

Inductive Proximity Sensor IC



FEATURES

- Wide supply voltage range (5.5V to 38V)
- Fully integrated low cost proximity sensor IC
- User-adjustable sensing range and hysteresis
- Built-in voltage regulator
- NPN open collector output with guaranteed sink current of 150mA
- Output overload/over-current protection
- Broad range of operating frequency (100 kHz to 1 MHz)
- Small package footprint (4 mm x 4 mm)

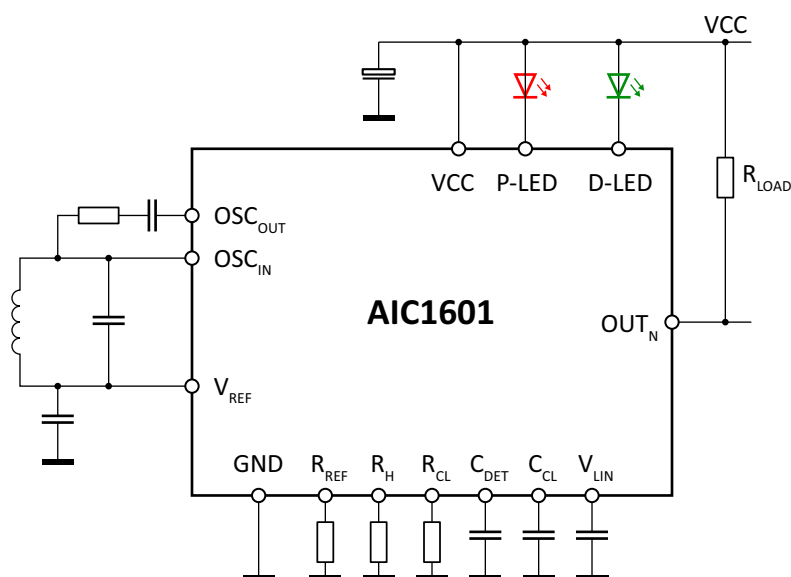
APPLICATIONS

- Inductive Proximity Detection

DESCRIPTION

The AIC1601 is a sensor IC for inductive proximity applications and can be used with a range of inductive transducers. It does have the analog front end, the detection logic, output stage and the status LED drivers (Detection and Power) integrated.

Figure 1: Simple Application Circuit



BLOCK DIAGRAM

Figure 2: Block Diagram

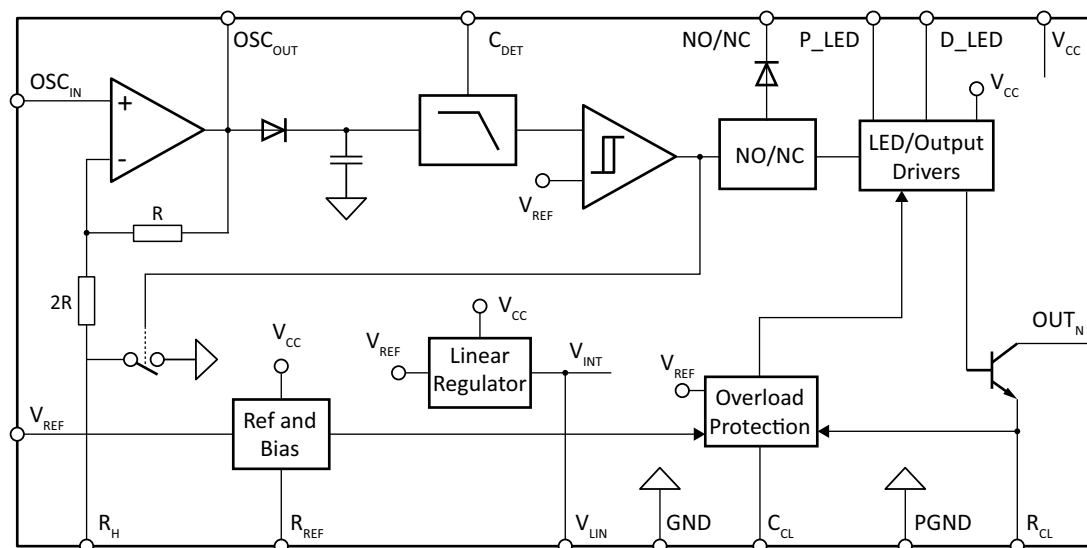
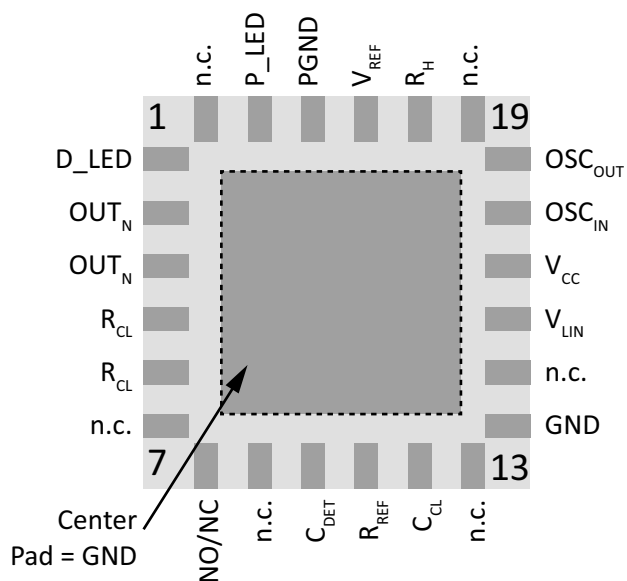


