Sources:

Race Track Experience

Innovation and Performance

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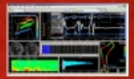

Current state of Technology

Embedded Electronic Systems

Exploring Electronic Control Units (ECUs)

So what goes into it?

What are ECUs?

- Embedded electronic systems
- Used to control different sub-systems/ electrical systems in a vehicle
- They can be used to monitor functionality or control funcitons.
  - They can be a standalone module or as part of a larger unit.

Some examples...

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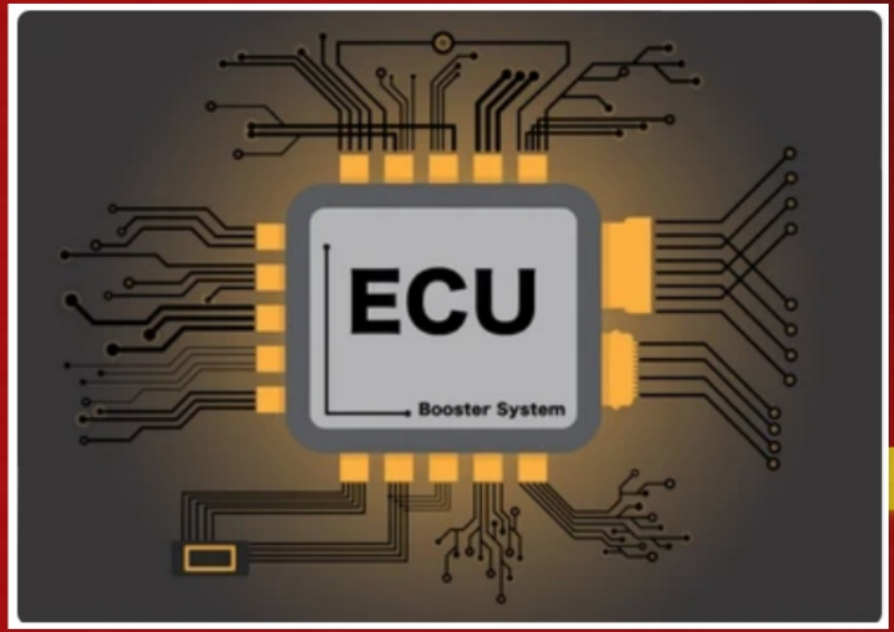
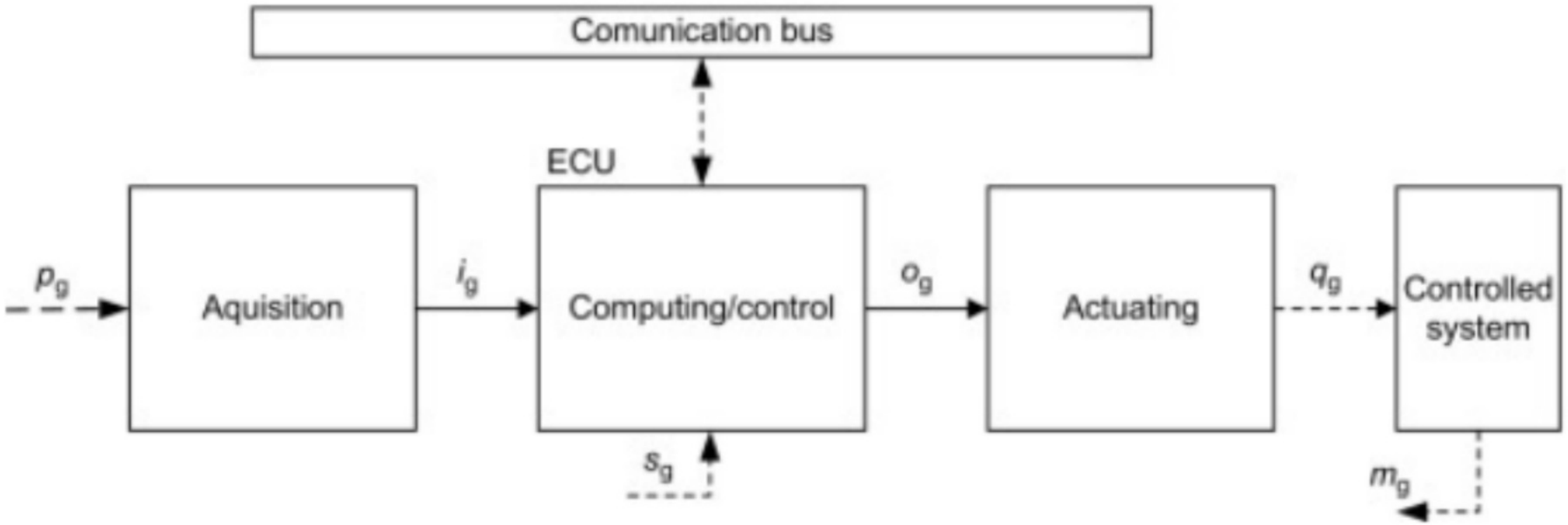


