School of Mechanical Engineering
FACULTY OF ENGINEERING

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MECH5170M
Connected and Autonomous Vehicles Systems

Actuators and automation for autonomous drive

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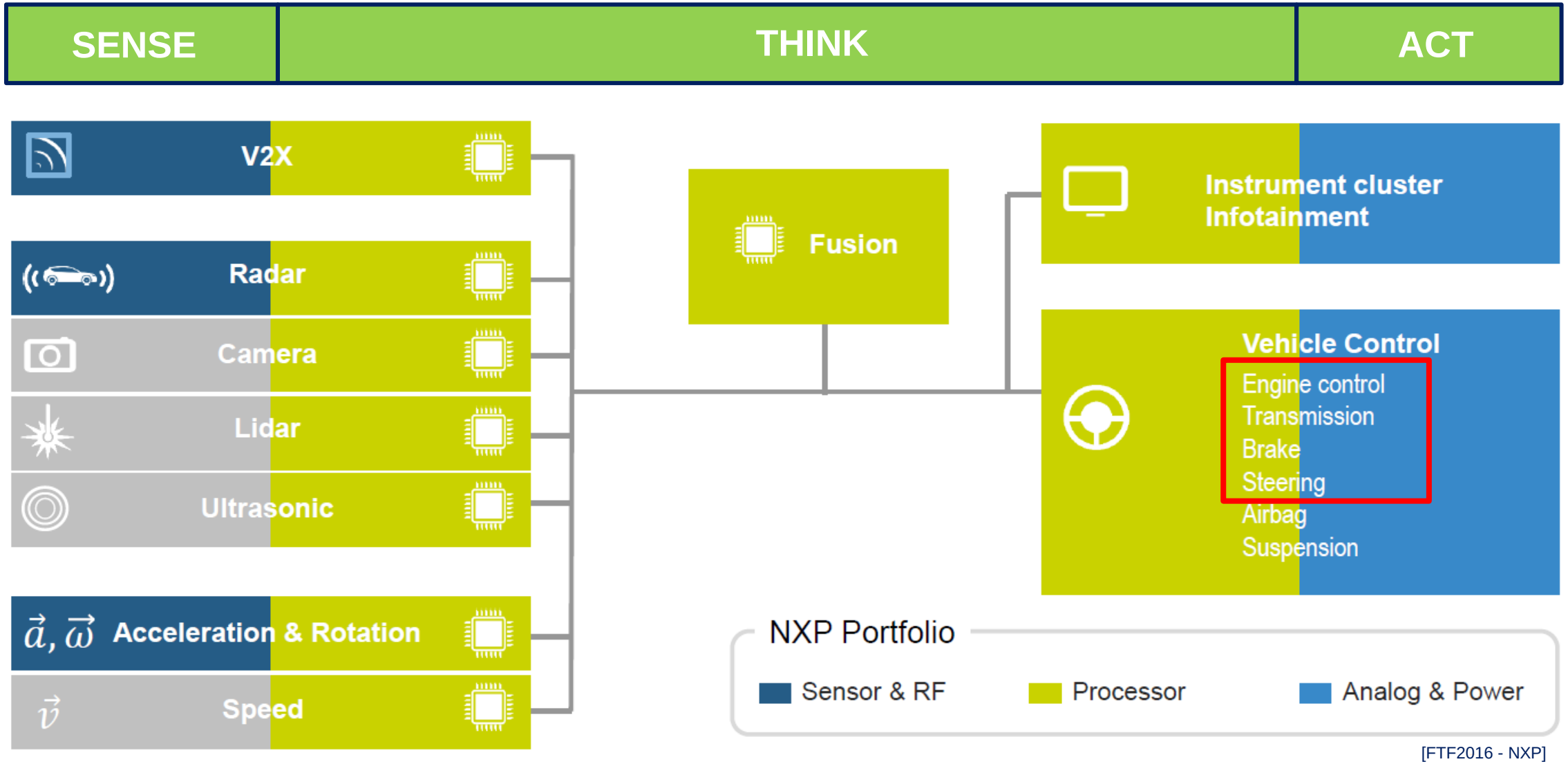
Introduction

- Autonomous driving framework/requirement
- Engine/Motor control
- Transmission (gear selection)
- Braking control

