Application Notes
Version 1.0

Using CJ125 for Lambda Sensor LSU4.2/4.9

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Revision History

Version	Date	Author	Remark
0.1	17-03-05	QZ	Initial drafts start with 0.10
0.2	22-02-06	QZ	Preliminary version
1.0	02-05-09	QZ	Adding information for the choice of the heater transistor (chapter 6) Formal modification

References:

[1] Data Sheet CJ125, ver. 05, 1 279 923 679, 21.04.2009

[2] Technical Customer Information LSU4.2, Y 258 K01 010-000, 27.05.2003

[3] Technical Customer Information LSU4.9, Y 258 K01 013-000e, 25.06.2003

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1 Introduction

This document provides information about the external circuits of the CJ125. It describes how to integrate the chip into a control system. This document also provides guidelines for controlling power supply to the chip, sizing components in the external circuits and communicating with the chip.

The CJ125 is an integrated control and amplifier circuit that has been designed for use with the Bosch LSU4.2 and LSU4.9 wide band oxygen sensors. When properly incorporated in an engine control system, the CJ125 & LSU4.x can be used to monitor and control air fuel ratio.

The CJ125 performs three primary functions. They are measurement of oxygen concentration, sensor temperature control and diagnostics of sensor wiring.

Measurement of Oxygen concentration is performed by a combination of passive measurement and active control. The CJ125 measures the Nernst voltage between a reference chamber and the diffusion gap in the oxygen sensor. Based on that measurement, the CJ125 generates a pumping current (I_{IA}) to pump oxygen into or out of the diffusion gap to maintain the Nernst voltage at 450 mV, which is equivalent to a $\lambda = 1$ atmosphere. That pumping current is used by the CJ125 to generate the voltage UA, an output to the ECU. UA is a function of oxygen concentration in the monitored gas.

Sensor temperature must be controlled because measurement of oxygen concentration is temperature sensitive. The internal resistance is a function of the sensor temperature. The CJ125 measures the internal resistance of the Nernst cell and generates an output signal, UR. That signal can be used by the ECU to duty cycle the sensor heater to control sensor temperature.

By monitoring line voltages, the CJ125 diagnoses shorts to ground and shorts to battery in IA, IP, VM, UN and the heater wires. It also diagnoses an open loop condition in the heater circuit. Open loops in IA, IP, VM and UN must be detected via software algorithms. This information is communicated to the ECU via the SPI interface.

This document is only applicable to the package SOIC24 and must be used in conjunction with the CJ125 datasheet [1].

