MLX90109

125kHz RFID Transceiver

Features and Benefits

- Integrated transmitter-receiver for 120kHz ASK transponders (tags)
- Unique Parallel Antenna concept for maximum power efficiency.
- No external quartz reference required. No zero modulation problems.
- SO8 package and high level of integration for compact reader design
- On chip decoding (Biphase and Manchester ASK) for fast system design and ease of use
- Baudrate selectable On chip filtering for maximum sensitivity.
- Open drain data and clock outputs for 2 wire serial communication
- Power down mode available
- Transparent ASK modulation for the downlink communication to the tag,including ON/OFF keying (100%) and FDX-B20.

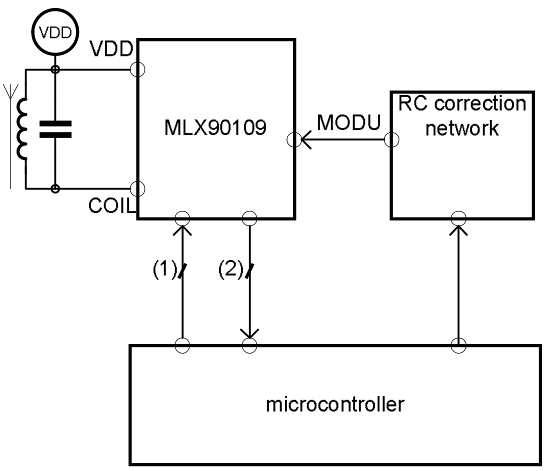
Applications

- Portable tools and appliances, doorlocks ... and any RFID system requiring a large number of readers for proximity Read and Write.

Ordering Information

Part No.	Temperature suffix	Package code
MLX90109	C (0°C to 70°C)	DC (SOIC 8)
MLX90109	E (-40°C to 85°C)	DC (SOIC 8)

Functional Diagram



1: MODE/SPEED config settings
2: DATA/CLOCK outputs

Description

The MLX90109 is a single chip RFID transmitter-receiver for the 125kHz range. It has been conceived to realize a state of the art Read and Write performance for minimum system cost, and minimum power consumption.
An external L and C are connected as a parallel resonant circuit, which will determine the carrier frequency and the oscillator frequency of the reader. This eliminates zero modulation effects, and avoids the need for an external oscillator.
The antenna amplitude can be adjusted externally on the fly. This allows straightforward modulation of the antenna amplitude to write to the transponder.
The reader IC can easily be switched to power down by setting the antenna amplitude to zero.
The MLX90109 can be configured to decode the transponder signal on-chip. In this case the decoded signal is available through a 2-wire interface of clock and data. For minimum interface wiring, the undecoded transponder signal can also be made available on a single wire interface.

