Optical switch with high ambient light immunity

Features

- Small footprint, SOP16 or TSSOP16 package
- Operational up to 200klux ambient light
- Proximity, touch, switch and wipe function
- Supply voltage range: 3.3V to 5.0V
- Parameter adjustment and functional data read back via SPI interface
- Status output for switch and proximity function
- -40°C to 85°C operating temperature

Applications

- Waterproof switches
- switch for anti-septic environment
- Switch with background lighting function in case of approach
- Mechanic-less key pad array
- Motion switch for example in vacuum cleaner application
- Proximity sensing

General Description

The E90901 is an optical switch based on the HALIOS (High Ambient Light Independent Optical System) working principle, which is very effective in suppression of ambient light and has inherent self calibration capabilities to eliminate disturbances caused by housing reflections and scratches.

The device is capable of indicating the situation when objects are entering the detection area of the sensor. Further a switch event is recognized when an object touches the surface of the sensor. Both functions are available with the static output signals PROX and TOUCH.

Additionally it is possible to observe the movement of objects in the detection area. The corresponding measurement values are proportional to the distance and the velocity of the object and can be read out via SPI interface.

Typical Application

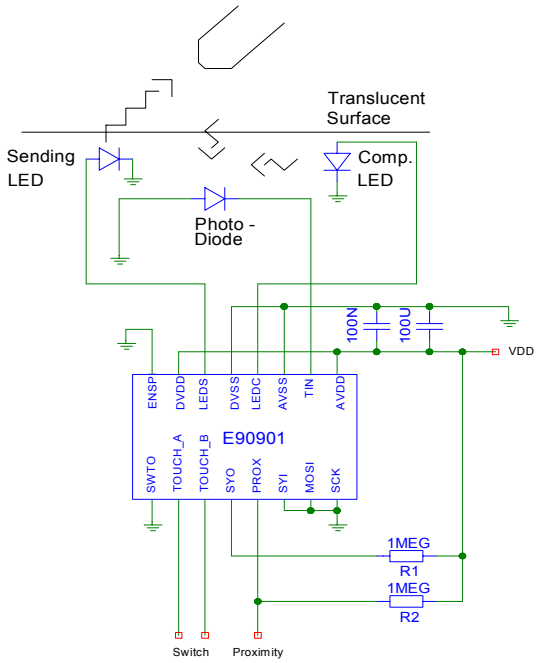


Figure 1: Typical application

Package SOP16/TSSOP16

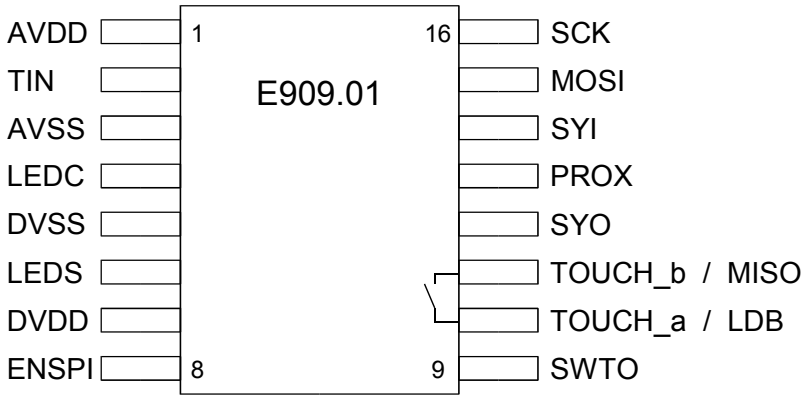


Figure 2: Pin-Out E909.01

Pin Description

Pin Nr.	Name	Type [1)]	Function
1	AVDD	A I	Analog supply
2	TIN	A I	Transimpedance amplifier input
3	AVSS	A G	Analogue ground
4	LEDC	A O	Output compensation LED
5	DVSS	D G	Digital ground
6	LEDS	A O	Output sending LED
7	DVDD	A I	Digital supply
8	ENSPI	D I	Enables the SPI Interface
9	SWTO	D I	Select touch or toggle mode
10	TOUCH_a / LDB	A I/O D I	Output of the „Touch“ function with an analogue switch of typical 30 Ohm between pin 10 and pin 11. In SPI operation mode (ENSPI=HIGH) this pin is redefined to the LDB „chip select“ input
11	TOUCH_b / MISO	A I/O D Z	Output of the „Touch“ function with an analogue switch of typical 30 Ohm between pin 10 and pin 11. In SPI operation mode this pin is redefined to the MISO „master input slave output“ output
12	SYO	D Z*	Synchronisation output (*high ohmic for a short time after power on and SPI reset)
13	PROX	D I	„Proximity“ function output (active low)
14	SYI	D I	Synchronisation input
15	MOSI	D I	SPI „master output slave input“
16	SCK	D I	SPI serial clock

1) A = Analog, D = Digital, G = Ground, I = Input, O = Output, I/O = Bidirectional and Z = Tristate Output

SOP16 Package Outline and Description

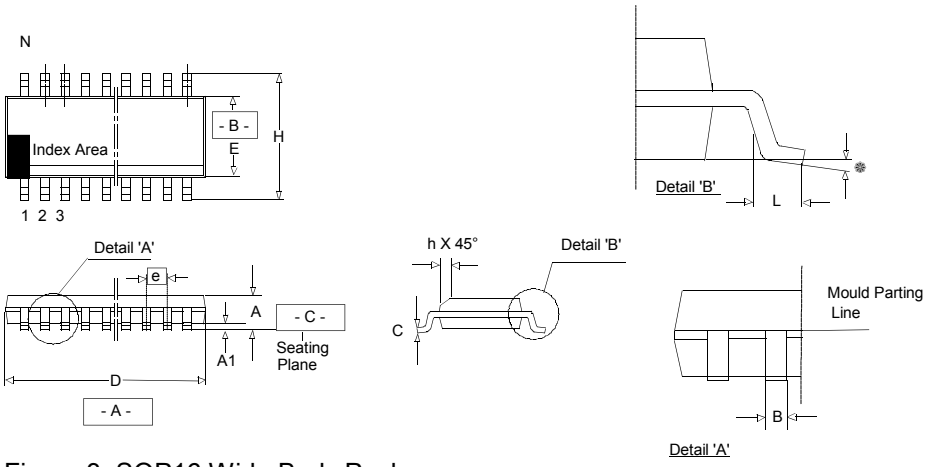
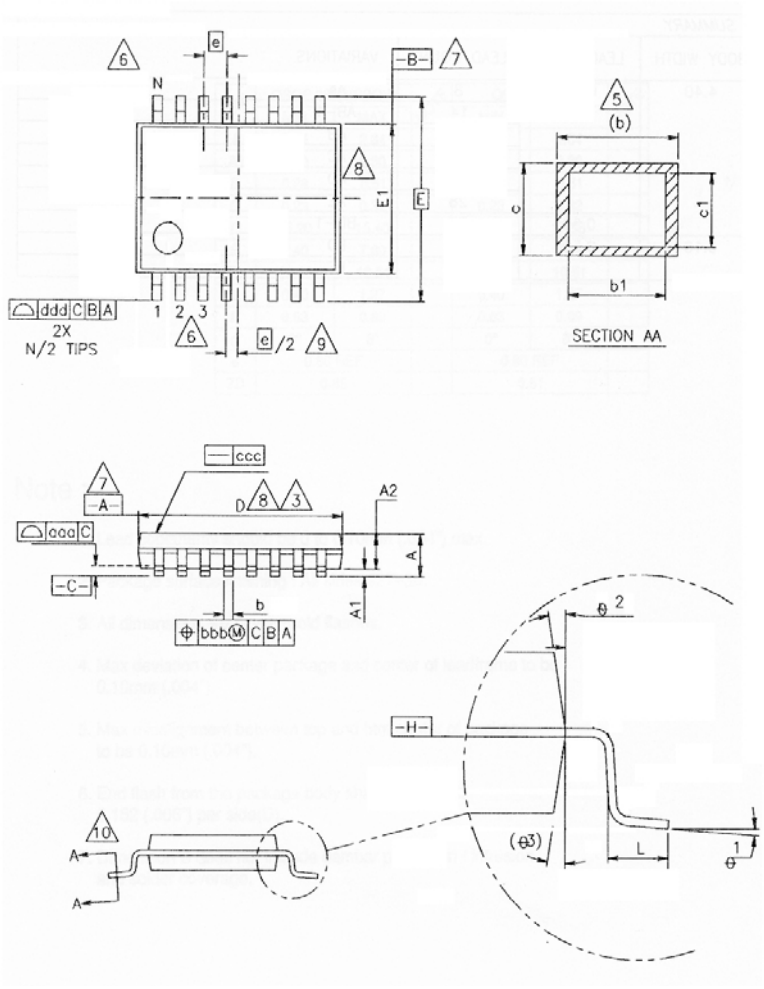