Figure 3: Device Pinout (Top View)



PINOUT AND DESCRIPTION TABLE

Pin Number	Name	Description
1	D_LED	Detection LED-driver output. LED signals detection of object. Current is controlled by a source of typical 1.2mA
2,3	OUT _N	External load, for example switch-relay (three-wire technique), NPN transistor output configured as “open collector”, switch is connected to VCC
4,5	R _{CL}	sense resistor to limit the current in OUT _N (collector current)
6		n.c.
7	NO/NC	Selection switch Normally Open / Normally Closed (please see description in the manual)
8		n.c.
9	C _{DET}	Filter capacitor (C _{DET}) to detect oscillation of Inductive Transducer (C _{DET} to GND)
10	R _{REF}	Resistor R _{REF} sets the operating current for internal circuits (amplifier, voltage reference, et.al). The voltage at this pin is about 1.2V
11	C _{CL}	Capacitor for current limiter, determines the sampling rate of current limiter
12		not connected (n.c.)
13	GND	Supply ground
14		not connected (n.c.)
15	V _{LIN}	Blocking capacitor for internal regulator
16	V _{CC}	Supply voltage
17	OSC _{IN}	Oscillator input (LC tank)
18	OSC _{OUT}	Oscillator output
19		not connected (n.c.)
20	R _H	Resistor R _{HYST} , hysteresis adjustment
21	V _{REF}	Reference voltage output (decoupling capacitor to GND). V _{REF} is about 1.2V
22	PGND	Power ground (GND based on output stage OUT _N)
23	P_LED	Power LED driver output. LED signals operation supply voltage V _{CC} > 5.5V. Current is controlled by a source of typical 1.2mA
24		not connected (n.c.)

SPECIFICATIONS

Unless otherwise noted: $T_J = 25^{\circ}\text{C}$, $V_{CC} = 38\text{ V}$

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Min	Max	Unit
Supply voltage	V_{CC}	-0.3	40	V
Voltages at pins OSC_{IN} , R_H , OSC_{OUT} , C_{DET} , R_{REF} , V_{REF} , V_{LIN} , and C_{OVL}	V_{MAX}	-0.3	$V_{LIN} + 0.3$	V
Voltage at pin NO/NC	$V_{NO/NC}$		V_{CC}	V
ESD test voltage ¹	V_{ESD}	-1	1	kV
Storage temperature range	T_{STG}	-55	150	$^{\circ}\text{C}$
Junction temperature ²	T_J		150	$^{\circ}\text{C}$

1. Human Body Model (HBM)

2. $T_J = T_A + P_{TOT} * R_{THJA}$, where T_A is ambient temperature, P_{TOT} is total power dissipation and R_{THJA} is thermal resistance junction to ambient

NORMAL OPERATING RANGE

Parameter	Symbol	Min	Typ	Max	Units
DC supply voltage ^{1 2}	$V_{CC,DC}$	5.5		38	V
Ambient temperature range	T_A	-25		90	°C
Junction temperature	T_J	-25		120	°C
Total power dissipation	P_{TOT}			1	W
Thermal resistance junction-ambient	R_{THJA}			42	K/W

1. Amplitude of allowable low-frequency ripple (100 Hz to 120 Hz) is not higher than +/- 10%. V_{CC} operational limits may not be exceeded
2. For supply voltages below 6.5V, it is mandatory to use low ESR blocking caps and that the supply voltage is stable.

