endrich
components of life

novitronic
powered by endrich

SENSORS

Innovative Products for Intelligent Applications

endrich ... represents

CROCUS TECHNOLOGY
Intelligence in Sensing

EVERLIGHT
the source of light

JRC

MICRONAS

MPS

NICERA

Panasonic

RFbeam

SEMITEC®

SENSOLUTE

TAKEYAMA

TEWA
Electronics Group

Table of contents

1. TEMPERATURE SENSORS – THERMISTORS

NTC (Negative Temperature Coefficient) thermistors are resistors which show a decrease in resistance as temperature increases, available as semiconductor type or thick film type. The benefits of NTCs based on semiconducting ceramics are high precision whereas thick film types are more costefficient.

The current flowing through a thermistor may cause some heat which increases the thermistor's temperature above the temperature of the environment. For small currents this effect of self-heating is negligible (unloaded thermistor). We will describe only unloaded NTC thermistors in this application note.

Temperature dependence of the resistance

The resistance of an NTC as a function of temperature can be approximated by the following equation:

$$R(T_1) = R(T_2) \exp (B (1/T_1 - 1/T_2)) \qquad (1)$$

$R(T_1)$: resistance in unit Ω at temperature T_1 in unit K
$R(T_2)$: resistance in unit Ω at temperature T_2 in unit K
B: B-value, material-specific constant of the NTC

This exponential law only roughly describes the characteristics of an NTC. This formula is suitable for describing the resistance in a small range around the temperature T_2 (see Fig.1). If a more precise formula is needed, the STEINHART-HART equation provides a more accurate description of the behaviour of the NTC. The parameters used in this equation (STEINHART-HART-coefficients) are dependent on the material of the NTC and are available on request.

B-value

The B value is dependent on the NTC technology and the materials used. It describes the slope of the R/T curve in a ln R-T diagram. The B value can be calculated by using two points of the R-T curve $R(T_1)$ and $R(T_2)$, i. e.:

$$B = T_1 \cdot T_2 / (T_1 - T_2) \cdot \ln (R(T_2)/R(T_1))$$

The B-values of this catalogue are calculated based on temperatures 25 °C (T_1) and 85 °C (T_2).

Dissipation factor δ_{th}

The dissipation factor δ_{th} is defined as the ratio of the electrical power dissipated in the NTC and the resulting change of the thermistor´s temperature. It is expressed in mW/K and is a measure for the load which causes a thermistor in steady state to raise its body temperature by 1 K. $\delta_{th} = dP/dT$

Tolerance

The resistance R_{25}- and the B-value are subject to manufacturing tolerances. Due to those tolerances of the B and R_{25}-value, the resistance of a NTC varies within a certain tolerance area above and below the theoretical curve. The tolerance in resistance of the NTC thermistor is specified for one temperature point (usually 25°C). Using those tolerance values the temperature accuracy of the NTC can be calculated, i. e. the maximum error of temperature measurement at a given temperature.

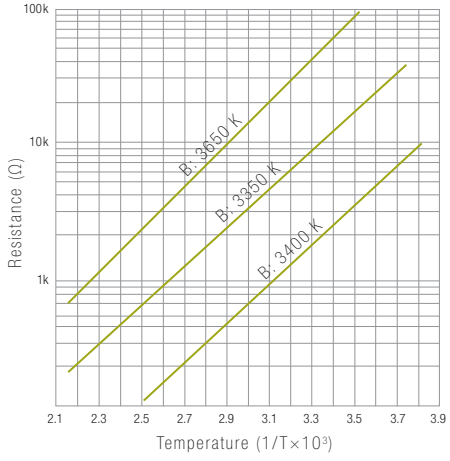
Zero-power measurement

The zero-power resistance is the resistance value measured at a given temperature with the electrical load kept so small that there is no noticeable change in the resistance value if the load is further decreased. If the electrical load is increased the self-heating will distort the measuring result.

Thermal time constant

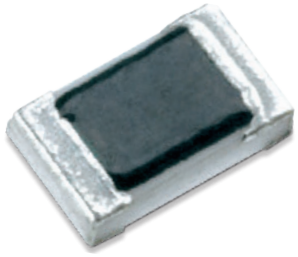
In most cases the NTC has to measure the temperature of the surrounding air or the temperature of an object, which has to be in thermal contact with the NTC. If the temperature of the air or the object changes, the NTC has to adopt the new temperature which does not happen instantaneously but needs some time. The so called thermal time constant refers to the time it takes for an unloaded thermistor to raise its temperature from 25°C ... 62.9°C when it is immersed in a medium having a temperature of 85°C.

Fig. 1 - Characteristic resistance curve of NTC



1.1 THICK FILM CHIP THERMISTORS

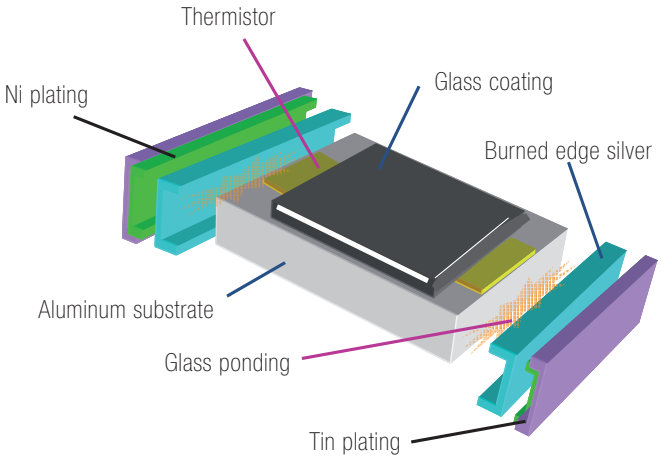
TATEYAMA



Thick film chip thermistors offer high mechanical strength and reliability due to the thermistor film and glass-coated structure on an aluminium substrate. The thickness is fixed and not related to the resistance value. High solderability and heat resistance are available due to triple structure electrodes.

The thermistor element material, based on Mn, Co and Ni, is produced in-house. This core material technology allows us to adjust the thermistor features and R/T curve.
The thermistors are TS/IATF 16949 and AECQ-200 certified.

PART NUMBER	RESISTANCE VALUE R_{25} [Ω]	TOLERANCE R_{25} [%]	B-VALUE (25/85) [K]	TOLERANCE B-VALUE [%]	DISSIPATION FACTOR [mW/°C]	THERMAL TIME CONSTANT [s]	MAX. POWER DISSIPATION [mW]	TEMPERATURE RANGE [°C]
Specifications of TFT series								
TFT6G	100 ... 2 M	±1 ... ±10	2700 ... 4900	±1 ... ±5	1.3	2.5	5	-40 ... +150
TFT3G				±1 ... ±5	1.2	2.0	5	
TFT16G				±1 ... ±5	1.1	1.5	5	
TFT20G				±1 ... ±5	1.1	1.5	5	



Applications

- Heat cost allocators
- Automotive (climate control, air conditioning, etc.)
- Battery management systems
- Blood sugar measurement
- White goods
- Medical

PART NUMBER	SMD SIZE (INCH)	QUANTITY PER REEL
Specifications of TFT series		
TFT 6G	0805	5,000 pcs
TFT 3G	0603	5,000 pcs
TFT 16G	0402	10,000 pcs
TFT 20G	0201	15,000 pcs

1.2 THIN FILM CHIP THERMISTORS

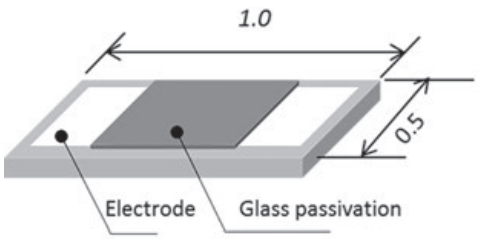
SEMITEC®

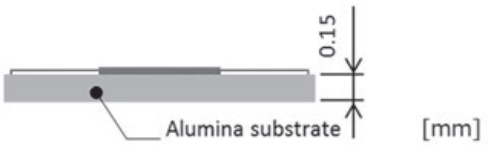
Features

- High heat resistance
- Extremely quick response time
- Miniature size (0401)
- World-first development of this type of thermistor

Applications

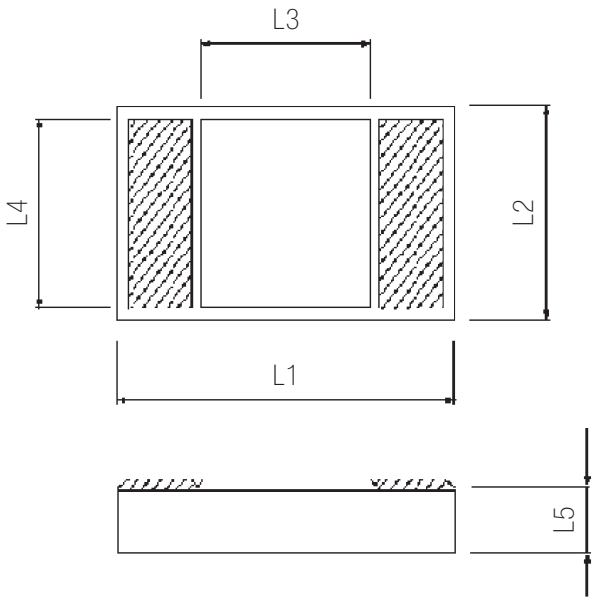
- Medical devices
- Wearable devices
- Laser diodes
- Measurement instruments
- LCDs





Dimensional drawing

FT dimensions — Shaded area: electrodes



(Unit: mm)

Size	L1	L2	L3	L4	L5
1005	1.00±0.05	0.50±0.05	(0.50)	(0.44)	(0.15)
0603	0.60±0.05	0.30±0.05	(0.15)	(0.25)	(0.15)

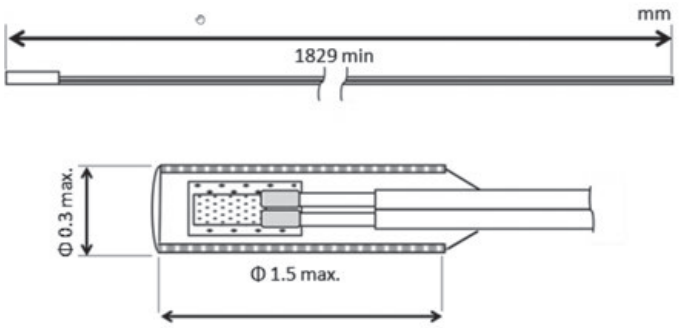
PART NUMBER	R_{25} VALUE (kΩ) + TOLERANCE	B25/85 VALUE (K) + TOLERANCE	DISSIPATION FACTOR (mW/°C)	THERMAL FACTOR CONSTANT t(S)	MAXIMUM DISSIPATION AT 25°C	TEMPERATURE RANGE (°C)
Electrical specification and product numbers						
103FT1005A5P	10 ± 5%[1]	3370 ± 1%	0,3	1	1,5	Au/Ni electrode (soldering): -40 to 125 Au electrode (wire bonding): -40 to 250 Pt electrode (conductive resin): -40 to 250 (350)
103FT1005B5P	10 ± 5%[1]	3435 ± 1%				
103FT1005D5P	10 ± 5%[1]	3969 ± 1%				
503FT1005A5P	50 ± 5%[1]	3370 ± 1%				
503FT1005B5P	50 ± 5%[1]	3435 ± 1%				
364FT1005A5P	360 ± 5%[1]	3370 ± 1%				
364FT0603A5P	360 ± 5%[1]	3370 ± 1%	0,2	0,5	1	

[1] Other tolerance values and sizes available on demand.

