

## Features

- ☐ Frequency range from 425 MHz to 445 MHz
- ☐ Fully integrated PLL-stabilized VCO
- ☐ Single-ended RF output
- ☐ FSK via crystal pulling
- ☐ Wideband FSK deviation possible
- ☐ ASK/OOK via power amplifier modulation
- ☐ Wide power supply range from 1.95 V to 5.5 V
- ☐ Very low standby current
- ☐ Low voltage detector
- ☐ High over-all frequency accuracy
- ☐ FSK deviation and center frequency independently adjustable
- ☐ Data rates from DC to 40 kbps
- ☐ Adjustable output power range from -16 dBm to +12 dBm
- ☐ Adjustable current consumption from 3.5 mA to 15.9 mA
- ☐ Conforms to EN 300 220 and similar standards
- ☐ 8-pin Small Outline Integrated Circuit (SOIC)

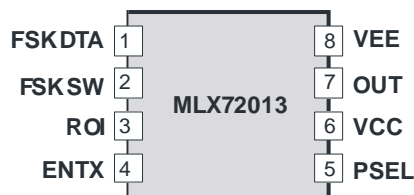
## Ordering Information

Part No.	Temperature Code	Package Code	Delivery Form
MLX72013	C (0 C° to 70 °C)	DC (SOIC8)	98 pc/tube 2500pc/T&R
MLX72013	K (-40 C° to 125 °C)	DC (SOIC8)	98 pc/tube 2500pc/T&R

## Application Examples

- ☐ RF remote controls
- ☐ Automatic meter reading (AMR)
- ☐ Tire pressure monitoring systems (TPMS)
- ☐ Remote keyless entry (RKE)
- ☐ Alarm and security systems
- ☐ Garage door openers
- ☐ Home automation

## Pin Description



## General Description

The MLX72013 transmitter IC is designed for applications in the European 433 MHz industrial-scientific-medical (ISM) band, according to the EN 300 220 telecommunications standard; but it can also be used in any other country with similar frequency bands.

The transmitter's carrier frequency  $f_c$  is determined by the frequency of the reference crystal  $f_{ref}$ . The integrated PLL synthesizer ensures that each RF value, ranging from 425 MHz to 445 MHz, can be achieved by using a crystal with a reference frequency according to:  $f_{ref} = f_c/N$ , where  $N = 16$  is the PLL feedback divider ratio.

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## 1 Theory of Operation

### 1.1 General

As depicted in Fig.1, the MLX72013 transmitter consists of a fully integrated voltage-controlled oscillator (VCO), a divide-by-16 divider (div16), a phase-frequency detector (PFD) and a charge pump (CP). An internal loop filter determines the dynamic behavior of the PLL and suppresses reference spurious signals. A Colpitts crystal oscillator (XOSC) is used as the reference oscillator of a phase-locked loop (PLL) synthesizer. The VCO's output signal feeds the power amplifier (PA). The RF signal power  $P_{out}$  can be adjusted in four steps from  $P_{out} = -16$  dBm to  $+12$  dBm, either by changing the value of resistor RPS or by varying the voltage  $V_{PS}$  at pin PSEL. The open-collector output (OUT) can be used either to directly drive a loop antenna or to be matched to a 50Ohm load. Bandgap biasing ensures stable operation of the IC at a power supply range of 1.95 V to 5.5 V.