Autonomous vehicle control framework



[FTF2016 - NXP]

Motor control

Engine/Motor control

IC (petrol, diesel, hydrogen) engine control

- ECU control instead of driver input
- Servo or stepper motor operated throttle

Accelerator pedal replaced by ECU

Servo-motor actuator

EV motor control

- Control signal comes from CPU/ECU
- Inverter control the motor current/voltage

Stepper motor throttle

Fuel Cell powered vehicle control

- Similar to EV but ECU must control hydrogen flow

EV motors

- Brushed DC motor
- Brushless DC motor
- Permanent magnet synchronous motor
- **AC Induction motor (asynchronous motor)**

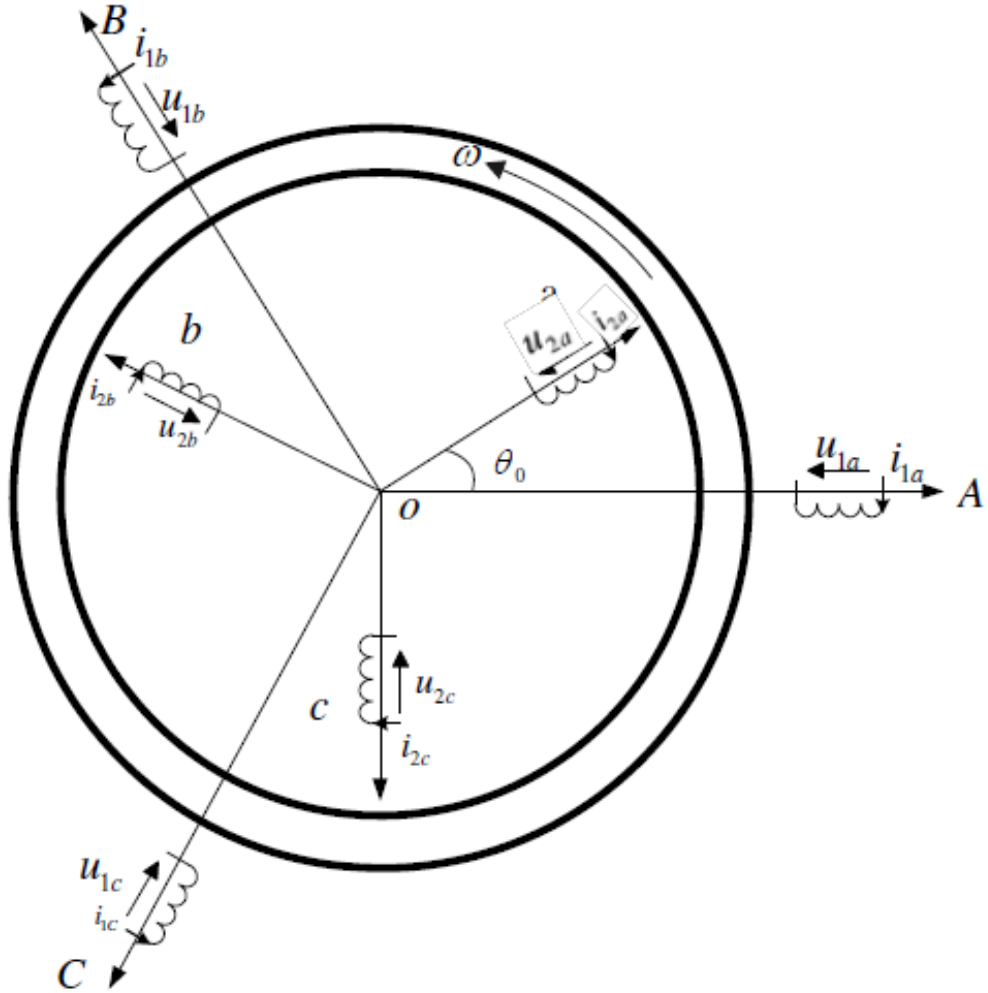
$$u = Ri + L\frac{di}{dt} + \omega_r \frac{\partial L}{\partial \theta_0} i$$ voltage equation

$$\frac{\partial^2 \theta_0}{\partial t^2} = \frac{\partial \omega_r}{\partial t} = \frac{1}{J}(T - T_L) = \frac{1}{J}(\frac{1}{2} i^T \frac{\partial L}{\partial \theta_0} i - T_L)$$ kinetic equation

