

Hybrid Sports Car Energy Management

Racing regulation limits, vehicle model and control strategies

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Max corner speed	$v_{\max} = \sqrt{(\mu g r)}$	Lateral force balance. r = corner radius; μ tuned for dry, ideal conditions
Tractive force	$F_t = F_a + F_r + F_g + m_v a$	$F_a = \frac{1}{2} \rho A_f C_d v^2$, $F_r = \mu m_v g \cos \alpha$, $F_g = m_v g \sin \alpha$
Wheel torque to gearbox	$\tau = F_t R_w / FD$	Then divided again by the gear ratio
Battery (OCV-R model)	$P = V_{oc} I - I^2 R$, $dSOC/dt = -I / Q$	V_{oc} and R depend on SOC. Battery energy scaled to 1.35 kWh
Equivalent fuel (ECMS)	$\dot{m}_{eq} = \dot{m}_f + s \cdot P_{batt} / Q_{LHV}$	Minimized each step; s is the equivalence factor to tune
Braking assumption	$a = -1.2 g$	Used to find where braking must begin before each corner

Key takeaways

- Racing rules cap energy use: **110 kg fuel** per race distance, **100 kg/h** peak fuel flow, **120 kW** motor power, **2 MJ** regen per lap, **920 MJ** per stint.
- A **parallel** hybrid with a fixed-gear transmission suited the sports-car case. Series favors slow urban cycles; parallel favors high-speed and track driving.
- Model: backward-looking (the car follows the Daytona speed profile exactly), longitudinal dynamics only, flat track, 20°C, 1,700 kg, two laps of 300 s total.
- Strategies tested: engine only (baseline), ECMS fuel-rate control, engine optimum operating line (OOL), and dynamic programming (DPM).
- Baseline: about 2,750 g fuel and 58 MJ. The fuel-rate strategy with acceleration check (Strategy 5) had the lowest fuel and energy use among valid strategies.
- DPM broke the limits (about 30 g/s peak fuel flow, 8 MJ over the energy cap), likely a model error, so it was rejected.
- ICE peaks near 40% efficient while the motor is about 90%, so more time in electric mode saves energy. Gasoline holds 43.4 MJ/kg but most is lost as heat.
- A BMS protects the battery (SOC/SOH, balancing, thermal limits). It does not decide the engine/motor split.