DC CHARACTERISTICS

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply current of pin V_{CC}	$I_{VCC,OFF}$	Output off		3.8	4.8	mA
Supply current of pin V_{CC}	$I_{VCC,ON}$	Output on		8.5	12	mA
Output saturation voltage	$V_{SAT,OUT}$	$I_{out}=150mA$		0.50	0.70	V
LED current	I_{LED}		1.0	1.2	1.6	mA
Average overload current	I_{OVL}		5	8	14	mA
Output leakage current	I_{LKG}				5	μA
Overload threshold voltage ¹	$V_{TH,OVL}$		250	290	330	mV
Output of linear regulator ²	V_{LIN}		4.1	4.45	4.8	V

1. Overload threshold voltage is the level of the voltage across the current limiting resistor which triggers the overload protection circuit; for more information on this refer to "Overload Protection Circuits" on page 9.
2. For supply voltages below 6.5V, V_{LIN} will follow V_{CC} less the dropout voltage

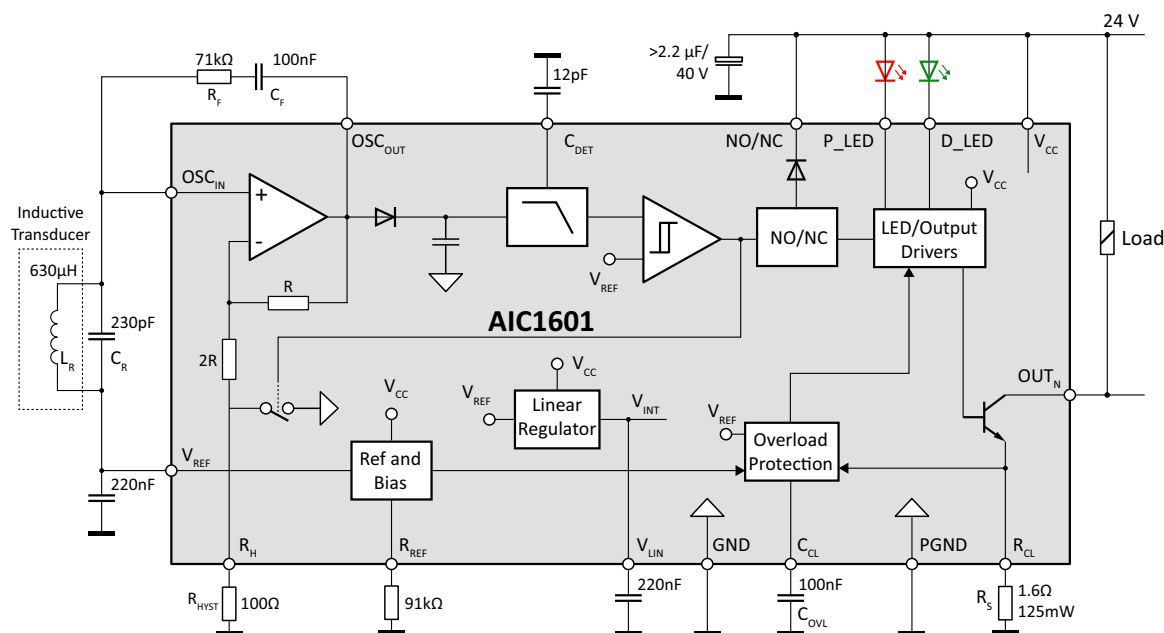
AC CHARACTERISTICS

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Operating frequency	f_{OSC}	$L_R=630\mu H$, $C_R=230pF$		420		kHz
Output rise time	t_R	1k Ω load, 10% to 90%			1.5	μs
Output fall time ¹	t_F	1k Ω load, 10% to 90%)			1	μs
Sampling period in overload mode ²	$T_{S,OVL}$	set by C_{OVL}	50	120	250	ms
Start-up time ³	$T_{STARTUP}$		50	120	250	ms