Figure 3: SOP16 Wide Body Package

Description	Symbol	mm			inch		
		min	typ	max	min	typ	max
Distance from the seating plane to the highest point of body	A	-	-	2.64	-	-	.104
Distance between the seating plane and the base plane	A1	0.10	-	-	.004	-	-
Width of terminal leads, including lead finish	B	0.36		0.51	.014	-	.020
Coplanarity lead to lead	b2	-	-	0.10	-	-	.004
Thickness of leads measured in a plane perpendicular to the seating plane including lead finish.	C	0.23	-	0.33	.009	-	.013
The longest body dimension measured perpendicular to the body width E	D	10.11	-	10.50	.398	-	.413
The smallest body width dimension	E	7.40	-	7.60	.291	-	.299
Linear spacing between true lead positions which applies over the entire lead length or at the gauge plane	e	-	1.27	-	-	.050	-
Largest overal package width dimension of mounted package	H	10.11		10.65	.398		.419
Body chamfer angle	h	0.25	-	0.75	.010	-	.029
Length of terminal for soldering to substrate	L	0.51	-	1.01	.020	-	.040
Number of terminal positions	N	-	16	-	-	16	-
Angle of lead mounting area	a	0°	-	8°	0°	-	8°

TSSOP16 Package Outline and Description



Description	Symbol	Dimension (mm)		
		min	typ	max
Distance from the seating plane to the highest point of body	A	-	-	1.20
Distance between the seating plane and the base plane	A1	0.05	-	-
Thickness of package body	A2	0.80	0.90	1.05
Width of terminal leads, including lead finish	b	0.19	-	0.30
Thickness of leads measured in a plane perpendicular to the seating plane including lead finish.	c	0.09	-	0.20
The longest body dimension measured perpendicular to the body width E	D	4.90	-	5.10
The smallest body width dimension	E1	4.30	4.40	4.50
Linear spacing between true lead positions which applies over the entire lead length or at the gauge plane	e	-	0.65	-
Largest overall package width dimension of mounted package	E	6.40 BSC		
Body chamfer angle	Θ 2/3	-	-	12°
Lead angle	Θ1	0	-	8
Length of terminal for soldering to substrate	L	0.45	-	0.75
Number of terminal positions	N	16		
Tolerances	aaa	0.10		
	ddd	0.20		

1. Working Principle

1.1. Block Diagram

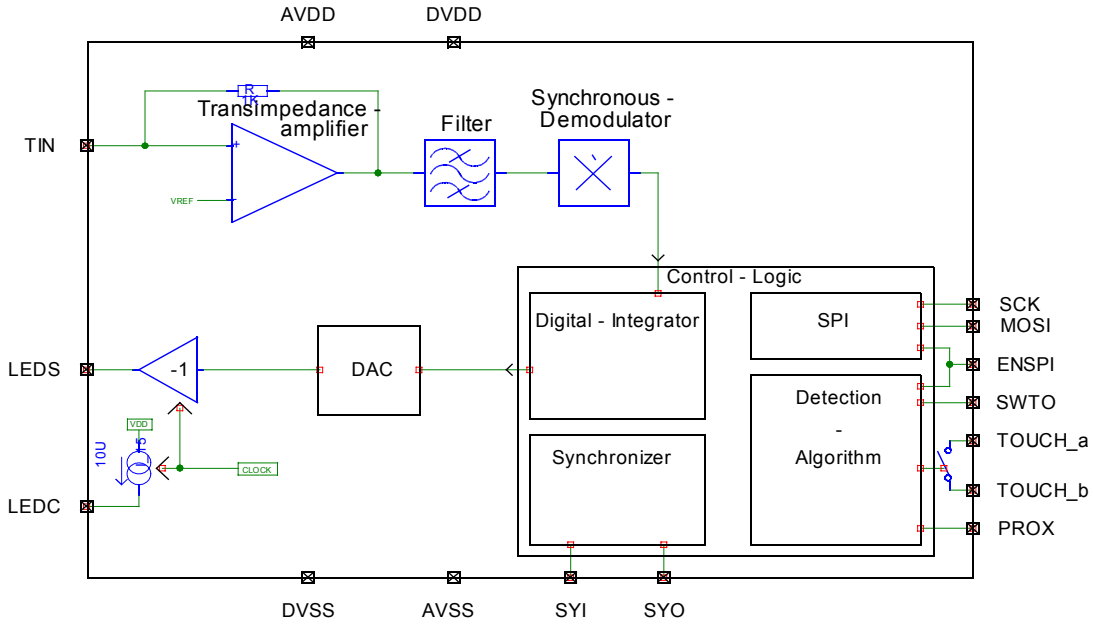


Figure 5: Block Diagramm E90901

The high ambient light suppression using the HALIOS principle is based on two light sources which are clocked by inverted phases. The photo-current receiver amplifies the difference of the received signal in both clock phases and modulates the light source intensity in a negative feedback loop in order to compensate the received signal to zero. Thus the input amplifier is always regulated to it´s most sensitive operation condition independent of ambient light.

The receiving path uses a transimpedance amplifier with DC-current control to transfer the photo current into a voltage. The signal is then amplified and filtered to remove disturbing signals and amplifier offsets. The demodulator samples the voltages at the output of the amplifier synchronously to the LED clocks, takes the difference of the signal in phase A and phase B and delivers the sign of this difference to the digital integrator.

The transmitting path produces the signals for the LED modulation by converting the integrator output to an analogue voltage. The output drives the compensation LED (LEDC) as shown in figure 4 with a voltage controlled current source of maximum 1.5mA output current. The sending LED (LEDS) is driven by a constant current of 10mA. Both outputs are clocked synchronously to the demodulator.

The detection algorithm analyses the data sequence of the digital integrator to detect if an object is approaching to the sensor and if an object has touched the surface of the switch.

1.2. Overview Basic Functions

When an object appears in the detection range of the sensor the signal PROX is activated. If a touch on the sensors surface has occured this is signalled by closing an analogue switch of 40 Ohm between the pins TOUCH_a, TOUCH_b. With a wipe over the sensors surface a reset of the detection algorithm is activated.
In order to reduce the current consumption the measurement cycle is activated only for a short time $T_{measure}$.