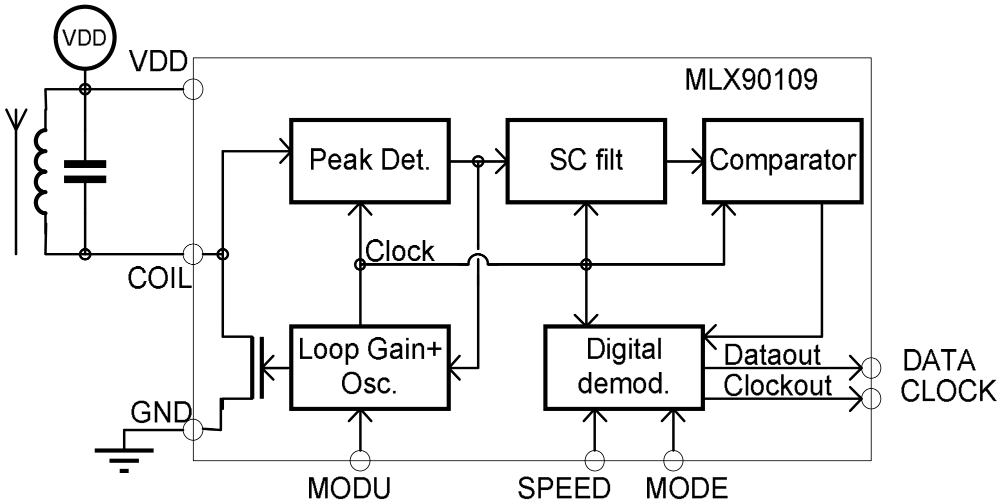
MLX90109 Electrical Specifications

DC Operating Parameters T_A = -40°C to 85°C, Fres = 125kHz, Lant = 73.6uH, Qant=17.3 , V_{DD} = 5V (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Voltage	VDD		4.5	5	5.5	V
Serial Resonance Freq.	SRF		100	125	150	kHz
Temperature drift	Δ(T)Fres		-1		+1	%
Sensitivity	Vsens	VMODU = 1V		10	30	mV
MODU voltage	VMODU		0.8		4.12	V
Amplitude Overshoot	Vos	VMODU=1V	0	.15	0.3	V
Antenna Amplitude	Vant	VMODU=1V Calculated: Vant = VDD-VMODU+Vos		4.15		V
Power down voltage	VMODUpd		4.13		4.7	V
Power up voltage	VMODUpu		3.3		4.12	V
Power down Current	IDDpd	VMODU = 5V			1	uA
Power down Pull up	RMODUpu	VMODU = 5V	20		100	kΩ
Max. Operating Current	IDDmax (1)	MODU = 1V, excluding IDDant (*)		2	3	mA
Antenna Driver Current	Idriver	VMODU = 1V, Vos > 0.1V			14	mA
Auto start up Idriver	Idriver_auto	By design : Idriver_auto = Idriver/2			7	mA
AC Antenna Operating current	IDDant	Calculated: IDDant = 0.63*Idriver			8.6	mA
Antenna Impedance	Zant	Calculated Zant = Vant / IDDant	0.5		5	kΩ
Auto start up Zant	Zant_auto	Calculated Zant_auto = Vant / IDDant_auto	1		5	kΩ
Filter Gain				28		dB
Filter ripple				3		dB
Filter 3db BW 2kbaud		SPEED = 1, By design	400 – 3.6k			Hz
Filter 3db BW 4kbaud		SPEED = 0, By design	800 - 7.2k			Hz
Output voltage DATA and CLOCK pin	Vout	Isink = 2.5mA			0.4	V
Start up time	Tstartread	By design: time before ready to read			1024	Clock periods

(*)Maximum operating current is slightly dependent on Iant. A good reference calculation is IDD = 1.3 + Idriver/10

Block Diagram



1. Basic operating principles

The MLX90109 is a 125kHz reader IC designed for use with a parallel LC antenna. This concept requires significantly less current than traditional serial antennas, for building up the same magnetic field strength. The concept is limited to proximity read/write basestations (less than 25cm range), since the voltage amplitude (Vant) is limited by the applied supply voltage.

Vant < VDD.

Antenna voltage definition

In order to use the driver FET as an ideal current source, the voltage on the coil pin should remain higher than 0.5V for up to 14mA driver current (IDDant).
The voltage on the MODU pin (VMODU) controls Vant, as follows:

Vant = VDD - VMODU + Vos

with Vos, the overshoot due to the inertia of the LC antenna.
Because the overshoot can be as much as 300mV, VMODU should be higher than 0.8V for correct operation.

Power Down/Power On

By setting VMODU higher than Vpd (preferably to VDD) the MLX90109 goes in power down. The Antenna Voltage will fade to 0V.
When the antenna impedance is higher than Zant, the MLX90109 powers on (POR) by pulling VMODU below Vpu. The antenna Voltage will rise proportionally to the applied voltage step. 1024 carrier periods after the POR the MLX90109 goes from its power-on sequence to normal operating mode with normal sensitivity.

Write operation

A sequence of power on / power down periods sets the antenna voltage ON and OFF. This features allows to simply realize an ON/OFF keying downlink to the transponder.
Typically VMODU is toggled between 5V and 0.8V. Antenna fade out is related with the antenna Q, start up takes typically 3 carrier periods.
The MLX90109 can also be used to write to FDX-B20 tags, which can not permit to loose clocks. In tihis case we toggle VMODU between according to the wanted modulation depth on the reader, without allowing the antenna voltage to fade out completely.