So what goes into it?

- The ECU controls a physical system based on a physical input variable
- within this system, you have numerous processes/variables/stages:
    - **Acquisition Stage =** sensors capable of executing the needed conversion from physical values to ECU input signals
    - **Actuation Stage:** actuators are electronic/mechanic devices which convert electrical control signals (o) into q, the physical input variable
    - **p=** (approximately equivalent to m).
    - **i =** ECU input signals, subject to approximation due to external influences and disturbances, analog to digital conversion whose rate and precision depends on characteristics of the system.
    - **o =** the setpoints based off the ECU's function on i. these maintain the defined relationship with the measured values.
    - **q =** physical input variable, the result of the actuation stage
    - **m =** measured physical variable, subject to approximation due to external influences and disturbances (approximately equivalent to p).


Comunication bus
ECU
p_g
Aquisition
i_g
Computing/control
o_g
Actuating
q_g
Controlled system
s_g
m_g

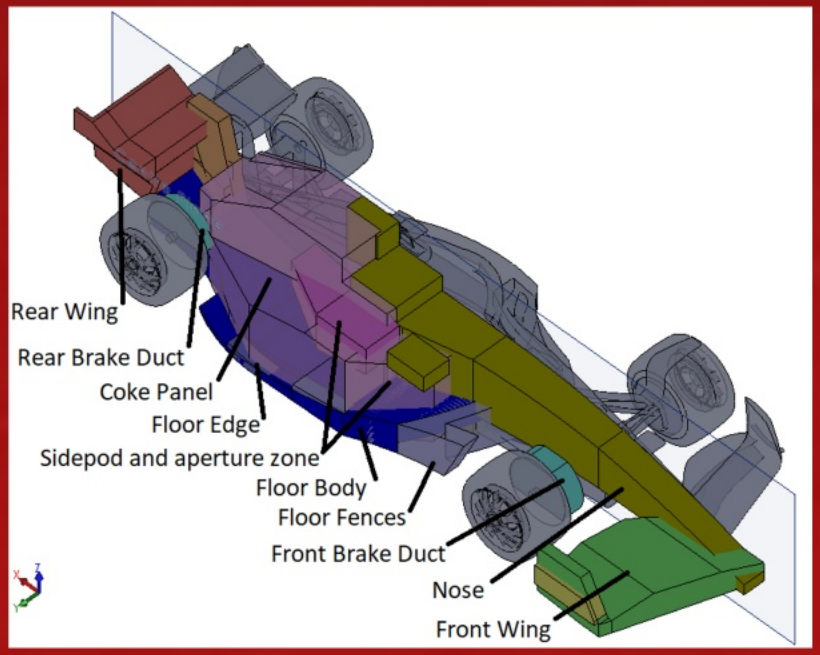
Pieces of the puzzle:

- Central unit: automotive microcontroller
- Memory: SRAM, EEPROM, FLASH
- Inputs: supply voltage and ground, digital inputs, analog inputs
- Outputs: actuator drivers (injectors, relays, valves), Hbridge drivers, logic outputs
- Communication links
- Embedded software: Boot loader, metadata for ECU and software ID, version management, and checksums
- Configuration data

Some examples...