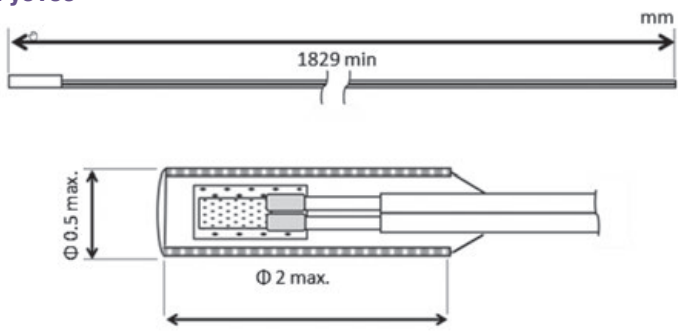
1.3 F-MICRO THERMISTORS

The F-micro thin film thermistor sensor probe has been developed applying SEMITEC's proprietary thin film thermistor technology, specifically for medical purposes. It is highly suited for catheter applications with its reliability, accuracy and faster response than existing thermistors.

Fy3122

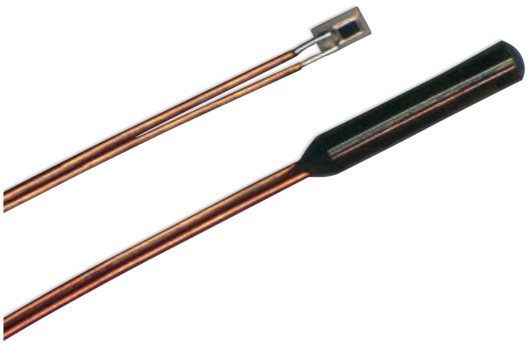


Fy5183



Features

- High mechanical strength and reliability
- Extremely fast response time
- Excellent accuracy
- Miniature size (min. ø 0.3 mm)
- Special development using SEMITEC's FT thermistor



Applications

- Medical catheters
- Guide wires
- Testing equipment
- Handheld medical devices
- Body temperature monitoring
- Other applications that require very small probes

Specifications

Part number	R_{37} [1]	R_{37} tolerance	B value [2]	Dissipation factor	Thermal time constant	Rasted power at 25°C	Operating temperature range
223Fμ5183	14.015 KΩ	± 0.5 % [4]	3454 K ± 1%	approx. 0.35 mW/°C	approx. 52 ms [3]	1.75 mW	-10...70°C
223Fμ5122	14.015 KΩ	± 3 % [4]	3454 K ± 1%	approx. 0.22 mW/°C	approx. 20 52 ms [3]	1.1 mW	-10...70°C

[1] Rated zero-power resistance at 37 °C of the thermistor chip without lead wires
[2] B value calculated from rated zero-power resistance at 0 °C and 50 °C without lead wires
[3] Time required to reach 63.2 % of temperature difference. Measured with sensor suspended in still water
[4] If your application requires other tolerance values please contact sales staff

1.4 HIGH ACCURACY THERMISTORS

Features

- High accuracy
- Long term reliability
- Ideal for automatic assembly (AT-5)
- Created world standard specification (10 kΩ, 3435 K)
- Special development using SEMITEC's FT thermistor

Applications

- Battery packs
- Home electronics
- Cooled product showcases
- Measurement instruments
- Automotive applications
- White goods
- HVAC

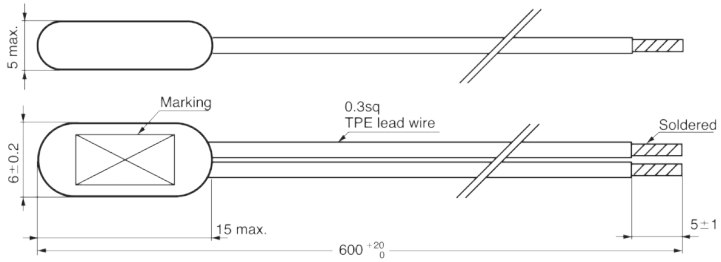
SHAPE	PART NUMBER	RESISTANCE VALUE R_{25} [kΩ]	TOLERANCE OF R_{25} [%]	B-VALUE (25/85) [K]	TOLERANCE OF B-VALUE [%]	TEMPERATURE RANGE (°C)
Specifications of AT series						
	102AT-2	1.00	±1	3100	±1	-50 to +90
	202AT-2	2.00	±1	3182	±1	
	502AT-2	5.00	±1	3324	±1	
	103AT-2	10.0	±1	3435	±1	-50 to +110
	203AT-2	20.0	±1	4013	±1	
	102AT-11	1.00	±1	3100	±1	-50 to +90
	202AT-11	2.00	±1	3182	±1	
	502AT-11	5.00	±1	3324	±1	
	103AT-11	10.0	±1	3435	±1	-50 to +110
	203AT-11	10.0	±1	3435	±1	
	103AT-4 Shape 1	10.0	±1	4013	±1	-30 to +90
	682AT-4	6.8	±1	3975	±1	
	103AT-4 Shape 2	10.0	±1	3435	±1	-30 to +90
	682AT-4	6.8	±1	3975	±1	
	103AT-5	10.0	±1	3435	±1	-50 to +110

HIGH ACCURACY THERMISTORS

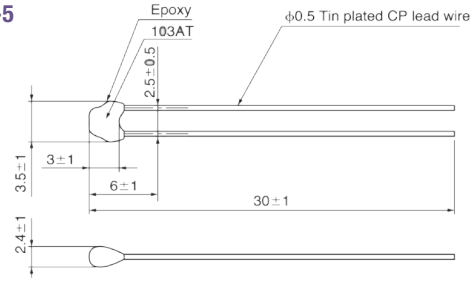
SEMITEC®

SHAPE	PART NUMBER	RESISTANCE VALUE R_{25} [kΩ]	TOLERANCE OF R_{25} [%]	B-VALUE (25/85) [K]	TOLERANCE OF B-VALUE [%]	TEMPERATURE RANGE (°C)
Specifications of AP series						
	202AP-2	2.000	±0.5	3976	±0.5	-60 to +150
	232AP-2	2.252	±0.5	3976	±0.5	
	502AP-2	5.000	±0.5	3976	±0.5	
	103AP-2	10.00	±0.5	3435	±0.5	
	103AP-2-A	10.00	±0.5	3976	±0.5	
	203AP-2	20.00	±0.5	3976	±0.5	
	503AP-2	50.00	±0.5	4220	±0.5	
	104AP-2	100.00	±0.5	4261	±0.5	
	204AP-2	200.00	±0.5	4470	±0.5	

AT-11

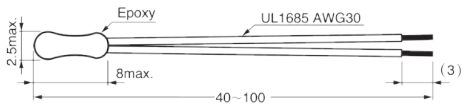


AT-5

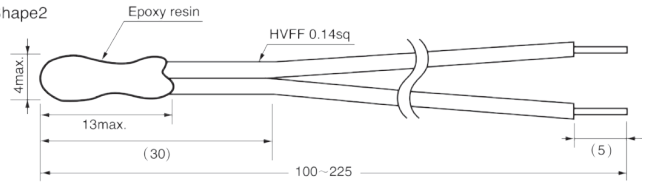


AT-4

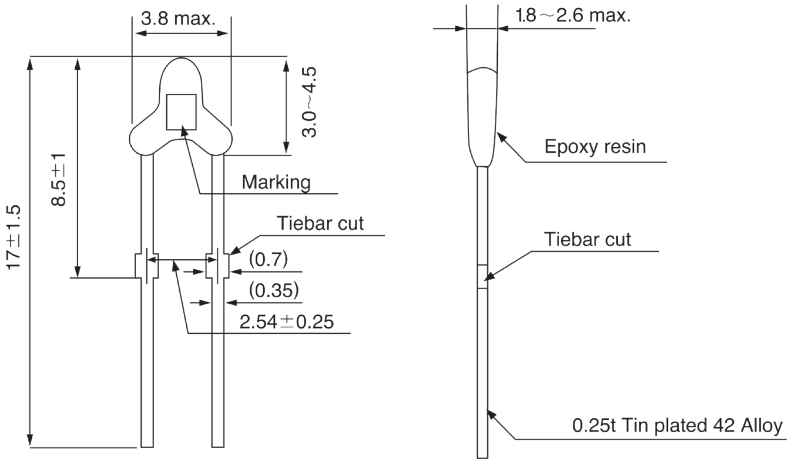
Shape1



Shape2



AP



Dimensions (mm)

1.5 EPOXY COATED INTERCHANGEABLE THERMISTORS

The TT-3 series NTC thermistors are small size epoxy coated sensing devices. Wide range of RT characteristics, tolerances and wire configurations makes them an ideal choice for temperature sensing, control and compensation.

Very tight resistance tolerance up to +/-0.05°C makes them one of the highest precision NTC thermistors available on the market.