See the section on 'application information' further in this document for more detailed information and practical hints .

2. Functional blocks description

Oscillator

The oscillator frequency is locked on the antenna frequency. The clock of the filter is derived from the oscillator. In this way the filter characteristics are locked to the transmission frequency. Consequently the MLX90109 is not sensitive to zero modulation.

Amplitude detection

The AM signal generated by the tag is detected by the amplitude demodulator of the transceiver. This signal is filtered and amplified by an on-chip switched capacitor filter before feeding it to the digital decoder. The same signal is fed back to close the control loop of the antenna voltage.

Filter settings

	VSS	FLOAT (*)	VDD
SPEED	4kBaud	-	2kBaud
MODE	Biphase	No decoding	Manchester

By setting the SPEED pin to VDD or to GND the filtering characteristics are optimized for either 2kbaud or 4kbaud respectively.

Digital decoding

The MODE pin allows to define whether to issue directly the filtered data stream on the DATA pin (MODE floating), or to have the MLX90109 decoding manchester (MODE = VSS) or biphase (MODE = VDD) data. In the decoding mode the digital receiver gets the filtered data stream and issues the tag data on the DATA pin at the rising edge of the clock, which is issued on the CLOCK pin. Both CLOCK and DATA are open drain outputs and require external pull-ups.
(*) Internally strapped to VDD/2

3. Reference docs:

- EVB90109: Evaluation board and case study with MLX90127 transponder
- DVK90109: Development kit for advanced system evaluation of 90109.
- DS90125: Dedicated reader coils for MLX90109

4. System design parameters

The antenna driver FET is switched on as soon as the antenna voltage drops below VDD, see graphical representation below. The MLX90109 will inject current into the antenna to guarantee an antenna amplitude as set by the voltage on the MODU pin.

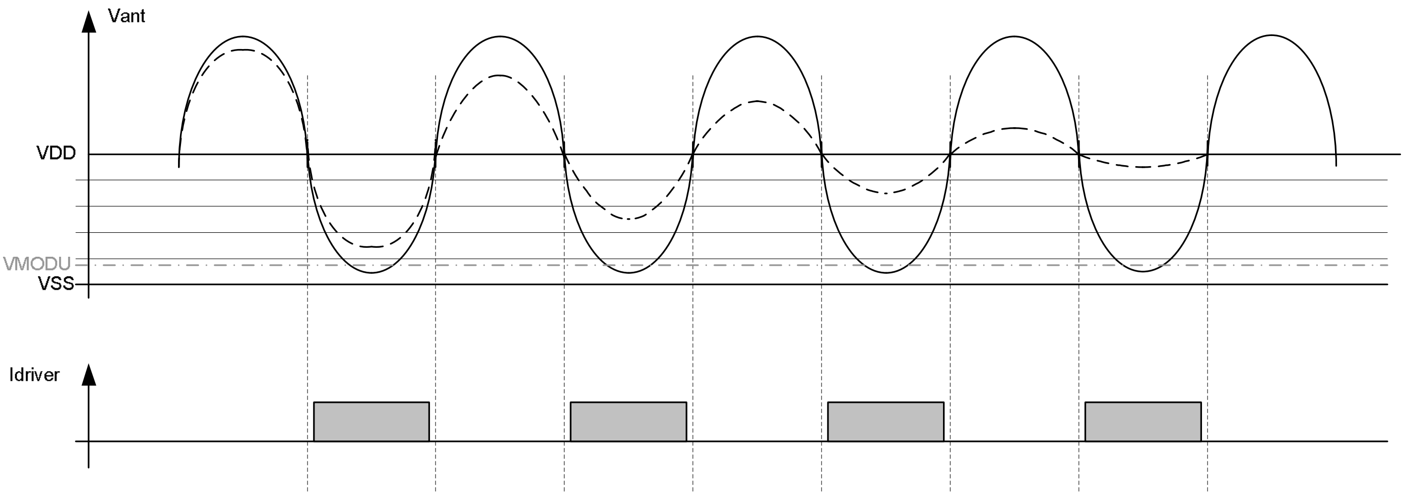
This operation is guaranteed as long as the voltage swing guarantees the voltage on the COIL pin to drop 100mV below VDD.
If Vant < 100mV the MLX90109 may not be able to retrieve its clock.