Names are generally self-explanatory:

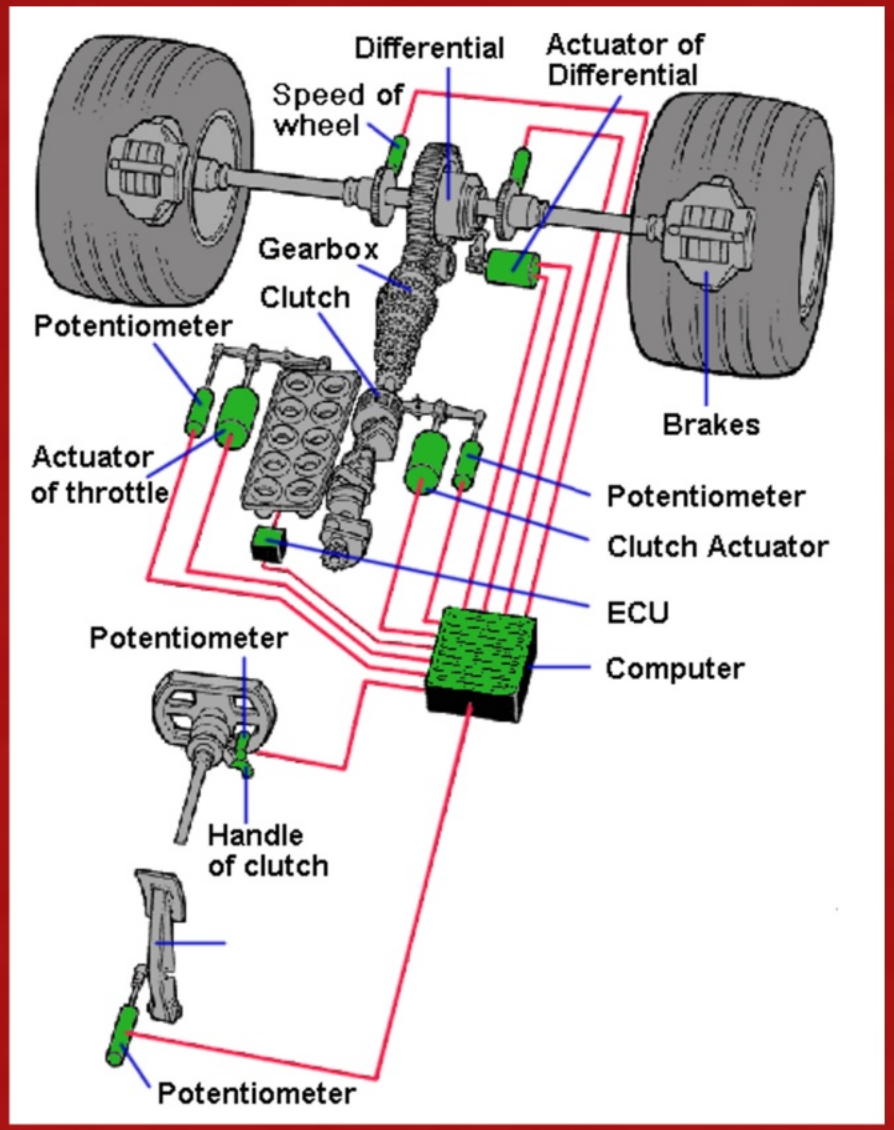
- Door control unit (DCU)
- Speed Control unit (SCU)
- Drag reduction system (DRS)
- Brake Control Module (BCM/ABS/ESC)
- Battery management system (BMS)
- Electronic power steering control unit (PSCU)
- Engine control unit (ECU)



So what OS runs it?