### 1.2 Block Diagram

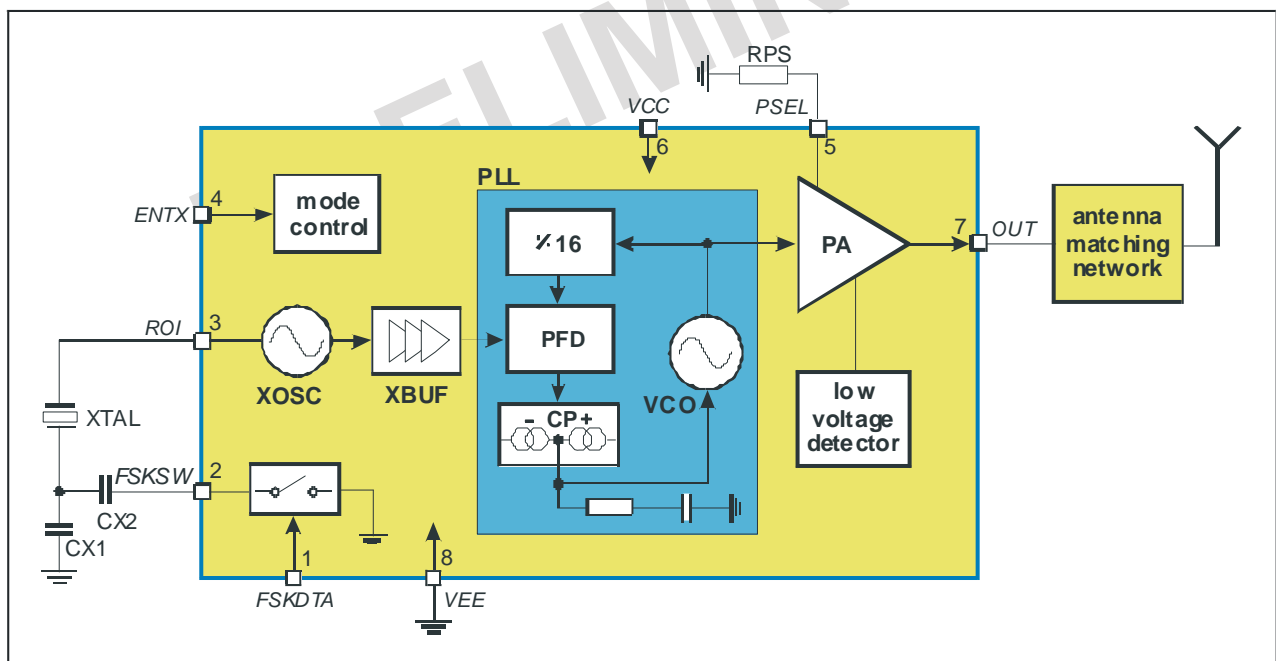


Fig. 1: Block diagram with external components

## 2 Functional Description

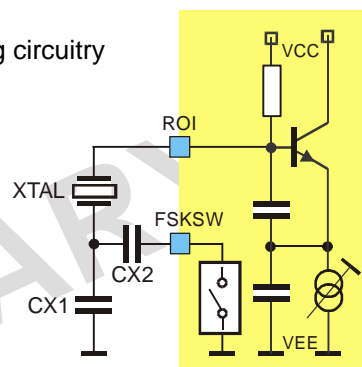
### 2.1 Crystal Oscillator

A Colpitts crystal oscillator with integrated functional capacitors is used as the reference oscillator for the PLL synthesizer. The equivalent input capacitance CRO offered by the crystal oscillator input pin ROI is about 18pF. The crystal oscillator is provided with an amplitude control loop in order to have a very stable frequency over the specified supply voltage and temperature range in combination with a short start-up time.

### 2.2 FSK Modulation

FSK modulation can be achieved by pulling the crystal oscillator frequency. A CMOS-compatible data stream applied at the pin FSKDTA digitally modulates the XOSC via an integrated NMOS switch. Two external pulling capacitors CX1 and CX2 allow the FSK deviation  $\Delta f$  and the center frequency  $f_c$  to be adjusted independently. At FSKDTA = 0, CX2 is connected in parallel to CX1 leading to the low-frequency component of the FSK spectrum ( $f_{min}$ ); while at FSKDTA = 1, CX2 is deactivated and the XOSC is set to its high frequency  $f_{max}$ . An external reference signal can be directly AC-coupled to the reference oscillator input pin ROI. Then the transmitter is used without a crystal. Now the reference signal sets the carrier frequency and may also contain the FSK (or FM) modulation.