During the passive time $T_{passive}$ the IC is switched to an operation mode with reduced current consumption. When an object is in the detection area of the sensor the proximity signal is activated and the sampling rate is high. If no object is detected the sensor is switched to stand-by mode with reduced sampling rate in order to minimize the mean current consumption.

To change this default configuration a full bidirectional SPI interface consisting of the pins LDB, SCK, MOSI and MISO can be activated with the pin ENSPI. It is possible to adjust several thresholds and time constants which are used for the proximity, touch and wipe function. Additionally reading back data from the switch to the supervising µ-Controller is possible. Then the output of the digital integrator can be observed directly by the µC and it is possible to implement different algorithms for signal detection.

If several switches are located near together the measurement phases can be synchronised in order to minimise disturbances between the switches. The synchronisation bus consists of the pins SYI and SYO and connects all switches in a loop.

1.2.1. Synchronization

The synchronisation is done by passing a pulse from one switch to the next. The sensor which has activated the measurement cycle switches the output SYO to 'HIGH'. When the first switch delays the new cycle until the passive time $T_{passive}$ has passed. The first switch is defined with a pull-up resistor at pin SYO. The synchronisation leads to reduced noise and improves the ambient light suppression.

If the synchronization pulse is observed by the µC it is possible to delay the SPI commands until the measurement cycles are finished.

1.2.2. Active - and Stand-by - Operation Mode

To reduce the current consumption the measurement phase is only activated for a short time of 25 clock periods (200 µs) and the LED´s are clocked with 125 kHz. Together with a settling time for the amplifiers the total measurement time has a value of $T_{measure}$ = 464 µs. Afterwards during the passive time the measurement is stopped and the LED´s are switched off. When an object (movement) is detected and the proximity signal becomes '0' the sensor is in the active operation mode for minimum 260 ms (minimum active time). In this case the measurement is activated with a rate of 244 Hz. When no movement has been detected during this time the sensor is switched to stand-by mode and the sampling rate is reduced to 15 Hz. If the object is still in the detection area (without a movement) the PROX-output stays active ('0') independently of the operation mode (default).

By connecting the PROX output to the interrupt pin of the supervising µC it is possible to use the proximity event as a wake-up signal for the µC.

1.2.3. Detection Algorithms

The algorithms for detecting the switch state observe the integrator output which is proportional to the modulation current of the compensation LED. If no object is in the detection area of the sensor and the regulation loop has settled the integrator signal has a static value. If an object approaches to the sensor the integrator output changes its value and if a threshold value is reached the proximity signal PROX is activated.

To detect the touch down event additionally the 1st and 2nd derivative of the integrator output is used. These values are functions of the objects velocity and acceleration. A touch down is detected if the object is approaching with a minimum velocity, stops on the sensors surface with a minimum of negative acceleration and remains after the touch down for a minimum time of 130 ms on the surface of the sensor without moving. The time criterion is used to be sure that it was a valid TOUCH event on the sensors surface.

If the object is removed from the sensors surface the stand-by mode is activated again if the output of the integrator reaches the old value which it had before entering the active mode. If something falls onto the surface and activates the TOUCH a time-out function switches back into stand-by mode after global time out (TIMOV) and the recent static value of the integrator output is used as the new reference value for the proximity function.

The TOUCH signal output (on pins 10,11 or via SPI) depends on the pin SWTO. When this pin is connected to ground TOUCH is only active as long as the object touches the surface (**touch-mode**). When it is connected to supply it is in **toggle-mode:** A TOUCH event closes the switch and the TOUCH output stays active as long as the next TOUCH event opens the switch.

With a wipe over the sensors surface a reset in detection algorithm is activated. If after a touch some dirt is left on the sensor the system would not turn to stand-by mode because there is a higher reflection. In this case a wipe stops the time-out and a new reference will be found.

2. General Device Specification

2.1. Absolute Maximum Ratings

Currents are positive into, and negative out of the specified terminal.

Parameter	Condition	Symbol	min	max	Unit
Supply voltage range VS	continuously	VS	-0,3	+5.5	V
Junction temperature		T_J		150	°C
Storage temperature range		T_{STG}	-55	150	°C
Soldering temperature (10 Seconds)		T_{Lead}		240	°C

Stresses beyond those listed under „absolute maximum ratings“ may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated above is not implied. Expose to absolute maximum rated conditions for extended periods may affect device reliability and are not permitted.

2.2. Recommended Operating Conditions

The following conditions apply unless otherwise stated.

Parameter	Conditions	Symbol	min	typ	max	Unit
Supply voltage range	$T_{AMB} \leq +85$ °C	V_{BAT}	3.0	3.3	5.5	V
Ambient operating temperature range		T_{OPT}	-40	27	85	°C
Junction temperature		T_J	-40	27	125	°C

2.3. Electrostatic Discharge Sensitivity

This integrated circuit can be damaged by ESD. ELMOS recommends that all integrated circuits must be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure.

3. Detailed Electrical Characteristics

T_A = -40°C to 85°C and T_A = T_J. Typical values are at T_A = +25°C and AVdd/DVdd 3.3V (unless otherwise noted).

3.1. Receiving Path

Spec.-No	Parameter	Symbol	Min	Typ	Max	Unit
	Input terminal TIN					
1	Transimpedance	Rf	70	100	130	kΩ
2	DC-current compensation optimized for SFH229 (OSRAM PIN Photodiode)	Idc		1000		µA
3	Capacitance of photo diode @ 0.7V	Cd		50	100	pF
4	Voltage at TIN-Pin	Vtin	0.3	0.7	1	V
5	Settling time (1mA step)	Ts		150		us
6	Corner frequency 1st highpass filter	fg1		20		kHz
7	1st gainstep 1st amplifier	G01		17		dB
8	2nd gainstep 1st amplifier	G02		23		dB
9	Corner frequency 2nd highpass filter	fg2		20		kHz
10	1st gainstep 2nd amplifier	G11		11		dB
11	2nd gainstep 2nd amplifier	G12		23		dB
12	Minimum total gain	Gmin		128		dBΩ
13	Maximum total gain	Gmax		146		dBΩ
14	Gain step width	Gstep		6		dBΩ
15	Center frequency	fc		125		kHz

3.2. Transmitting Path

Spec.-No	Parameter			Symbol	Min	Typ	Max	Unit
1.1	DAC resolution			N		10		bit
1.2	DAC INL			Ei		2		lsb
1.3	DAC DNL			Ed		2		lsb
1.4	Dac output voltage at full scale			Vmax		1.22		V
Spec.-No	Parameter	SPI-Param.		Symbol	Min	Typ	Max	Unit
		FIXS	HICS					
	Output terminal LEDS							
2.1	Bias Current (permanent part of LED current)			ICb		0.3	0.5	mA
2.2	Current LEDS (switched part of LED current)	'0'	'0'	IS0min			4	mA
				IS0max		18		mA
		'0'	'1'	IS1min			6	mA
				IS1max		36		mA
2.3	Current LEDS (fixed level, switched part of LED current)	'1'	'0'	ISfix0		10		mA
		'1'	'1'	ISfix1		20		mA
Spec.-No	Parameter	SPI-Param.		Symbol	Min	Typ	Max	Unit
		HICC						
	Output terminal LEDC							
3.1	Bias Current (permanent part of LED current)			ICb		0.25	0.5	mA
3.2	Current LEDC (switched part of LED current)	'0'		IC0min			0.05	mA
				IC0max	0.85			mA
		'1'		IC1min			0.05	mA
				IC1max	1.5			mA

