Technical Analysis & Engineering Practice of CNG/LPG Dual-Fuel Conversion Systems

Based on ECU Closed-Loop Control & Multi-Point Sequential Fuel Injection Technology

Author: Engineering & Technical Dept. | Sichuan Yuncheng Vehicle Gas Equipment Co., Ltd. Category: Automotive Engineering / Autogas Systems

Table of Contents

1. Introduction: Autogas Conversion Under Fuel Cost & Emission Pressures

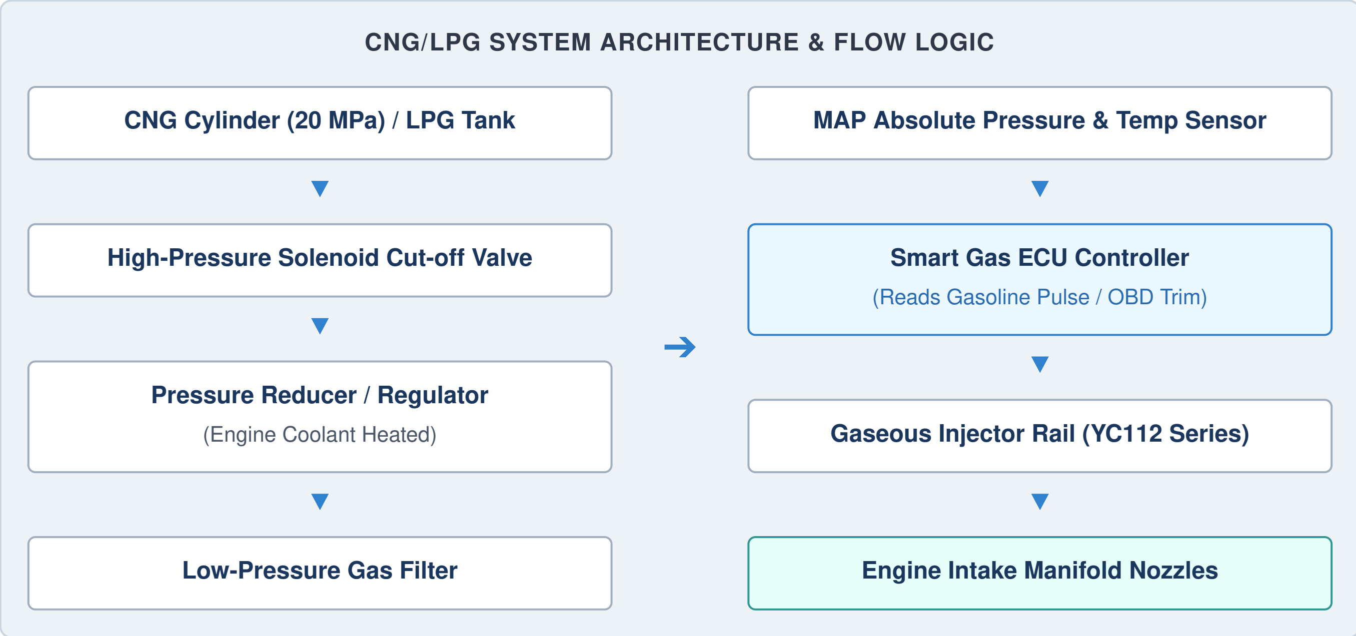
With fluctuating global oil prices and increasingly stringent carbon emission regulations, converting original gasoline engines into **CNG (Compressed Natural Gas) / LPG (Liquefied Petroleum Gas) dual-fuel systems** has become the most cost-effective, low-carbon solution for taxis, ride-hailing services, light commercial vehicles, and logistics fleets.

Compared to gasoline, CNG and LPG feature higher octane ratings (CNG octane exceeds 120), offering superior anti-knock capabilities while significantly reducing CO, HC, and particulate matter (PM) emissions. However, gaseous fuels differ drastically from liquid gasoline in physical state, density, and flame propagation speed. Engineering a seamless transition—delivering precise fuel metering without altering the engine's core mechanical structure—requires robust hardware design and advanced closed-loop control logic.

This technical whitepaper draws upon the engineering practices of **Sichuan Yuncheng Vehicle Gas Equipment Co., Ltd.** to analyze the architecture, hardware precision, and dynamic calibration algorithms of modern 5th and 6th generation sequential injection autogas systems.

2. Core Architecture of CNG/LPG Gaseous Fuel Systems

The operating principle of modern dual-fuel conversion systems is: *"Intercepting the original vehicle ECU injection timing, factoring in real-time gas temperature and pressure corrections, and recalculated by the Gas ECU to drive high-speed gas injector rails."*



3. Key Hardware Components & Engineering Selection Analysis

System stability and low failure rates depend directly on component material selection, CNC machining tolerances, and embedded control algorithms.

3.1 Pressure Reducer/Regulator: Pressure Step-down & Heat Exchange

CNG high-pressure cylinders store gas at pressures up to **20 MPa (200 bar)**, whereas intake manifold sequential injection requires a stable working pressure of only **0.12 to 0.20 MPa**. This 100-fold pressure reduction triggers the *Joule-Thomson effect* (adiabatic expansion cooling), causing severe temperature drops in the regulator body.