Fig. 2: Crystal pulling circuitry



FSKDTA	Description
0	$f_{min} = f_c - \Delta f$ (FSK switch is closed)
1	$f_{max} = f_c + \Delta f$ (FSK switch is open)

### 2.3 Crystal Pulling

A crystal is tuned by the manufacturer to the required oscillation frequency  $f_0$  at a given load capacitance CL and within the specified calibration tolerance. The only way to pull the oscillation frequency is to vary the effective load capacitance  $CL_{eff}$  seen by the crystal.

Figure 3 shows the oscillation frequency of a crystal as a function of the effective load capacitance. This capacitance changes in accordance with the logic level of FSKDTA around the specified load capacitance. The figure illustrates the relationship between the external pulling capacitors and the frequency deviation.

It can also be seen that the pulling sensitivity increases with the reduction of CL. Therefore, applications with a high frequency deviation require a low load capacitance. For narrow band FSK applications, a higher load capacitance could be chosen in order to reduce the frequency drift caused by the tolerances of the chip and the external pulling capacitors.

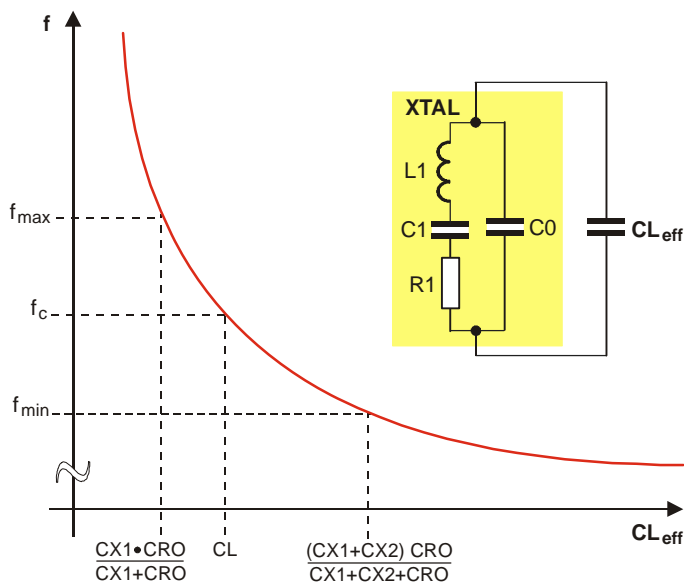


Fig. 3: Crystal pulling characteristic

## 2.4 ASK Modulation

The MLX72013 can be ASK-modulated by applying data directly at pin PSEL. This turns the PA on and off and therefore leads to an ASK signal at the output.

## 2.5 Output Power Selection

The transmitter is provided with an output power selection feature. There are four predefined output power steps and one off-step accessible via the power selection pin PSEL. A digital power step adjustment was chosen because of its high accuracy and stability. The number of steps and the step sizes as well as the corresponding power levels are selected to cover a wide spectrum of different applications.

The implementation of the output power control logic is shown in figure 4. There are two matched current sources with an amount of about 8  $\mu$ A. One current source is directly applied to the PSEL pin. The other current source is used for the generation of reference voltages with a resistor ladder. These reference voltages are defining the thresholds between the power steps. The four comparators deliver thermometer-coded control signals depending on the voltage level at the pin PSEL. In order to have a certain amount of ripple tolerance in a noisy environment the comparators are provided with a little hysteresis of about 20 mV. With these control signals, weighted current sources of the power amplifier are switched on or off to set the desired output power level (Digitally Controlled Current Source). The LOCK signal and the output of the low voltage detector are gating this current source.