1. Fall time right after start-up depends on the load used and can be as long as 10 ms
2. For more information on capacitive loads refer to “Overload Protection Circuits” on page 9
3. This is the maximum start-up time of the IC itself, it does not consider the performance of a sensor. During start-up, the output is inactive (off) regardless of the state of the NO/NC pin

APPLICATION AND FUNCTIONAL BLOCKS

Figure 4: Example Application Circuit



LC OSCILLATOR

The LC oscillator utilises the operational amplifier OA featuring a high gain-bandwidth product. The positive feedback of this operational amplifier produces negative resistance at Pin OSCin in order to compensate for energy losses in the external LC tank.

Depending on the external circuitry the LC oscillator is able to oscillate in a range of about 100 kHz to 1 MHz as long as no metallic object is present within the sensing range of the sensor. As soon as a metallic object is placed in close proximity of the external inductor (called proximity transducer in proximity detection applications) its Q factor drops due to eddy currents induced in the object. This leads to higher energy losses in the LC tank, and if the distance between the transducer and the object is small enough, the oscillations are broken.

OSCILLATION DETECTOR

This block, consisted of a peak detector, low-pass filter and comparator with hysteresis, determines whether the oscillator oscillates or not. It also implements a hysteresis function. The output of the detector is used to drive, through the NO/NC multiplexer, the output drivers of the chip. The detector features a dedicated pin Cdet to connect an external capacitor controlling the cut-off frequency of the low-pass filter. This low pass filter eliminates malfunction of the sensor in the presence of short interfering signals which might be received by the magnetic field-sensitive inductive transducer. Therefore, if the IC is expected to work in a 'harsh' environment it is advised that the value of C_F be increased at the expense of reaction time of the IC. Please refer to the available application note for a more detailed description and how to dimension the cut off frequency and the related filter capacitor C_F , as well as the hysteresis and the related resistor R_{HYST} .

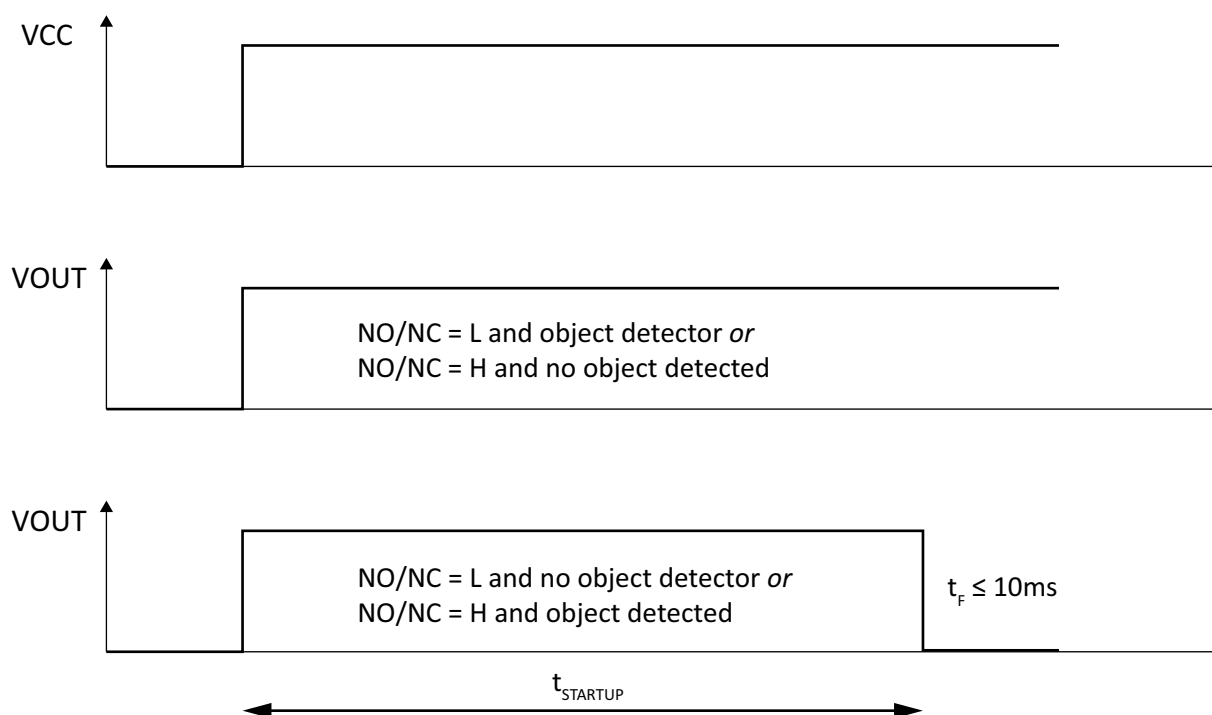
NORMALLY OPEN/NORMALLY CLOSED (NO/NC) BLOCK