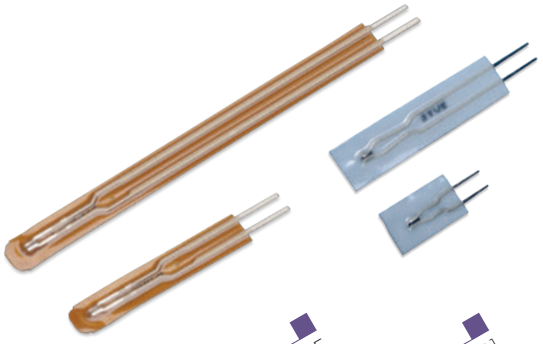
Applications

- HVAC
- Ambient temperature sensing
- Control and compensation
- Liquid or gas temperature control and monitoring
- Assembled into probes for automotive (air conditioning, cabin climate management, heated seats, other), industrial applications, white goods

Specifications of TT-3:	
PART NUMBER	TT3
RESISTANCE VALUE R_{25} [Ω]	100 ... 1 M
RESISTANCE TOLERANCE [°C]	±0.05,±0.1, ±0.2
B-VALUE (25/85) K	3348 ...4261
WIRES/CABLES	AWG28 to AWG36 with/without Teflon insulation
DIAMETER [mm]	1.2 ... 5
TEMPERATURE RANGE (°C)	-40 ... +150

1.6 FILM TYPE THERMISTORS

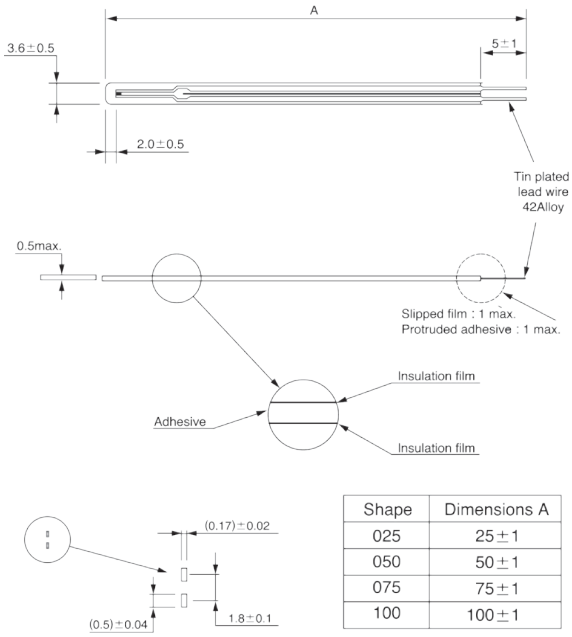
SEMITEC®



JT thermistors feature an ultra thinness of 500 µm and a superior electrical insulation. The usage in battery packs and heat allocators is possible.

PART NUMBER, XXX = SHAPE	RESISTANCE VALUE R_{25} [kΩ]	B-VALUE (25/85) [K]	DISSIPATION FACTOR [mW/°C]	THERMAL TIME CONSTANT [s]	TEMPERATURE RANGE [°C]
Specifications of JT series					
103JT-XXX	10 ± 1 %	3435 ± 1 %	0.7	5	-50 to +90
104JT-XXX	100 ± 1 %	4390 ± 1 %	0.7	5	-50 to +125
103JT-W	10 ± 1 %	3435 ± 1 %	1,4	3,4	-50 to +125

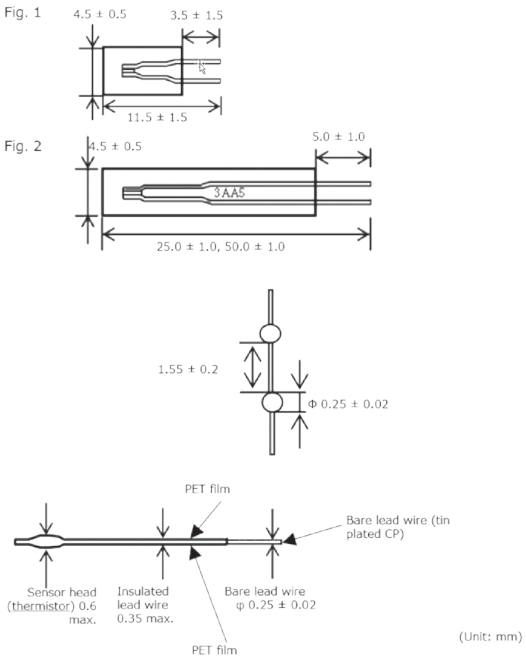
JT thermistor



Shape	Dimensions A
025	25±1
050	50±1
075	75±1
100	100±1

Dimensions (mm)

JT-W thermistor



Features

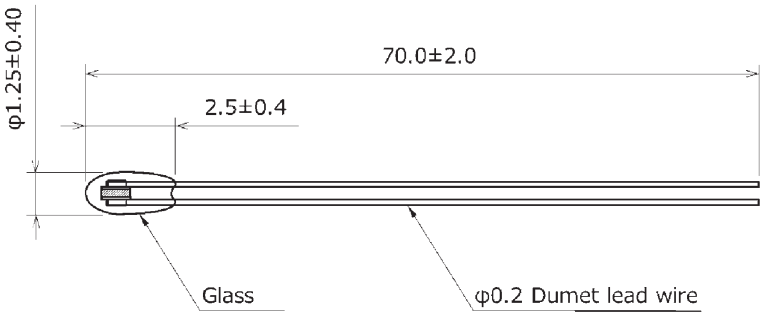
- Tight tolerance for B value and resistance (±1%)
- Ultra thin
- Perfect for tight spaces
- Excellent electrical insulation
- World-first development and manufacturer of this type of thermistor

Applications

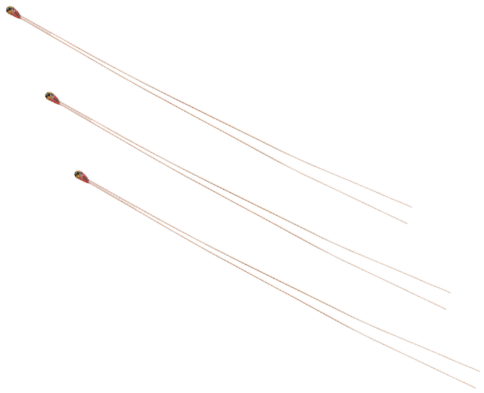
- Battery packs
- IT and mobile devices
- Surface temperature sensors
- Fast response air temperature sensors
- Wearables

1.7 GLASS ENCAPSULATED THERMISTORS

Semitec's glass encapsulated NT-4 series thermistors feature high heat resistance and high sensitivity. Compared with conventional thermistors, the NT-4 thermistors are smaller, faster in response, and more reliable which renders them suitable for various applications.



Dimensional drawing



Features

- High heat resistance
- High sensitivity
- Small size
- Fast response time
- Highly reliable for long-term use

Applications

- Automotive electronics
- HVAC equipment
- Water heaters
- Home appliances
- 3D printer

PART NUMBER	TEMPERATURE [°C]	RESISTANCE [Ω]	TOLERANCE	B-VALUE TEMPERATURE [°C]	B-VALUE [K]	TOLERANCE OF B-VALUE [%]	TEMPERATURE RANGE [°C]
Electrical specification and product numbers							
502NT-4-R025H39G	25	5		25/85	3964		
852NT-4-R050H34G	50	3,485		0/100	3450		
103NT-4-R025H34G	25	10		25/85	3435		
103NT-4-R025H41G	25	10		25/85	4126		
203NT-4-R025H42G	25	20		25/85	4282		
493NT-4-R100H40G	100	3,3		0/100	3970		
503NT-4-R025H42G	25	50	±1%	25/85	4288	± 2%	-50 to +300 (+500)
104NT-4-R025H42G	25	100		25/85	4267		
104NT-4-R025H43G	25	100		25/85	4390		
204NT-4-R025H43G	25	200		25/85	4338		
234NT-4-R025H42G	200	1		100/200	4537		
504NT-4-R025H45G	25	500		25/85	4526		
105NT-4-R025H46G	25	1000		25/85	4608		

[1] Other tolerance values available on demand.

1.8 GLASS ENCAPSULATED NTC THERMISTORS

The TT-2 series NTC thermistors are glass encapsulated sensing devices with standard electrical characteristics. Custom electrical characteristics can be produced in this configuration too.

The glass encapsulation provides excellent stability and durability in an established product style. TT-2 series thermistors are available with dumet wire with or without polyimide tubes for insulation.

Applications

- HVAC
- White goods
- Industrial
- Medical

Specifications of TT-2:	
PART NUMBER	TT2
RESISTANCE VALUES R_{25} [Ω]	1 K ... 1.4 M
RESISTANCE TOLERANCE [%]	±1 ... ± 20
B-VALUE (25/85) K	2700 ... 4535
WIRES/CABLES	bare dumet wire or with polyimide insulation
DIAMETER [mm]	0.75 ... 3.0
TEMPERATURE RANGE [°C]	-50 ... +500

1.9 WATERPROOF TEMPERATURE SENSORS

TT-O series sensors are IP68 waterproof temperature probes encapsulated with thermoplastic elastomer materials in overmoulding technology. Excellent performance in extreme freeze-thaw conditions resulting from a wide choice of insulation material. The TT-O overmoulded probes are a perfect solution for applications where the best waterproof and moisture protection is required.

Applications

- Refrigeration applications (evaporator)
- Air conditioning
- Underfloor heating
- Climate control systems
- Industrial process control
- Automotive

Specifications of TT-O:	
PART NUMBER	TTO
MEASUREMENT ELEMENT	NTC, PTC, PtRTD, KTY
RESISTANCE TOLERANCE [%]	±0.5 ... ±5
B-VALUE (25/85) K	3187 ... 4262
WIRES/CABLES	TPE single & double / insulated
DIAMETER [mm]	3.9, 5.0, 6.5
TEMPERATURE RANGE (°C)	-50 ... +105 (+150)

1.10 CUSTOMIZED TEMPERATURE SENSORS

TEWA temperature sensors offer a wide range of standard and customized temperature sensors designed according to individual customer's requirements covering applications in temperature range between -80 °C and +800 °C. The TT-4 series group contains temperature sensors using NTC/PTC thermistors, PTRTDs and other sensing elements mounted into a wide range of metal/plastic housings.