Most likely, the software executed by the ECUs is going to be Linux
You have options depending an the criteria: you might encounter AUTOSAR-based RTOS (real time OS).

For F1 cars, McLaren says the standard is generally TAGOS RTOS, since the goal is SPEED.



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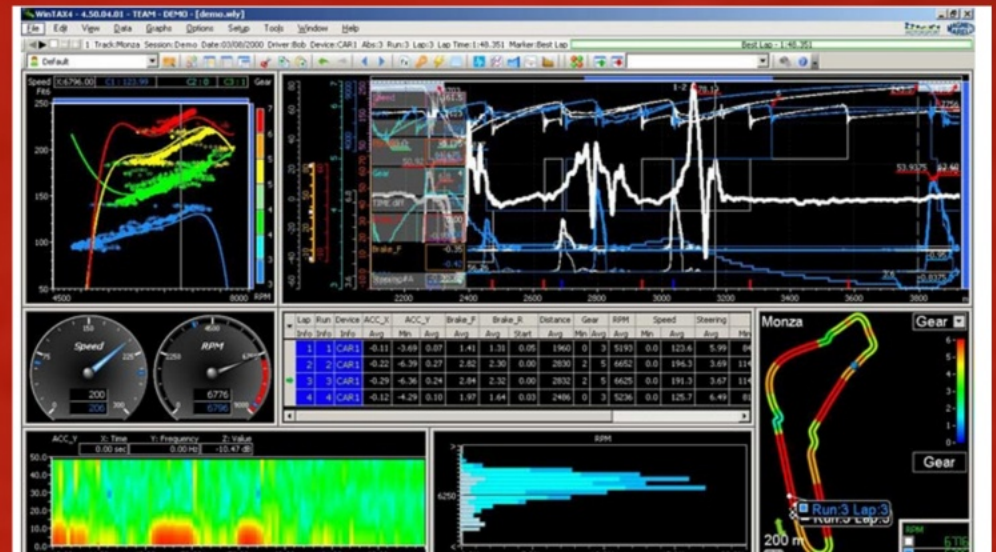
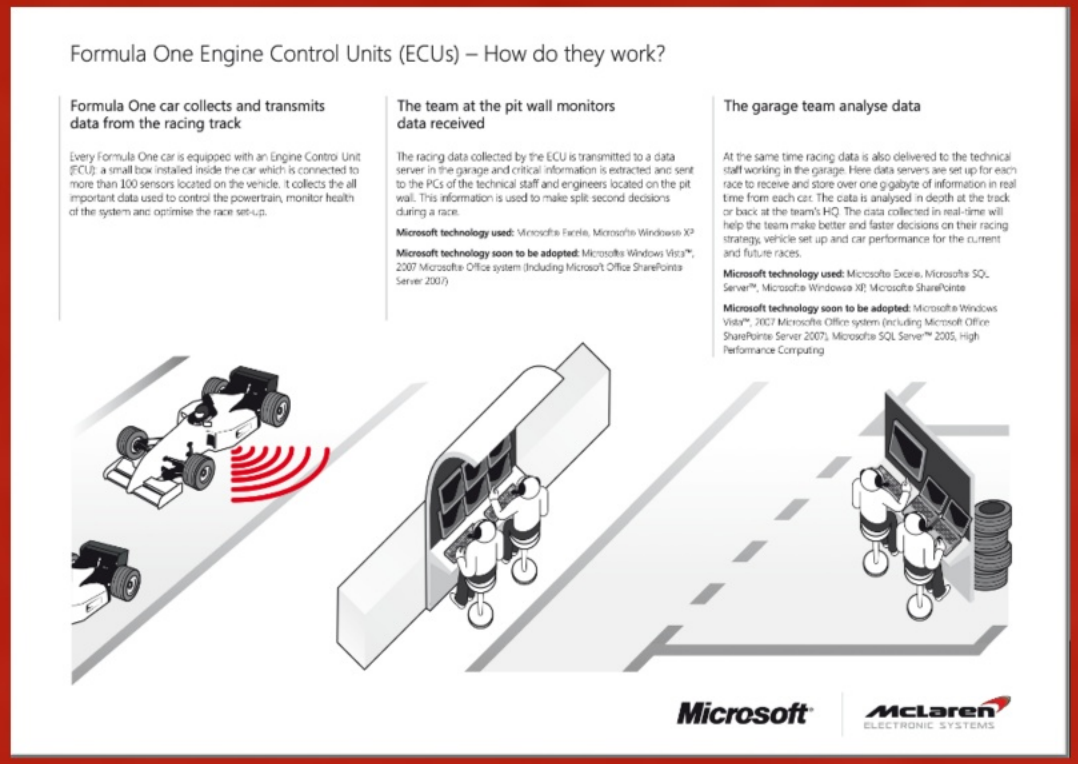