3.3. Internal References and Parameters

Spec.-No	Parameter	Symbol	Min	Typ	Max	Unit
1	Reference voltage	Vref	1.45	1.65	1.85	V
2	Bias current	Ib	7	10	15	µA
3	Oscillator frequency	fosc	300	500	700	kHz

3.4.SPI Interface

3.4.1.SPI DC characteristics

Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Output terminal Touch_b / MISO						
	SPI-Mode:	SPI enabled					
1.1	Output voltage low	I = 0.5mA				0.4	V
1.2	Output voltage high	I = -0.2mA		V_{DD} - 0.4			V
1.3	Tristate leakage	0 < V_{MISO} < V5		-5		5	µA
Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Input terminal Touch_a / LDB						
	SPI-Mode:	SPI enabled					
2.1	Input voltage low			-0.3		0.4 V_{DD}	V
2.2	Input voltage high			0.6 V_{DD}		V_{DD} + 0.3	V
2.3	Hysteresis[1]		V_{Dhys}		0		mV
2.4	Leackage	0 < V_{IN} < V_{DD}		-5		5	µA
	Input terminals SCK, MOSI						
3.1	Input voltage low		V_{DSl}	-0.3		0.4 V_{DD}	V
3.2	Input voltage high		V_{DSh}	0.6 V_{DD}		V_{DD} + 0.3	V
3.3	Hysteresis[1]		V_{Dhys}		0		mV
3.4	Leackage	0 < V_{IN} < V_{DD}		-1		1	µA

3.4.2.SPI AC characteristics

Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Terminal LDB, SCK						
	SPI-Mode: SPI enabled						
1.1	Time of ↓ LDB (10%) to ↑ SCK (90%)[1]		T_{LS1}	90			ns
1.2	Time to ↓ SCK (10%) to ↑ LDB (90%)[1]		T_{LS2}	80			ns
Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Terminal SCK						
2.1	Period SPI clock		F_{SCK}			8.1	MHz
	Terminal MOSI, SCK						
3.1	Data setup time: Time from changing MOSI (10%, 90%) to ↑ SCK(90%)[1]		T_{SET}	30			ns
3.2	Data hold time: Time of ↑ SCK (90%) to changing MOSI (10%,90%)[1]		T_{HOLD}	30			ns
3.3	Time of ↓ SCK (10%) to stable MISO (10%, 90%)[1]	Load capacitance at MISO < 15 pF.	T_{VAL2}			30	ns
	Terminal LDB, MISO						
	SPI-Mode: SPI enabled						
4.1	Time of ↓ LDB (10%) to stable MISO (10%, 90%)[1].	Load capacitance at MISO < 15 pF	T_{VAL1}	20		80	ns
4.2	Time of ↑ LDB (90%) to high impedance state of MISO[1].	Load capacitance at MISO < 15 pF	T_{LZ}	20		80	ns
4.3	Time between SPI cycles: LDB at high level (90%)[1].		T_{LH}	250			ns

[1] not production tested

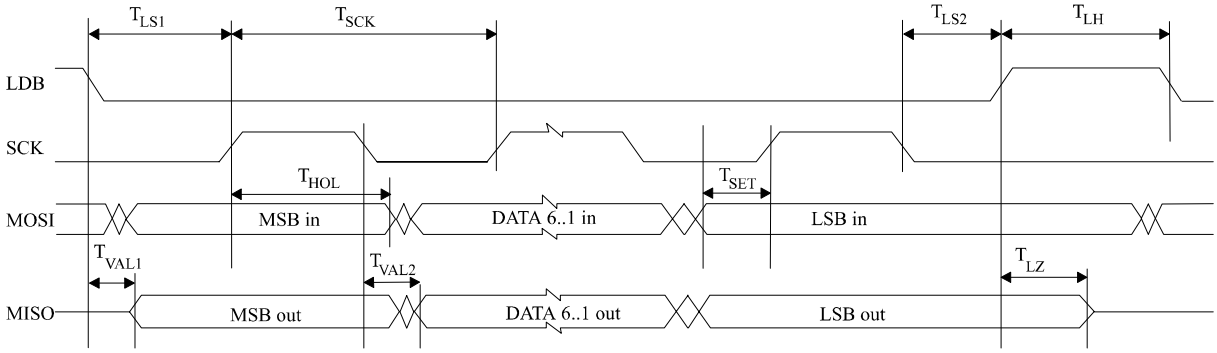


Figure 6: SPI bus timing diagram

3.5. Status output

Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Output terminal Touch_a / LDB - output terminal Touch_b / MISO						
	SPI-Mode:	SPI disabled					
1.1	Resistance between both pins (Resistance is V_{DD} dependant)				40	100	Ω
1.2	Maximum current					30	mA
Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Output terminal PROX						
	SPI-Mode:	SPI disabled					
2.1	Output voltage low	I_{PROX} = 5mA			0.5	1.0	V
2.2	Input voltage high		V_{DSI}	-0.3		0.4 V_{DD}	V
2.3	Input voltage low		V_{DSh}	0.6 V_{DD}		V_{DD}+ 0.3	V
2.4	Leackage	0 < V_{IN} < V_{dd}		-5		5	µA

3.6. Synchronisation

Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Input terminal SYI						
1.1	Input voltage low		V_{DSI}	-0.3		0.4 V_{DD}	V
1.2	Input voltage high		V_{DSh}	0.6 V_{DD}		V_{DD} + 0.3	V
1.3	Hysteresis[1]		V_{Dhys}		0		mV
1.4	Leackage	0 < V_{IN} < V_{DD}		-5		5	µA
	Output terminal SYO						
2.1	Output voltage low	I = 0.5mA				0.4	V
2.2	Output voltage high	I = -0.2mA		V_{DD} - 0.4			V
2.3	Tristate leakage	0 < V_{SYO} < V5		-5		5	µA

3.7. Mode selection

Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Input terminal ENSPI, SWTO						
1.1	Input voltage low		V_{DSl}	-0.3		0.4 V_{DD}	V
1.2	Input voltage high		V_{DSh}	0.6 V_{DD}		V_{DD} + 0.3	V
1.3	Hysteresis[1]		V_{Dhys}		0		mV
1.4	Level for Testmode Selection			0.5 V_{DD} -100mV	0.5 V_{DD}	0.5 V_{DD}+100 mV	V
1.5	Leackage	0 < V_{IN} < V_{DD}		-5		5	µA

3.8. Supply

Spec.-No	Parameter	Conditions	Symbol	Min	Typ	Max	Unit
	Input terminal AVDD						
1.1	Supply voltage		V_{DD}	3.0	3.3	5.5	V
1.2	Supply current	SYI = 0; Slave mode; standby	I_{ADD}		14		µA
1.3	Supply current	SYI = 1; Slave mode; active; FRQVAL=1	I_{ADD}		215		µA
1.4	Supply current	STOP mode (Oscillator off)	I_{ADD}		0		µA
	Input terminal DVDD						
2.1	Supply voltage			V_{DD} - 0.1	V_{DD}	V_{DD} + 0.1	V
2.2	Supply current	LEDC,LEDS open,SYI =0; Slave mode; standby	I_{DDD}		125		µA
2.3	Supply current	LEDC,LEDS open,SYI =1; Slave mode; active; FRQVAL=1	I_{DDD}		125		µA
2.4	Supply current	STOP mode (Oscillator off)	I_{DDD}		5		µA
	Supply ripple						
3.1	Supply ripple	AVDD, DVDD, f<100kHz				10	mV

4. Functional Description

4.1. Digital integrator

The digital part of the HALIOS loop is a digital integrator which integrates the output of the synchronous demodulator in a 10 bit register. This 10 bit word is DA-converted to modulate the compensation LED.
During a measurement cycle this integrator works with a frequency of 125 kHz.