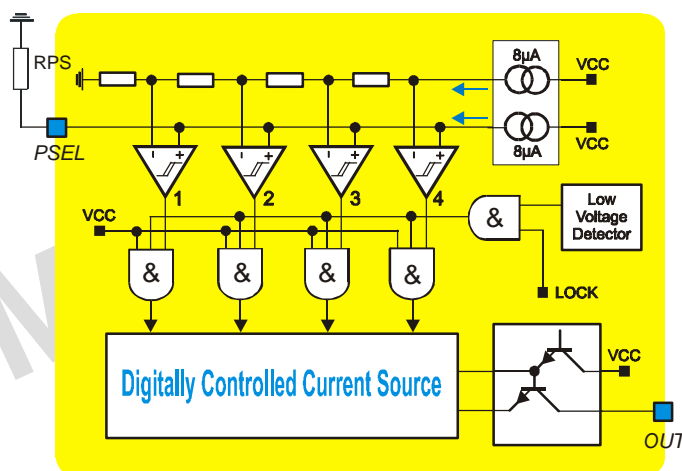


Fig. 4: Block diagram of output power control circuitry

There are two ways to select the desired output power step. First by applying a DC voltage at the pin PSEL, then this voltage directly selects the desired output power step. This kind of power selection can be used if the transmission power must be changed during operation. For a fixed-power application a resistor can be used which is connected from the PSEL pin to ground. The voltage drop across this resistor selects the desired output power level. For fixed-power applications at the highest power step this resistor can be omitted. The pin PSEL is in a high impedance state during the "TX standby" mode.

## 2.6 Lock Detection

The lock detection circuitry turns on the power amplifier only after PLL lock. This prevents from unwanted emission of the transmitter if the PLL is unlocked.

## 2.7 Low Voltage Detection

The supply voltage is sensed by a low voltage detect circuitry. The power amplifier is turned off if the supply voltage drops below a value of about 1.85 V. This is done in order to prevent unwanted emission of the transmitter if the supply voltage is too low.

## 2.8 Mode Control Logic

The mode control logic allows two different modes of operation as listed in the following table. The mode control pin ENTX is pulled-down internally. This guarantees that the whole circuit is shut down if this pin is left floating.

ENTX	Mode	Description
0	TX standby	TX disabled
1	TX active	TX enable

## 2.9 Timing Diagrams

After enabling the transmitter by the ENTX signal, the power amplifier remains inactive for the time  $t_{on}$ , the transmitter start-up time. The crystal oscillator starts oscillation and the PLL locks to the desired output frequency within the time duration  $t_{on}$ . After successful PLL lock, the LOCK signal turns on the power amplifier, and then the RF carrier can be FSK or ASK modulated.

