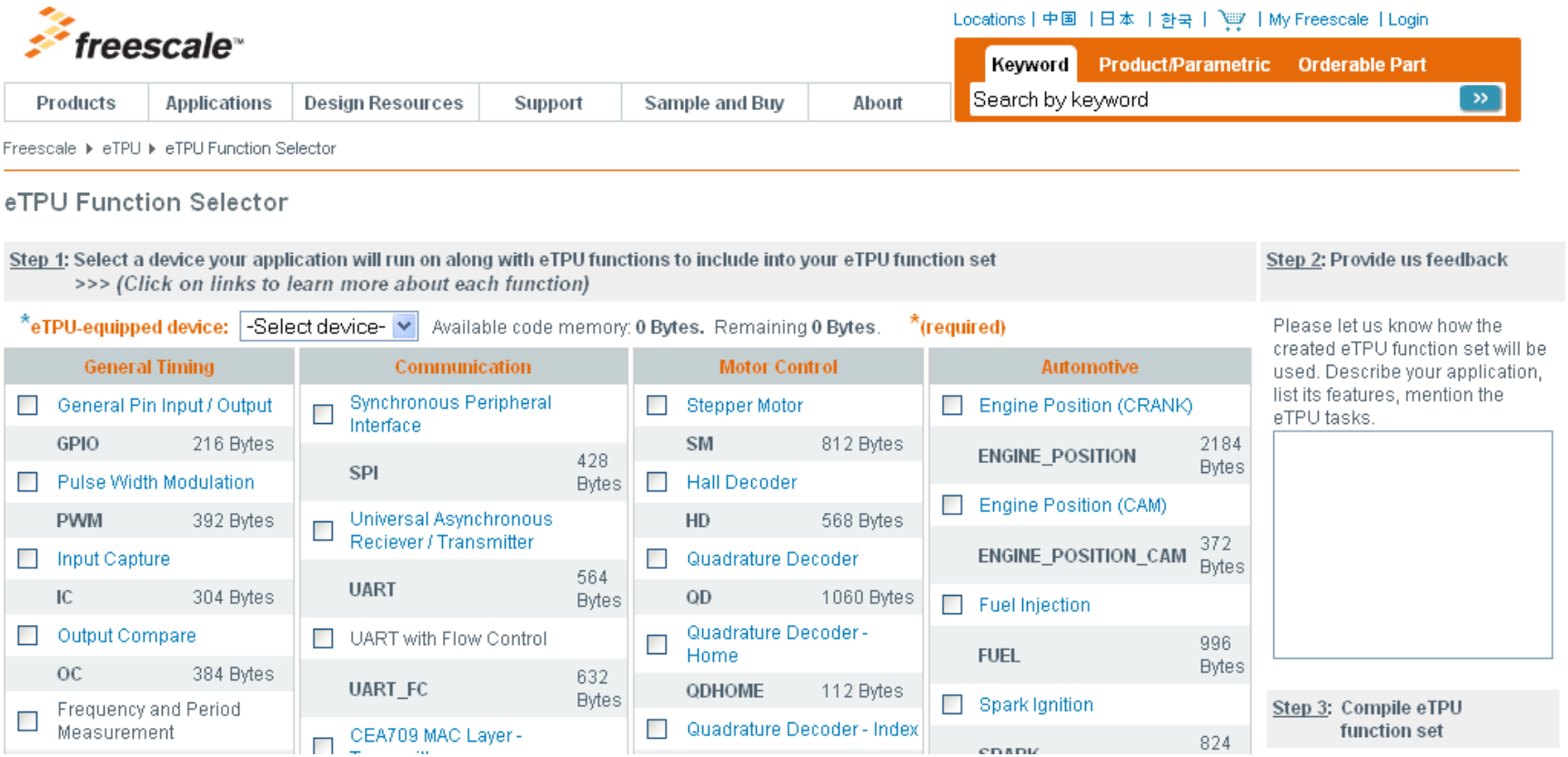
www.freescale.com/codewarrior



eTPU

www.freescale.com/eTPU

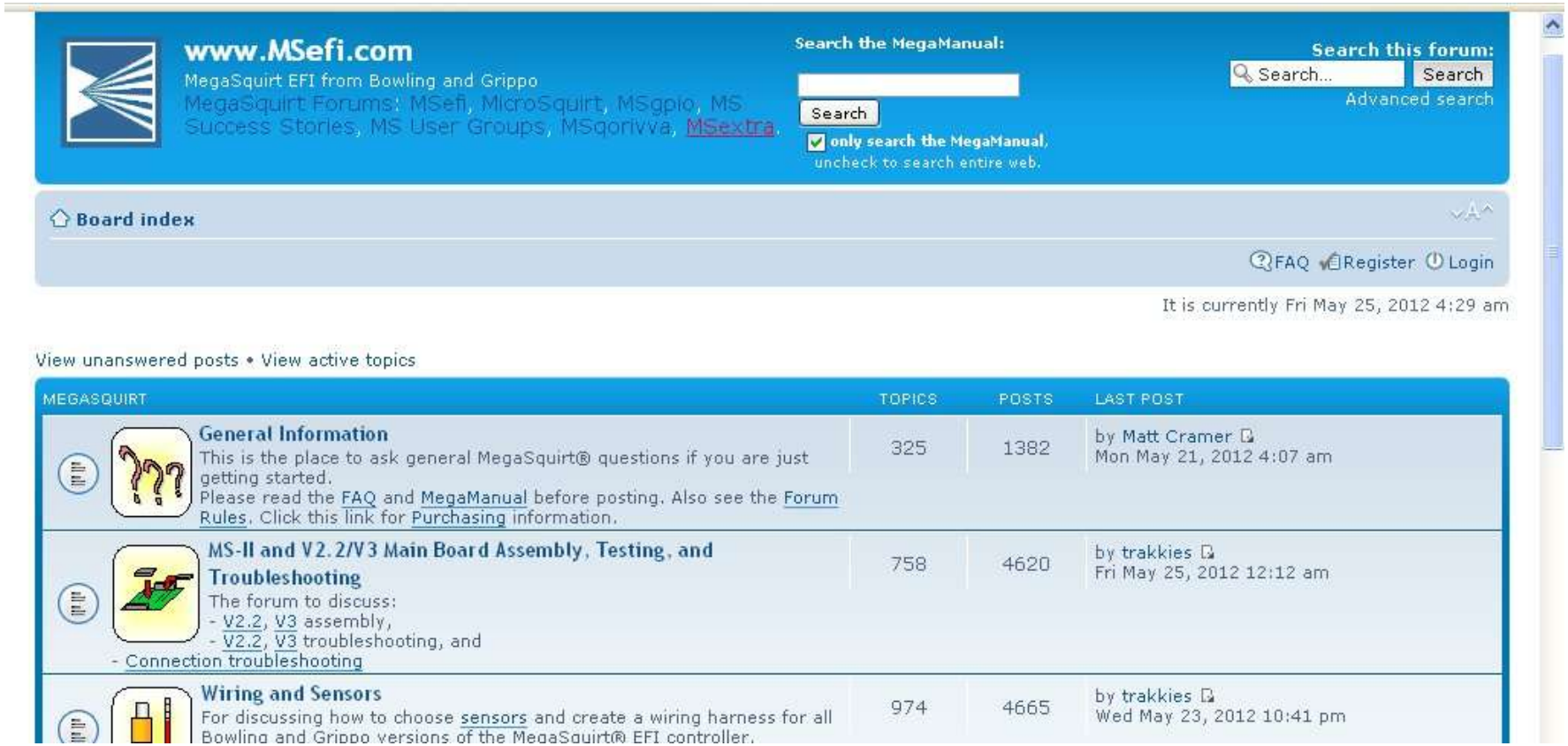
http://www.freescale.com/webapp/etpu



Megasquirt Homepage

www.MSefi.com

Links to information, training, MegaManual and forums

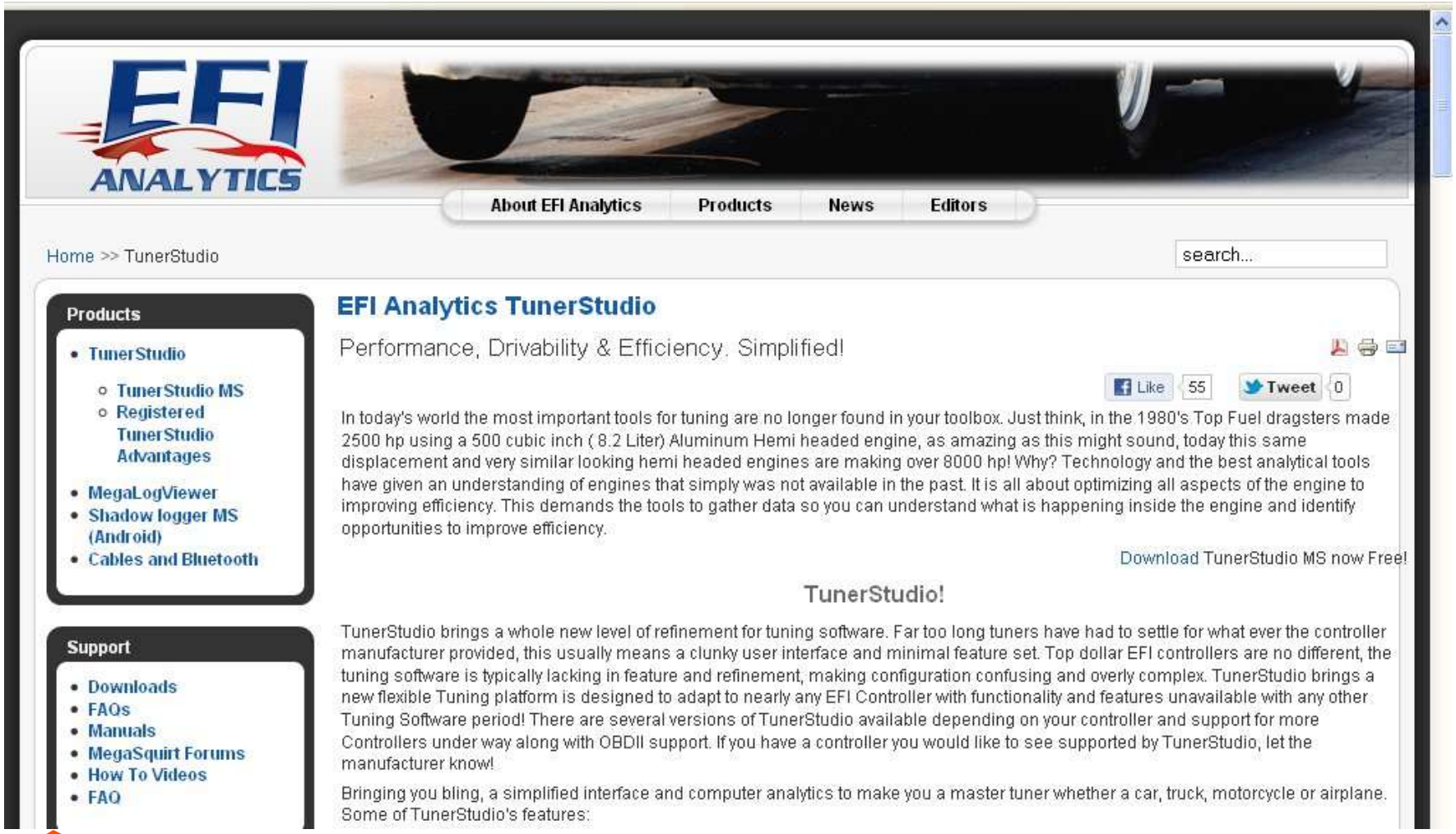


Qorivva Forum Startup

http://www.msqorivva.com/forum/index.php

Tuner Studio

www.efianalytics.com



Operating System cocoOS

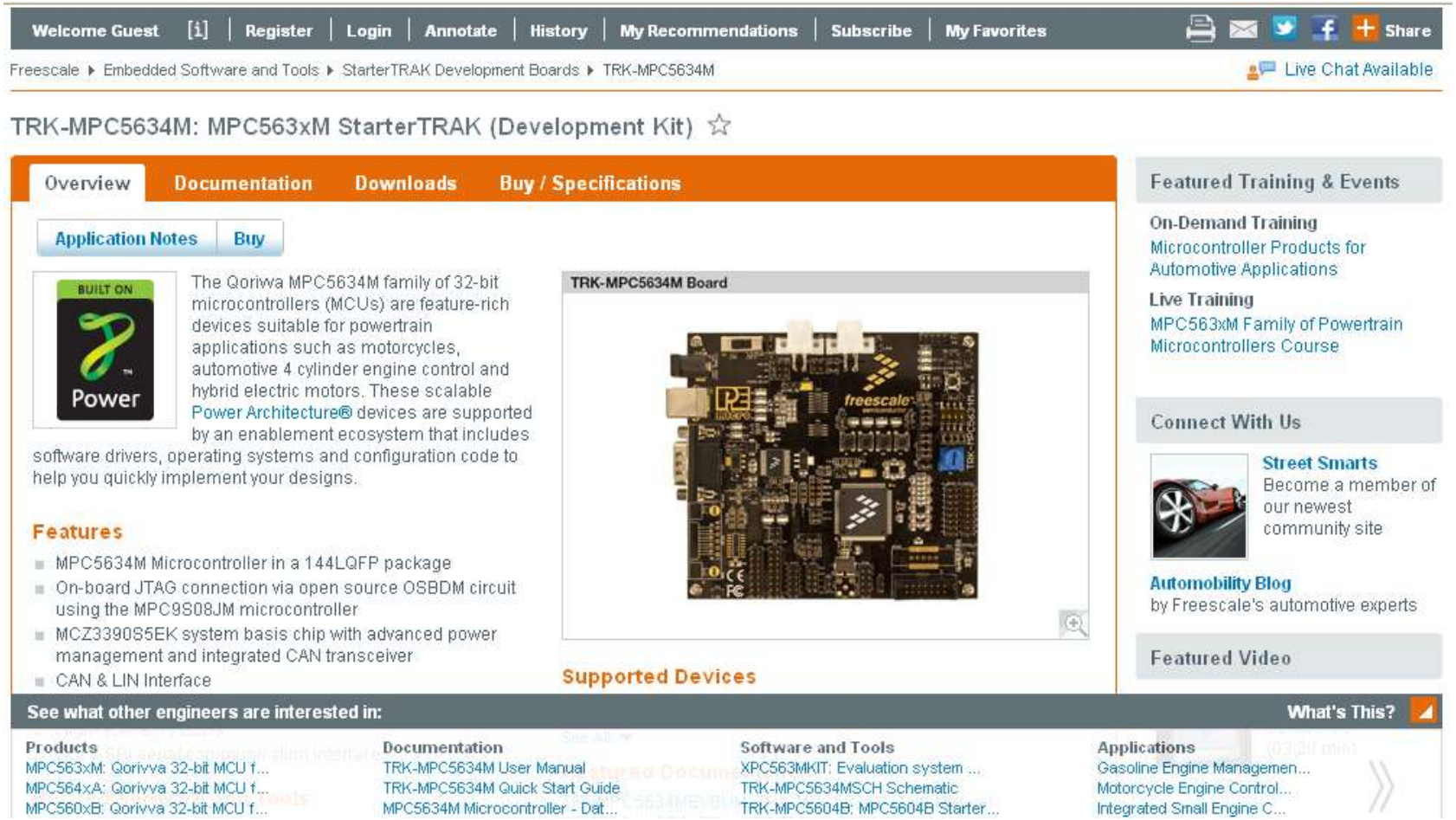
http://www.cocoos.net/

P&E Debugger

www.pemicro.com -> Products -> USB Multilink Universal ($119)

