High Temperature Electronics

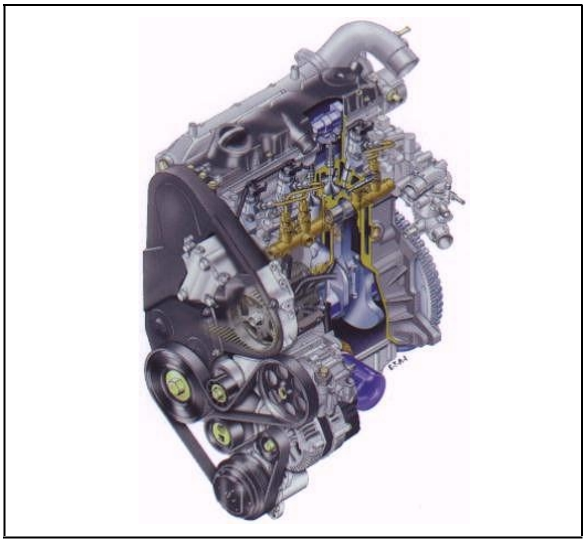
1 Introduction

In the semiconductor world, there are numerous products specified with an industrial temperature range (-40/+85°C), and somewhat fewer with an automotive temperature range (-40/+125°C).

It is much more difficult to find products specified and guaranteed for temperature above +125°C.

However, since applications requiring high temperature components are growing, the demand for "hot" silicon devices has increased tremendously.

One of the leading markets concerned here is automotive, which continues to show a relatively good growth rate despite economic crisis.

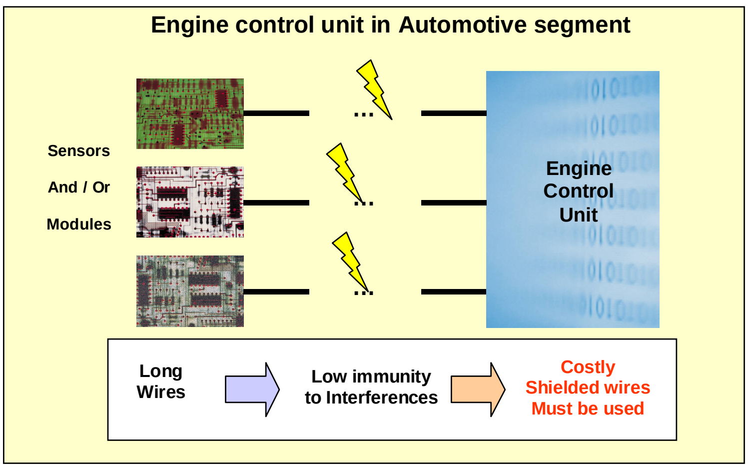


2 Why the need for high-temperature semiconductors?

Automotive and industrial environments are responsible for most high temperature requirements. In these segments, for instance, sensors and electronics have to be placed right near to their function modules. This is done to limit the use of high-cost, high-end wiring needed to avoid interference effects. All experts know that long wires are much more sensitive to EMI point and to control this, costly wiring that offers interference-immunity must be used. Placing the semiconductor next to the module it controls reduces the need for such wiring.

However, the environment for semiconductors can be very harsh in the Automotive and Industrial segments. Typical examples are the electronics used in the ECU (Engine Control Unit) which monitors and optimizes an automotive engine. This unit is increasingly found in the engine compartment where temperature variations are extreme.