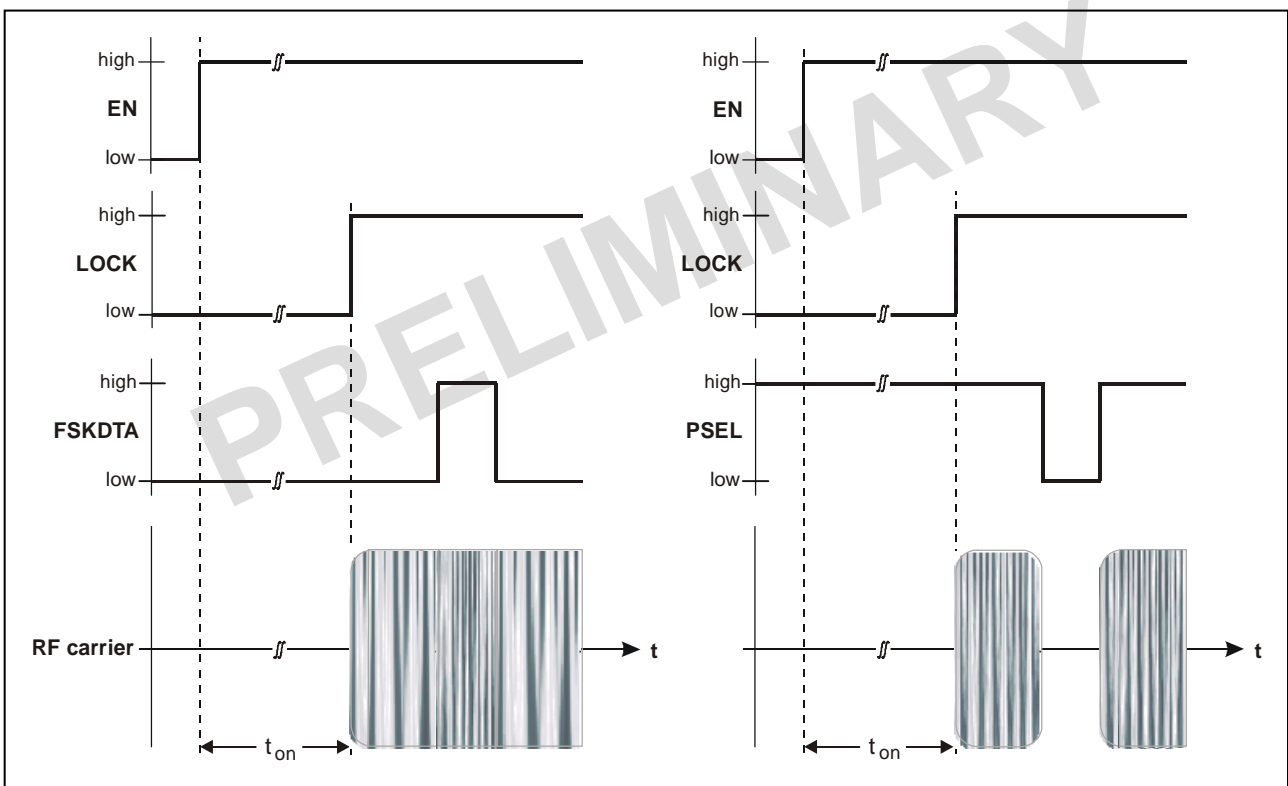


Fig. 5: Timing diagram for FSK and ASK modulation

### 3 Pin Definition and Description

Pin No.	Name	I/O Type	Functional Schematic	Description
1	FSKDTA	input	<p>0: ENTX=1 1: ENTX=0</p>	FSK data input, CMOS compatible with operation mode dependent pull-up circuit  TX standby: no pull-up TX active: pull-up
2	FSKSW	analog I/O	<p>FSKSW</p>	XOSC FSK pulling pin, MOS switch
3	ROI	analog I/O	<p>ROI</p>	XOSC connection to XTAL, Colpitts type crystal oscillator
4	ENTX	input	<p>ENTX</p>	mode control input, CMOS-compatible with internal pull-down circuit
5	PSEL	analog I/O	<p>PSEL</p>	power select input, high-impedance comparator logic  TX standby: $I_{PSEL} = 0$ TX active: $I_{PSEL} = 8\mu A$
6	VCC	supply		positive power supply
7	OUT	output	<p>OUT</p>	power amplifier output, open collector
8	VEE	ground		negative power supply

## 4 Electrical Characteristics

### 4.1 Absolute Maximum Ratings

Parameter	Symbol	Condition	Min	Max	Unit
Supply voltage	$V_{CC}$		0	7.0	V
Input voltage	$V_{IN}$		-0.3	$V_{CC}+0.3$	V
Storage temperature	$T_{STG}$		-65	150	°C
Junction temperature	$T_J$			150	°C
Thermal Resistance	$R_{thJA}$			163	K/W
Power dissipation	$P_{diss}$			0.15	W
Electrostatic discharge	$V_{ESD}$	human body model (HBM) according to CDF-AEC- Q100-002	±2.0		kV

### 4.2 Normal Operating Conditions

Parameter	Symbol	Condition	Min	Max	Unit
Supply voltage	$V_{CC}$		1.95	5.5	V
Operating temperature	$T_A$	MLX72013 C	0	70	°C
		MLX72013 K	-40	125	
Input low voltage CMOS	$V_{IL}$	ENTX, FSKDTA pins		$0.3 \cdot V_{CC}$	V
Input high voltage CMOS	$V_{IH}$	ENTX, FSKDTA pins	$0.7 \cdot V_{CC}$		V
XOSC frequency	$f_{ref}$	set by the crystal	26.5	27.8	MHz
VCO frequency	$f_c$	$f_c = 16 \cdot f_{ref}$	425	445	MHz
FSK deviation	$\Delta f$	depending on CX1, CX2 and crystal parameters	±5	±25	kHz
Data rate	R	NRZ code		40	kbit/s