Auto start up condition

Pulling VMODU, at power on, from 5V to less than 3.3V (VMODUpu) will set the driver FET on. The voltage drop on the coil pin will be large enough (Vant>100mV) to be coupled back into the MLX90109, so as to close the feedback loop.
To obtain the required positive feedback to start up the oscillation successfully Zant should be larger than 1kOhm. This is the so-called ‘auto start-up condition’.
If the antenna is (still) oscillating when VMODU is pulled from 5V to less than 3.3V, the positive feedback is not required, and the normal operating conditions (Zant>500Ohm) apply. See application notes for alternative start up methods, and consequences for ON/OFF keying.

Currents.

The MLX90109 is specified to drive maximum 14mA antenna current (Idriver) in normal operation. (See



Graph:
Antenna voltage and Driver current during normal operation. VMODU=0.8V for VDD=5V. The overshoot is visualized. The dashed curve shows the antenna voltage when the reader has been powered down.

the DVK90109 development kit for a current measurement schematic).
The AC equivalent supply current (IDDant) can be calculated:

IDDant = 2/π*sin(π*α) *Idriver
= 0.63*Idriver

with α the duty cycle which is typically 45%.

The current that the MLX90109 can inject each oscillation onto the total antenna current is therefore limited to 9mA in correctly designed reader base stations.
For auto start up (see above) of the antenna the maximum driver current is specified to maximum 7mA, or IDDant<4.5mA .

The actual antenna current that generates the magnetic field can be calculated as

Iant = Qant*IDDant

A typical coil quality factor (Qant) value is 23 (see MLX90125), resulting in antenna currents of about 100mA for auto start up.

This current resonance of the parallel antenna allows to build very low power reader base stations, as opposed to serial antenna based version. Using discrete power transistors, the serial antenna can however leverage its voltage resonance to drive bigger antenna's for long distance reading up to 1m, whereas the MLX90109 is designed to drive antennas of 1cm up to 15cm (6"). Maximum read performances of up to 25cm (9") have been demonstrated.

Voltages

The antenna voltage amplitude can easily be calculated as

Vant = VDD - VMODU+Vovershoot

Antenna Impedance.

Clearly the antenna impedance is an important system design parameter for the MLX90109.

Zant = Vant / IDDant

For IDDant<4.3mA (auto start up) and Vantmax = 4.2V, we find Zant should be 1kOhm.
A good approximation is

Zant = Qant.Wres.Lant
with Wres = 2*pi*Fres

From the above we find that

Iant = Qant*IDDant
= Vant / (Wres*Lant)

The total number of ampere-turns is then:

Nant * Iant ~ 1 / sqrt(Lant)
for Lant ~ $Nant^2$

Qant has no influence on Iant, it only reduces the overall current consumption.

REMARK!
Mind that in reality the strong coupling with the tag may drastically reduce the antenna impedance. This is why the MLX90127 transponder can not be read at 0mm distance by the MLX90109 using the 18mm MLX90125-CZA-A reader antenna coil with VMODU = 0.8V. See the MLX90126 for a complete case study with the MLX90127.

In practice the inductance values are matched with standard capacitor values to realize the resonance frequency (Fres). Below some typical values are given for 125kHz.

For Vant = 4.4V the maximum antenna currents for auto start up systems can be found in the table below.
Remark that IDDant is 4mA if we match Qant such that Zant = 1.1kOhm. However if we keep Qant constant IDDant will further reduce for higher Lant.

Changing the MODU voltage, will change the antenna voltage, and hence also the field strength. This will be used to amplitude modulate for writing to the transponder.
In the table above the antenna currents for VMODU = 2.2V (Vant = 2.9V) and VMODU = 4.0V (Vant = 1.1V) are given.