Features

- Proven stability and reliability
- Low cost
- Variety of metal and plastic housings and tubings designed for specific applications
- Potted with different kinds of resin for reliable sensor protection
- Provides good protection from the environmental against the environmental conditions
- Proven high voltage and dynamic strength
- Available with special cables (2-core cables or stranded with PVC, teflon or kynar insulation, cables with screen & other), connectors and other attachments
- Wide range of resistance and temperature characteristics
- Designed for temperature measurement, temperature control and temperature compensation

Specifications of TT-4:	
PART NUMBER	TT4
MEASUREMENT ELEMENT	NTC, PTC, PtRTD, KTY, DS1820
RESISTANCE TOLERANCE [%]	±0.2 ... ±5
B-VALUE (25/85) K	2700 ... 5100
WIRES/CABLES	PVC, Silicone, FEP, Fiberglass insulation, etc.
DIAMETER [mm]	>1.25
TEMPERATURE RANGE (°C)	-80 ... 800

Applications

- Automotive applications
- Consumer products
- Instrumentation industrial ovens
- Electric showers
- HVAC and refrigeration
- Fire detectors
- Battery management systems
- E-mobility

1.11 AUTOMOTIVE TEMPERATURE SENSORS

SEMITEC®

Battery module

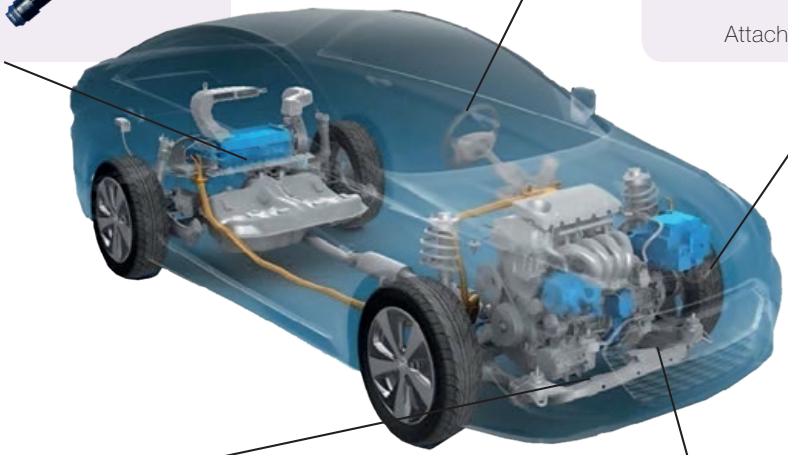
Cell pack

Steering- & Seat Heater

Foil NTC

Inverter/Converter

Attached to PCB by crew

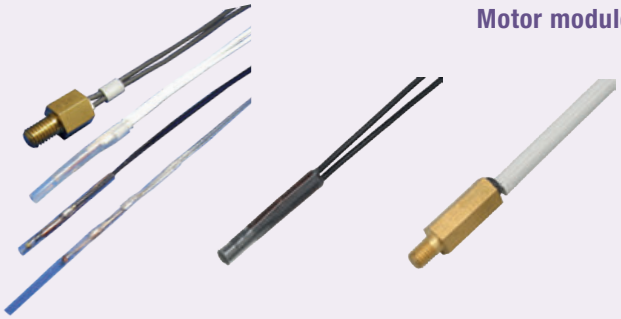


Air conditioning module

Epoxy dipping type

High precision type

Motor module



ATF oil submersion

High temp. range type

Screw fix type

Features

- Extensive use in all global automotive brands
- Dozens of customized assemblies for battery and EV motor applications
- Already high market share for Japanese hybrid car batteries
- Competitive pricing especially for integrated design assemblies (sensor part + resin mold)

Applications

- EV batteries
- Electric motors
- Air conditioners
- Capacitors

2. MAGNETIC SENSORS

In 1879 Edwin H. Hall (1855-1938), an American physicist, discovered this effect. The electrons of the current flowing in an electrical conductor are diverted from their normal direct path by an external magnetic field perpendicular to their motion.

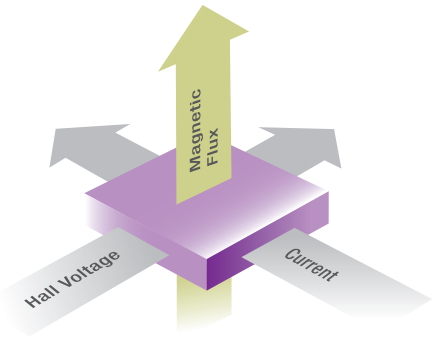
Due to the so-called Lorentz force a potential difference (the Hall voltage) is created, proportional to the field strength of the magnetic field and to the current. Silicon is used almost exclusively as a basic material for the technical implementation of magnetic field sensors as the Hall-effect is most pronounced in semiconductors. In modern Hall-effect sensor devices the magnetic field sensitive Hall element is combined with the signal processing on a single silicon chip. Three different types of sensor architecture are available today:

- Digital switches
- Linear sensors
- Direct angle sensors

Linear Hall sensors

Linear Hall sensors differ from the switches as follows: Depending on the magnetic field, the output does not have a discrete switching state, but provides a signal proportional to the magnetic field strength.This output signal can be delivered as an analog output voltage, a pulse-width-modulated signal (PWM) or even as a modern bus protocol (LIN, SENT).

Principle of the Hall effect

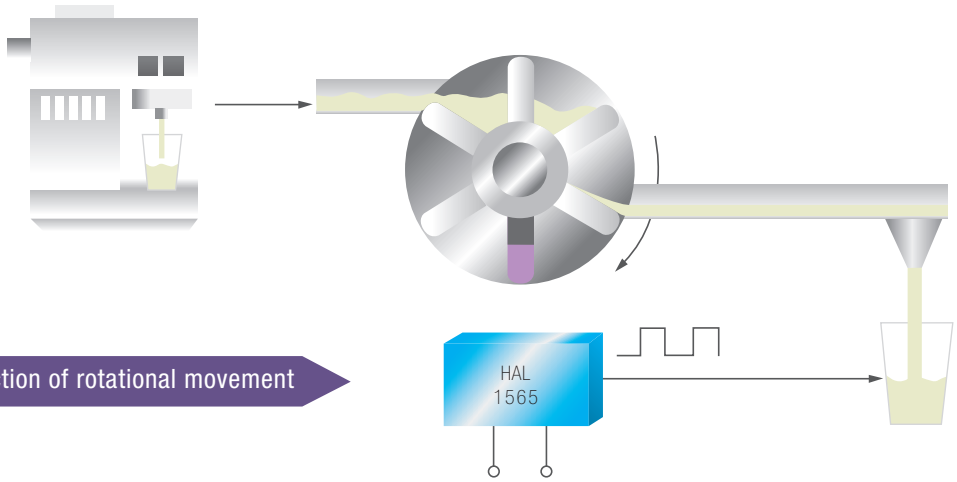


Hall switches

The simplest application is to use the sensor as a “digital switch“. The magnetic field strength is measured and compared with a fixed threshold level predefined or programmable in the sensor. As soon as this value is exceeded (switching point) the switching state at the output of the sensor changes and the output transistor is switched on or off. Two types of switches are available: 3-wire versions with an open-drain output or 2-wire versions with a current-coded output.

Direct angle sensors

New types of Hall-effect sensors do not measure the absolute magnetic field anymore. So-called direct angle sensors capture the field vector by measuring sine and cosine components of the magnetic field. This is possible due to the new 3D-HAL technology from Micronas. Vertical Hall plates measure the magnetic field components in the chip plane as well as the components perpendicular to the chip surface. This kind of sensors provide angular and position information directly via an output signal proportional to the measured angle or position.



Application example: Detection of rotational movement

2.1 HALL SWITCH OVERVIEW

HALL SWITCHES FOR POSITION DETECTION

MICRONAS

Hall switches are commonly used for endposition detection. The sensor recognizes the presence of a magnetic field by signalling an ON/OFF state. Therefore, Hall switches are widely used to replace micro switches, offering superior quality and durability performance.

HAL1002 switch

- Open-drain output (3-wire)
- Different switching points
- T_J = -40 ... 170°C
- TO92 package

HAL15 switch family

- Open-drain output (3-wire) or current output (2-wire)
- Chopper stabilized
- High-precision thresholds
- Different switching points and behaviour
- T_J = -40 ... 170°C
- SOT23 or TO92 package

2.1.1 HAL1002

PROGRAMMABLE HALL SWITCH

MICRONAS

The major sensor characteristics, the two switching points B_{ON} and B_{OFF}, and the output behavior are programmable for the specific application. The sensor can be programmed to be unipolar or latching, sensitive to the magnetic north pole or sensitive to the south pole, with normal or with an electrically inverted output signal.

Applications

- End position detection
- Kick down
- Bending lights

Features

- Programmable through modulation of supply voltage
  - Switching points programmable from -150 ... 150 mT independent programming of B_{ON} and B_{OFF}
  - Output behavior (unipolar [inverted] or latching)
  - Temperature coefficient
- Short-circuit protected push-pull output
- Over and under voltage detection
- Over and reverse voltage protection at all pins
- Wire break detection (VDD and GND)
- Supply voltage range: 4.5 ... 8.5 V (target 11 V)
- T_J range: -40 ... 170°C
- ESD HBM protection up to 8 kV

Specifications of HAL 1002	
PART NUMBER	HAL1002
TYP. B_{ON} / TYP. B_{OFF}	programmable
TYPE	Unipolar, unipolar inverted, latching
CONFIGURATION	3-wire

2.1.2 HAL15xy FAMILY

LOW-POWER HALL SWITCH

MICRONAS

The HAL15xy family consists of different Hall switches containing a temperature-compensated Hall plate with active offset compensation and comperator, available optionally with open-drain or current output.

Applications

- Endposition detection
- BLDC motor commutation
- Brake light switch
- Clutch pedal position
- Gear shift lever
- Window lifter

Features

- ISO 26262 compliant, ASIL A ready device
- Very low current consumptions of typ. 1.6 mA (3-wire)
- Wide supply voltage operation from 2.7 ... 24 V, over voltage protection capability up to 40 V
- Highest HBM ESD performance up to ±8 kV
- Reverse-voltage protection at supply pin
- Operating with static and dynamic magnetic fields up to 12 kHz at lowest output jitter
- T_J -40 ... 170 °C
- SOT23 JEDEC package
- AEC-Q100 qualification

PART NUMBER	TYP. B_{ON}	TYP. B_{OFF}	TYPE	CONFIGURATION
Specifications of HAL 15XY				
HAL1501	0.4 mT	-0.4 mT	bipolar, high sensitivity	
HAL1502	2.5 mT	-2.5 mT	latching, high sensitivity	
HAL1503	5.5 mT	3.7 mT	unipolar, medium sensitivity	
HAL1506	18.9 mT	17.3 mT	unipolar, low sensitivity	3-wire
HAL1507	28.2 mT	23.9 mT	unipolar, low sensitivity	
HAL1508	-5.5 mT	-3.7 mT	unipolar, medium sensitivity	
HAL1509	3.7 mT	5.5 mT	unipolar inverted, medium sensitivity	
HAL1562	12 mT	-12 mT	latching, low sensitivity	
HAL1563	7.6 mT	9.4 mT	unipolar inverted, medium sensitivity	
HAL1564	4.1 mT	6 mT	unipolar inverted, medium sensitivity	2-wire
HAL1565	6 mT	4.1 mT	unipolar, medium sensitivity	
HAL1566	9.4 mT	7.6 mT	unipolar, medium sensitivity	

HAL 8 product family

- T_J = -40 ... 170°C
- TO92 package
- Programmable (EEPROM)
- Proven-in-use quality
- Temperature stability

HAL 83x

- Analog output

HAC 830

- Integrated caps
- High accuracy
- Analog output

HAL 24 product family

- T_J = -40 ... 170°C
- TO92, SOIC8 or TSSOP14 package
- Programmable (EEPROM)
- On-board diagnostic features
- Versatility and high precision

HAL 2420

- 2-point calibration
- Analog output

HAL 2425

- 2-point calibration
- 16 set points linearization
- Analog output

HAR 2425

- Dual-die version
- Analog output

HAL 2455

- 2-point calibration
- 16 set points linearization
- PWM output

HAR 2455

- Dual-die version
- PWM output

Linear Hall sensors for linear movement

Linear sensors are used to obtain a signal proportional to a linear movement or an electric current level being measured. The output signals can be analog or in digital formats. Due to these proven advantages Hall-effect sensors are widely used to replace conventional potentiometers.

