IDS-SL900A-AN2-SFE

Application note – External sensor interface

Revision 1.02

Content

1. Introduction

This document describes the External sensor interface (SFE – sensor front end) on the SL900A smart label device. For a complete description of the SL900A device, please refer to the datasheet.

The pinout is:

Pin #	Pin Name	Description
1	VPOS	RF rectifier output
2	VSSA	Chip substrate ground – connect to antenna ground
3	ANT2	Antenna coil – higher capacitance, higher current
4	ANT1	Antenna coil – low capacitance, low current
5	VREF	Reference voltage output (Vo2)
6	EXT1	Analogue input for external sensor
7	EXT2	Analogue input for external sensor
8	VSS	Chip substrate ground – connect to negative battery terminal
9	SEN	Enable input for the SPI interface
10	SCLK	SPI clock
11	DIN	SPI data input
12	DOUT	SPI data output
13	VBAT	Positive supply input
14	MEAS	Test pin for use during test
15	EXC	Supply voltage for the external sensors or a AC signal source for external sensors
16	ANA-TEST	Analogue test pin

Table 1: SL900A pin description

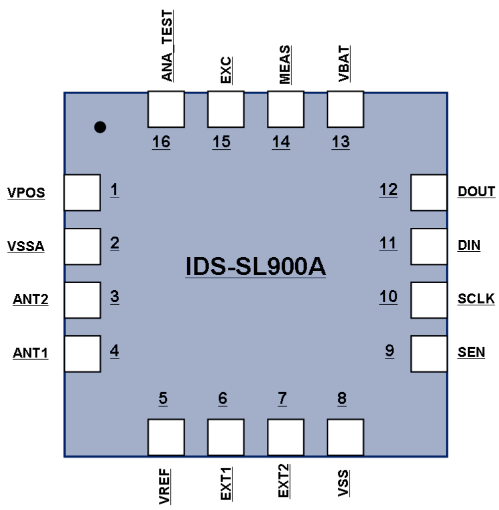


Figure 1: SL900A E.S. pinout

The pins that are used for SFE:

- *EXT1* – connection for external sensor 1 that can be a linear-resistive sensor, a DC voltage source (sensor with external analog processing), capacitive and resistive sensors with AC driving,
- *EXT2* – connection for external sensor 2 that can be a linear-conductive sensor, a reverse-polarized diode, DC voltage source with serial resistance or a DC current source to VSS,
- *EXC* – supply voltage for the external sensors or a AC signal source for external sensors that do not allow a DC voltage.
- *VREF* – reference voltage (Vo2) pin used for capacitive and resistive sensors with AC excitation.

The SL900A has 2 inputs for analogue external sensors. The following type of sensors can be used:

- Resistive with linear resistance,
- Resistive with linear conductance,
- Capacitive without DC voltage (AC excitation),
- Resistive without DC voltage (AC excitation),

- Resistive bridge,
- Opto sensors (opto diode),
- Current source sensor,
- Voltage source sensors.

Sensor type	**Manufacturer**	**Model**	**Comment**
Resistive bridge	x	x	any resistive sensor (pressure, humidity, temperature...)
Capacitive - no DC (AC excitation)	E+E Elektronik	HC105, HC109, P14thermo	humidity
Resistive - no DC (AC excitation)	GE Sensing, Ghitron Technology	EMD4000, HCZ-D5	
Resistive - linear conductance	FlexiForce	A201	pressure
Resistive - linear resistance	x	x	
Photodiode, opto-sensors	Hamamatsu	S10170	light, color
Voltage source	x	x	
Current source	x	x	

The SFE interface is optimized for low-power operation. The external sensor excitation or supply will only be active for the duration of sampling and AD conversion. All other time the SFE is in stand-by mode and consumes only the leakage current. It is also optimized for minimum count of external components, so in most cases only the sensor itself is needed. Some types of sensors (with AC excitation or resistive bridge) require an external reference component (resistor or capacitor).