Race Track Experience



1980's: **'burst' telemetry**

1990's: New computing technology advancements

1994: FIA actually banned technology like ECUs which provided more precision in calcualtions and adjustments

2006: in order to "even the playing field" and lower the cost of competing for many teams, ECU's in a more complex capacity were allowed in F1 cars. McLaren applied is the sole supplier of the SECU for FIA, and hold this contract until 2030.

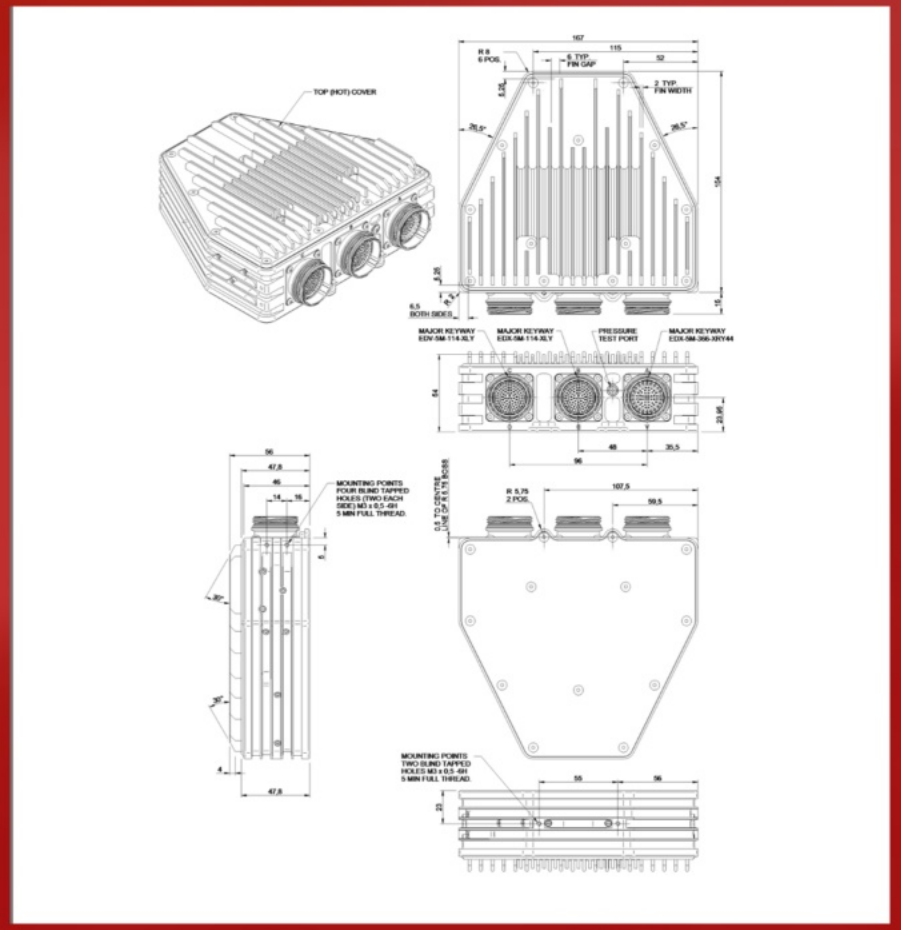
Current state of Technology

McLaren applied creates ECUs built for the specifics of F1 cars:
you're looking at high-revving engines, seamless shift gearboxes, various drive by wire controls, multiple of these, and regulations which demand a single hardware unit and software platform to control all of this.