HAL 18 product family

- T_J = -40 ... 170°C
- TO92 or SOT89 packages
- Ratiometric analog output
- Value optimized version (10bit)
- Versatility and high precision

HAL 1820

- Programmable (EEPROM)

HAL182x

- Pre-configured sensitivity (EEPROM)

HAL 28 product family

- T_J = -40 ... 170°C
- TO92 package
- High-precision sensors
- Digital signal processing
- Direct 12V battery supply

HAL 283x

- SENT interface (SAE J2716 rev.3)
- Up to 16-bit resolution

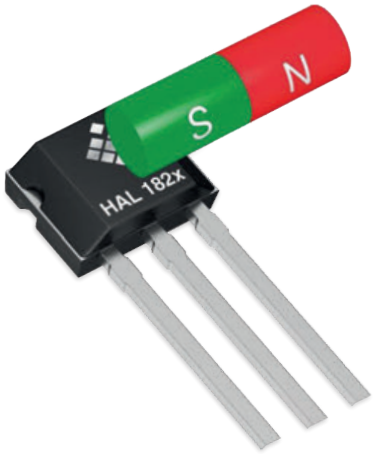
HAL 2850

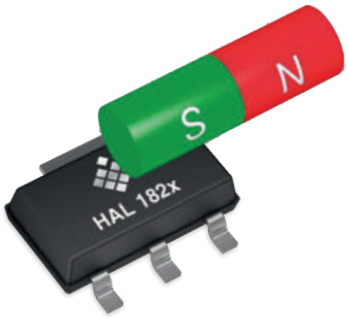
- Programmable PWM output
- 12-bit resolution

2.2.1 HAL182x

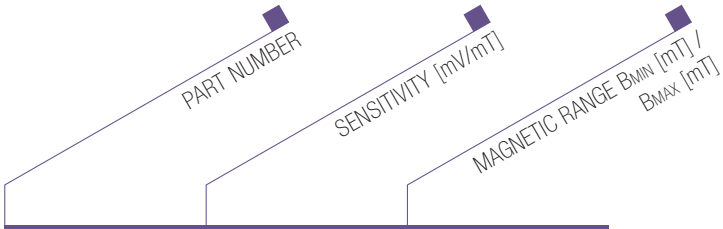
PROGRAMMABLE OR WITH FIXED SENSITIVITY LINEAR HALL SENSORS MICRONAS

HAL182x consists of an universal magnetic field sensor with a linear analog output based on the Hall effect. The ICs can be used for angle and linear measurements if combined with a rotating or moving magnet.





The major characteristics of the HAL1820 such as magnetic field range, sensitivity, offset (output voltage at zero magnetic field) and the temperature coefficients are programmable in a non-volatile memory. The sensors HAL1821, HAL1822, and HAL1823 have a fixed sensitivity.



Specifications of HAL 182x		
HAL1820	programmable	±20 / ±160
HAL1821	50	-50 / +50
HAL1822	31.25	-80 / +80
HAL1823	25	-100 / +100

Features

- Magnetic field range: ± 20 ... ± 160 mT
- Under/over-voltage protection
- Junction temperature -40°C ... 170°C
- ESD protection up to 6kV
- AEC-Q100 qualification

Applications

- Linear movement e.g. gear position in dual clutch transmission
- Motor control

2.2.2 HAL83x

ULTRA-RELIABLE MULTI-PURPOSE LINEAR HALL-SENSORS

MICRONAS

The HAL83x family combines over of 15 years know-how and a proven-in-use quality experience. It can work in harsh environment due to high temperature stability and offers flexibility thanks to the selectable output (analog & PWM) of the HAL835.

Applications

Linear movement, angle detection, pedal, throttle, turbo charger, transmission and joystick

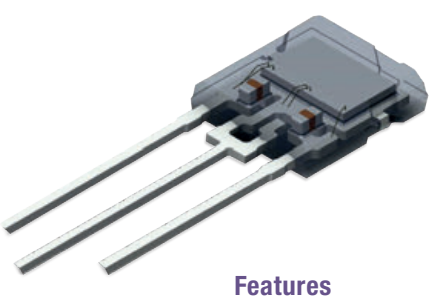
Features

- Junction temperature -40 ... 170°C
- Under/over-voltage & wire break detection
- ESD protection @ 7.5 kV
- Reverse-voltage protection at all pins

PART NUMBER	MAGNETIC RANGE [mT]	OUTPUT	PACKAGE
Specifications of HAL 83x			
HAL830	± 30 ... 100 mT	Analog (12 bits)	TO92-UT
HAC830	± 30 ... 100 mT	Analog (12 bits)	TO92-UP
HAL835	± 15 ... 150 mT Low offset and sensitivity drift	Analog (12 bits) & PWM (125 Hz, 11 bits)	TO92-UT

2.2.3 HAC830

NEW CONCEPT OF INTEGRATED CAPACITORS



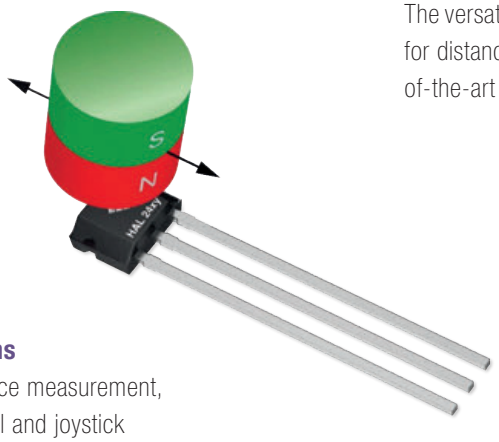
Features

- Same features as HAL830
- EMC robustness (BCI up to 300 mA)
- Available in the TO92UP-package

2.2.4 HAL24xy –

PRECISE AND ROBUST PROGRAMMABLE LINEAR HALL-EFFECT SENSORS

MICRONAS



The versatile **HAL24xy family** offers the possibility of an extended measurement for distances up to 2 times of the magnet length & angle up to 180° and state-of-the-art diagnostic functions for applications under stringent conditions.

Applications

Linear distance measurement, throttle, pedal and joystick

Features

- 16 set points for output linearization
- Junction temperature -40 ... 170°C
- Under/over-voltage & wire break detection
- ESD protection @ 8 kV
- On board diagnostics
- AEC-Q100 qualification

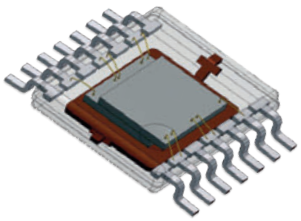
PART NUMBER	CHARACTERISTICS	OUTPUT	PACKAGE
Specifications of HAL 24x5			
HAL2420	± 25 ... 200 mT magnetic range Programmable temperature compensation for sensitivity and offset Continuous self-test	Analog (12 bits)	TO92-UT, SOIC8
HAL2425		Analog (12 bits) with 16 programmable setpoints	TO92-UT, SOIC8
HAL2455		PWM (2 kHz, 12 bits) with 16 programmable setpoints	TO92-UT, SOIC8
HAR2425		Analog (12 bits) with 16 programmable setpoints	TSSOP14
HAR2455		PWM (2 kHz, 12 bits) with 16 programmable setpoints	TSSOP14

2.2.5 HAR24xy

REDUNDANCY IN A VERY THIN PACKAGE

Features

- Same features as HAL24xy
- Redundancy with stacked die configuration
- Package height < 1 mm



2.3 MULTI-AXIS SENSORS

OVERVIEW

MICRONAS

Two-dimensional measurement with vertical Hall plates

In the area of position detection in automotive or industrial applications, the requirements for sensors are steadily increasing. Their accuracy and reliability in harsh environments has to grow continiously. For applications measuring small distances (up to 6 mm) or small angle ranges (up to 60°), established linear (1D) Hall-effect sensors are showing excellent and reliable performance. For larger ranges a new technology is needed. To this end, Micronas has developed the new Hall-effect sensor family HAL 37xy.

This family represents a new level of performance for Hall-effect sensors enabling a significant simplification in the design of magnetic systems. The sensors are based on Micronas' innovative 3D HAL® technology. A major advantage of this technology is the use of the so-called pixel cell. It consists of a combination of two vertical and one horizontal Hall plate. With this pixel cell you are able to measure the three magnetic field vector components at one spot. Magnetic field lines parallel to the sensor surface are detected by the vertical Hall plates, whereas the component perpendicular to the chip surface is measured by the horizontal Hall plate. The measurement of the relative strength of both components is the key for the excellent angular performance. Even a varying distance between magnet and sensor does not prevent a stable output signal. Temperature effects are mainly suppressed by relative measurement of the two components.

The combination of vertical and horizontal Hall plates enables robust linear position measurements with reduced magnet sizes. Using a magnet with a length of 10 mm, distances of ≥15 mm can be easily achieved. Overall 40 mm movement can be realized with simple magnetic setups.

Overall, the various family members support different output formats like ratiometric analog PWM and SENT. The devices can be easily adapted to the different applications by providing easy programmability. Key parameters like offset, gain, zero angle, output offset and gain, 33 set points for linearization and clamping levels can be stored in the built-in memory.
Today the whole product family consists of the second generation HAL 37xy featuring further improved angular performance.