2. SFE detailed description

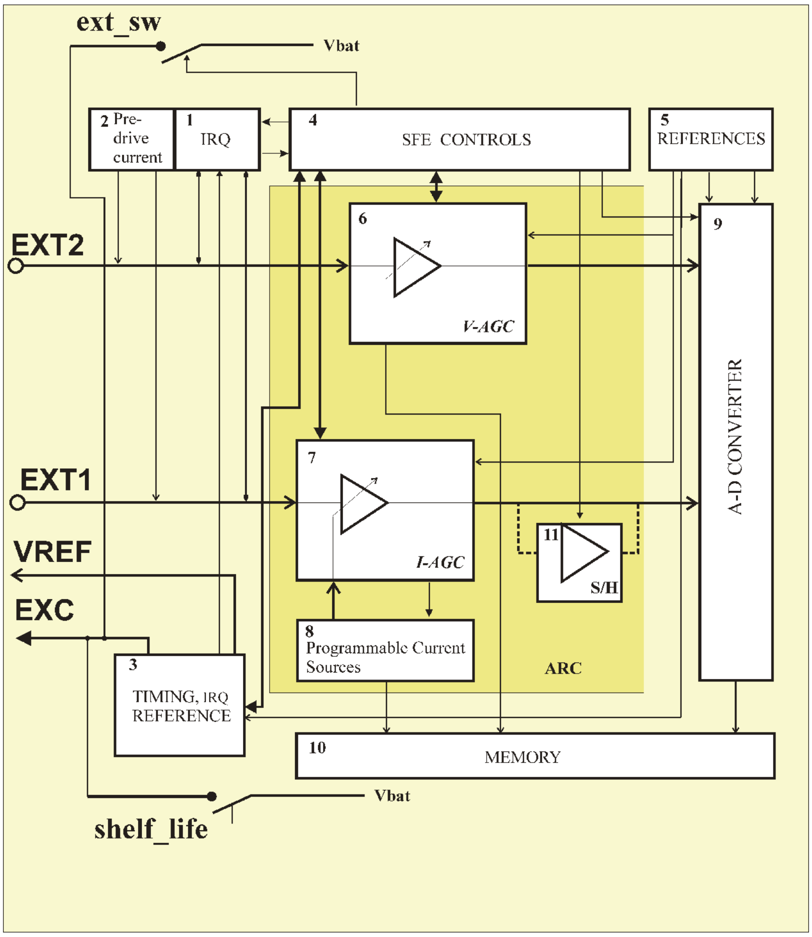


Figure 2: SFE block diagram

The SFE interface can be used in manual gain selection or in automatic gain selection (autorange). The SFE interface is programmed with the “Set SFE Parameters” custom command, or with the SPI interface (EEPROM address 0x017 and 0x018):

SFE GROUP BITS	FUNCTION	DESCRIPTION
rang[4:0]	External sensor 2 range	Resistor feedback ladder – see application note for SFE
seti[4:0]	External sensor 1 range	Current source value – see application note for SFE
EXT1[1:0]	external sensor 1 type	00 – linear resistive sensor
		01 – high impedance input (voltage follower), bridge
		10 – reserved
		11 – capacitive or resistive sensor without DC (AC signal on EXC pin)
EXT2	external sensor 2 type	0 – linear conductive sensor
		1 - high impedance input (voltage follower), bridge
Range preset	Use preset range	Autorange function is turned off
Verify sensor ID[1:0]	Sensor used in limit check (sensor enable bits in log mode group)	00 – first selected sensor
		01 – second selected sensor
		10 – third selected sensor
		11 – fourth selected sensor

The rang[4:0] and seti[4:0] bits are used only if the Autorange function is turned off (Range Preset). The rang[4:0] value is coded is one-hot and selects the feedback resistor value for the EXT2 input in linear conductance mode (EXT2=0). The seti[4:0] value is binary coded and selects the current source value for the EXT1 input in linear resistance and capacitance mode (EXT1=00 or 10) Otherwise those values are ignored. The values are defined as:

rang[4:0]	**feedback resistor value [kΩ] (EXT2)**
00000	Not allowed
00001	3875
00010	1875
00100	875
01000	400
10000	185
All other values	Not allowed

seti[4:0]	**current source value [µA] (EXT1)**
00000	0
00001	0.25
00010	0.5
00011	0.75
…	
11110	7.5
11111	7.75

The external sensor type is selected with the EXT1[1:0] and EX2 bits. The ‘Verify Sensor ID[1:0]’ value is used for the sensor selection in limits mode. By default the integrated temperature sensor is selected.

For the case where limits are used with any of the external sensors, the auranging has to be disabled and manual gain selection has to be used. The limits are used only on the 10-bit AD converter value and not on range bits, so in case that autoranging would be enabled, the limit comparison would not be reliable.