### 4.3 Crystal Parameters

Parameter	Symbol	Condition	Min	Max	Unit
Crystal frequency	$f_0$	fundamental mode, AT	26.5	27.8	MHz
Load capacitance	$C_L$		10	15	pF
Static capacitance	$C_0$			7	pF
Series resistance	$R_1$			50	Ω
Spurious response	$a_{spur}$			-10	dB



## 4.4 DC Characteristics

all parameters under normal operating conditions, unless otherwise stated;  
typical values at  $T_A = 23\text{ }^{\circ}\text{C}$  and  $V_{CC} = 3.6\text{ V}$

Parameter	Symbol	Condition	Min	Typ	Max	Unit
<b>Operating Currents</b>						
Standby current	$I_{SBY}$	MLX72013 C, ENTX=0		0.2	200	nA
		MLX72013 K, ENTX=0		0.2	4000	
Supply current in power step 0	$I_{CC0}$	ENTX=1		2.5		mA
Supply current in power step 1	$I_{CC1}$	ENTX=1		3.5		mA
Supply current in power step 2	$I_{CC2}$	ENTX=1		6.5		mA
Supply current in power step 3	$I_{CC3}$	ENTX=1		9.8		mA
Supply current in power step 4	$I_{CC4}$	ENTX=1		15.9		mA
<b>Digital Pin Characteristics</b>						
Input low voltage CMOS	$V_{IL}$	ENTX, FSKDTA pins	-0.3		$0.3 \cdot V_{CC}$	V
Input high voltage CMOS	$V_{IH}$	ENTX, FSKDTA pins	$0.7 \cdot V_{CC}$		$V_{CC} + 0.3$	V
Pull down current ENTX pin	$I_{PDEN}$	ENTX=1	0.2	2.0	20	$\mu\text{A}$
Low level input current ENTX pin	$I_{INLEN}$	ENTX=0			0.02	$\mu\text{A}$
High level input current FSKDTA pin	$I_{INHDTA}$	FSKDTA=1			0.02	$\mu\text{A}$
Pull up current FSKDTA pin active	$I_{PUDTAa}$	FSKDTA=0 ENTX=1	0.1	1.5	12	$\mu\text{A}$
Pull up current FSKDTA pin standby	$I_{PUDTAs}$	FSKDTA=0 ENTX=0			0.02	$\mu\text{A}$
<b>FSK Switch Resistance</b>						
MOS switch On resistance	$R_{ON}$	FSKDTA=0 ENTX=1		20	70	$\Omega$
MOS switch Off resistance	$R_{OFF}$	FSKDTA=1 ENTX=1	1			$\text{M}\Omega$
<b>Power Select Characteristics</b>						
Power select current	$I_{PSEL}$	ENTX=1	7.0	8.6	9.9	$\mu\text{A}$
Power select voltage step 0	$V_{PS0}$	ENTX=1			0.035	V
Power select voltage step 1	$V_{PS1}$	ENTX=1	0.14		0.24	V
Power select voltage step 2	$V_{PS2}$	ENTX=1	0.37		0.60	V
Power select voltage step 3	$V_{PS3}$	ENTX=1	0.78		1.29	V
Power select voltage step 4	$V_{PS4}$	ENTX=1	1.55			V
<b>Low Voltage Detection Characteristic</b>						
Low voltage detect threshold	$V_{LVD}$	ENTX=1	1.75	1.85	1.95	V

## 4.5 AC Characteristics

all parameters under normal operating conditions, unless otherwise stated;  
typical values at  $T_A = 23\text{ °C}$  and  $V_{CC} = 3.6\text{ V}$ ; test circuit shown in Fig. 6,  $f_c = 433.92\text{ MHz}$