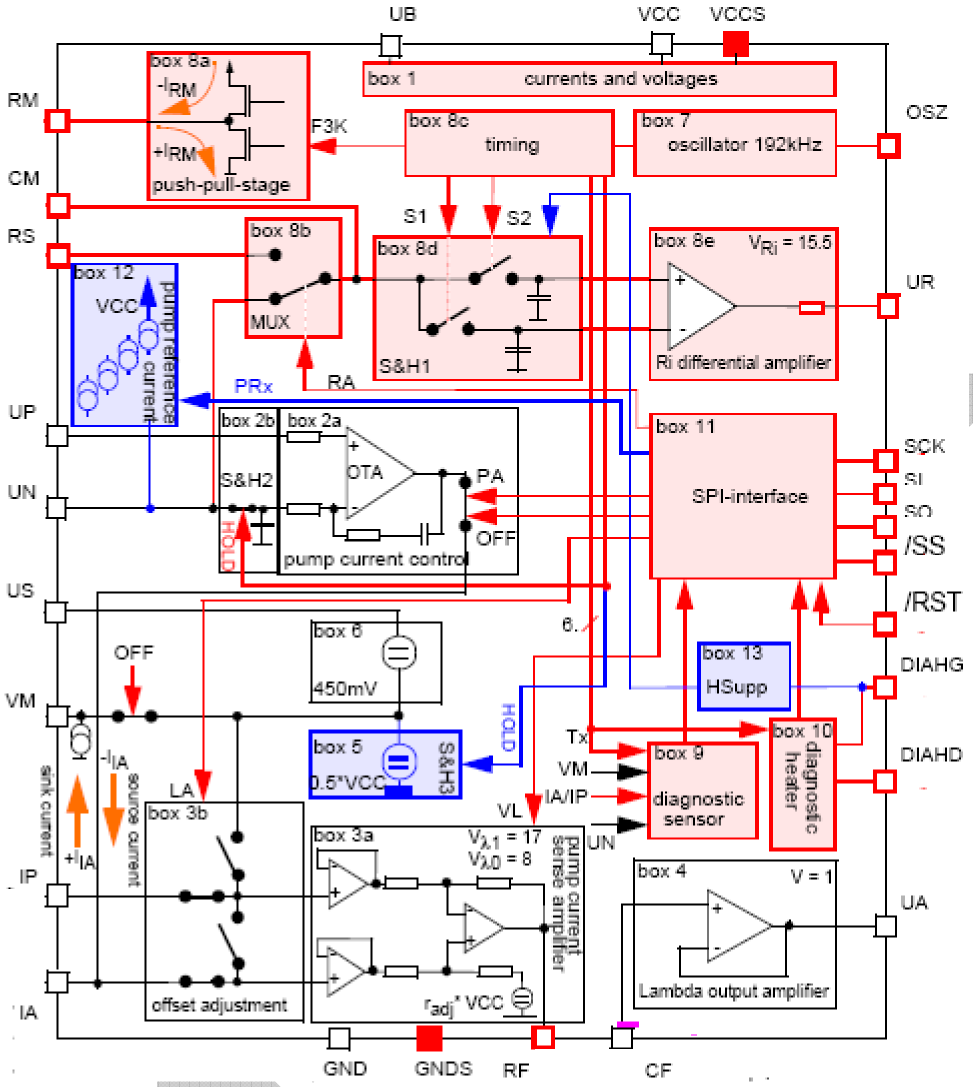

Figure 1.1: Block diagram of IC CJ125 [1]

2 Power supply considerations for CJ125

Protection of pin UB

In this application note the voltage applied to the pin UB is expressed as V_{UB} and the battery voltage is called $V_{battery}$.

The pin UB is designed for a static voltage in the range of -0.3 to +28V ([1] 7.1.1). However, the power supply voltage for the ECU (Engine Control Unit) could exceed this value for a short time, for example, due to load dump or a large peak pulse (positive or negative). The load dump voltage can even exceed 36V and the negative pulse can be as low as -1.5V. Therefore, a pulse test and a load dump test on the battery lead connecting to the ECU are recommended. If the voltage is out of the permissible range a counter measure should be implemented to limit the voltage at the pin UB.

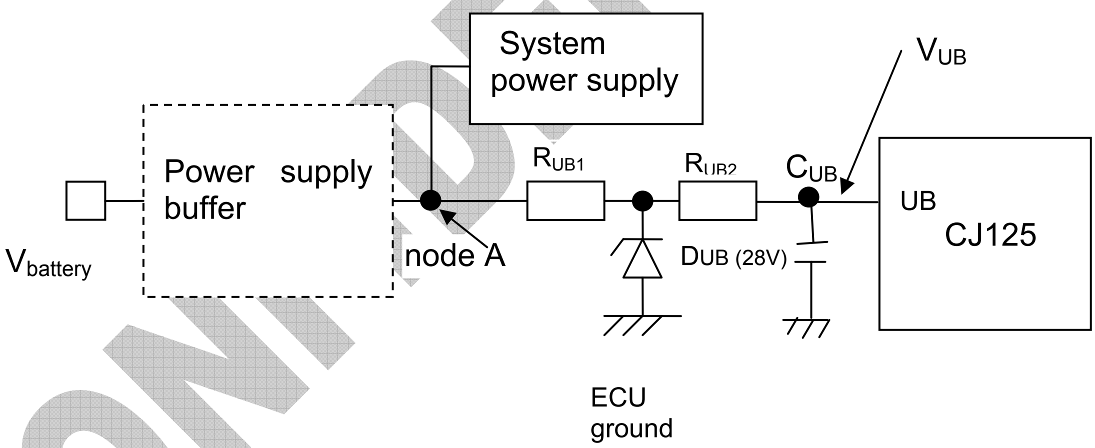

Figure 2.1: A suggested external circuit for pin UB transient pulse protection

As shown in figure 2.1, a Zener diode D_{UB} with maximum voltage of 28V, together with a resistor R_{UB1} in series is suggested to limit the voltage at the pin UB. For a possible negative pulse, the Zener diode, and a resistor R_{UB2} together with a large capacitor can be used to prevent the voltage at pin UB from dropping below -0.3V. The component values should be chosen according to the pulse test requirements of the system.

