LM71

Energy Efficiency & Reliability in Automatic Transmission Systems (High Temperature Digital Temp Sensor)

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No. 116

Energy Efficiency and Reliability in Automatic Transmission Systems

— *By Juliano Vidi, Design Engineer*

After price, reliability and fuel efficiency are primary decision factors for car buyers. When buying a new car, the last thing you want to worry about is being stuck on the side of the road with car trouble. Drivers want to have confidence that their cars are reliable and long lasting, with excellent fuel efficiency and low CO2 emissions.

The automotive powertrain system consists of an internal combustion engine, a multiple ratio-geared transmission, and wheels. Engine torque and speed are converted in the transmission in accordance with the tractive power demand of the vehicle. The vehicle's transmission can also control the direction of rotation being applied to the wheels.

Transmissions are generally referred to as manually-actuated or automatic transmissions. Automatic transmissions are designed to take automatic control of the frictional units, gear-ratio selection, and gear shifting.

For purposes of lubrification and cooling, a hydraulic fluid is used in automatic transmissions. The following are the primary functions of the automatic transmission fluid (ATF):

- Transfer power from the engine to the driveline via the torque converter.
- Absorb heat from the torque converter and transmit it to the cooler located in the front of the vehicle.
- Act as a clutch pack, friction element coolant. It must absorb and dissipate the heat energy dissipated by a clutch or band engagement.
- Transmit hydraulic pressure through a complex hydraulic control system which uses valves, servos, pumps, clutch cylinders, fluid lines, and passages.
- Act as a lubricant and coolant for the planetary gears, bearings, servos, clutches, and bushings.

Cold Start

ATF normally has a low viscosity at its working temperature (approximately 90°C/195°F). If, however, the oil temperature is very low (considerably below 0°C/30°F), there is an extreme increase in its viscosity, resulting in very high-

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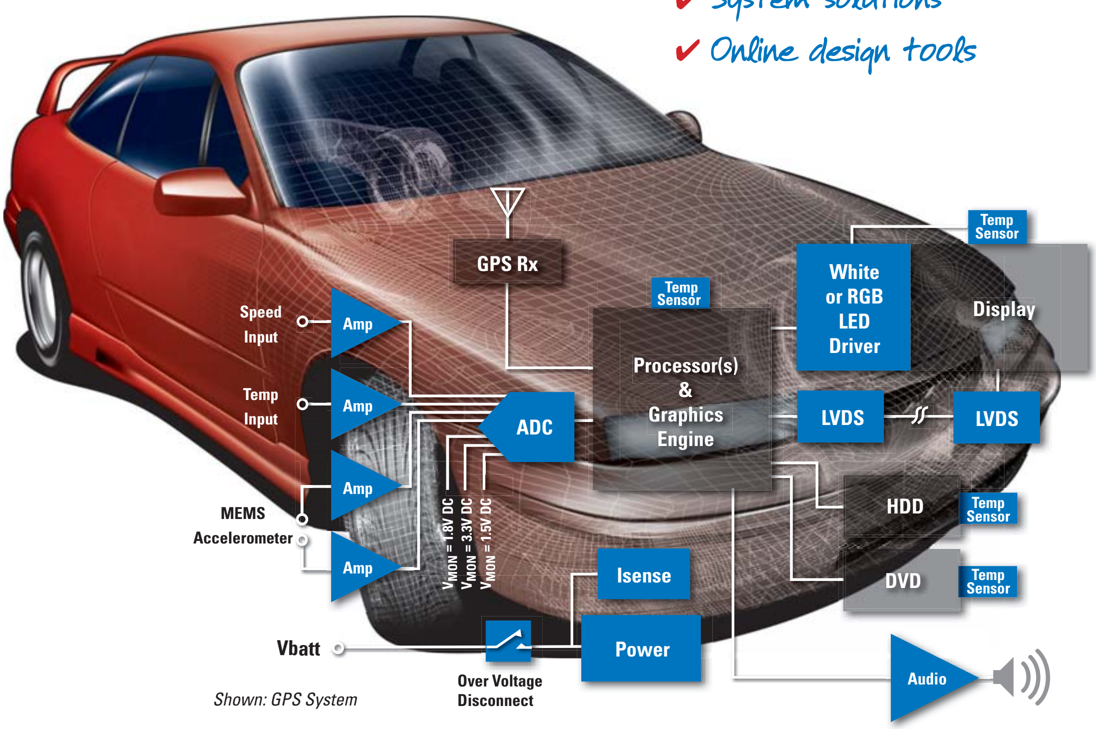

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drag torques. As a consequence, it can become impossible to engage a gear since the synchronizing devices are designed for much lower torques. Based on the oil temperature, a "cold start" program can be activated to make sure that at least one gear will be engaged.