The ECU also has to support different telemetry systems between the car and the garage.

Each year you'll probably see new advances for things lie V8/ GDI turbocharged parallel hybrid engines/power units.
Currently, the TAG-320 ECU is in use, but 2026 will bring the TAG-320B

TAG-320B



- It can be used with an external driver unit to provide direct control of ignition and manifold injection and powertrain control over a racing car
- Powerful processing platform with minimum latencies
- Based on 32-bit microprocessors
- Application code is automatically generated from MATLAB/ Simulink models.
- Provides advanced data logging, high speed telemetry control and communications

APPLICATION
- Control and monitoring of a racing car powertrain
- Up to 8-cylinder engines
- Throttle-by-wire
- Clutch-by-wire
- Semi-automatic gearbox
- Reduced Data Access support for application IP protection
- Powerful onboard data logging and telemetry control
- Ethernet connection to application and data analysis tools (System Monitor and ATLAS)

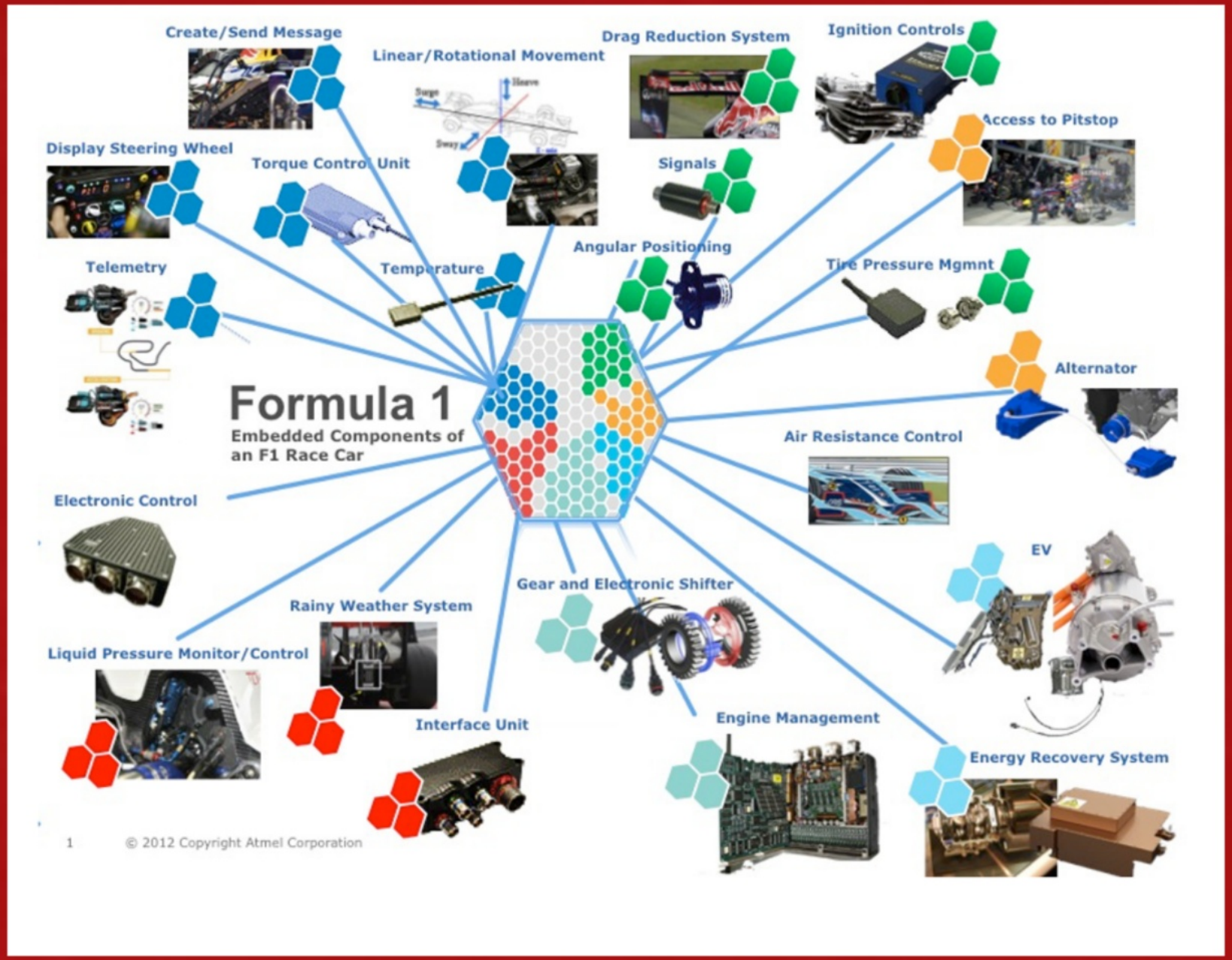
KEY FEATURES
- Application processing power Coremark ~16,000
- Extremely low latency, high frequency input sampling
- Digital filtering and anti-aliasing on all analogue inputs
- Data logging memory 4GB Flash