Figure 1



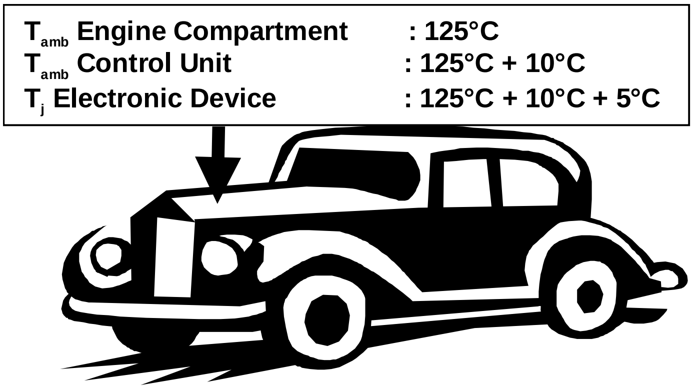
Example of a typical application:

An electronic module (ECU, Engine cooling fan, automatic gearbox...) is adjusted directly in the engine compartment and is usually thermally connected to the engine cooling water or engine oil circuit.

Because of this, ambient temperatures for the electronic control unit are in the range of 125°C. The power dissipation of the semiconductor components results in a further increase of temperature in the ECU of around 10°C. This means that every semiconductor device is subject to an ambient temperature of about 135°C. On top of this, the power dissipation of each component has to be added, resulting in the maximum temperature of the silicon. In the example below, the standard operational amplifier or comparator has to operate at around 140°C.

Therefore a device is required that is specified for and guarantees operation for at least 140°C.

Figure 2

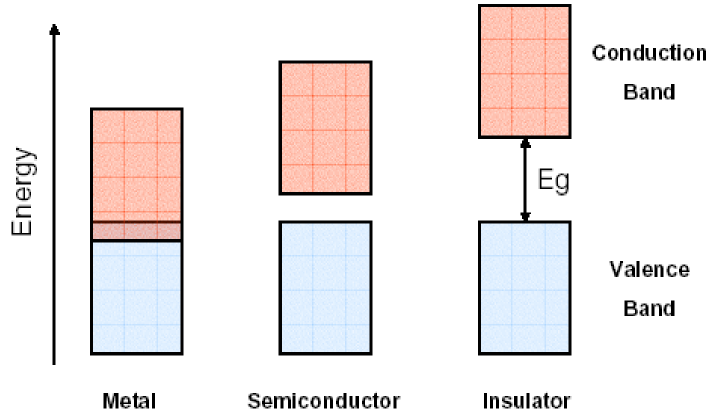


3 High temperature silicon: a great challenge

At elevated temperatures, semiconductors are affected by physical laws which can modify of their electrical properties. In addition to a transistor's reduction in gain with increasing temperature, designers face problems caused by a phenomenon called leakage current. The degree to which leakage current presents an important problem can vary depending on the technologies used and the design optimization, but it is always present at elevated temperatures. For example, there is lower leakage current in gallium arsenide (GaAs) technologies, versus silicon (Si) technologies, but silicon devices are much more common and widely used.

The basic operating principle of semiconductors is the management of energy. At the atomic scale, there are two different levels of energy for the electrons: the valence level and the conduction level. The separation between the two energy bands is called the band gap, often specified as the parameter *Eg*. The value of *Eg* is large for an insulator but very small (or zero) for metals, which are known to be good conductors. In semiconductors, when electrons have enough energy (through thermal excitation, for instance) to move from the valence band to the conduction band, the conductivity of the inner material increases. In the case of a silicon-based semiconductor, the band gap energy decreases as the temperature increases. Thus, at elevated temperature, electrons can move easier from the valence band to the conduction band creating what we call leakage current.

Figure 3

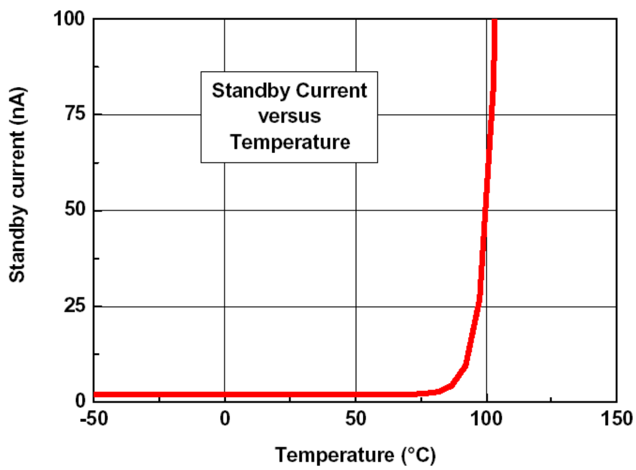


	+25°C	+125°C	+150°C
Ge	0.664 eV	0.624 eV	0.614 eV
Si	1.121 eV	1.094 eV	1.086 eV
GaAs	1.423 eV	1.377 eV	1.365 eV