It is important to mention that the protection measures described above cannot be used as an endurance reverse polarity protection. In this case additional system components or other system strategies have to be implemented to protect the IC.

Additional cautions must be also paid for the dimension of the resistor so that the voltage at the pin UB cannot fall bellow 9V in the normal case.

It is strongly recommended that the node A in figure 2.1 is not directly connected to the car main power supply due to the high noise in the line and instable voltage value, which may introduce further noise into the measured output results. Moreover, only the ECU local ground should be used to avoid any ground potential shift.

For choosing the geometry size of R_{UB1}, the power dissipation should be taken into account.

It should be checked if V_{UB} becomes smaller than VCC for certain operation conditions (e.g. shortly after the V_{UB} is switched off). In this case the reliability and the life time of the IC will be negatively affected ([1] 8.2.4.2).

3 Application diagram and component dimensions

Component functions and dimension guideline:

The resistance R_{ical} (301 Ohm) refers to the Nernst cell internal resistance at 780°C. It will be used as a reference for the evaluation of R_i to determine the sensor temperature [3].

R_{mes} is used for the pump current measurement. A value of 61.9 ohms is used for lambda sensor calibration.

R_{fb1} and R_{fb2} are used to feedback the pump voltage signal to improve the measurement accuracy.

R_{OSC} is intended for the 3kHz generation.

R_{RM} and C_{CM} are the external components, which generate the AC current for the Ri measurement.

R_{UP_UN} is used to ensure that the potential of pin UP is closed to the one of pin UN in case of cold sensor.

Above values are fixed.

A low pass filter defined by R_F and C_F is able to suppress the influence of the Ri measurement on the lambda-signal. A large time constant can improve the measurement accuracy but can also reduce the cut off frequency. Please choose the values according to the application for accuracy and dynamic behavior respectively.

The components C_{UA}, R_{UA}, C_{UR} and R_{UR} should be selected according to dynamic requirements and noise level of the electronic circuit respectively.

- The minimum values of the capacitors C_{UA}, C_{UR} depend on the input capacitance of the ADC. Usually, a SAR type (Successive Approximated Algorithm) of embedded ADC (Analog Digital Converter) from a microcontroller is connected to both outputs. Based on the data sheet of the microcontroller, it should be ensured that the capacitor C_{UA} or C_{UR} is at least 2^{10} larger than the input capacitance of an 10bit-ADC in order to avoid any side effect during ADC sampling phase.

- A clamping resistor may be used in order to limit the current injection to the input channel of the embedded ADC. The leakage current from the input pin of the ADC should be checked. This leakage current causes an undesired voltage drop on the clamping resistor. Hence, the value of the resistance should be dimensioned in a way that the error due to the input leakage current is smaller than 1LSB for a 10bit-ADC.

The resistor R_{limit} is intended to limit the injected current to the pin DIAHD ([1] 8.15.2.7.1-2).

The R_{heat} keeps the power MOSFET shut off when it does not operate. The choice of its value depends strongly on the pin properties of the MCU and the used MOSFET. Generally speaking, the value should fulfill two requirements:

- The voltage drop on the resistor due to the maximum leakage current (e.g. from the MCU pin) must be smaller than the threshold voltage of the power MOSFET.
- By logic “1” at the MCU pins, the minimum drive current from the MCU must keep the gate voltage closed to VCC, so that the power MOSFET can be fully switched on.

In summary, the suggested dimensions of the external components are listed in Table 3.1.

Recommendations for the EMC/ESD capacitors are described in charter 5.