SENSOR INPUTS
- Up to 66 general-purpose 0 to 5V analogue inputs (12-bit, 10ksps, four of which are software configurable as general-purpose TTL outputs)
- 16 general-purpose configurable 0 to 5V or Pt1000 analogue inputs (12-bit, 10ksps)
- Eight general-purpose configurable 0 to 5V analogue inputs with optional strong pull-ups for use with digital switches (12-bit, 10ksps)
- Four high-speed 0 to 5V analogue inputs (12-bit, 100ksps)
- "Pits pedal" and "Ethernet IP address" analogue inputs (12-bit, 1ksps)
- Three inductive or DHE speed inputs (factory configured)
- Eight DHE speed inputs
- Two K-type thermocouple inputs (12-bit)
- Two wide-band lambda interfaces (12-bit)
- Lap trigger interface
- Ignition switch input

OUTPUTS
- Ten ±12mA servo valve drive stages (10ksps)
- Ten 3A low-side drive stages
- Ten 1A high-side drive stage
- One 3A high-side drive stage
- Eight 7A high-side drive stages
- Eight TTL injection control outputs
- Eight open-drain ignition control outputs
- Eight general purpose open-drain outputs
- Two RS422 differential outputs for 1ms time synchronisation and engine synchronisation signals
- Up to four general-purpose TTL outputs (all of which are software configurable as analogue inputs)
- Two oscilloscope outputs
- Four 150mA 12V sensor supplies
- One 150mA 10V sensor supply
- One 150mA 5V supply for lap trigger receiver
- Eight 100mA 5V precision sensor supplies

COMMUNICATIONS
- One Wired Ethernet interface (10/100/1000Mbps)
- One ARCNET interface (10Mbps maximum)
- One dual-channel FlexRay interface (20Mbps)
- Eleven CAN interfaces (1Mbps maximum)
- One RS232 interface (1Mbps maximum)

CONNECTION DEFINITION
- Integral, sealed, Lemo 5M motorsport connectors
- Connector A 66-way
- Connector B 114-way
- Connector C 114-way