4.1.1. Integrator stepsize

To follow fast and large changings the stepsize of integration can vary between 1- 8 LSBs.

The maximum stepsize can be adjusted with the SPI parameter SELACC and the accelerated integration can be switched off with the parameter ACC_ON (see 4.3.3).

4.1.2. Measurement cycle

A measurement cycle starts with switching on the analogue components. After the amplifiers have settled to a DC value the HALIOS loop is closed and the integrator is working for 25 clock cycles. A whole measurement cycle takes 464 µs.

4.2. Detection-Algorithm

4.2.1. Operation modes

The E90901 has two operation modes with different sampling rates. The sampling rate describes the time distance between two measurement cycles. During a measurement cycle the digital integrator approximates the value to compensate the difference between the LED signals. If there is no moving object in the detection area it is not necessary to operate with a high sampling rate. So the system is in **stand-by mode** and the measurement cycles follow every $T_{standby}$= 64 ms. If an object is recognized in the detection area the system changes into **active mode** with a sampling period of T_{active}= 4 ms.

4.2.2. Event detection

The Algorithm is able to detect three different events:
1. PROX: indicates a movement (proximity) in the detection area.
2. TOUCH: indicates a touch down on the sensors surface.
3. WIPE: indicates a wipe over the sensors surface.

4.2.2.1. Proximity event

If a moving object is detected the signal on output pin PROX (see figure 2) is '0'. There are two different modes for this output pin which can be chosen with the parameter HOLDPROX (see 4.3.3). In case of default (HOLDPROX = '1') the PROX output is independent of the operation mode and held '0' as long as the object is in the detection area. When HOLDPROX = '0' the PROX output is '0', when the system is in **active mode.**

The internal PROX signal (=not STANDBY) can also be read out via SPI (see 4.3.3).
To change the sensibility for proximity detection the parameters THZ1, PROXNUM1, PROXNUM2 und DYNSTEP (see 4.3.3; figure 6) can be changed via SPI.

4.2.2.2. Touch event

To detect a valid TOUCH signal five conditions must be fulfilled:

1. The dynamic (distance between reference and recent value) must pass the minimum which is set with the parameter THZ2 (see 4.3.3; figure 7).
2. The approach to the surface must pass a minimum speed which can be tuned by THD1 (see 4.3.3; figure 7).
3. The object must stop on the surface with a minimum of negative accelleration which is defined with THA (this parameter is coupled with THD1, see 4.3.3; figure 7).
4. After touch down the finger must be left calm on the surface. The deviation THD0, called touch tolerance, depends on the dynamic and is adjusted automatically. Higher dynamic causes higher tolerance.
5. The finger must stay calm for the hold time T_{touch} which can be adjusted by the parameter TOTIM.

When all this conditions were fulfilled the switch between the pins TOUCH_a and TOUCH_b (see figure 2) is closed when the SPI is disabled (ENSPI), otherwise the TOUCH signal can be read out via SPI.

With the pin SWTO you can decide between **touch-** and **toggle-mode.** In **touch-mode t**he TOUCH signal output (on pins 10,11 or via SPI) is only active as long as the object touches the sensors surface. In **toggle-mode** every TOUCH event toggles between open and closed switch.

4.2.2.3. Wipe event

When the system is in **touch-mode** and a wipe over the surface is detected a reset in the detection algorithm is activated and the system changes to **stand-by mode.**

When it is in **toggle-mode** the WIPE event can also be read out via SPI but in case of default no reset is activeted. This is to prevent that the switch opens with an accidental movement over sensors surface.
With the SPI parameter RSWIPE it is possible to enable this reset also in **toggle-mode.**

4.2.3. Timeout

If the system is in **active mode** and after the time $T_{timeout}$ no further movement is recognized it switches back to **stand-by mode**. This time can be set with the parameter TIMOV (see 4.3.3).

4.2.4. Reset

A reset of the detection algorithm can be done via SPI with RESET (see 4.3.3).

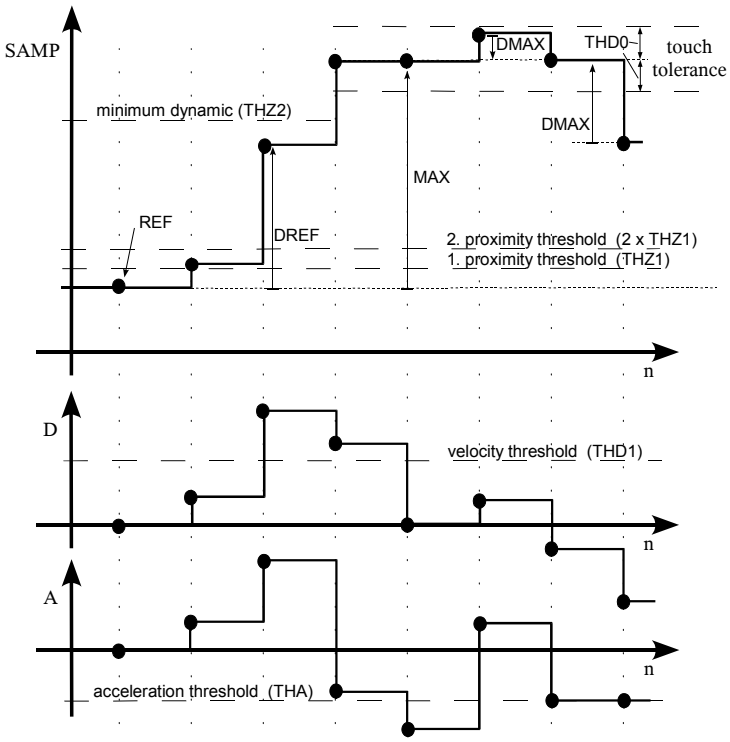


Figure 7: Signals and parameters

4.3. SPI Interface

16 data bits are sent to the E90901 via SPI. The first four bits contain the address bits. These four bits tell the E90901 its general operation. The next four bits contain the Data information. The last eight bits are not used.

The SPI interface consists of 4 pins:

1.	MOSI	:	Master Out Slave In :	µC	=> ASIC
2.	SCK	:	Serial Clock :	µC	=> ASIC
3.	LDB	:	Load (active low):	µC	=> ASIC
4.	MISO	:	Master In Slave Out :	ASIC	=> µC

4.3.1. SPI Transmission

Each transmission starts with a falling edge on LDB and ends with a rising edge. During transmission commands and data are shifted according to the following rules

1. LDB line is active (active 'LOW').
2. MOSI data are shifted in on the rising SCK edge MSB first and LSB last.
3. MOSI data are read on the falling SCK edge.
4. A command is only executed on the rising edge of LDB when 16 clock cycles are counted durning the last transmission.
5. MISO is active during LDB is 'LOW' and is tristated during LDB is 'HIGH'.
6. SCK should remain 'LOW' after the 16th SCK falling edge.

The following diagram shows one data transmission over the SPI-bus. For exact timing see chapter 3.4.2.