Parameter	Symbol	Condition	Min	Typ	Max	Unit
CW Spectrum Characteristics						
Output power in step 0 (Isolation in off-state)	P <sub>off</sub>	ENTX=1			-70	dBm
Output power in step 1	P <sub>1</sub>	ENTX=1	-16	-15	-13	dBm
Output power in step 2	P <sub>2</sub>	ENTX=1	0	1	2	dBm
Output power in step 3	P <sub>3</sub>	ENTX=1	6	7	9	dBm
Output power in step 4	P <sub>4</sub>	ENTX=1	10	11	12	dBm
Phase noise at 5kHz offset	L(f <sub>m</sub> ) <sub>5</sub>	@ 5kHz offset		-98		dBc/Hz
Phase noise at 200kHz offset	L(f <sub>m</sub> ) <sub>200</sub>	@ 200kHz offset		-97		dBc/Hz
Spurious emissions according to EN 300 220-1 (2000.09) table 13	P <sub>spur</sub>	47MHz< f <74MHz 87.5MHz< f <118MHz 174MHz< f <230MHz 470MHz< f <862MHz B=100kHz			-54	dBm
		f < 1GHz, B=100kHz			-36	dBm
		f > 1GHz, B=1MHz			-30	dBm
Start-up Parameters						
Start-up time	t <sub>on</sub>	from standby to transmit mode		0.6	1.0	ms
Frequency Stability						
Frequency stability vs. supply voltage	df <sub>VCC</sub>				±3	ppm
Frequency stability vs. temperature	df <sub>TA</sub>	crystal at constant temperature			±10	ppm
Frequency stability vs. variation range of C <sub>RO</sub>	df <sub>CRO</sub>				±20	ppm

## 4.6 Output Power Steps

Power step	0	1	2	3	4
RPS / kΩ	< 3	22	56	120	not connected

## 5 Test Circuit

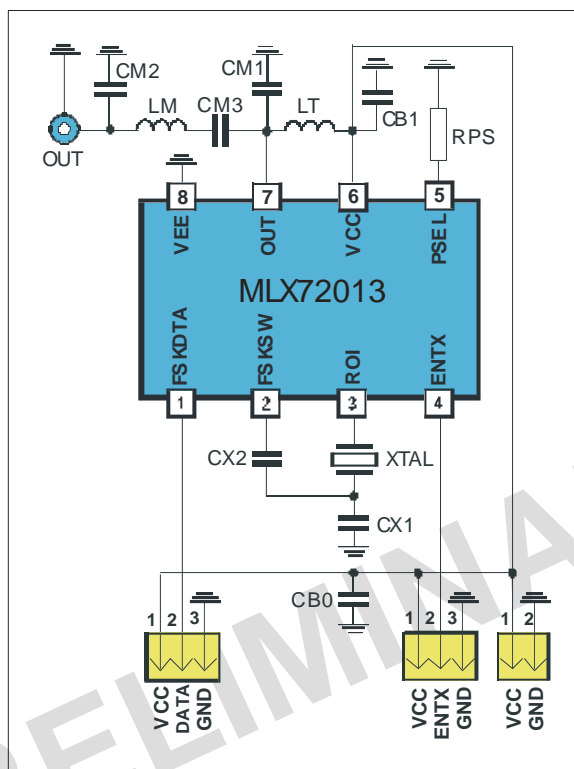


Fig. 6: Test circuit for FSK with 50  $\Omega$  matching network

### 5.1 Test circuit component list to Fig. 6

Part	Size	Value @ 433.92 MHz	Tolerance	Description
CM1	0805	8.2 pF	$\pm 5\%$	impedance matching capacitor
CM2	0805	12 pF	$\pm 5\%$	impedance matching capacitor
CM3	0805	82 pF	$\pm 5\%$	impedance matching capacitor
LM	0805	22 nH	$\pm 5\%$	impedance matching inductor, <b>note 2</b>
LT	0805	33 nH	$\pm 5\%$	output tank inductor, <b>note 2</b>
CX1	0805	10 pF	$\pm 5\%$	XOSC capacitor, <b>note 1</b>
CX2	0805	12 pF	$\pm 5\%$	XOSC capacitor, <b>note 1</b>
RPS	0805	see para. 4.6	$\pm 5\%$	power-select resistor
CB0	1206	220 nF	$\pm 20\%$	blocking capacitor
CB1	0805	330 pF	$\pm 10\%$	blocking capacitor
XTAL	SMD 6x3.5	27.1200 MHz	$\pm 20$ ppm calibr. $\pm 20$ ppm temp.	fundamental wave crystal, $C_L = 10$ pF, $C_{0, \max} = 7$ pF, $R_1 = 40$ $\Omega$