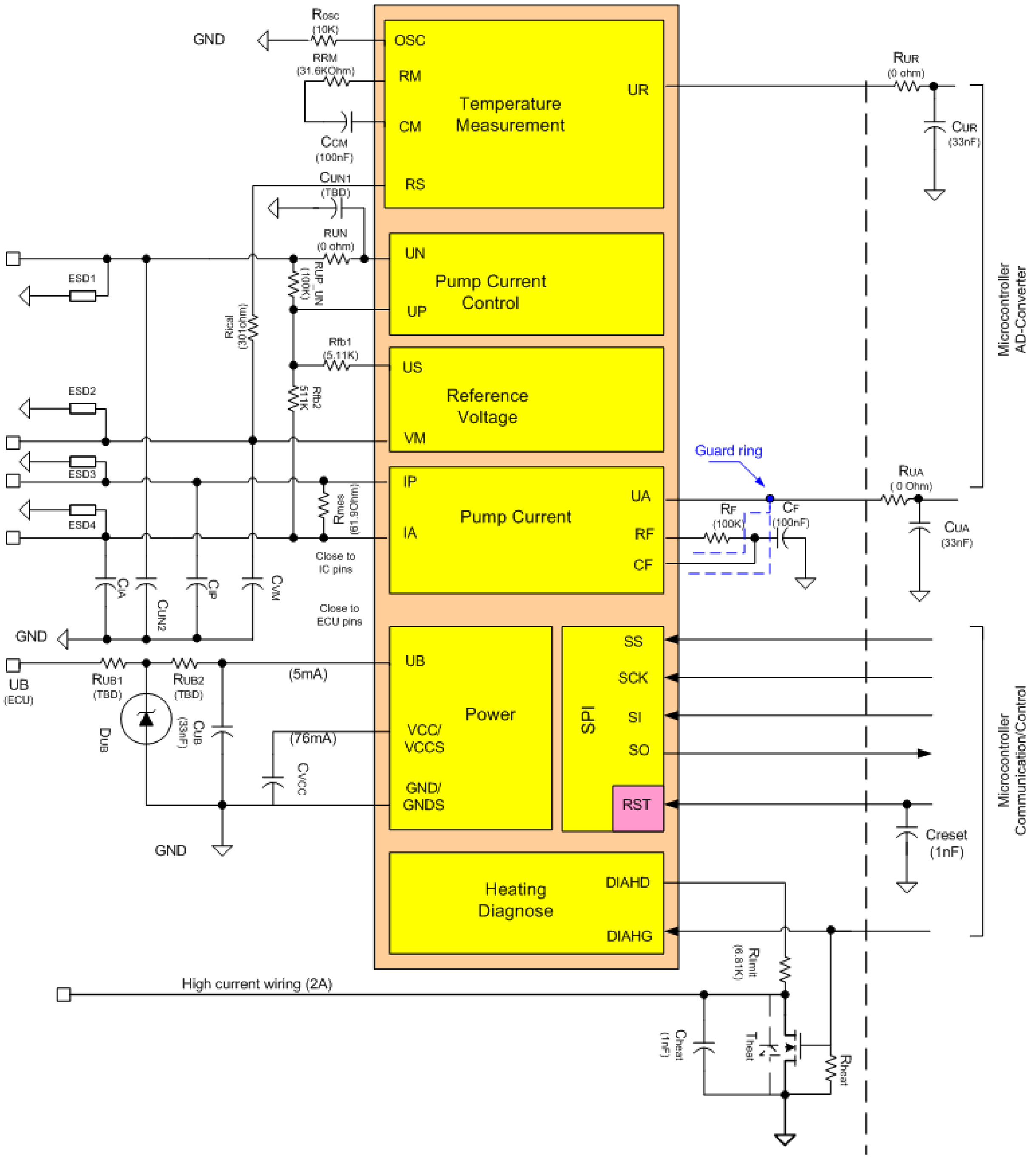

Figure 3.1: Suggested CJ125 application schematic for LSU4.9 in SOIC24 package

Function block	External component	Default Value	Type	Accuracy	Remark
Temperature measurement	R_{RM}	31.6k		1%	
	R_{OSC}	10k		1%	
	C_{CM}	100nF	Ceramic	10%	
	R_{ical}	301Ω		1%	
	C_{UR}	33nF	Ceramic	10%	Other larger value can be used depending on your application.
	R_{UR}	0Ω		1%	Keep mounting place in layout, other large value can be chosen
Pump current	R_{UN}	0Ω		1%	Allowed to be increased up to 5.11Ω,
	R_{UP_UN}	100kΩ		1%	
	R_{fb1}	5.11kΩ		1%	R_{fb1}:R_{fb2}=4.7K:470K mentioned in the CJ125 data sheet should not be more used for the new design
	R_{fb2}	511kΩ		1%	
	R_{mes}	61.9Ω		1%	
	R_F	100kΩ		1%	Chosen resistance value depending on the application, see description page 9
	C_F	100nF	Ceramic	10%	
Lambda measurement	R_{UA}	0Ω		1%	Keep the mounting place in layout, other large value can be chosen
	C_{UA}	33nF	Ceramic	10%	Other larger value can be used depending on your application.
EMC capacitance for sensor pin	C_{IA}	C_{IA}≤10nF	Ceramic	10%	
	C_{IP}	C_{IP}≤10nF	Ceramic	10%	
	C_{UN1}+C_{UN2}	≤10nF	Ceramic	10%	
	C_{VM}	≤10nF	Ceramic	10%	
Power supply	R_{UB1}			1%	Refer to chapter 2 for the component dimension
	R_{UB2}			1%	
	D_{UB}				
Block capacitor for power supply	C_{UB}	33nF	Ceramic	10%	
	C_{VCC}	33nF	Ceramic	10%	
Heating	R_{limit}	6.81kΩ		1%	
	C_{heat}	1nF	Ceramic	10%	
	C_{reset}	1nF	Ceramic	10%	Other larger value can be used depending on your application.
	R_{heat}			1%	Refer to chapter 3 for the component dimension
	T_{heat}				Refer to chapter 6 for the component dimension

Table 3.1: Recommended external component values for LSU 4.9 applications

4 Differences by using LSU4.2 and LSU4.9

	LSU4.9	LSU4.2
R_{ical}	301 Ohm	82.5 Ohm
R_{RM}	31.6 K	10 K
Pump reference current	Programmable according to the applications	switched off (default setting)
*Minimum Heating PWM frequency	High	Low

*refer to [2], [3]

5 EMC and ESD

Recommended EMC and ESD counter measures for the sensor pins

The customer must perform the EMC/ESD measurement and ensure that the measurement results meet its applications. Additional counter measures on a systems level might be necessary depending on the system requirements. Below measures are described how to increase the EMC/ESD capability of the ASIC in the system.