The AD converter can be started with the RFID command GET SENSOR VALUE or with SPI commands 0x01, 0x02, 0x03 and 0x04. The reply in both cases is 16 bits long (in RFID also CRC is attached), where the MSb is the Error bit, next 5 bits are the Range (set[4:0] or rang[4:0]) and the lower 10 bits are the AD converter output code:

A/D error	Range	Sensor value
1 bit - error [1]	5 bits	10 bits

3. AD converter description

The SL900A device has an integrated 10-bit AD converter with selectable input voltage range. The voltage input range is selected with the 2 voltage references (*Vo1* and V_{REF}). The V_{REF} voltage defines the lower voltage limit. The upper voltage limit is defined with $2 * V_{REF} - Vo1$.

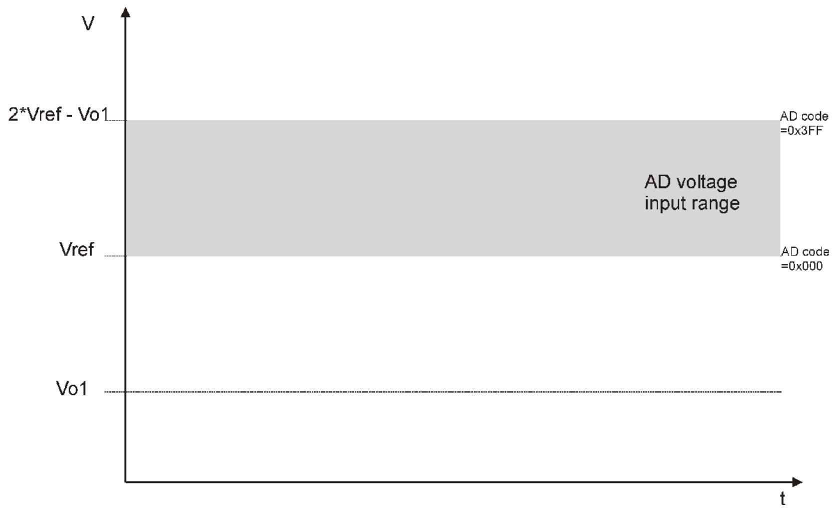


Figure 3: AD converter voltage input range

The references can be selected in steps of 50mV:

CALIB. CODE	VO1	VO2 (VREF)
0b000	160mV	260mV
0b001	210mV	310mV
0b010	260mV	360mV
0b011	310mV	410mV
0b100	360mV	460mV
0b101	410mV	510mV
0b110	460mV	560mV
0b111	510mV	610mV

The default voltage reference values set in production are:

Vo1 = 0V (VSS)

$V_{REF} = 310mV$

The input voltage can be calculated from the following equation:

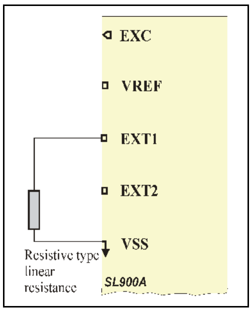
$$V_{SENS} = ADcode \cdot \frac{V_{REF} - Vo1}{1024} + V_{REF}$$

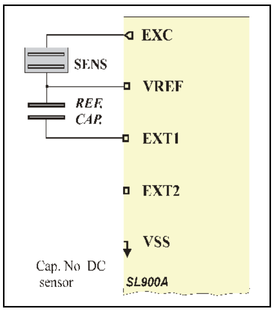
$$\frac{V_{REF} - Vo1}{1024} = resolution$$

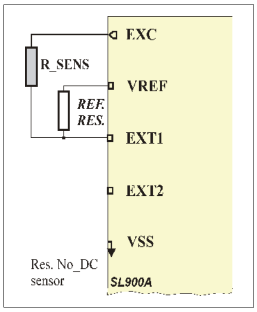
$$V_{REF} = offset$$

4. Connection diagrams for external sensors

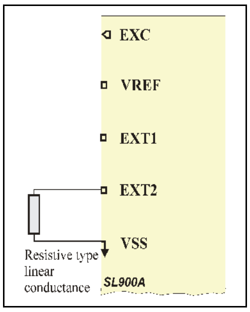
EXT1:

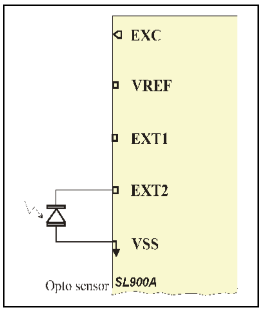


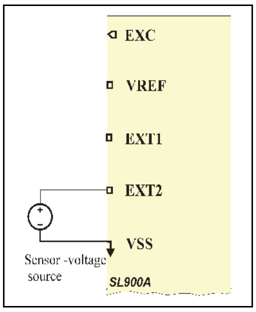


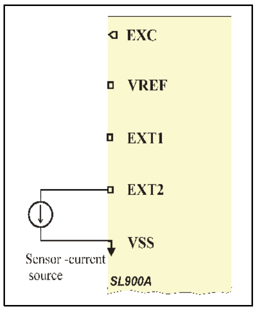


EXT2:

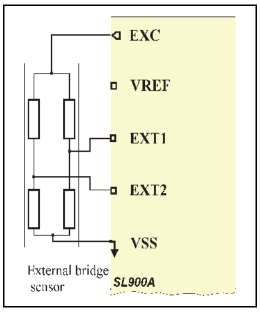








EXT1 + EXT2:



5. External sensor input 1 (EXT1)

The external sensor 1 interface (EXT1 pin) can be used for measurements with linear resistive sensors and capacitive sensors with AC excitation. It can also be used to measure 1 point of a resistive bridge (with the second point connected to the EXT2 pad).

Capacitive sensor without DC

The processing of an external capacitive sensor without DC voltage is possible in case an external reference capacitor is used. The external sensor in is excitated with an AC signal from the EXC pin. The connection for this kind of sensors is shown on Figure 4. There is no autoranging functionality in this mode, so the reference capacitor needs to be selected according to the expected sensor capacitance.

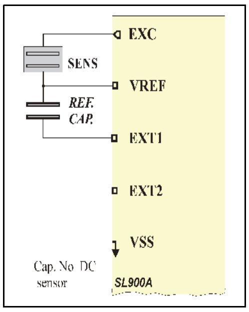


Figure 4: External capacitive sensor with AC excitation (EXT1[1:0] = 11)

The external capacitive sensor in Figure 4 is excitated with a square wave signal around the reference voltage VREF (by default this is 310mV, but can be changed by the application). The amplitude of the AC signal is equal to the VREF voltage. The input *AC* amplitude is defined as:

$$V_{EXT1} = V_{REF} \cdot \frac{C_{SENS}}{(C_{REF} + C_{SENS})} + V_{REF}$$

The selection of the reference capacitor depends on the AD converter input voltage range and expected capacitance range of the sensor. The input AC amplitude V_{EXT1} at minimum capacitance C_{SENS} must be at a maximum AD level:

$$V_{AD\_max} = 2 \cdot V_{REF} - Vo1$$

The input AC amplitude V_{EXT1} at minimum capacitance C_{SENS} must be close to minimum AD level:

$$V_{AD\_min} = V_{REF}$$

The sensor capacitance value is calculated using the below relations:

$$C_{SENS} = C_{REF} \cdot \frac{V_{EXT1} - V_{REF}}{2V_{REF} - V_{EXT1}} \Rightarrow C_{SENS} = C_{REF} \cdot \frac{ADcode(V_{REF} - Vo1)}{1024V_{REF} - ADcode(V_{REF} - Vo1)}$$

<u>Resistive sensor with linear resistance (EXT1 to VSS)</u>

The minimum and maximum resistance values that can be measured on the EXT1 input are:

$R_{SENS\text{-}min}=33.5k\Omega$

$R_{SENS\text{-}max}= 4.9M\Omega$

The external sensor interface can also be used for resistive sensor with linear resistance and with resistive sensor that do not allow any DC voltage (AC excitation). The connection diagrams are on Figure 5 and Figure 7.

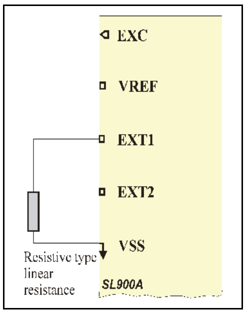


Figure 5: External linear resistive sensor (EXT1[1:0] = 00)

Autoranging: Voltage on linear resistive sensor increases with increasing current to excite limit V_{REF}:

$$seti < 4:0 > \cdot I_{step} \cdot R_{SENS} > V_{REF} ,$$

where I_{step} is 0.25uA - see Table below:

seti<4:0>	**I_{EXT1} [uA]**	Comment
00000	0	The absolute value of the current depends on integrated resistors value and can vary within process tolerances.
00001	0.25	
00010	0.5	
....	...	
10000	4.0	
10001	4.25	
....	...	
11111	7.75	