HAL 37 product family

- T_J = -40 ... 170°C
- SOIC8, TO92 package
- Superior accuracy
- Programmable characteristics in a non-volatile memory
- Diagnostic functions
- Measurement of angular and liniar position

HAL 3715
- 12 bit analog module output

HAL 372x
- 12 bit analog output

HAL 373x
- PWM and SENT output

HAR 3715
- 12 bit analog module output
- Dual-die version

HAR 372x
- 12 bit analog output
- Dual-die version

HAR 373x
- PWM and SENT output
- Dual-die version

HAC 3715
- 12 bit analog module output
- Integrated capacitors

HAC 372x
- 12 bit analog output
- Integrated capacitors

HAC 373x
- PWM and SENT output
- Integrated capacitors

2.3.1 HAL37XY

SECOND GENERATION OF MULTI-AXIS HALL SENSORS

MICRONAS

Applications

Clutch position, turbo charger actuators, transmission position, chassis position sensors, fuel level and steering angle detection, encoder, linear distance measurement

Features

- High ESD protection according to stringent requirements of the automotive industry
  - ESD protection 8 kV (active pins)
- Wide junction temperature range from -40 ... 170°C
- SOIC8 SMD, TO92-UP for pin leaded package
- No output linearization required for rotary applications
- "open source" programming interface and software
- Unique „Virtual Offset Feature" to
  -> reduce magnet size & cost
  -> Accuracy of <0.5% full scale for linear or angular measurements

PART NUMBER	OUTPUT	MAGNETIC FIELD AXIS	MAGNETIC RANGE [MT]	SETPOINTS	MAGNETIC SETUP
Specifications of HAL 37xy					
HAL 3725	Analog	XY	± 20 ... ±100	33	End of shaft
HAL 3726		YZ			Off-axis or linear position
HAL 3727		XZ			Off-axis or linear position
HAL 3735	PWM or SENT SAE-J2716 Rev. 2010	XY			End of shaft
HAL 3736		YZ			Off-axis or linear position
HAL 3737		XZ			Off-axis or linear position

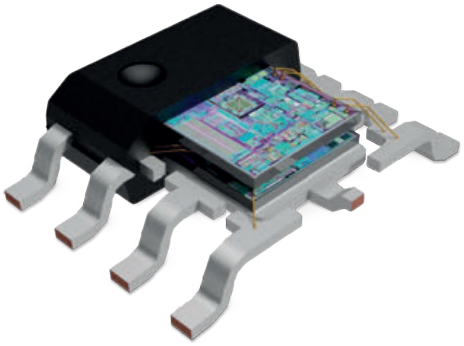
Additional features

- Supply voltage range 4.5 ... 5.5 V
- Programming via sensor output TTL-level (0 ... 5 V)
- Memory with redundancy and lock function
- AEC-Q100 qualification
- Various safety features
  - Wire-break & under/over-voltage detection
  - Full signal path and memory supervision
  - Overflow and state machine self-test
  - Magnet lost detection

2.3.2 HAR37xy

REDUNDANT MULTI-AXIS HALL SENSORS

MICRONAS



The HAR37xy Hall-effect sensors offer redundant high-precision angle and linear position measurement in a small SOIC8 package for demanding automotive and industrial applications.

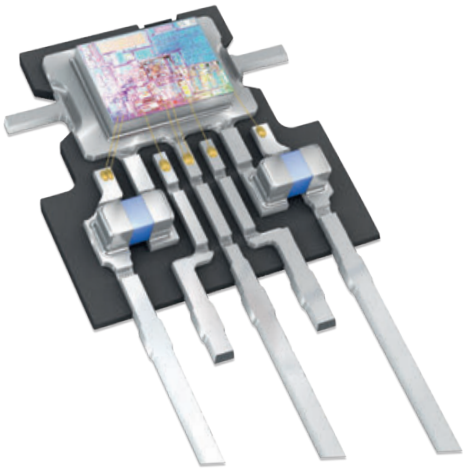
Stacked Die Technology

- Small distance between the two dies sensitive area
- Each die is bonded on a separate side of the package
- Isolated per construction

2.3.3 HAC37xy

MULTI-AXIS HALL SENSORS WITH INTEGRATED CAPACITORS

MICRONAS



The HAR37xy Hall-effect sensors offer redundant high-precision angle and linear position measurement in a small SOIC8 package for demanding automotive and industrial applications.

Stacked Die Technology

- Robust and compact single-mold leaded package TO92UF
- Fault coverage according to ASIL-B
- Analog or digital (PWM / SENT / triggered SENT) output signal
- BCI test class A

2.4 PROGRAMMING TOOLS

FOR MICRONAS HALL-EFFECT SENSORS

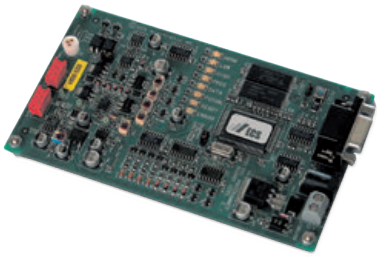
MICRONAS

These programmer boards are used as a general-purpose programming interface, which is capable of addressing all programmable Micronas Hall-effect sensor families within the Micronas sensor portfolio.

Programming hardware:

- HAL8xy
- HAL85x
- HAL1000
- CUR31xy

HAL-APB V5.1



Programming hardware:

- HAL1820
- HAL/R24xy
- HAL28xy
- HAL36xy/38xy
- HAL/R/C37xy

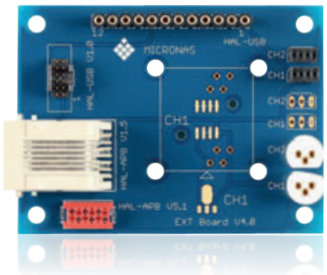
Magnetic sensor programmer V1.0

or

HAL-USB Kit

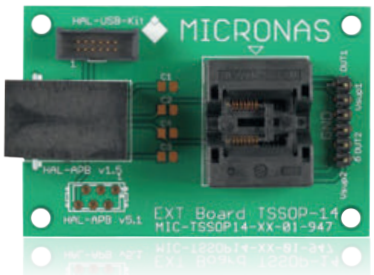
Evaluation boards:

Extension board V4.0



or

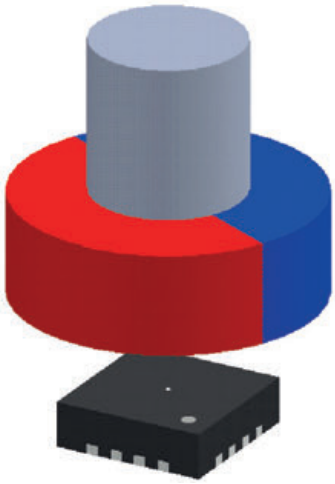
TSSOP14 extension board

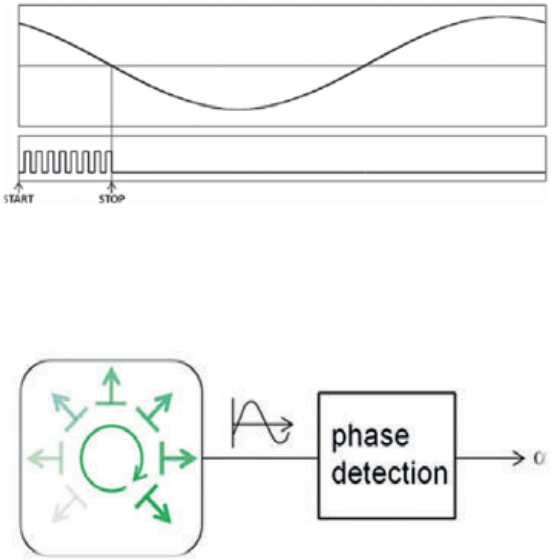


Programming software based on LabView:

2.5 MAGNETIC ANGULAR POSITION SENSORS

MPS MagAlpha™ magnetic angle position sensors offer a revolutionary way to measure angles. MagAlpha™ sensors use the patented "SpinAxis™" measurement system in which the phase angle output from a Hall sensor array is compared against time to give the instantaneous angle position in digital format. See Fig 1.





MagAlpha™ angle sensors offer the following advantages:

- Instantaneous angle sensing: up to 1 µs sample rate, 3 µs latency at 100 k RPM
- High resolution up to 14 bit
- Support for shaft rotation speeds from 0 to over 100 K RPM
- Wide magnetic field range support from 15 ... 150 mT working range
- End and side shaft magnet positioning
- Low power consumption: 3.3 V, 12 mA
- Small package form factor: 3 x 3 QFN16 package
- Cost effecting solutions

Figure 1: SpinAxis™ Technique

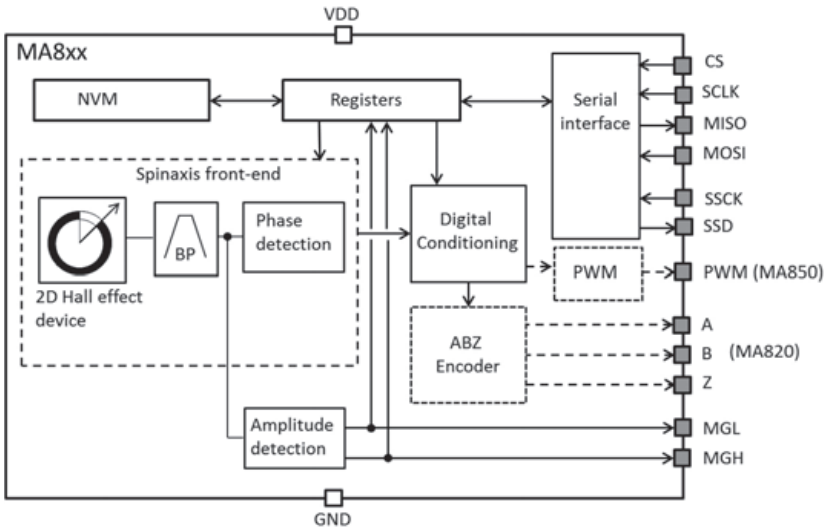
The "SpinAxis™" technique has allowed MPS to develop a range of angle sensors fitting different types of end application from low cost consumer rotary knobs to high speed motor commutation, position control, and general high resolution angle measurement.

2.5.1 MA8xx FAMILY

The MagAlpha™ MA8xx family was designed to replace analog potentiometers or **rotary switches in user interface applications**. Contactless sensing eliminates the lifetime issues of conventional potentiometers or mechanical switches. The sensor detects the absolute angular position of a permanent magnet, attached to the rotating knob. Typically a simple diametrically magnetized cylinder of 3 … 8 mm diameter is suitable.

Different options are available including digital angle output via SPI/SSI bus, incremental ABZ interface or PWM output. Configuration parameters are stored in a non-volatile memory.

Programmable threshold magnetic field strength detection is built in to enable implementation of a contactless push or pull button. Detection is performed by reading the device registers or the logic state of the two output signals. In this way, a combined rotary knob with "push or pull to select" functionality can be created.