Create/Send Message
Linear/Rotational Movement
Drag Reduction System
Ignition Controls
Display Steering Wheel
Torque Control Unit
Signals
Access to Pitstop
Telemetry
Temperature
Angular Positioning
Tire Pressure Mgmnt
Alternator
Formula 1
Embedded Components of an F1 Race Car
Air Resistance Control
Electronic Control
EV
Gear and Electronic Shifter
Rainy Weather System
Liquid Pressure Monitor/Control
Interface Unit
Engine Management
Energy Recovery System
1
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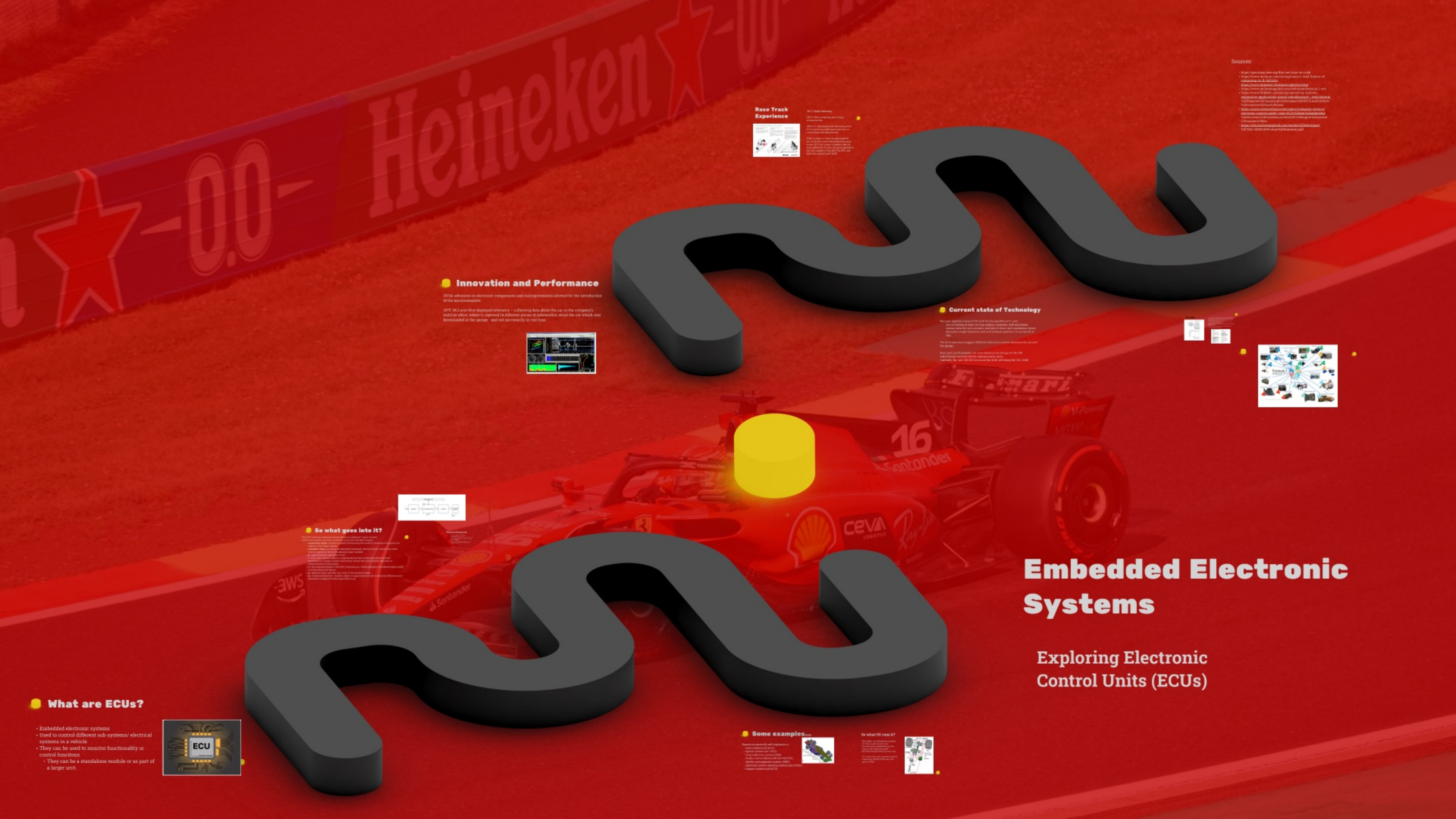
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