The sensor resistance can be calculated from:

$$R_{SENS} = \frac{V_{EXT1}}{seti < 4:0 > \cdot I_{step}} , \qquad V_{EXT1} = ADcode \cdot \frac{V_{REF} - Vo1}{1024} + V_{REF}$$

$$R_{SENS} = \frac{ADcode \cdot \frac{V_{REF} - Vo1}{1024} + V_{REF}}{seti<4:0> \cdot I_{step}}$$

If default values for the AD reference voltages are used (V_{REF}=310mV, Vo1=0V), then the equation can be simplified to:

$$R_{SENS}[k\Omega] = \frac{ADcode \cdot 302.7 \cdot 10^{-3} + 310}{seti<4:0> \cdot 0.25}$$

Resistive sensor with linear resistance (EXT1 to VREF)

The minimum and maximum resistance values that can be measured in this configuration is:

$R_{SENS\text{-}min}$=6.3Ω *(maximal* possible *resolution)*

$R_{SENS\text{-}max}$= 2.44MΩ

The internal ESD PAD resistance on VREF and EXT1 needs to be taken into account for low-resistance measurements. The resistance value is 200Ω for VREF and EXT1. The pad resistance tolerance is ±37.5% with a temperature dependence of +0.18Ω/°C.

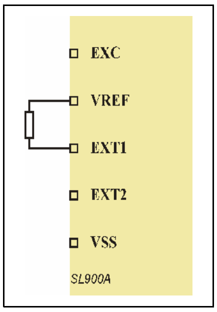


Figure 6: linear resistive sensor (EXT1[1:0] = 00)

The resistive sensor is supplied with a current where I_{step} is 0.25uA. This current can be manually selected, or can be automatically selected:

seti<4:0>	**I_{EXT1} [uA]**	Comment
00000	0	The absolute value of the current depends on integrated resistors value and can vary within process tolerances.
00001	0.25	
00010	0.5	
....	...	
10000	4.0	
10001	4.25	
....	...	
11111	7.75	

The sensor resistance can be calculated from:

$$R_{SENS} = \frac{V_{EXT1}}{seti<4:0>\cdot I_{step}}, \qquad V_{EXT1} = ADcode \cdot \frac{V_{REF} - Vo1}{1024}$$

$$R_{SENS} = \frac{ADcode\cdot(V_{REF} - Vo1)}{1024\cdot seti<4:0>\cdot I_{step}}$$

If default values for the AD reference voltages are used (*V_{REF}=310mV, Vo1=0V*), then the equation can be simplified to:

$$R_{SENS}\left[k\Omega\right] = \frac{0.31\cdot ADcode}{0.256\cdot seti<4:0>}$$

Resistive sensor without DC

An additional external reference resistor has to be used for processing external resistive sensor with AC excitating. For a resistive sensor with AC excitation the following relation is valid:

$$V_{VREF} < V_{VREF} + \frac{V_{VREF}}{R_{SENS} + R_{REF}}\cdot R_{REF} \le 2\cdot V_{VREF} - Vo1$$

The proper ratio between sensor and reference resistor can be chosen to fulfill the upper relation and the range of sensor resistance.

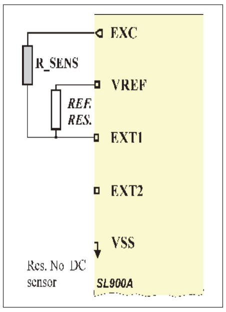


Figure 7: External resistive sensor with AC signal (EXT1[1:0] = 11)

The sensor resistance is calculated in the formula:

$$R_{SENS} = R_{REF}\cdot\left(\frac{V_{REF}}{V_{EXT1} - V_{REF}} - 1\right)$$

If default values for the AD reference voltages are used (*V_{REF}=310mV, Vo1=0V*), then the equation can be simplified to:

$$R_{SENS}\left[\Omega\right] = R_{REF} \cdot \left(\frac{1024}{ADcode} - 1\right)$$

Resistive bridge

A resistive bridge has to be connected to both sensor inputs (Figure 8). The 2 input voltages are converted one after the other. In automatic logging both external sensors have to be enabled. If the resistor bridge is also used with the GET SENSOR VALUE RFID command, this command has to be sent twice – first for external sensor 1, second for external sensor 2. The resistve bridge can be supplied from the EXC pin. The battery voltage is internally switched to the EXC pin only for the duration of the measurement. All other time the EXC pin is in tri-state and the bridge does not consume any current.