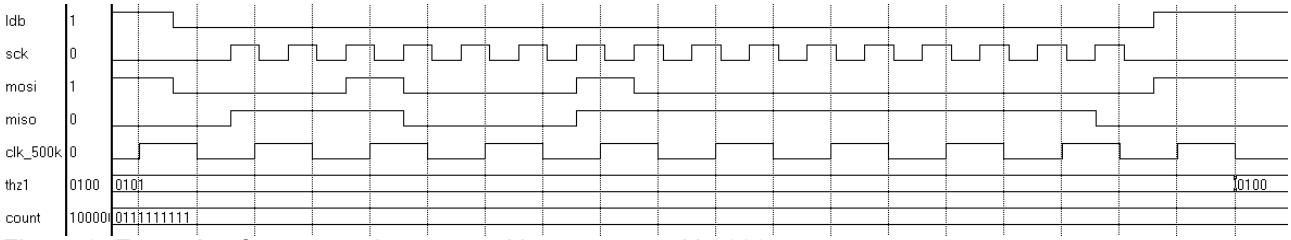


Figure 8: Example of a correct data transmition, command h2200

The adjusted parameter is valid with the first falling edge of the internal oscillator (CLK_500K) after LDB is 'HIGH'. In the example of figure 8 THZ1 is set to 4 LSB.

4.3.2. MISO Line

16 bits of Data are returned to the µC on the rising edge of SCK. The data that is returned contains information about the state of the switch and the value of the DAC or the received command. This is depending on the parameter RETUR (default 'LOW').

RETUR	**MISO LINE**									
	MSB [1]	[2]	[3]	[4]	[5]	[6:13]		[14]	[15]	**LSB**[16]
'LOW'	not STANDBY	MOVEDO	PRETO	TOUCH	WIPE	COUNT[9:0]				TMODE
'HIGH'	not STANDBY	MOVEDO	PRETO	TOUCH	WIPE	ADDR[0:3]	DATA[0:3]	RETUR	TMODE	TMODE

In the example of figure 8 the received bits are: 1110001111111110 (with default parameters).
This means the E90901 is in **active mode** (internal PROX,here: high active !), the states MOVEDO and PRETO are low active and TOUCH, WIPE are high active. The integrator value is COUNT="0111111111"(511) and the LSB: TMODE (high active) indicates that the E90901 is not in **test-mode**.

4.3.3. Address decoding

Address	Data	Hex	Default	Signal	Description	
“0000”	“0000”	00**	-	-	-	Unused
	“0001”	01**	-	-	-	Unused
	“0010”	02**	-	-	-	Unused
	“0011”	03**	-	-	-	Unused
	“0100”	04**	-	-	-	Unused
	“0101”	05**	-	-	-	Unused
	“0110”	06**	enabled	G0	disabled	Gainsetting 6 dB.
	“0111”	07**			enabled	
	“1000”	08**	disabled	G1	disabled	Gainsetting 12 dB.
	“1001”	09**			enabled	
	“1010”	0A**	enabled	HICC	disabled	High current for compensation LED.
	“1011”	0B**			enabled	
	“1100”	0C**	disabled	HICS	disabled	High current for sending LED.
	“1101”	0D**			enabled	
	“1110”	0E**	enabled	FIXS	disabled	Fixed current for sending LED.
	“1111”	0F**			enabled	

Address	Data	Hex	Default	Signal	Description	
„0001“	“0000”	10**	enabled	ACC_ON	disabled	En/Disables the counters acceleration (see 4.1) : - enabled -> step size: 1-8 LSB , - disabled -> step size: 1 LSB.
	“0001”	11**			enabled	
	“0010”	12**	4 LSB	SELACC	4 LSB	Select the maximum integrator stepsize (see 4.1) .
	“0011”	13**			8 LSB	
	“0100” - “0111”	14** - 17**	-	-	-	Unused
	“1000”	18**	disabled	SELDELAY	disabled	En/Disables an additional touch time, which is depending on the signals dynamic. Its used for synchronization (see 4.4)
	“1001”	19**			enabled	
	“1010”	1A**	disabled	RSWIPE	disabled	Disables the reset caused by a detected WIPE signal when the switch is in **toggle-mode** (SWTO='1') (see 4.2).
	“1011”	1B**			enabled	
	“1100”	1C**	return counter value	RETUR	return counter value	RETUR switches the data which is send out via MISO, see section 4.1.3
	“1101”	1D**			return command	
	“1110”	1E**	enabled	HOLDPROX	disabled	If enabled the PROX output is held active (low) as long as an object is inside the detection area.
	“1111”	1F**			enabled	

Address	Data	Hex	Default	Signal	Description		
„0010“	“0000”	20**	4 LSB	THZ1	Sets to 3 LSB	1st Threshold for promixity. 2nd Threshold for promixity is 2*THZ1.	sensitive
	“0001”	21**			Sets to 4 LSB		
	“0010”	22**			Sets to 4 LSB		
	“0011”	23**			Sets to 5 LSB		not sensitive
	“0100” - “0111”	24** - 27**	-	-	-	Unused	
	“1000”	28**	32 LSB	THZ2	Sets to 8 LSB	Minimum dynamic for touch detection	sensitive
	“1001”	29**			Sets to 16 LSB		
	“1010”	2A**			Sets to 32 LSB		
	“1011”	2B**			Sets to 64 LSB		
	“1100”	2C**			Sets to 128 LSB		
	“1101”	2D**			Sets to 192 LSB		
	“1110”	2E**			Sets to 256 LSB		not sensitive
	“1111”	1F**			Sets to 512 LSB		

Address	Data	Hex	Default	Signal	Description		
„0011“	“0000” - “0111”	30** - 37**	-	-	-	Unused	
	“1000”	38**	4 LSB / -4 LSB (soft)	THD1 / THA	4 LSB / -1LSB	Velocity and acceleration threshold for touch.	very soft
	“1001”	39**			4 LSB / -4 LSB		soft
	“1010”	3A**			7 LSB / -7 LSB		middle
	“1011”	3B**			10 LSB / -10 LSB		hard
	“1100” - “1111”	3C** - 3F**	-	-	-	Unused	

Address	Data	Hex	Default	Signal	Description				
“0100”	“0000” - “0111”	40** - 47**	-	-	-		Unused		
	“1000”	48**	130 ms	TOTIM	65 ms		Touch time (holdtime), constant part of T_{valid}		
	“1001”	49**			130 ms				
	“1010”	4A**			130 ms				
	“1011”	4B**			260 ms				
	“1100”	4C**	48 s	TIMOV	TOUCHED	32 s	PROX	8 min.	Duration of timeout when system state is TOUCHED or PROX
	“1101”	4D**				48 s		12.5min.	
	“1110”	4E**				60 s		16 min.	
	“1111”	4F**				No timeout		No timeout	

Address	Data	Hex	Default	Signal	Description	
"0101"	"0000"	50**	-	-	-	Unused
	"0001"	51**	enabled	OSCON	disabled	Switches internal oscillator off
	"0010" - "0100"	52** - 54**	-	-	-	Unused
	"0101"	55**	-	RESET + OSCON	-	Resets the whole digital part, Switches the oscillator on
	"0110" - "1111"	56** - 5F**	-	-	-	Unused

Address	Data	Hex	Default	Signal	Description	
"0110"	"0000" - "1111"	6***	-	-	-	Unused

Address	Data	Hex	Default	Signal	Description		
"0111"	"0000"	70**	2	DYNSTEP	Sets to 0	Pos./Neg. steps greater than DYNSTEP are counted up in the dynamic counters: NEGCNT and POSCNT, otherwise they are in reset.	sensitive
	"0001"	71**			Sets to 1		
	"0010"	72**			Sets to 2		
	"0011"	73**			Sets to 3		not sensitive
	"0100"	74**	2	PROXNUM1	Sets to 0	If PROXCNT, which counts the number of subsequent samples that pass the 1st threshhold THZ1, is greater than PROXNUM1, then proximity is detected.	sensitive
	"0101"	75**			Sets to 1		
	"0110"	76**			Sets to 2		
	"0111"	77**			Sets to 3		not sensitive
	"1000" - "1001"	78** - 79**	-	-	-	Unused	
	"1010"	7A**	2	PROXNUM2	Sets to 2	If POSCNT or NEGCNT > PROXNUM2 proximity is detected	sensitive
	"1011"	7B**			Sets to 3		not sensitive
	"1100" - "1111"	7C** - 7F**	-	-	-	Unused	

Address	Data	Hex	Default	Signal	Description	
"1XXX"	"XXXX"	****	-	-	**Test mode commands**	Don't use !

