

Hybrid Electric Vehicles Cheat Sheet

Series, parallel and power-split architectures; motor maps

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Motor efficiency map	$\eta_m = \eta_m(\tau_m, \omega_m)$	Stationary map that depends on motor torque and speed
Electrical power (motoring)	$P_{elec} = \tau_m \omega_m / \eta_m$	Battery supplies more than the shaft delivers
Electrical power (regen)	$P_{elec} = \tau_m \omega_m \cdot \eta_m$	τ_m negative when braking; battery receives less than the shaft gives
Power loss map	$P_{loss} = P_{elec} - \tau_m \omega_m$	Often used instead of an efficiency map
Torque limits	$\tau_{m,min}(\omega) \leq \tau_m \leq \tau_{m,max}(\omega)$	Both limits depend on motor speed
Planetary power-split gear	$\omega_s Z_s + \omega_r Z_r = \omega_c (Z_s + Z_r)$	Sun, ring, carrier speeds. Lets engine speed be set independently of wheel speed

Key takeaways

- An HEV cannot be plugged in. The battery is charged by regenerative braking and the engine; the motor adds power so a smaller engine works.
- **Series:** wheels always electrically driven; engine only makes electricity (smooth, but an extra conversion step). **Parallel:** engine and motor both can drive the wheels; most common.
- **Power-split (series-parallel):** a planetary gear set blends engine and motor power with infinite effective ratios. Used by Toyota, Lexus and Ford.
- Power-split engines often run Atkinson or Miller cycles: less power density and low-RPM torque, higher efficiency. The motor covers the torque gap.
- Quasistatic models are the standard tool for designing and evaluating energy management strategies.
- PHEVs add a bigger battery and plug: roughly 20–40 miles of electric range, but heavier and less efficient once the charge is gone.
- Hybrids brake more gently on pads and rotors (regen does the work), and need no separate starter motor.

Architectures at a glance

Type	Wheels driven by	Strength
Series	Motor only	Smooth power, slow/urban driving
Parallel	Engine, motor or both	Highway and quick acceleration
Power-split	Mechanical + electrical paths	Blends both; high efficiency
Split axle	Engine on one axle, motor on other	Adds a driven axle