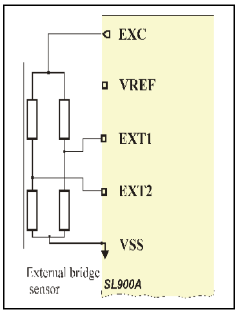


Figure 8: Resistor bridge sensor (EXT1[1:0] = 01, EXT2 = 1)

The voltages on inputs EXT1 and EXT2 are calculated from:

$$V_{EXT1,EXT2} = ADcode \cdot \frac{V_{REF} - Vo1}{1024} + V_{REF}$$

The overall minimum voltage that can be measured on the external sensor inputs EXT1 and EXT2 is 260mV, the maximum is 1.22V. Those values depend on the selected V_{REF} and Vo1 reference voltages.

6. External sensor input 2 (EXT2)

The external sensor 2 interface (EXT2 pin) can be used for measurements with linear conductive sensors, optical sensors (diode and to measure the second point of a resistive bridge (with the first point connected to the EXT1 pad).

Resistive sensor with linear conductance

The minimum and maximum resistance values that can be measured on the EXT2 input are:

$R_{SENS\text{-}min}$=20.5kΩ

$R_{SENS\text{-}max}$= 2MΩ

The Figure 9 shows the connection diagram for a resistive sensor with linear conductance (like a pressure sensor). In this mode, the sensor is supplied with a constant voltage of 135mV.

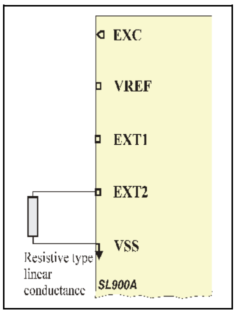


Figure 9: External resistive sensor - linear conductance (EXT2 = 0)

The input voltage on the AD converter V_{AD} is defined as:

$$V_{AD} = 135mV \cdot \frac{\text{rang} < 4:0 > \cdot R_f}{R_{SENS}}$$, *rang<4:0>* is one-hot coded,

R_f=[185kΩ, 400kΩ, 875kΩ, 1875kΩ, 3875kΩ]

v135mv is the constant sensor supply voltage. The code *rang<4:0>* selects the feedback resistor value R_f of the input amplifier and is [185kΩ, 400kΩ, 875kΩ, 1875kΩ, 3875kΩ]. Sensor resistance is therefore:

$$R_{SENS} = 135mV \cdot \frac{rang < 4:0 > \cdot R_f}{V_{AD}}$$, voltage V_{AD} is then converted to digital – 10 bit fine code.

Ranges are shown in table below:

rang<4:0>					**R_f [kΩ]**	**Comments**
0	0	0	0	1	3875	TC of the gain depends only on TC of the external sensor. The tolerance of the integrated resistors used in the feedback loop is ±17%
0	0	0	1	0	1875	
0	0	1	0	0	875	
0	1	0	0	0	400	
1	0	0	0	0	185	

The V_{AD} voltage is:

$$V_{AD} = ADcode \cdot \frac{V_{REF} - Vo1}{1024} + V_{REF}$$

The sensor resistance can be calculated from:

$$R_{SENS} = 135mV \cdot \frac{rang < 4:0 > \cdot R_f}{ADcode \frac{V_{REF} - Vo1}{1024} + V_{REF}}$$

If default values for the AD reference voltages are used (*V_{REF}=310mV, Vo1=0V*), then the equation can be simplified to:

$$R_{SENS}[\Omega] = 0.135 \frac{rang < 4:0 > \cdot R_f}{ADcode \cdot 302.7 \cdot 10^{-6} + 0.31}$$

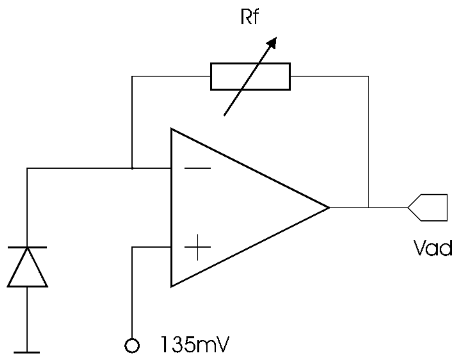


Figure 10: EXT2 input for conductance measurement

Optical sensor

The EXT2 pad can also be used for measurements with an optical sensor based on reverse polarized diode current (Figure 11).