4.4. Synchronisation

The synchronisation is done by passing a pulse from one switch to the next. Each switch has an input SYI and an output SYO. The output SYO is connected to the input SYI of a neighbouring E90901 in a chain of E90901s or connected to it own SYI if there is only one switch. The output SYO is 'HIGH' when an E90901 is conducting a measurement cycle. An E90901 activates when

1. It is a slave E90901 and there is a falling edge on the input SYI.

2. It is the master E90901 and the passive time has elapsed.

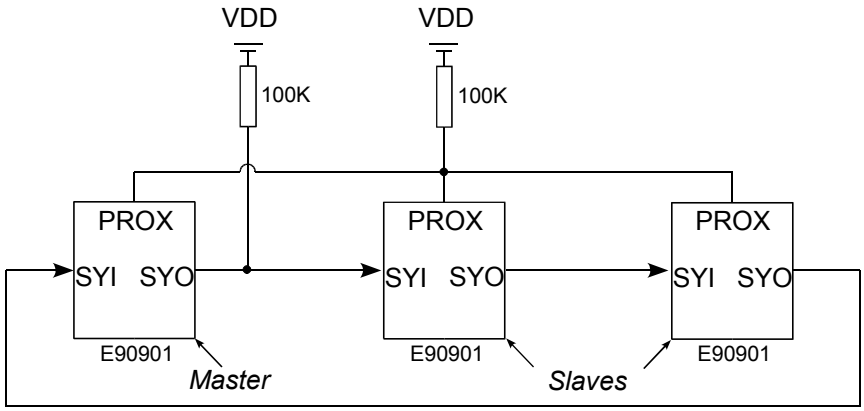


Figure 9: Example for synchronization of three E90901

4.4.1. Decision of master

In a chain of E90901 there is only one master E90901. The decision of which depends on the output pin SYO. The master E90901 is defined by a pull-up resistor of 100K on its SYO output. Initially the digital output of this pin is tristated so the value on the pin depend on weather it is connected to a pull-up.

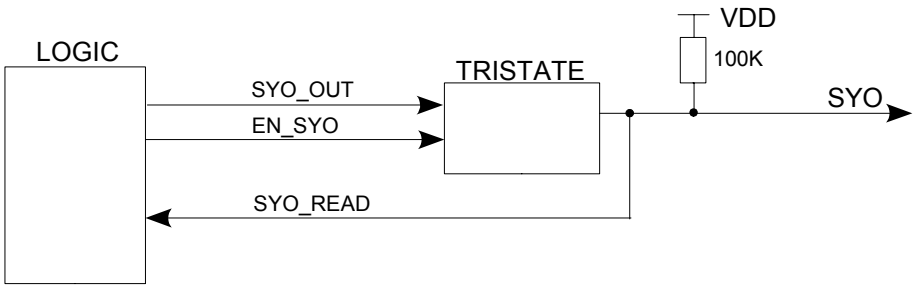


Figure 10: Decision of master

After the initial power on or a SPI-reset each E90901 checks to see if it is a master or a slave. This decision depends on the value of SYO_READ while EN_SYO is 'LOW'. The signal EN_SYO is an enable for a tristate, while it is 'LOW' the signal SYO_OUT is in effect disconnected from the circuit.
The value of EN_SYO is the delayed power-on or SPI reset.

4.4.2. Cancelling a touch signal

To avoid the case where there is a touch by two or more switches at the same time a cancel-pretouch signal is sent over the SYO line to all switches. To ensure that the switch with the highest dynamic detects its TOUCH event, the additional touch time with SELDELAY (see 4.3.3) should be enabled. This means a higher dynamic causes less delay.
The first switch to detect a TOUCH sends a cancel-pretouch signal on the SYO line. Each switch in turn cancels its PRETOUCH and send the cancel-pretouch signal to the next switch. Only the switch that originally detected the touch can stop this pulse, so the pulse is going round for ones and afterwards all other switches can detect another TOUCH event.

The cancel-pretouch signal is a small pulse that is sent after the measurement cycle has finished and a TOUCH has been detected. To decide on if this signal has been sent or not, the time that SYI is zero after a falling SYI event has occurred is measured. If this time is to short then the switch knows that a TOUCH was detected by a neighbouring switch and when it is in state PRETOUCH it will change its state to APPROX.

4.4.3. Proximtiy detection and change of sampling rate

If in a chain of several E90901 one of the slaves detects a proximity, it can't speed up the sampling rate by itself. Only the master chip is able to do this. So all E90901 in a synchronized chain are connected parallel to a pullup resistor and the master chip can read the common PROX signal to change the sampling rate (see figure 9). For correct working the parameter HOLDPROX should be set to '0' to get the internal PROX = not STANDBY which indicates the sampling rate.

4.5. Analog parameters

The parameters HICC (High Current Compensation) and HICS (High Current Sender) can be used to set the operating point of the HALIOS loop. Additonally a selftest can be implemented when using SPI interface. By switching the sending current from low to high a touch should be detected. The same effect can be achieved when switching the compensation current from high to low.

With FIXS the LED driver of the sender can be set to regulated (FIXS=0) or fixed mode (FIXS=1). FIXS=1 means that the sending LED is pulsed with a constant current. By setting FIXS=0 the sending current is inversely controlled to the compensation current. This means if the compensation current increases the sending current is decreased by the same relative amount. In this mode the system never saturates and can handle a great variation in optical reflections.

With G0, G1 the gain of the amplifer is set. It should be set to value that the modulator can differ between single one LSB changes of the DAC. The limiting factor here is the noise of the amplifier which is about 2.7nArms refered to the input.

With OSCON=0 (see 4.3.3) the system can be set into a **sleep mode**. If this command is sent during a measurement phase the system waits until the measurement has finished before it stops.