Where, u - vectors of stator and rotor voltages; i - vectors of stator and rotor current; $d\theta/dt$ - the angular speed of rotation, J - the total moment of inertia; R - resistances of rotor/stator windings; T_L: load torque

[more details in: Control of Electric Vehicle Qi Huang, Jian Li and Yong Chen]

3-phase AC induction Motor



Transmission control

Transmission - gear selection

Do we need transmission in **Hybrid Vehicles**:

- Include both IC engine and Electric motor
- Clutch is required if IC propels the vehicle

Do we need transmission in **Electric and Autonomous Vehicles**:

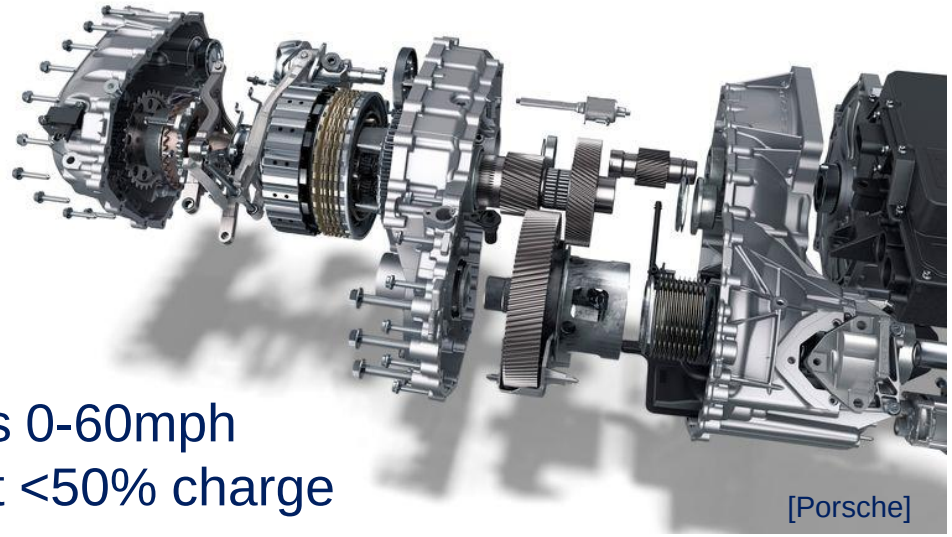
- Simple answer is NO (no idling, all torque available)
- However, it can be used for driving comfort or regeneration performance (engine braking)
- RPM speed can be limited due to whirl (shaft deflection)
- **Examples**: Formula E Renault team used 2 speed gearbox
- Ford Mustang 6 speed gearbox (800V, 900HP)

Porsche Taycan EV

Transmission in EV

- improved low-speed acceleration
- increased efficiency at high velocity by lowering the rotating speed of the power source

Porsche Taycan
2 speed automatic
750-hp
10 consecutive 2.6s accelerations 0-60mph
No degradation in performance at <50% charge



[Porsche]