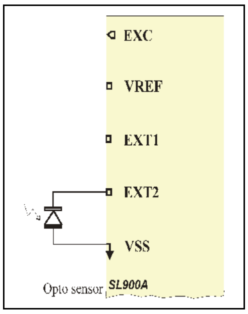


Figure 11: External optical sensor (EXT2 = 0)

The current input range in this mode is defined as:

$$I_{\min} = \frac{V_{REF} - 135mV}{R_{f-\max}}, \qquad I_{\max} = \frac{(2 \cdot V_{REF} - Vo1) - 135mV}{R_{f-\min}}$$

R_{f-min} = 185kΩ, R_{f-max} = 3.875MΩ

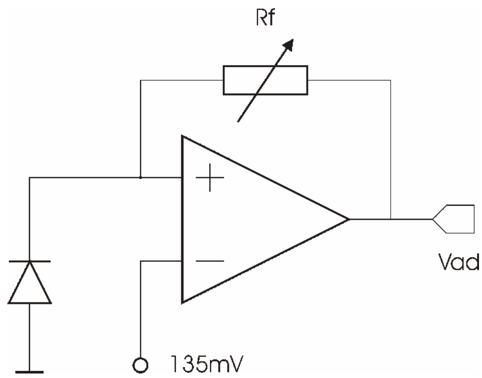


Figure 12: EXT2 input for opto diode current measurment

The diode current can be calculated with:

$$I_D = \frac{V_{AD} - 135mV}{rang<4:0> \cdot R_f},$$ *R_f=[185kΩ, 400kΩ, 875kΩ, 1875kΩ, 3875kΩ]*

If we exchange V_{AD} with the AD converter equation we get:

$$I_D = \frac{ADcode \frac{V_{ref} - Vo1}{1024} + V_{REF} - 135mV}{rang<4:0> \cdot R_f},$$

If default values for the AD reference voltages are used (*V_{REF}=310mV, Vo1=0V*), then the equation can be simplified to:

$$I_D = \frac{ADcode \cdot 302.7 \cdot 10^{-6} + 0.175}{rang < 4:0 > \cdot R_f}$$

Voltage output sensor

A voltage source output sensor can be connected to the EXT2 pin. This can be used for integrated sensors with an analogue output signal.

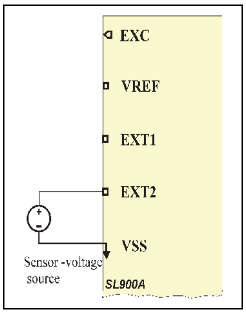


Figure 13: External voltage source sensor (EXT2 = 1)

The voltage input range in this mode is the same as the AD converter voltage input range, as defined on Page 7. The overall minimum voltage that can be measured on the external sensor inputs EXT1 and EXT2 is 260mV, the maximum is 1.22V. Those values depend on the selected V_{REF} and Vo1 reference voltages.

Current source output sensors

The EXT1 interface can also be used for external current source output sensors (Figure 14).

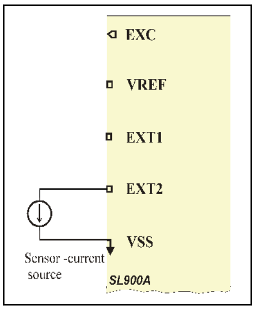


Figure 14: External current source sensor (EXT2 = 0)

The current input range in this mode is defined as:

$$I_{\min} = \frac{V_{REF} - 135mV}{R_{f-\max}}, \qquad I_{\max} = \frac{(2 \cdot V_{REF} - Vo1) - 135mV}{R_{f-\min}}$$

$R_{f\text{-}min}$ = 185kΩ, $R_{f\text{-}max}$ = 3.875MΩ

The sensor current can be calculated with:

$$I_S = \frac{V_{AD} - 135mV}{rang<4:0> \cdot R_f}, \quad R_f = [185k\Omega, 400k\Omega, 875k\Omega, 1875k\Omega, 3875k\Omega]$$

If we exchange V_{AD} with the AD converter equation we get:

$$I_S = \frac{ADcode \frac{V_{ref} - Vo1}{1024} + V_{REF} - 135mV}{rang<4:0> \cdot R_f},$$

If default values for the AD reference voltages are used (V_{REF}=310mV, Vo1=0V), then the equation can be simplified to:

$$I_S = \frac{ADcode \cdot 302.7 \cdot 10^{-6} + 0.175}{rang<4:0> \cdot R_f}$$

7. External sensor interface settings

The external sensor interface is set up either with the SPI interface or with RFID custom commands. The commands required for external sensor operation are: SET LOG MODE, SET SFE PARAMETERS, SET CALIBRATION DATA and INITIALIZE.