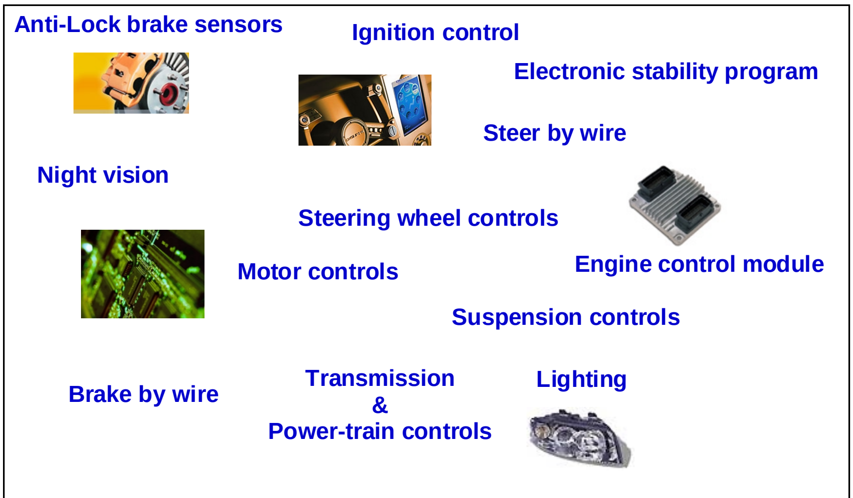
Band Gap Energy (Eg) of different semiconductors
using Varshni model

In order to visualize the leakage current phenomenon, the graph below represents a standby current variation versus temperature on a voltage reference product designed for an industrial -40°/+85°C temperature range. At low temperature, the standby current is very low (as required by its electrical specifications). However, as the temperature increases, the leakage current becomes dominant. Because the leakage current value increases in an exponential way after a threshold temperature, the product shown has a very real temperature range where it can be considered fully functional. It should be noted however, that the position of the "knee" of the curve can be shifted in depending on manufacturing process variations.

Figure 4



4 What are the applications for high temperature components.



High temperature for Automotive Applications

5 High temperature products proposed by STMicroelectronics

ST has performed in-depth reliability testing in order to qualify a selection of standard products within the extended -40°/+150°C temperature range. Of course, specific production processes have been put in place to ensure the high level of quality required by such electronic components. These specific processes are based on 100% test coverage in temperature on the production lines. Testing is performed at +150°C during wafer conditioning and at +125°C for SO packages with a guarantee by correlation up to +150°C. This test coverage allows customers to use these products with a high confidence level.

COMPARATORS							
Sales Types	**Temperature Range**	**Supply Voltage**	**Supply Current**	**Response Time**	**Type**	**Package**	**Status**
LM2901H	-40/+150°C	2 to 36V	1.1mA	1.3µs	Quad	Wafer SO14	Available
LM2903H			0.4mA		Dual	Wafer SO8	
OPERATIONAL AMPLIFIERS							
Sales Types	**Temperature Range**	**Supply Voltage**	**Supply Current**	**GBP**	**Type**	**Package**	**Status**
LM2902H	-40/+150°C	3 to 30V	0.7mA	1.3MHZ	Quad	Wafer SO14	Q2 2004
LM2904WH				1.1MHZ	Dual	Wafer SO8	Available
TS922H		2.7 to 12V	2mA	4MHZ			

For more information about STMicroelectronics range of high temperature devices, please contact your local ST sales office.