Ctune	Lant	Qant (Zant=1.1kΩ)	Zant (Q=23)
12nF	135uH	10	2.4kΩ
15nF	108uH	13	2.0kΩ
18nF	90uH	16	1.6kΩ
22nF	74uH	19	1.3kΩ
30nF	54uH	26	1.0kΩ

Lant	Iant (Vant = 4.2V)	IDD (Qant=23)
135uH	40	1.7
108uH	50	2.2
90uH	60	2.6
74uH	70	3.1
54uH	100	4.3

Lant	Iant (Vant = 3.0V)	Iant (Vant=1.1V)
135uH	28	10
108uH	35	13
90uH	42	15
74uH	51	18
54uH	70	26

Also the current consumption (IDDant) is reduced by reducing Vant. We will use this to artificially change the impedance specification in some application specific circumstances. (see READ: close coupling.)

5. Applications information: READ

- Absolute minimum schematic
- Power consumption
- Noise suppression
- Integrated decoding
- Close coupling (impedance, frequency)

Absolute minimum schematic

The MLX90109 is a highly integrated reader IC. As can be seen in the application schematic below only two resistors (to set VMODU) are required, next to the antenna inductance and tune capacitor.
The interface with the microcontroller can be realized with 1 connection plus the supply lines. In this case the MODE is left floating, and the integrated decoding is not used.

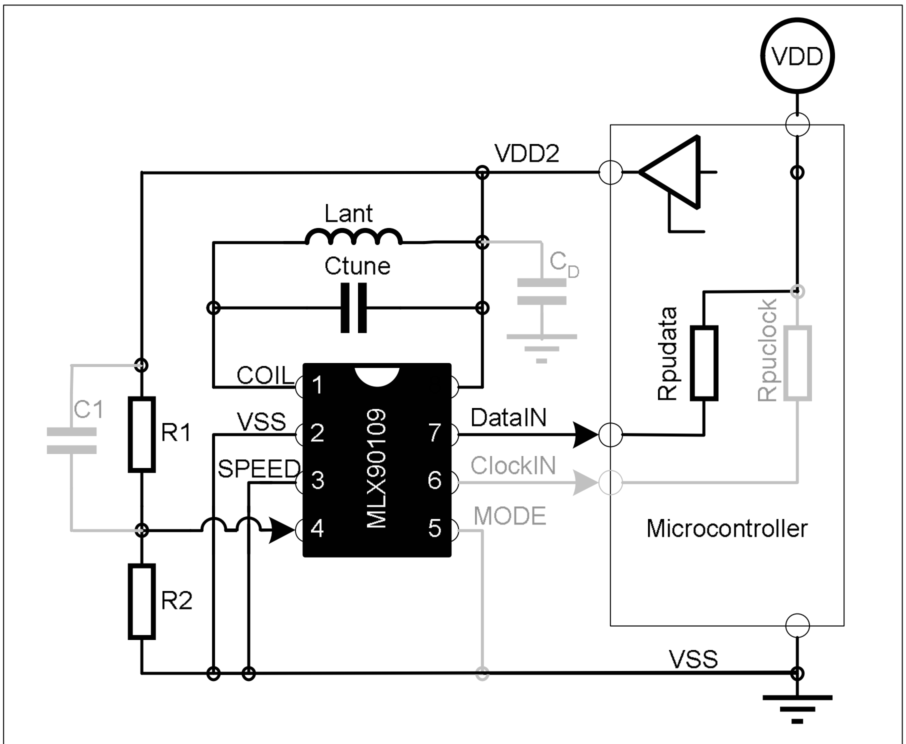
Power consumption

If power consumption is not critical and the reader does not have to be put in power down, the MODU voltage can be strapped to the required level (between 0.8V and 4.2V).
However the power consumption can be reduced in between operations.

1) Supply from microcontroller IO port
The total maximum current consumption of the MLX90109 plus the antenna is

IDDtot = IDDant + IDD90109 + IRmodu

With IRmodu, the trickle current through the resistances R1 and R2, which can be chosen large



Minimum Read Application schematic in black; Options in grey enough such that they can be neglected in this calculation.