- **Two-Stage Pressure Reduction:** Designed with a dual-chamber diaphragm mechanism. The first stage reduces pressure from 20 MPa down to 0.4–0.6 MPa, and the second stage stabilizes output to the set operating pressure, minimizing pressure fluctuation under high engine loads.
- **Integrated Heat Exchanger:** Engine coolant channels (-40°C to 120°C operational range) are integrated directly into the aluminum alloy regulator housing, using engine waste heat to prevent internal valve icing and freeze-ups.
- **Precision CNC Machining:** Housing and sealing surfaces are machined from aviation-grade aluminum alloys using high-precision CNC milling to ensure pressure integrity and corrosion resistance over extended lifespans.

3.2 Smart Gas ECU & Closed-Loop Emulation Algorithms

The Gas ECU serves as the central processing unit. Utilizing advanced processor architectures (e.g., MP48 series OBD-II integrated controllers):

- **Signal Interception & Emulation:** Reads the original petrol injector timing (Injection Pulse Width). When switched to gas mode, internal emulator resistors bypass the petrol injectors to eliminate open-circuit Fault Codes (DTCs) on the OEM engine control module.
- **Dynamic Compensation Formula:** Based on the ideal gas equation ($PV = nRT$), the Gas ECU calculates real-time gaseous injection duration (T_{gas}) by compensating for gas rail pressure and gas temperature:

$$T_{gas} = T_{petrol} \times K_{map} \times F_{temp}(T_{gas}) \times F_{press}(P_{rail}) + T_{dead}$$

Where K_{map} is the mapping calibration coefficient, and T_{dead} represents injector rail solenoid latency response time.

- **OBD-II Real-Time Trim Adaption:** Interfacing directly with the vehicle's CAN bus, the system monitors Short-Term Fuel Trim (STFT) and Long-Term Fuel Trim (LTFT) to adjust gas pulse width on-the-fly, holding the air-fuel ratio near stoichiometry ($\lambda = 1.0$) to avoid Check Engine Lights (CEL) or engine knock.

3.3 Gaseous Injector Rail Dynamic Response

Because gaseous fuel occupies a significantly larger volumetric flow rate than liquid gasoline, valve stroke speed and opening latency are critical:

- **Response Speeds:** High-performance injector rails (e.g., YC112 Series) achieve opening speeds under **2.0 ms** and closing speeds under **1.5 ms**, preventing valve lag even at high engine speeds (4,000+ RPM).
- **Modular Coil Configuration:** Low-impedance coils (1Ω – 3Ω) ensure rapid current saturation for precise fuel metering across 3, 4, 6, and 8-cylinder configurations.

4. Multi-Point Sequential Injection vs. Traditional Single-Point Systems

Engineering Feature	Traditional Single-Point System	5th/6th Gen Sequential System
Injection Location	Throttle Body / Main Intake Duct	Individual Intake Runner Ports (Near Valves)
Air-Fuel Ratio Control	Open-loop / Mechanical Mixer (Slow)	Digital ECU Closed-Loop (Individual Cylinder)
Power Output Loss	15% – 25% Power Reduction	Minimal Loss (< 5% – 8%)
Backfire Risk	High (Intake manifold filled with gas mix)	**Eliminated** (Intake manifold contains air only)
Emissions Standard	Euro 1 / Euro 2 Compliant	**Euro 5 / Euro 6 / EPA Compliant**

5. System Reliability & Engineering Testing Under Extreme Conditions

Vehicle retrofit hardware must withstand rigorous operating environments including severe engine vibration, extreme heat, ambient humidity, and gas impurities.

1. **Extreme Temperature Leakage Testing:** Pressure reducers and solenoid valves undergo high-pressure helium/nitrogen leakage testing across temperature ranges from -40°C up to +120°C (Zero-Leakage standard).
2. **Fatigue Endurance Cycling:** Injector rails and regulator diaphragms are tested up to **10 million pulse cycles**, simulating over 200,000 km of real-world driving.
3. **Environmental Protection:** Anodized anti-corrosion aluminum bodies and IP67 waterproof harness connectors ensure operational stability in high-humidity tropical environments (e.g., Southeast Asia, Latin America, West Africa).

6. Summary & Future Outlook

The advancement from basic single-point gas mixers to **OBD-II closed-loop sequential injection systems** has dispelled early misconceptions regarding autogas power loss and reliability issues. High-precision CNC manufacturing, combined with dynamic calibration algorithms, enables modern CNG/LPG conversion systems to deliver gasoline-like drivability with lower operational expenses and reduced carbon emissions.

As clean fuel infrastructure continues to expand globally, CNG and LPG solutions remain vital bridge technologies for sustainable transport fleets worldwide.

Technical parameters and system architecture referenced from Sichuan Yuncheng Vehicle Gas Equipment Co., Ltd. official product specifications and engineering documentation.