5. ESD-Protection

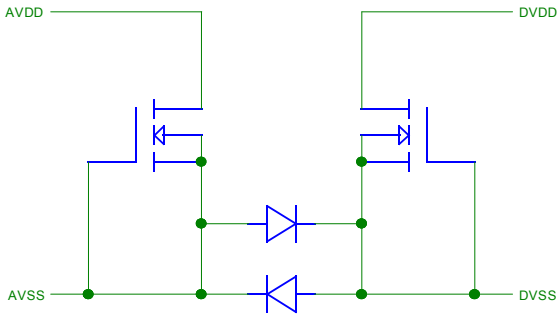


Figure 11: ESD-Protection for power supply pins

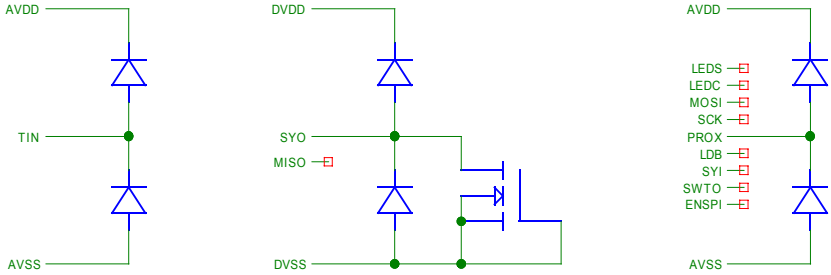


Figure 12: ESD-Protection for all other signal pins

Test Method

The ESD protection circuitry is measured using MIL-STD-883C Method 3015 (Human Body Model) with the folllowing conditions:

- VIN = 2000 Volt
- REXT = 1500 Ohm
- CEXT = 100 pF

6.Latch up Test

200mA positive and negative pulses at room temperature according to JEDEC-17

7.Quality and Reliability

7.1. Qualification Flow

See ELMOS document:
Standard Qualifikations Plan QM-No.: 07PL0009.XX

8.Handling and Packaging

8.1. Handling

Devices are sensitive to damage by Electro Static Discharge (ESD) and should only be handled at an ESD protected workstation.

8.2. Packaging

See ELMOS document QM-No: 02SP0002.XX Packaging for automatic assembly.

9. Record of Revision

CHAPTER		REASON FOR AND DESCRIPTION OF CHANGE	DATE	APPROVAL
	REV			ELMOS
	00	Initial release	09.10.02	
3.2.3.2	01	Changed current for LEDC	11.06.03	
4.2	01	Changes in the algorithm	11.06.03	
4.3.3	01	Reduced parameters	11.06.03	
3.2/3.5	01	Parameter adaptation	11.06.03	
Intro	02	TSSOP16 package added	20.10.03	
1.2.2	02	Active-mode description corrected	20.10.03	
4.2.2.1	02	Active-mode description corrected	20.10.03	
2.1	02	Prox-Pin-specification added	20.10.03	
10.1	02	Application example updated	20.10.03	
4.2.3	02	Timeout now also in PROX	24.02.04	
4.3.3	02	New default for THD1/THA + add. value	24.02.04	
4.3.3	02	Timeout value for PROX added	24.02.04	
4.5	02	OSCON description corrected	24.02.04	

10. Application examples

10.1. Power Supply

Care should be taken when switch-mode power supplies (SMPS) are used. When the primary side is not correctly connected to the mains the secondary side may float with up to 300V. This may cause malfunction of the device due to capacitive coupling from the TIN-pin to any ground connection outside the system.

Generally the use of switch-mode power supplies is not recommended.

10.2. Application with SPI interface

Note: Pins MOSI (15), SCK (16) and in SPI-Mode TOUCHB/LDB (10) are CMOS-inputs and should be fixed to VDD or GND when not in use. If cases where the SPI-programming device may be disconnected pull-down resistors should be used. Please note that pins with pulldown/pullup resistors are EMI sensitive. Layout and PCB are available on request.

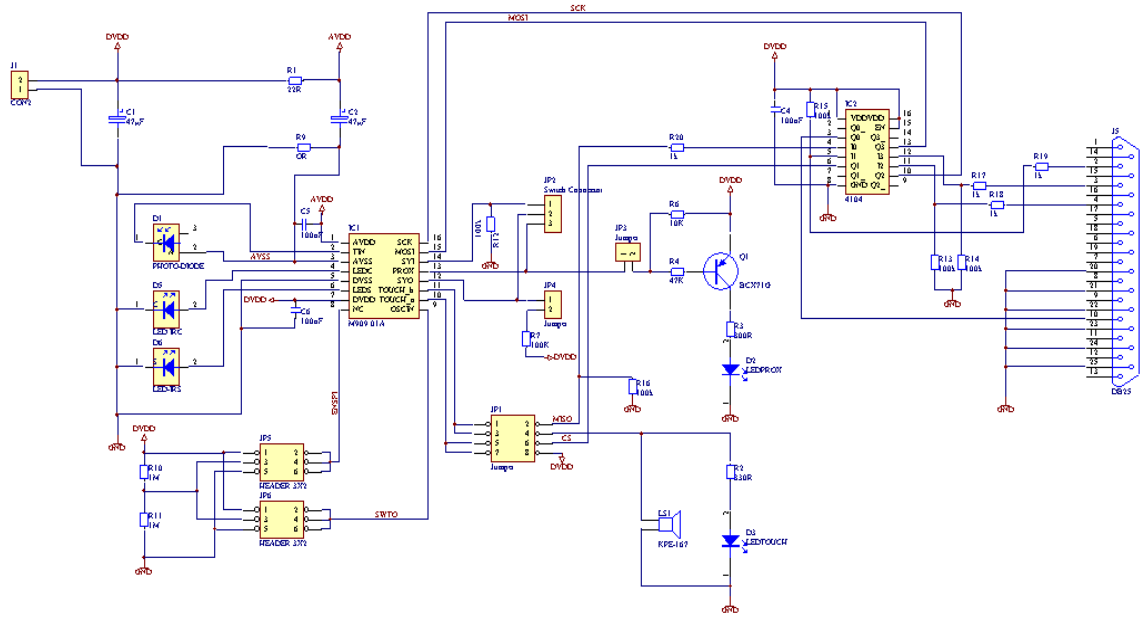


Figure 13: Evaluation board with SPI-interface

Device Type	Footprint	Designators	Supplier	Order code	Comment
47µF	SMD ELKO	C1	Bürklin	10D382	
47µF	SMD ELKO	C2	Bürklin	10D382	
100K	DIN45921T.404	R7	Bürklin	07 E788	
100nF	SMD 2220 CAP	C4	Bürklin	41D4324	
100nF	SMD 2220 CAP	C5	Bürklin	41D4324	
100nF	SMD 2220 CAP	C6	Bürklin	41D4324	
10K	DIN45921T.404	R6	Bürklin	07 E692	
1M	DIN45921T.404	R10	Bürklin	07 E884	
1M	DIN45921T.404	R11	Bürklin	07 E884	
22R	DIN45921T.404	R1	Bürklin	07 E436	
300R	DIN45921T.404	R3	Bürklin	07 E544	
330R	DIN45921T.404	R2	Bürklin	07 E548	
4104	SO16	IC2	Bürklin	61S4310	
47K	DIN45921T.404	R4	Bürklin	07 E756	
1K	DIN45921T.404	R17,R18,R19,R20			
100K	DIN45921T.404	R13,R14,R15,R16			
BCX71G	SOT-23	Q1	Bürklin	12S9458	
CON2	SCC2	J1	Conrad	729949	Power connector
DB25	DB25RA/F	J5	Conrad	741361	D-Sub connector
Jumper 3X2	IDC6	JP5			connector
Jumper 3X2	IDC6	JP6			connector
Jumper 1X2	IDC2	JP4			connector
Jumper 1X2	IDC2	JP3			connector
Jumper 3X1	IDC2	JP2			connector
Jumper 4X2	IDC8	JP1			connector
SFH2400-FA		D1	Osram	Q62702-P5035	Photodiode
SFH4205	Side-LED	D5	Osram	Q62702-P5165	Compensation diode
SFH4200	Top-LED	D6	Osram	Q62702-P978	Sending-diode
LEDgr	SMD LED	D2	Bürklin	32G3110	
LEDred	SMD LED	D3	Bürklin	32G3140	
KPE-167		LS1	Farnell	927-041	Loudspeaker

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