Hybrid Electric Vehicle Architectures

Series, parallel, mild, strong, full, power-assist, one-mode, two-mode.....

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Objectives

• Recall the means by which HEVs improve fuel economy
• How do different architectures accomplish that?
• What are some tradeoffs that HEVs require to achieve improved fuel economy?
RECALL - Characteristics of HEV Drivetrains
(In approximate order of importance to efficiency)

• Isolation of Engine from Vehicle Operating Conditions
• Regenerative Braking
• Engine Downsizing
• Electric Drive Mode
• Electrified Accessories
• No Engine Idle
• Energy Banking
H/EV Architectures

1 Main EV Architecture
   – 1 Speed EV

3 Main HEV Architectures
   – Series
   – Parallel
   – Power-Split
Series Hybrid

- Two power sources feed a single powerplant

Note: Can act as a Strong or Mild Hybrid
Series Operation Modes

1. Pure electric traction – propelled by batteries
2. Pure ICE traction – engine to generator propulsion
3. Hybrid traction – both engine and batteries propel
4. Engine traction and battery charging – engine-generator both propels and charges batteries
5. Regenerative braking – Engine-generator off and the motor operates in reverse to charge batteries
6. Battery charging – no propulsive force provided and engine-generator charges batteries
7. Hybrid battery charging – both the engine-generator and the electric motor charge the batteries
Series Advantages

– Mechanical decoupling of the engine from the drive wheels allows operation anywhere on its speed-power curve – can aim for optimum operation as much as possible

– Electric motors spin to very high rpm – therefore the transmission unit requires less gears, is cheaper, and lighter

– Can use one electric motor per wheel – implications for AWD, traction and stability control

– Control systems are relatively simple
Series Disadvantages

– ICE energy converted twice (mechanical to electrical to mechanical) and therefore losses can be significant
– Requires a generator and its associated cost and weight
– Requires a large electric motor since it is the only powerplant directly propelling the vehicle
– Requires a full-sized ICE if battery does not have a high storage capacity (e.g., is not a PHEV).
Parallel Hybrid

- ICE and Electric Machine individually, or in combination, propel the vehicle

E.g.,

\[ P_2 \]

\[ P_1 \]
Parallel Operation Modes

1. Pure electric traction – propelled by batteries at low speed
2. Pure ICE traction
3. Hybrid traction – both engine and batteries propel
4. Engine traction and battery charging
5. Regenerative braking
6. Battery charging – ICE propels and electric machine charges battery (at the expense of the ICE)
Parallel Advantages and Disadvantages

• Advantages
  – Speeds and Torques of the two powerplants can be chosen independently (within constraints)
  – The powerplants can be smaller, and therefore cheaper and more efficient

• Disadvantages
  – More complex than series – in particular, control is far more complex
Power-Split Hybrid

Direct mechanical power path and an electromechanical path for the ICE. Sometimes termed a series-parallel hybrid.
Power-Split Operation Modes

1. Pure electric traction – propelled by batteries at low speed
2. Pure ICE traction
3. Hybrid traction – both engine and batteries propel
4. Engine traction and battery charging
5. Regenerative braking
6. Battery charging – ICE propels and electric machine charges battery (at the expense of the ICE)
7. Hybrid battery charging – both ICE (through MG1) and MG2 charge the batteries
Power-Split Advantages and Disadvantages

• Advantages
  – Combines the advantages of a Series and a Parallel
    • Has a direct mechanical path for the ICE, which is very efficient in steady operating conditions like cruising
    • Has an electromechanical path which allows for efficient operation of the ICE in unsteady driving, such as speed variations seen in city driving

• Disadvantages
  – Further complexity and cost
Modes of Operation

• “Charge-sustaining” HEV
  – Prius, Malibu
  – Batteries stay at about the same state of charge over the day
  – No need to charge from the wall

• “Charge-depleting” Plug-in HEV
  – Volt, EcoCAR2,
  – Batteries deplete over the driving day
  – Can charge from the wall
Types of PHEV Strategies

- Charge Depleting
- Green Zone
- HEVX, Range Extender

Fig. 2. J2841-type UF derived from the 2001 NHTS.
Discussion Points

• How far do you drive each day? What are the implications of your driving habits for your car purchasing decision?