IDDant < 14mA
IDD90109 < 2mA

So if a 20mA port is available to supply the transceiver it can easily be switched off.
Alternatively if no such port is available a switch in the ground (VSS) can be added. This is not recommended but in less critical application the performance may be acceptable.
The antenna current can be further reduced as explained previously (see System design parameters: Antenna Impedance) such that even a 5mA port could be used.

2) VMODU >VMODUpd
By controlling the Voltage on the MODU pin the device can be put to power down as described previously (see Basic operating principles: Power down / Power on).
Take into account that the trickle current from the resistor tree R1-R2 is NOT switched off. During power down this uA current may kill the lifetime of the battery.

Noise cancellation

The entire read performance of a reader is linked with its robustness versus noise. The IC design is made to realize the best signal to noise ratios (SNR).
The resonant antenna is a natural band-pass filter, which becomes more effective as Qr increases.
The MLX90109 has an internal first order filtering of the envelope that changes according to the setting of the SPEED pin to fit to the biphase and Manchester data spectrum:

- 2kbaud: 400Hz to 3.6kHz
- 4kbaud: 800Hz to 7.2kHz

But even this filter only has a limited gain of 28dB, such that noise should be avoided by carefull PCB design and adding decoupling capacitance(s) on the supply lines.

Most sensitive pins for noise injection (EMI) are MODU and VDD. Since they directly determine Vant, the noise will be considered to be AM data from a transponder by the sampler.
Now, if the noise on both pins were identical it would cancel itself, giving a very noise insensitive reader!
Adding C1 between MODU and VDD, together with R1 and R2 yields a high pass filter with cut off frequency at:

VMODU	0.8V	3.0V	4.0V
Vant	4.4V	2.2V	1.1V (*)
IDDant	8.8mA	4.4mA	2.2mA

(*) small amplitudes have smaller overshoot.

$$\frac{1}{2\Pi * (R1//R2) * C1}$$

Typically the filter should short all noise in the data spectrum, but for a lot of appliances it might be beneficial to set it to less than the net frequency (50Hz, 60Hz). For instance R1=100kOhm and R2=19kOhm for setting MODU, with C1=220nF gives a cut off frequency = 45Hz

Finally we want to draw your attention to the DATA and CLOCK open drain drivers. These have been dimensioned to drive strong loads. So take care to use high ohmic (100kOhm) pull up resistances if the loads are minimal.

Integrated decoding

The MLX90109 provides the option to have a decoded output. This significantly reduces the complexity of the microcontroller software.
The data is available when the clock output is high. And the clock output has a 50% duty cycle if the data is valid. When the noise level is stronger than the signal level, for instance when no tag is present in the reader field, the duty cycle will be random. When using this feature to detect the presence of a tag, allow some asymmetricity on the clock. The sampling error may be 4us, so allow 8 or 12us of margin.
Remark that when the MLX90109 picks up a Manchester encoded signal when the MODE pin is strapped to VSS (=biphase decoding), the clock will also be asymmetric.

Close coupling

If a tag is coupled too strong, such that Zant drops to 500Ohms Vant can be reduced. This should be evaluated case by case. See MLX90126 for a case study of the 18mm reader coil with the MLX90127, where at very close operating distances reading may be less reliable.

The solution for this is to increase the voltage on the MODU pin (VMODU), such that the current drawn by the antenna is reduced. See the explanation of theantenna impedance in the section of ‘System design parameters’.

Full Qualification of the write functionality is expected by early 2003. The basic operating modes are explained below.

6. Applications information: WRITE ON/OFF keying (FDX-B100)

- Schematic
- Power on Boost
- Noise suppression
- Switching between Read and Write

The basic principle is to switch the voltage on MODU between 0V and VDD. The antenna will reach its maximum amplitude in less than 4 periods when MODU is stepped down from VDD to VSS. Setting the chip in power down (step Vmodu up to VDD) will let the antenna fade out with a time constant=Qant/3. An additional drain resistor on MODU operated by the microcontroller can increase the fall time if required.