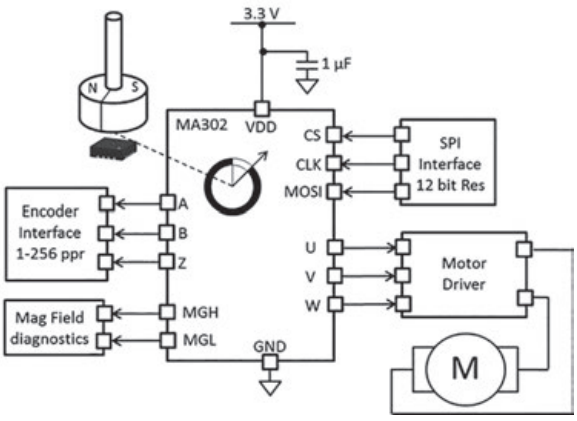


Block diagram of MA8xx family sensor

FEATURES	UNIT	MA800 DIGITAL OUT	MA820 ABZ OUT	MA850 PWM OUT
Rotary user interface sensor range		**Rotary knob applications**		
Effective angle resolution	bit	8	8	8
Magnetic field range	mT	30 … 150	30 … 150	30 … 150
Zero setting		✓	✓	✓
SPI register configuration		✓	✓	✓
Absolute angle on SPI	bit	8	--	--
Absolute angle on SSI	bit	8	--	--
ABZ incremental			✓	
ABZ resolution - pulses per channel	PPR		1 .. 64	
PWM output				✓
Magnetic field detection		✓	✓	✓

2.5.2 MA3xx AND MA7xx FAMILY

MPS offers a range of MagAlpha™ angle sensors optimized for brushless motor commutation (MA102), servo motor control (MA3xx family), and general angle measurement applications (MA7xx family). The MagAlpha™ sensors are able to generate the required signaling for each application, either as direct digital angle output over an SPI or SSI bus, UVW commutation signals or ABZ quadrature incremental encoder outputs.



MA302

MA302: 12 bit fast response servo motor sensor

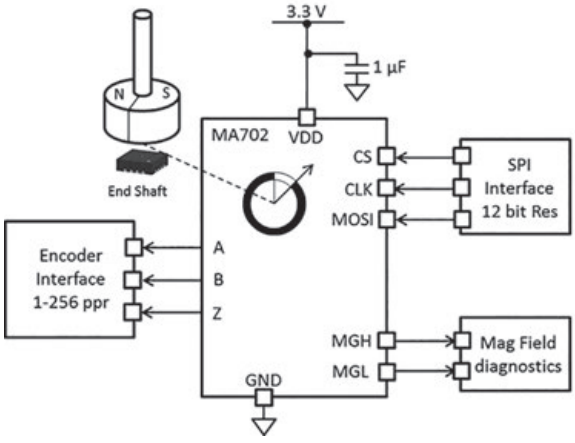
The MA302 is one of the latest generation of MagAlpha™ devices with higher resolution and additional features. It is optimised for high dynamic response and is suited for applications that experience rapid speed change and the need to support high rotation speeds. Examples include high speed brushless motors in servo applications.

The digital conditioning block is optimised to maintain the highest resolution over different operating conditions. Speeds of over 100k RPM are supported on the SPI, ABZ and UVW interfaces. End and side shaft topology is supported.

MA702: 12 bit fast response angle sensor

The MA702 is the latest generation of MagAlpha™ technology for general angle measurement. Example applications include position encoders on servo motor drives or industrial actuators. The internal signal conditioning is optimised to provide high resolution whilst maintaining low latency under rapid speed change. Speed ranges from 0 to over 100K RPM are supported.

12 bit absolute digital angle resolution has it's output via the SPI bus. A programmable ABZ quadrature encoder interface provides from 1 to 256 pulses per 360° rotation. End and side shaft magnet topologies are supported.

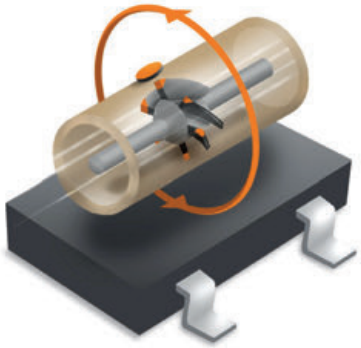


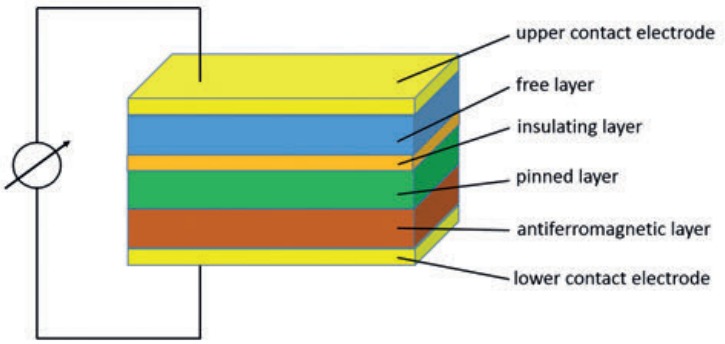
MA702

FEATURES BY PART	UNIT	MA102	MA302	MA310	MA702	MA704	MA710	MA730
MagAlphaTM High Performance Application Devices								
		Motor commutation	Motor commutation + position control		Rotary angle sensors			
Effective angle resolution	bit	12	12	12	12	10	12	14
Dynamic response		High	High	Medium	High	Ultra-High	Medium	Medium
Magnetic field range	mT	30 ... 150	30 ... 150	15 ... 150	30 ... 150	30 ... 150	15 ... 150	40 ... 150
Zero setting		✓	✓	✓	✓	✓	✓	✓
Side-shaft compensation		✓	✓	✓	✓	✓	✓	✓
SPI register configuration		✓	✓	✓	✓	✓	✓	✓
Absolute angle on SPI	bit	8	12	12	12	10	12	14
Absolute angle on SSI	bit				12	10	12	14
ABZ incremental			✓	✓	✓	✓	✓	✓
ABZ resolution	PPR		1 ... 256	1 ... 256	1 ... 256	1 ... 64	1 ... 256	1 ...1024
PWM output					✓	✓	✓	✓
PWM resolution					12	10	12	14
UVW output 1-8 pole pair		✓	✓	✓	✓	✓	✓	✓
UVW resolution	bit	12	12	12				
Differential UVW		✓						
Magnetic field monitoring		✓	✓	✓	✓	✓	✓	✓

2.6 TUNNELING-MAGNETO-RESISTIVE-SENSORS

TMR-sensors from CROCUS are based on a new technology for magnetic field measurement. The main advantages of the TMR-sensors compared to Hall-sensors are the low current consumption and the high sensitivity. The basic unit of TMR-sensors is the so called magnetic logic unit (MLU) which is a stack of several layers of different materials. The resistance of this stack perpendicular to the layers is depending on the orientation of an external magnetic field relative to a fixed axis.





Layer Structure TMR Sensors

The substrate for the stack is an antiferromagnetic layer. Above this layer there is a pinned layer which is a ferromagnetic layer that has a fixed magnetization in a fixed direction. The direction of this magnetization defines the reference direction and it cannot be changed by an external field. Above the pinned layer there is a very thin, insulating layer with a thickness of only a few nanometers. Above this insulating layer another magnetic layer is deposited. The orientation of the magnetization of this free layer can be influenced by an external field. The resistance of the whole stack of layers is depending on the angle between the magnetizations of the free and the fixed layer. It's measureable by applying a voltage at the conducting electrodes at the top and bottom side of the stack. The resistance of the stack varies between 10 kΩ and 60 kΩ. This resistance range of the MLU is much higher compared to other magnetoresistive technologies like AMR (Anisotropic Magnetic Resistance) und GMR (Giant Magneto Resistance). The field necessary to rotate the magnetization of the free layer is quite small. Most of the TMR-sensors operate below 10 mT, some even below 1 mT.

Basically this technology can be used to build magnetic switches or magnetic sensors with analog output. For magnetic switches the current through the MLU is measured and a comparator drives the output stage of the sensor (either open collector or push-pull) high or low, depending on fixed internal threshold values. The most important switch family is the CT83x-series. Latches, unipolar and omnipolar types with different switching fields are available. Most members of this family work internally in a pulsed mode and this leads to a current consumption down to 200 nA for some types, depending on the duty cycle.

However, TMR-sensors can also be used as analog sensors detecting the strength of the magnetic field as well. This allows to measure the distance between a magnet and the sensor. Current sensing is also possible with this technology because the electrical current always produces a magnetic field. Since this magnetic field decreases very strongly with the distance between the conducting wire and the sensor, the TMR-sensors are a good choice for simple current sensors due to their high sensitivity to small magnetic fields. There are special TMR current sensor devices available for closed-loop applications in which the sensor elements as well as the current path for compensating the external field are implemented. In a next step, the new CT400 will have an implemented current path for measuring currents from -10 to 10A or 0 to 50 A.

Typical applications for TMR sensors are low power assemblies like metering or general battery driven devices, where TMR-sensors could be used for detecting rotating wheels or controlling the positions of a flap. Current sensing will be more and more important for battery charging in consumer and automotive applications.

2.6.1 CT8XX: DIGITAL TMR LATCHES

Product description

The CT8xx product family of digital TMR latches based on Crocus' patented MLU™ technology is ideal for consumer and industrial markets. These latches offer superior sensing performance while having the industry's lowest power consumption that enables then to be used in a variety of applications. The digitial TMR latches are available in 3-lead SOT23 and 4-lead LGA packages.