Planetary Gear Set

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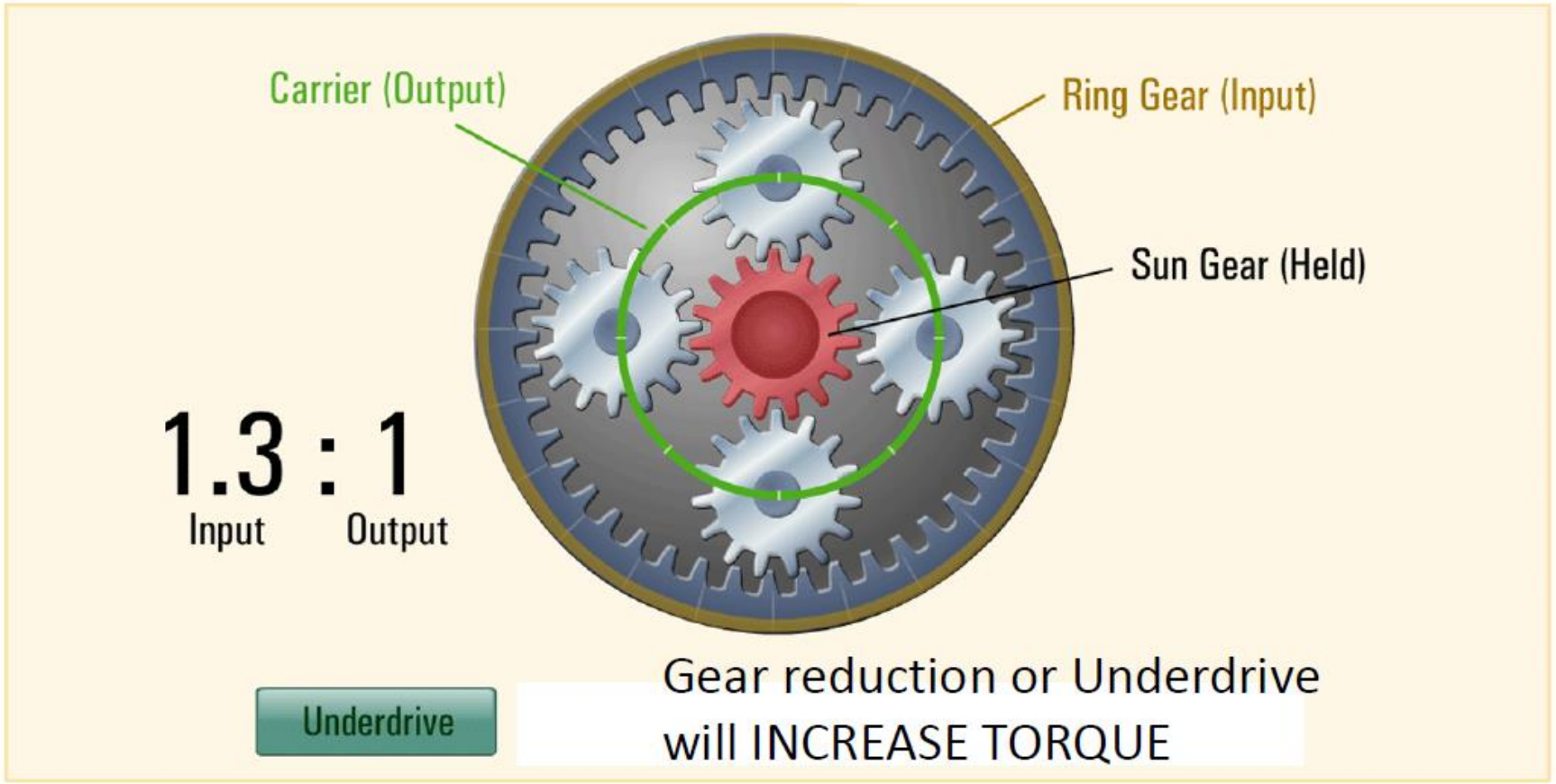

Brakes control

Hydraulic vs Electric brakes

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Hydraulic brakes

Advantages

- Tested and reliable technology
- Widely used on wide range of vehicles

Disadvantages

- Needs a high pressure pump
- Complex system, many mechanical parts

Hydraulic vs Electric brakes

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Electric brakes

Advantages

- Easy to control and power from battery
- Compact design, callipers only

Disadvantages

- High power requirement
- Larger unsprung weight
- New technology, potential for issues

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ABS System

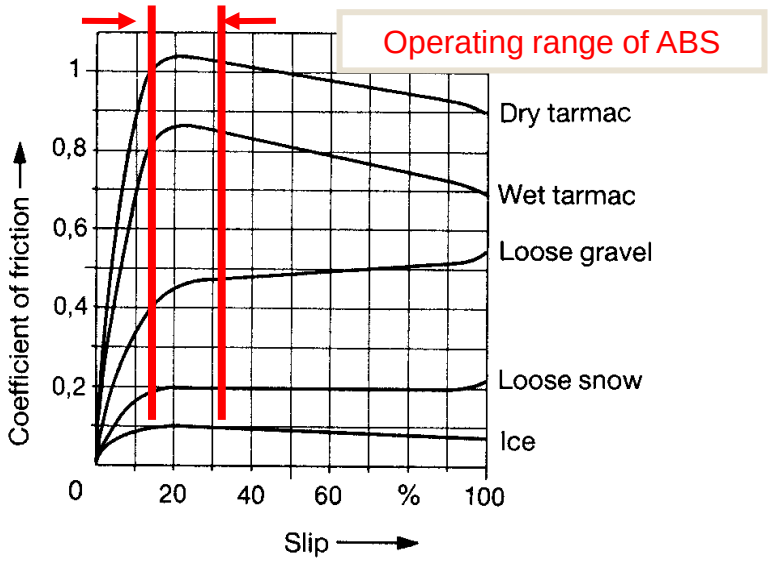
ABS main components:

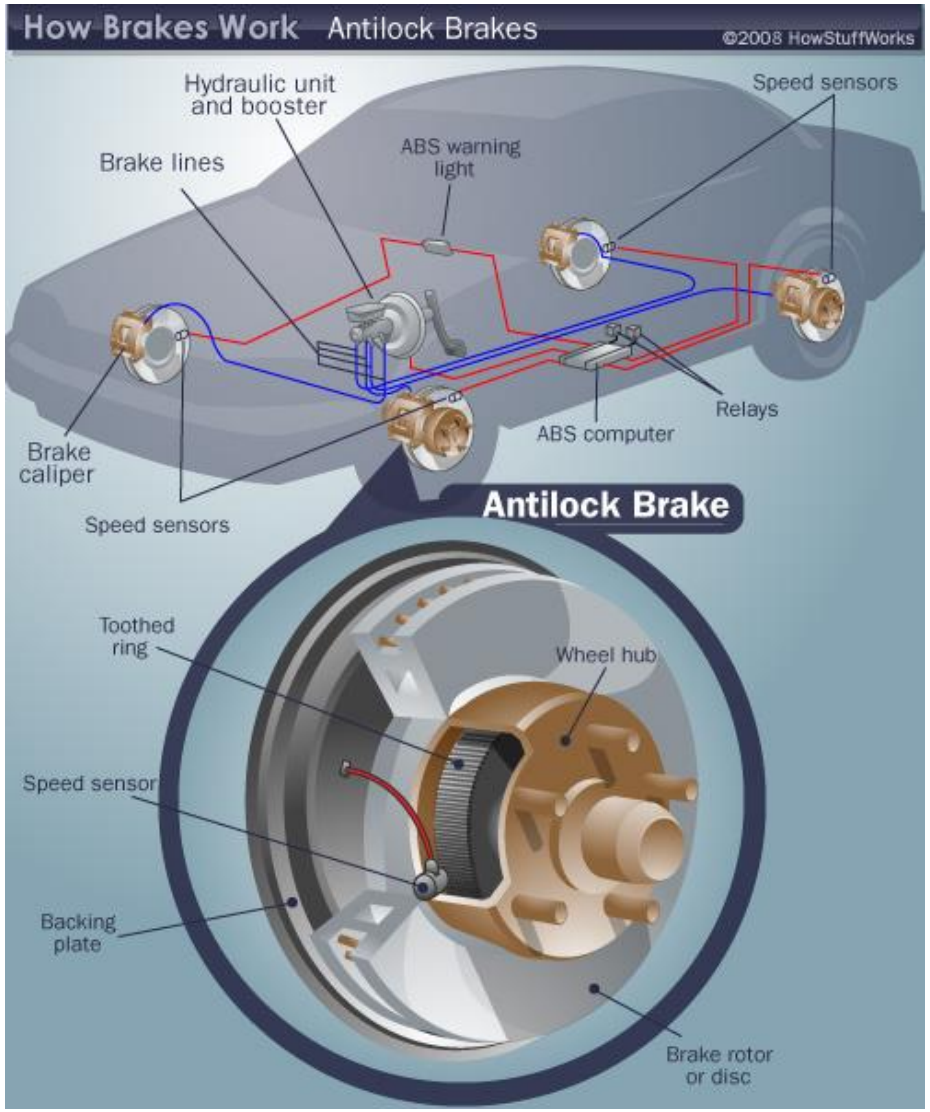
Speed sensors

Pump

Valves
(Open, Blocks, Releases)

Controller





Conclusions

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- Actuators required for autonomous drive can be adopted from driver vehicles
- Requirements for AV remains the same as for driver vehicles
- Engine control can be achieved using Drive-By-Wire technology
- Electric motors can be controlled electronically
- Gears selection in transmission can be achieved by clutches and hydraulic systems
- Braking control can be done by electric brake callipers

ANY QUESTIONS ???