7. Applications information: WRITE 20% to 60% modulation depth (FDX-B20 to – B60)

- Schematic
- Power on Boost
- Noise suppression
- Switching between Read and Write

The writing is done identically to the ON/OFF keying mode, but with an additional resistance R3 between the microcontroller and MODU to set the 'OFF level'. An additional capacitor C3 can improve the edges on VMODU.
Furthermore the falling edge on the transponder coil can be improved by setting the reader in power down for a few microseconds, and then turn it on again (to avoid the tag to loose clocks when it modulation resistance is ON). If this is done, capacitor C3 can be dimensioned to guarantee a spike below 3V to guarantee power on, with a target level of 4V for instance.

Packaging Information

SOIC8 outline see further.
MLP10 package is being reviewed This could reduce the footprint from 5*7mm to 3*3mm.

ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).
Always observe Electro Static Discharge control procedures whenever handling semiconductor products

Reliability Information

Melexis devices are classified and qualified regarding suitability for infrared, vapor phase and wave soldering with usual (63/37 SnPb-) solder (melting point at 183degC).
The following test methods are applied:

IPC/JEDEC J-STD-020A (issue April 1999)
Moisture/Reflow Sensitivity Classification For Nonhermetic Solid State Surface Mount Devices

CECC00802 (issue 1994)
Standard Method For The Specification of Surface Mounting Components (SMDs) of Assessed Quality

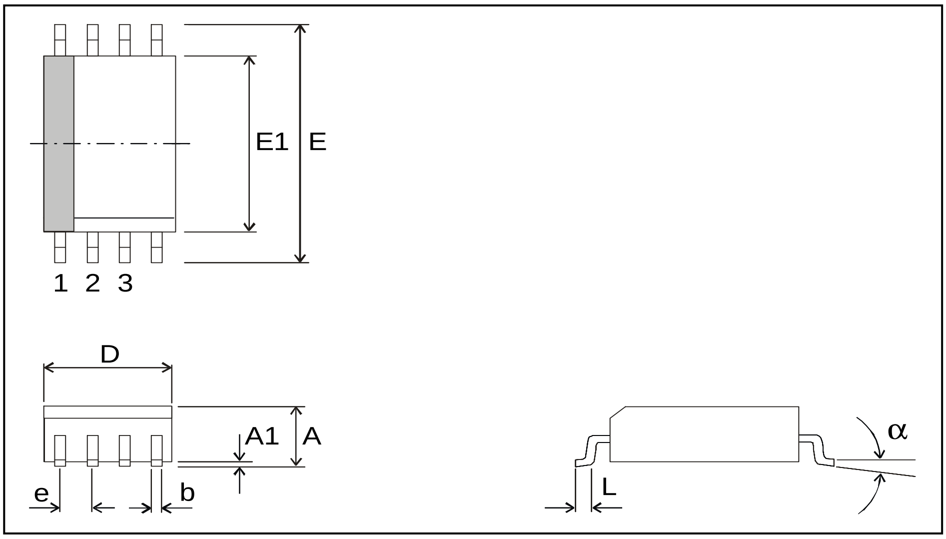
MIL 883 Method 2003 / JEDEC-STD-22 Test Method B102
Solderability

For all soldering technologies deviating from above mentioned standard conditions (regarding peak temperature, temperature gradient, temperature profile etc) additional classification and qualification tests have to be agreed upon with Melexis.

The application of Wave Soldering for SMD's is allowed only after consulting Melexis regarding assurance of adhesive strength between device and board.

For more information on manufacturability/solderability see quality page at our website: http://www.melexis.com/

Package Information



all Dimension in mm, coplanarity < 0.1mm									
	D	**E1**	**E**	**A**	**A1**	**e**	**b**	**L**	**a**
min	4.80	3.81	5.80	1.32	0.10	1.27	0.36	0.41	0°
max	4.98	3.99	6.20	1.72	0.25		0.46	1.27	8°
all Dimension in inch, coplanarity < 0.004”									
min	0.189	0.150	0.2284	0.060	0.0040	0.05	0.014	0.016	0°
max	0.196	0.157	0.2440	0.068	0.0098		0.018	0.050	8°

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