The ceramic capacitors $C_{UN1/2}$, C_{IA}, C_{IP} and C_{VM} are intended to increase the EMC/ESD capability. The choice of the values depends on the application requirements. Usually, the resistor R_{UN} is not needed. In this case both mounting pins for the resistor should be short-circuited. If the measurement result is not satisfying, a resistor with a value less than 5.11 Ω could be mounted. Since the measurement of the Nernst cell internal resistance is affected in this case the accuracy of the sensor is slightly decreased.

If additional ESD measures are needed, components with a low leakage current should be considered to avoid any potential influence on the output signal of the sensor.

EMC capacitance for the pin RST and the heating line

The capacitor C_{heat} with a value of 1nF has been chosen to smooth the edge of the PWM heating output signal. The value could be modified according to the measurement results and the system EMC requirements. To choose a proper capacitor, the electromotive force must be considerable larger than the clamping voltage of the MOSFET.

The capacitor C_{reset} is used to avoid any possible malfunction of the pin RST. A value of 1nF is recommended. Depending on the system requirements different values might be chosen.

6 Power transistor choice for heating control

It is strongly recommended to implement a monolithic intelligent power MOSFET to improve the reliability of the system. The intelligent MOSFET low side switch should have following features:

- Self-protected function against short-circuit to battery
- Over-temperature protection.
- The maximum current should be limited to 10A.
- Clamping voltage<50V
- ON-resistance <300mΩ
- To use the heater diagnostic features of the IC CJ125 properly, the leakage current of the power transistor must not exceed 100µA ([1] 4.10.2)

7 PCB layout consideration

The common practice of placing the blocking capacitors for the power supplies either close to the 5V pins or close to the pin UB should be applied. The ground connection should be routed in a star form.