The NO/NC block and its NO/NC pin are responsible for the output logic of the IC: the output logic can either be normally open (the output is off if no object is detected) or normally closed (the output is on if no object is detected).

Object detected	NO/NC	Status of OUTN and D-LED
NO	Not connected	OFF
NO	GND	ON
YES	Not connected	ON
YES	GND	OFF

The output logic setup will influence the start-up behavior of the output as shown in the following figure:

Figure 5: Startup behavior based on NO/NC setting



REFERENCE VOLTAGE AND CURRENT GENERATOR

This block provides the IC with a single reference voltage of about 1.2V and a set of reference currents, which are used to bias all building blocks of the IC.

LINEAR VOLTAGE REGULATOR

Since the level of external supply voltage of the IC is expected to vary considerably, an internal voltage regulator has been used to improve the immunity of the LC Oscillator and Oscillation Detector against variations thereof. That way the influence of supply voltage on the sensing distance of the sensor is minimized. This voltage regulator can supply an external circuitry with up to 5mA.

OUTPUT AND LED DRIVERS

This block senses the output of the NO/NC Block and uses this information to control the NPN output transistor depending on the detection status. Additionally, it provides a bias current for two external LEDs: the Power LED and the Detect LED.

OVERLOAD PROTECTION CIRCUITS

The function of this block is to protect the output transistor against destruction resulting from attempting to sink excessive current into the IC or shorting the output of the IC directly to the supply rail. The overload/over-current state of the IC is detected by comparing an internal reference voltage with the voltage drop over an external current limiting resistor connected in series with the emitter of the output transistor. The voltage threshold over the shunt resistor necessary to switch the protection circuit is given in “DC Characteristics” on page 5. If the overload/over-current state is detected (threshold exceeded), the state of the output is periodically sampled as long as the overload/over-current condition persists. In this state the average overload current flowing through the load is much lower than its guaranteed value in the normal operation mode, and the value of this overload current is given in “DC Characteristics” on page 5.

Apart from protecting the output transistor the Overload Protection block is also responsible for deactivating the output transistor shortly after the supply voltage was applied to the sensor. In this way any undesired transient behavior of the IC output is suppressed.

OUTPUT NPN TRANSISTOR

The output NPN transistor is capable of sinking at least 150mA of constant output current. In the overload mode the transistor delivers short current pulses used to test the state of the output and to provide a small charge (or overload) current for capacitive loads.

THERMAL CONSIDERATIONS

The AIC1601's QFN24 package has limited power dissipation capabilities. In case the ambient temperature is rising above 78°C, the package requires extra cooling to prevent the junction temperature to rise above specified limits. Such cooling can be achieved by having a GND layer in the PCB and connecting that with vias to the center pad of the QFN24.

As a rule of thumb, a 150 mm² GND area under the IC, connecting to the center pad with 16 thermal vias will usually provide for sufficient cooling. If a 150 mm² cooling area cannot be achieved, one should try to create star type traces originating from the center pad location to the rim of the PCB. These traces will work as heat pipes.