Warm-up Process

After the vehicle starts to move during normal driving, i.e. without pronounced acceleration or without the need to start off while pulling a heavy load (like a trailer), the fluid temperature increases relatively slowly. This means that the drag torques also decrease very slowly. Over long periods under high-drag torque conditions, the synchronizing device is overloaded and can be damaged.

Introducing some losses into the gearbox, moving the shift point to higher rotational-speed values, and controlling the quantity of oil in the gearbox can accelerate the warm-up process. Thus, the engine, the gearbox, and the catalyst reach the optimal operation temperature more quickly. The sooner the transmission reaches its ideal temperature, the sooner the consumption-optimized gearbox shift program begins to operate.

The gears are shifted with elements that are controlled by hydraulic or electronic-actuated valves. The actuation of such shift elements is highly temperature dependent since the oil viscosity changes markedly with the temperature. Temperature thus affects the level and the time behavior of the applied pressure. While the ATF warms up, the temperature varies in an extremely wide range. It is therefore desirable to take into account the temperature of the oil when setting the oil pressure to shift the gears properly.

Operation at High Temperatures

Heat, rather than cold, is the main concern for ATF. Automatic transmissions create a lot of friction, and friction produces heat. The greater the load on the transmission, the more heat it generates and the hotter the fluid becomes.

Normally, the maximum allowable temperature for conventional transmission oils is 80 to 100°C/175 to 212°F and for special transmission oils 110 to 130°C/230 to 265°F. Meanwhile, in transmission assemblies of modern automotive vehicles, the oil temperature may be as high as 120 to 150°C/250 to 300°F and in transmissions of more heavily loaded trucks (such as 18-wheel freight trucks) when operating in hot climates, the temperature may be as high as 160 to 170°C/320 to 340°F. High oil temperatures such as these lead to undesirable consequences, both for the oil itself and for the transmission parts.

Oil Service Life

Under these hot conditions, the service life of the oil is shortened. Once temperatures move above the normal operation levels (about 90°C/195°F), the lubricant's rate of oxidation will increase and shorten its effective life.

Wear on Working Surfaces

High temperatures also represent a major hazard to the working surfaces of the transmission's moving parts as less heat is removed from the abrasion zones and the danger of seizure is increased. At temperatures above 175°C/350°F, the hardness of the steel is reduced. Since the temperature of the gear-tooth and the clutch working surfaces are usually higher than the oil temperature, it becomes clear that a decrease in the hardness of the gear material is possible with oil temperatures even lower than175°C/350°F.

Seals and Flow Lines

The rubber seals and the coolant flow lines are highly sensitive to high oil temperature as well. Rubber seals become hard and brittle when exposed to high temperatures, with a consequent sharp reduction in their life and reliability. Coolant flow lines made of plastic material PA12 (polyanide12 or nylon 12) are used in installations that do not accommodate a metallic coolant flow line to connect the torque converter flow outlet port to the cooler. Under high temperature (over 175°C/350°F), the plastic cooler warps the oil can upstream and the cooler will probably fail.

Electronic Control Unit (ECU) Overheat

The ECU is used to monitor and control the activities of an automatic transmission system. In some cases, the ECU is placed inside the gearbox casing or hosing in order to utilize the space present in the gearbox. This means the control unit stays in direct contact with the ATF. Advantages of this configuration are the very short cables used to connect the ECU, sensors, and actuators; the small number of plugs and connectors; less noise in the lines; and consequently more accurate shift position detection.

If the transmission environment and the coolant oil reach extremely high temperatures, the power and the control electronic components cannot work properly, and therefore the lifetime is compromised, and damages can occur. Thus, overheating situations must be detected or even predicted. Actions must be taken to reduce heat production and/or improve heat dissipation. In some extreme cases, the temperature must be precisely detected and the most sensitive electronic components switched off to avoid complete failure of the control electronics.

The Solution: A Digital Temperature Sensor

To address all of these challenges in temperature monitoring inside automatic transmissions, National Semiconductor has optimized the LM71 temperature sensor, creating the LM71A1 for high-temperature applications.