The SET LOG MODE command is used to setup various parameters required for the automatic logging process. If external sensors are used in the logging process, they have to be enabled with this command.

The SET SFE PARAMETERS command is used to set up the SFE functionality. The SFE can be used as an automatic range selection block, for sensors with a wide output range. It can also be used as a fixed gain preamplifier for sensors with a low output range. In this case the user application has to preset the range and enable the preset values. The preset range has to be selected in case the internal limits are used with an external sensor.

The EXT1 interface gain is preset with the “seti [4:0]” field. The EXT2 gain is preset with the “rang [4:0]” field. The preset values are enabled with the “Autorange Preset” flag.

The external sensor type “EXT1[1:0]” and “EXT2” can be set with the SET SFE PARAMETERS command. This command is also used for selecting the sensor (“Verify Sensor ID”) that will be used with the limits in out of limits logging mode.

The SET CALIBRATION DATA command is used to set up the supply switch for external sensors (“sw_ext_en”) and to setup the interrupt voltage level for external sensors (“irlev[1:0]”). The external sensors can be supplied with the battery voltage from the EXC pin only during the conversion time. This will save power compared to a system where the sensor is supplied directly from the battery. This is especially useful for a resistive bridge sensor.

The INITIALIZE command is used to setup interrupt and timer logging modes in parallel (“IRQ + timer enable” flag). This special logging mode can be used for regular interval-based sensor sampling combined with the interrupt capability of the SFE.

8. External sensor interrupt

The external sensor interface can be used for sampling short events on the EXT1 and EXT2 pins. This can be used for shock sensors, acceleration sensors and other pulse response sensors. It is also useful for counting events on the external sensor pins.

The sensors are pre-driven with a small current of 125nA and are constantly observed with a very low consumption comparator. The overall current consumption of the interrupt block is 0.5µA at room temperature. In case the sensor voltage exceeds the specified threshold (“irlev[1:0]”), the SFE will generate and IRQ request. This will wake up the whole system and the sensor data, together with the real time information, will be logged to the memory.

The interrupt mode is selected with the SET LOG MODE command with the “Logging Mode[2:0]” field. The implemented IRQ modes are:

Bit 2	Bit 1	Bit 0	Logging Form	Description
1	0	1	IRQ, EXT1	Interrupt triggered on the EXT1 external sensor input
1	1	0	IRQ, EXT2	Interrupt triggered on the EXT2 external sensor input
1	1	1	IRQ, EXT1, EXT2	Interrupt triggered on the EXT1 and EXT2 external sensor input

Either of the 2 external sensor pads, or both of them, can be used for generating an interrupt. This function can also be used for button-triggered measurements, as the user can select which sensor will be logged during an interrupt event.

The interrupt level can be selected by the application with the SET CALIBRATION DATA command (“irlev[1:0]”). The setting is valid for EXT1 and EXT2:

Irlev [1:0]		EXT1 capacitive – [pF]	EXT2 resistive - [MΩ]	IRQ level - % of supply voltage
Bit 1	Bit 0			
0	0	> 500	< 3	< 25 %
0	1	> 160	< 1	< 8 %
1	0	> 115	< 4.2	< 35 %
1	1	> 290	< 5.2	< 43%

The IRQ threshold varies from chip to chip for a maximum of ±25% from its nominal specified value. The ratio between levels at different IRQ-level-CODE remains constant. The IRQ voltage levels are supply ratiometric.

Sales & Marketing Europe
IDS Microchip AG
Wächlenstrasse 5,
CH-8832 Wollerau, Switzerland
Phone: +41 43 8446-253
Fax: +41 43 8446-250
sales@ids-microchip.com

Sales & Marketing Americas
IC Magic Inc.
34 Granlea Rd,
Toronto, ON M2N 2Z5, Canada
Phone: +416 227 9196
Fax: +41 43 8446-250
sales@ids-microchip.com

www.ids-microchip.com