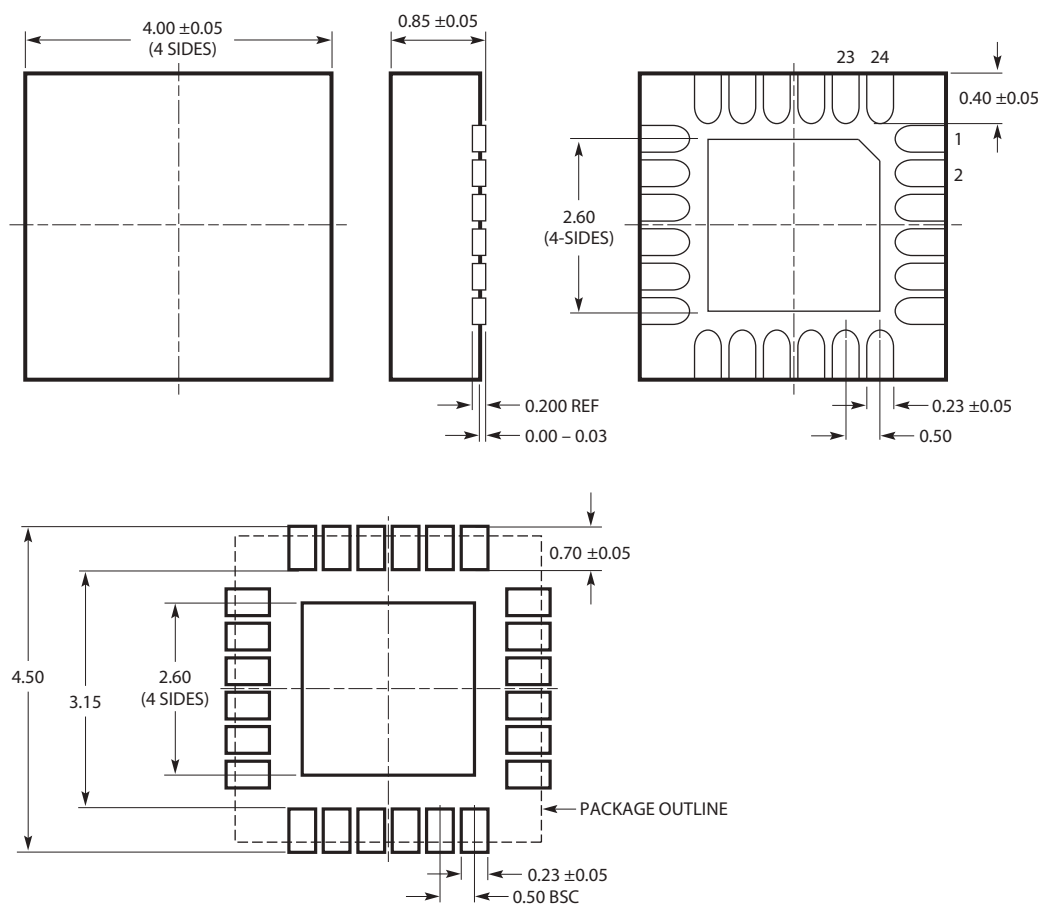
SURGE PROTECTION

Depending on the necessary surge protection class, surge protection diodes and low pass filter schemes might be necessary to protect the V_{CC} and OUT_N pins. For more information please refer to the application note.

PACKAGE OPTIONS

Part Number	Apex Package Style	Description
AIC1601	ZC	24-pin QFN

BOTTOM VIEW—EXPOSED PAD



ESD PROTECTION

The Requirements for Handling Electrostatic Discharge Sensitive Devices are described in the JEDEC standard JESD625-A. Please note the following recommendations:

- When handling the device, operators must be grounded by wearing a for the purpose designed grounded wrist strap with at least 1M Ω resistance and direct skin contact.
- Operators must at all times wear ESD protective shoes or the area should be surrounded by for ESD protection intended floor mats.
- Opening of the protective ESD package that the device is delivered in must only occur at a properly equipped ESD workbench. The tape with which the package is held together must be cut with a sharp cutting tool, never pulled or ripped off.
- Any unnecessary contact with the device or any unprotected conductive points should be avoided.
- Work only with qualified and grounded tools, measuring equipment, casing and workbenches.
- Outside properly protected ESD-areas the device or any electronic assembly that it may be part of should always be transported in EGB/ESD shielded packaging.

STORAGE CONDITIONS

The AIC1532 meets moisture sensitivity classification MSL3, according to JEDEC standard J-STD-020, and should be handled and stored according to J-STD-033.

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