The SPI can reach a transmission speed as high as 4 MHz ([1] 8.13.5). Hence, these wirings should be placed away from other sensitive or low speed wirings in order to avoid any coupling.

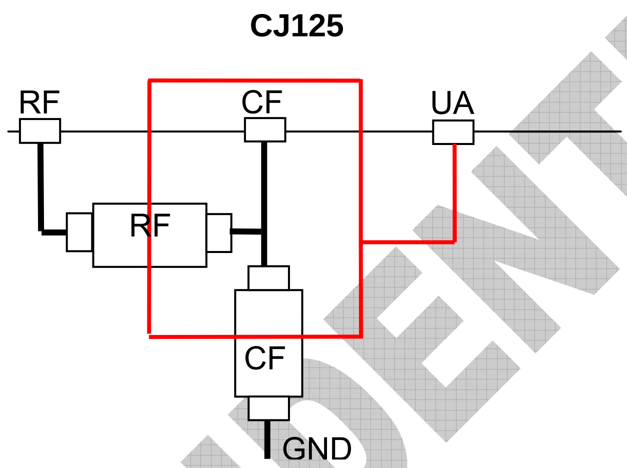

Figure 7.1: Guard ring in ideal case

To suppress any potential influence of the leakage current in the PCB due to soldering or possible contamination, a guard ring is suggested to shield the wirings and components RF and CF for the pins RF and CF. The shield wiring should be connected to the low impedance pin UA, which has nearly the same potential as pin CF for DC signal.

The ground line for the heating power transistor must be separated from the rest ground. Both the heating wiring and the heating ground wiring should be kept as short as possible. They should be kept away from other wirings as far as possible. It is advisable to put them at the edge of the PCB.

According to [2], the heating resistor typically amounts to 3.2 ohms. Taking into additional consideration of the on-resistor of the power MOSFET and the duty cycle of the PMW control, the heating wiring width must be able to bear a continuous current of at least 2A.

8 CJ125 Frequently asked questions

1) Which kind of chip should be chosen-CJ110, CJ120 or CJ125?

For the new projects CJ125 should be chosen. CJ125 can handle both broadband lambda sensor LSU4.2 and LSU4.9 and it shows better performance as well as more advanced diagnostic functions.

2) Can the current consumption be reduced by switching off the pump current?

Not considerably.

3) The "pump reference current" can be set by PR0, PR1 PR2 and PR3. What is the relationship between this digital code and the pump reference current? For example, how to set 20μA?

Bits 3210 in INIT-REG2 PR0 = 10uA = 0001 PR1 = 20uA = 0010 PR2 = 40uA = 0100 PR3 = 80uA = 1000. One example: 30uA = 0011

4) Could the customer rely on on-chip battery low voltage detector function for the proper functions of CJ125 and LSU4.2/LSU4.9?

This function is intended only for the diagnostic purpose. The threshold voltage is very rough, changing from 6V to 9V. CJ125 and it works correctly for a battery voltage larger than 9V and for 8V in a restricted condition. For battery voltage smaller than 8V, both of the measured signals for the pump current and the Nernst cell internal resistor (the temperature of the sensor) could be incorrect. Therefore, an accurate and dedicated ADC channel or comparator should be used for the system power supply monitor.

5) How does the suppression of Ri measurements works? Does a logical "1" (sensor is heating) on DIAHG stops or starts the measurement?

Every slope at DIAHG starts the suppression. If a slope is recognized, the switches S1 and S2 remains open for the next sampling period until end of hold phase. That means they cannot be closed for sampling. Therefore the S&H is not updated. The sampling frequency is normally 3kHz. The Frequency at DIAHG is normally 100Hz.

6) If a failure appears at the sensor lines, the VM pin will be cut off from the rest of the chip and the pump current will be switched off. This is done automatically by the ASIC CJ125. Does the bit PA change it value?

If a failure at the sensor lines occurs, an internal signal "OFF" will perform this function to protect the sensor. PA bit will not change its value.