**Note 1:** value depending on crystal parameters

**Note 2:** for high-power applications high-Q wire-wound inductors should be used

## 6 Package Information

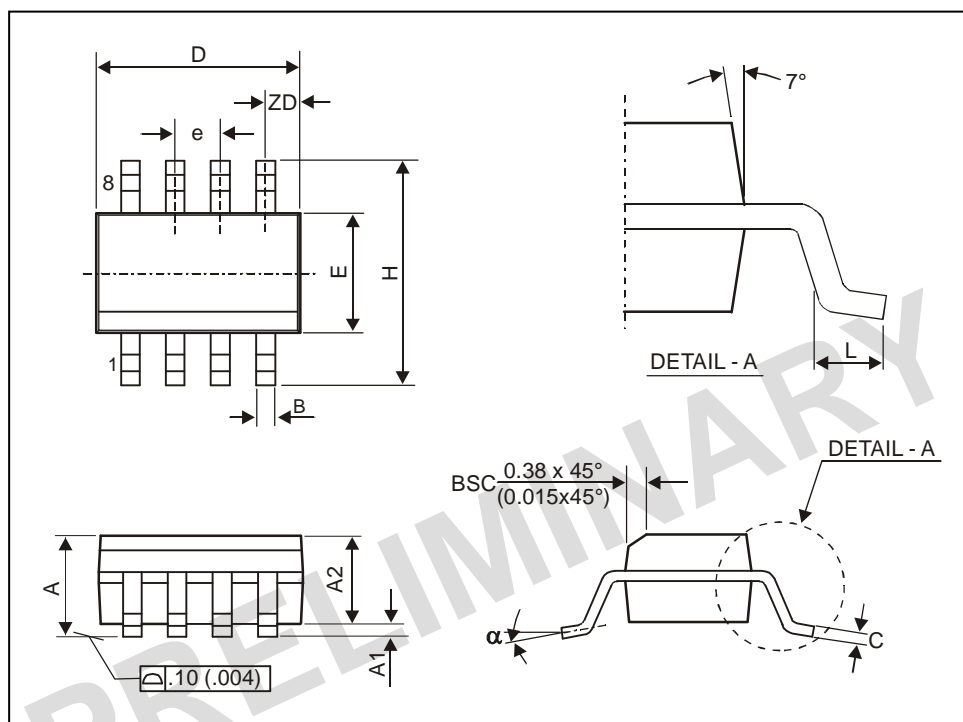


Fig. 7: SOIC8 (Small Outline Integrated Circuit)

all Dimension in mm, coplanarity < 0.1mm												
	D	E	H	A	A1	A2	e	B	ZD	C	L	α
min	4.80	3.81	5.80	1.52	0.10	1.37	1.27	0.36	0.53	0.19	0.41	0°
max	4.98	3.99	6.20	1.72	0.25	1.57		0.46		0.25	1.27	8°
all Dimension in inch, coplanarity < 0.004"												
min	0.189	0.150	0.2284	0.060	0.0040	0.054	0.050	0.014	0.021	0.075	0.016	0°
max	0.196	0.157	0.2440	0.068	0.0098	0.062		0.018		0.098	0.050	8°

### 6.1 Soldering Information

- The device MLX72013 is qualified for MSL1 with soldering peak temperature 260 deg C according to JEDEC J-STD-20.

## **7 Reliability Information**

This Melexis device is classified and qualified regarding soldering technology, solderability and moisture sensitivity level, as defined in this specification, according to following test methods:

### **Reflow Soldering SMD's (Surface Mount Devices)**

- IPC/JEDEC J-STD-020  
"Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices (classification reflow profiles according to table 5-2)"

### **Wave Soldering SMD's (Surface Mount Devices)**

- EN60749-20  
"Resistance of plastic- encapsulated SMD's to combined effect of moisture and soldering heat"

### **Solderability SMD's (Surface Mount Devices)**

- EIA/JEDEC JESD22-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.

## **8 ESD Precautions**

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

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