TRK-MPC5634M Board

Search www.freescale.com under *orderable part*



MegaSquirt retailer

www.diyautotune.com

Supplier hub: MS ECUs, spares, accessories, events and more

Agenda

- Background and motivation
- Freescale in powertrain
- Megasquirt overview and products
- MSQorivva hardware description
- Software structure
- Calibration tool
- Online resources
- Work products and timelines
- Summary and Q&A

Work products and timelines

Available now

Hardware:

- **Reference ECUs - $500, five in the FTF Store**
- **Sensors, Actuators, Megasquirt ECUs, repairs, accessories, loads board etc**
- **Debuggers from P&E**

Software:

- **Codewarrior, demo and full**
- **Tuner Studio Lite and Full**
- **eTPU code, engine functions**
- **cocoOS Operating System**
- **ETAS CAN XCP stack with INCA**

Probably posted by now

Hardware:

- Schematics in Altium and pdf format
- PCB layout in Altium and Gerber format

Software:

- Most LLD, device and peripheral specific files eg: SPI and SIU

Available by October:

Hardware:

- next build of Reference ECUs

Software:

- Engine Application
- Integrated TS interface

Resources:

- Freescale MegaSquirt Qorivva web page and links

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Objectives review

- We covered:
  - The origin, purpose and capability of a Megasquirt Qorivva ECU
  - Where to access existing material
  - What tools make up the development environment and how to obtain them
  - The plans for Open Source code and further ECU release

Question time ??

Qorivva EFI for the masses

or

How to have fun with 12V, an engine, and 20,000,000 transistors

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