The LM71A1 is a digital temperature sensor with integrated signal conditioning, control logic, a 14-bit A/D converter, and SPI interface ***(Figure 1)***. Its wide operating temperature range (-40 to +175°C/-40 to 350°F) makes monitoring possible under cold start and overheating conditions. But its most important feature is the tightest accuracy (±1°C/±1.8°F) at high temperature (130 to 150°C/165 to 300°F) as seen in ***Figure 2*** and the high resolution (0.03125°C/LSB). This allows precise sensing at the most critical of conditions; namely, extremely high temperatures.

This device is available in bare die form that guarantees faster thermal response, optimizing the warm-up process control. Different technologies may be used to assemble the unpackaged die on the board. Chip-on-board (COB), direct chip attachment (DCA) on boards, or substrates and flip-chips are the most commonly-used technologies to electrically interconnect the die to the final circuit.

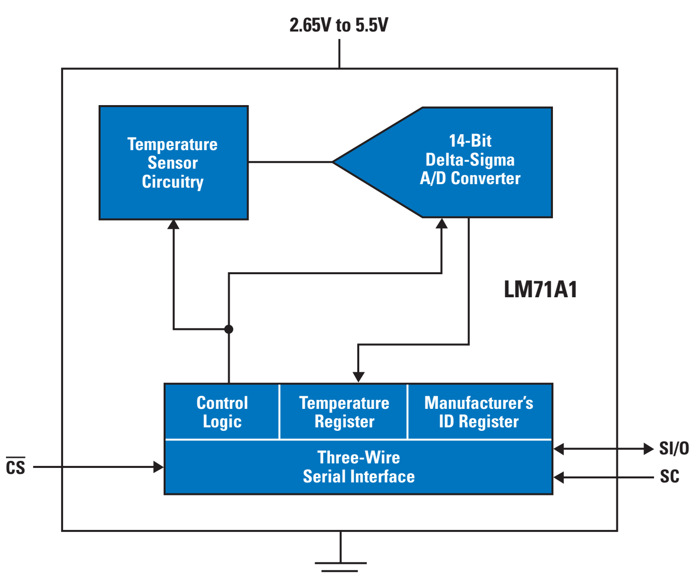


Figure 1. Simplified Block Diagram

Energy Efficiency and Reliability in Automatic Transmission Systems

To guarantee good thermal coupling, the ECU or the temperature sensing system can be found inside a metallic housing, placed in the oil sump, and partially or completely surrounded by the ATF.

In order to keep the oil temperature within the operation borders, to properly control valves and shifting times, and to protect against sharp deterioration and damages, accurate temperature detection is a key factor. Accurate temperature detection ensures higher fuel efficiency and elevated system reliability. The LM71A1 device can help designers develop high-performance thermal management systems for electronic control units in any transmission system.

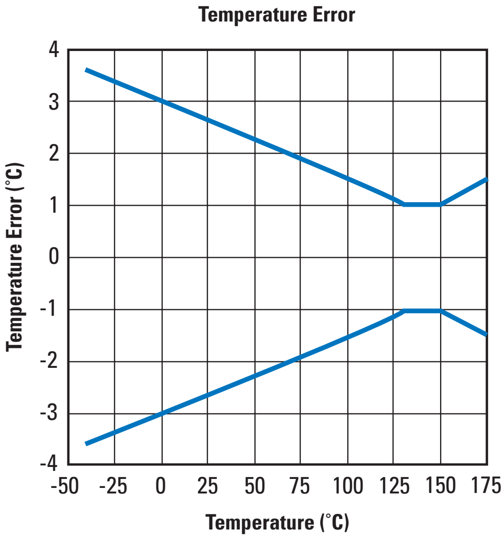
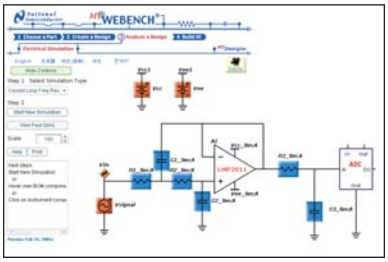


Figure 2. Temperature Error vs. Temperature

Design Tools



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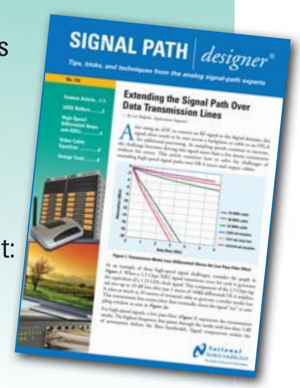

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