Advantages

- Low current consumption
- High sensitivity
- High reliability

Applications

- Window and door sensors
- Reed switch replacement
- Motor controllers
- Tamper-proofi ng for utility meters
- Proximity detection

Features

- High Sensitivity: BOP/BRP = ±0.9 mT/±0.5 mT
- Low Current Consumption - As Low As 200 nA
- Digital CMOS Outputs:
  - Push-pull
  - Open Drain
- Supply Voltage: 2.7 V to 3.6 V
- Resistant to Mechanical Stress
- Low Profi le and Small Form Factor Packages
  - RoHS and Green Compliant

PART NUMBER	POLARITY	OUTPUT TYPE	BOP [mT]	BRP [mT]	I_{DD} [AVG] [nA]	$f_{SAMPLING}$ [HZ]	PACKAGE	OPERATING TEMPERATURE [°C]
Specifications								
CT831BV-HS3	Omnipolar	Open Drain	±3.0	±2.0	200	2	3-lead SOT23	-40 ... +125
CT831BV-IS3								-40 ... +85
CT832BV-HL1	Omnipolar	Push-pull	±3.0	±2.0	200	2	4-lead LGA	-40 ... +125
CT832BV-IL1								-40 ... +85
CT832BV-HS3	Omnipolar	Push-pull	±3.0	±2.0	200	2	3-lead SOT23	-40 ... +125
CT832BV-IS3								-40 ... +85
CT832SK-HS3	Omnipolar	Push-pull	±0.9	±0.5	230	10	3-lead SOT23	-40 ... +125
CT832SK-IS3								-40 ... +85
CT832SL-HS3	Omnipolar	Push-pull	±0.9	±0.5	1.400 µ	250	3-lead SOT23	-40 ... +125
CT832SL-IS3								-40 ... +85
CT832BL-HS3	Omnipolar	Push-pull	±3.0	±2.0	1.400 µ	250	3-lead SOT23	-40 ... +125
CT832BL-IS3								-40 ... +85
CT832DM-HS3	Omnipolar	Push-pull	±1.5	±1.0	1200 µ	2.5 k	3-lead SOT23	-40 ... +125
CT832DM-IS3								-40 ... +85
CT832BH-HL1	Omnipolar	Push-pull	±3.0	±2.0	1.600 m	10 k	4-lead LGA	-40 ... +125
CT832BH-IL1								-40 ... +85
CT832EK-HS3	Omnipolar	Push-pull	±7.0	±5.0	230	10	3-lead SOT23	-40 ... +125
CT832EK-IS3								-40 ... +85
CT852AN-HS3	Bipolar	Push-pull	+1.0	-1.0	2.600 µ	500	3-lead SOT23	-40 ... +125
CT852AN-IS3								-40 ... +85

2.6.2 CT834: ANALOG TMR SENSORS

Product description

The CT834 is an analog TMR sensor based on Crocus' patented MLU™ technology usable for consumer and industrial markets. This sensor offers high sensitivity performance to detect a wide range of magnetic fields and outputs the field level while having the industry's lowest power consumption that enables it to be used in a variety of applications.

The analog TMR sensor CT834 is packaged in a 3-lead SOT23 and 4-lead LGA package formats.

Advantages

- Low current consumption
- High sensitivity
- High reliability

PART NUMBER	OUTPUT TYPE	SENSITIVITY	MAGNETIC FIELD RANGE	I_{DD} [AV] [mA]	PACKAGE	OPERATING TEMPERATURE [°C]
Specifications						
CT834DR-IS3	Analog	200 mV/V/mT	±1.0 mT	1.5	3-lead SOT23	-40 ... +85
CT834DR-IL1					4-lead LGA	

Features

- High sensitivity: 200 mV/V/mT
- Low current consumption: 1.5 mA
- Analog output
  - Output voltage: 19 ... 81% of VDD
- Supply voltage: 2.7 ... 3.6 V
- Under-voltage lock-out
- Resistant to mechanical stress
- Low profile and small form factor packages
  - RoHS compliant

Applications

- Window and door sensors
- Medical devices
- PC laptops
- Fluid level sensors

2.6.3 CT100: CONTACTLESS CURRENT SENSOR

Product Description

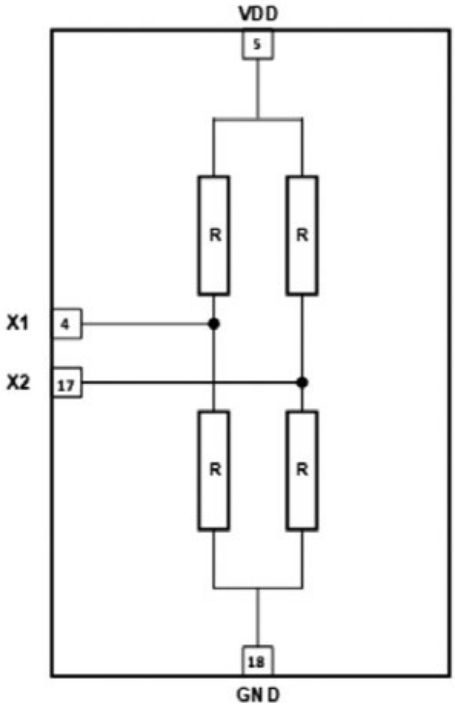
The CT100 is a linear contactless current sensor in full-bridge configuration from Crocus Technology developed on its patented MLUTM technology. It supports an operating voltage of 1.0 ... 5.5 V. The CT100 enables high accuracy current measurements for many consumer, enterprise and industrial applications. The CT100 is a non-intrusive current sensor that can be adapted to measure different current ranges.

Features

- High sensitivity
- Differential outputs
- Supply voltage: 1.0 ... 5.5 V
- Mass productiion: Q1/2019

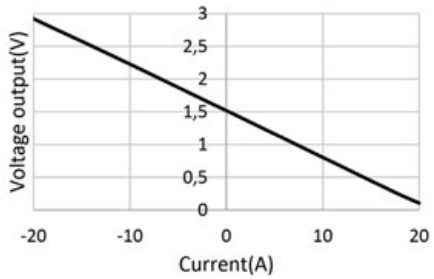
Applications

- UPS, SMPS and telecom power supplies
- Battery management systems
- Motor control
- White goods
- Power utility meters
- Over-current fault protection
- Induction cooking
- Renewable energy



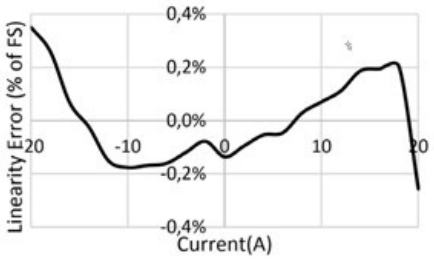
CT100: Block diagram (prelim.)

Volt vs Current



CT100: Linearity performance
Output voltage vs. current

Linearity Error



CT100: Linearity error vs. current

3. K-BAND RADAR TRANSCEIVERS

written by K. Mezger, RFbeam, St. Gallen, Switzerland

What does K-band mean? K-band stands for the radio frequency range of 18 ... 27 GHz. A portion of this range from 24 ... 24.250 GHz is a so called ISM (Industrial, Science and Medical) radio band. RFbeam sensors use the ISM K-band. The ISM K-band allows operating our sensors in nearly all countries worldwide.

What does "Radar transceiver" mean?

Transceivers are devices containing a transmitter and a receiver. RFbeam radar devices contain always a transmitter and at least one receiver in order to send an electromagnetic wave and to receive the echo of this wave. Radar transceivers are often simply called radar sensors.

Radar transceivers can be operated in different modes (Doppler, FMCW, FSK, ...) depending on the physical quantity that has to be detected, e. g. speed, distance, presence of objects.

What does Doppler sensor mean?

Doppler Radar is used to detect moving objects and evaluate their velocity. A reflective moving object in sight of the sensor generates a low frequency sine wave at the sensor output. The amplitude depends on the distance and the reflectivity of the moving objects. The output frequency is proportional to the object speed: 158 Hz per m/s or 44 Hz per km/h for a radial moving object. Some RFbeam sensors are "stereo" sensors with 2 outputs, called I (In phase) and Q (Quadrature). These sensors allow detecting the moving direction (approaching, receding).

About Doppler radar

A more precise title would be, "CW (Continuous Wave) Doppler Radar", when using RFbeam radar sensors. These sensors do not produce pulses, but send continuously in the K-band (24.125 GHz).

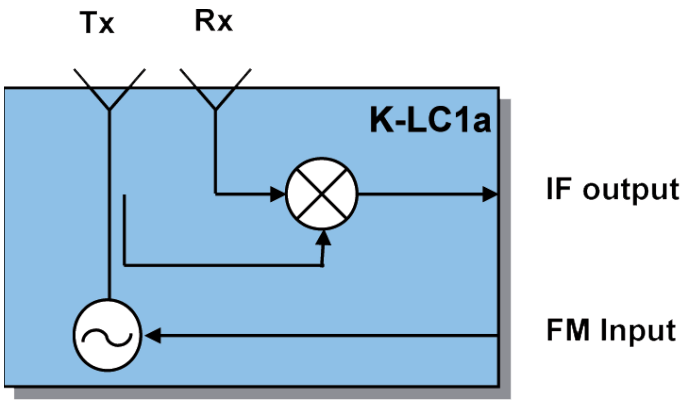


Fig. 1 - Typical radar transceiver

RFbeam radar transceivers (Fig. 1) return a so called IF signal, that is a mix-product of the transmitted (Tx) and the received (Rx) frequency. A moving object generates a slightly higher or lower frequency at the receiver. The IF signal is the absolute value of the difference between transmitted and received frequency. These transceivers operate in the CW (Continuous Wave) mode as opposed to the pulse radars, that measure time of flight. CW radars can operate with very low transmitting power (< 20 dBm resp. 100 mW).

Calculating the Doppler frequency

$$f_d = \frac{2 \cdot f_{Tx} \cdot v}{c_0} \cdot \cos \alpha \quad (1)$$

or

$$v = \frac{c_0 \cdot f_d}{2 \cdot f_{Tx} \cdot \cos \alpha} \quad (2)$$

f_d = Doppler frequency
f_{Tx} = Transmitting frequency (24 GHz)
c_0 = Speed of light (3×10^8 m/s)
v = Object speed in m/s
α = Angle between beam and object moving direction (see Fig. 2)

At a transmitting frequency of f_{Tx}= 24 GHz we get a Doppler frequency for a moving object at the IF output of

$$f_d = v \frac{44 \text{ Hz}}{\text{km/h}} \cdot \cos \alpha \, .$$

The angle α reduces the measured speed by a factor of cos α. This angle varies with the distance of the object. To evaluate the correct speed, you need a trigger criteria at a known point. This can be accomplished by measuring the distance with the radar sensor (e.g. using FSK technology) or by measuring the angle using a monopulse radar such as K-MC4.

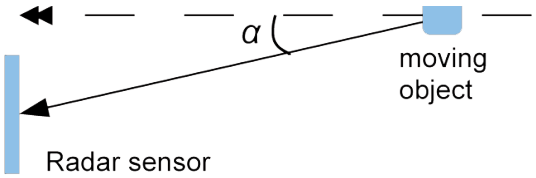


Fig. 2 – Definition of angle a

About FMCW

FMCW stands for Frequency Modulated Continuous Wave. This technique allows the detection of stationary objects. FMCW needs radar sensors with an FM input. This input accepts a voltage that causes a frequency change. There are also sensors with digital frequency control based on digital PLL designs. Modulation depth is normally a very small amount of the carrier frequency. In the K-band most countries allow a maximum frequency range of 250 MHz. Description of many effects such as velocity-range unambiguities go beyond the scope of this paper. Please refer to radar literature for more detailed explanations.

Triangle modulation

The transmitting frequency is modulated by a linear up and down ramp. Figs. 3a+3b show a typical signal f_{Rx} returned by stationary and constantly moving objects. Note, that the difference frequency f_b is constant throughout nearly the whole ramp up time. At the output of the radar transceiver we get a low frequency signal f_b called beat frequency. This is the result of mixing (=multiplying) transmitted and received frequencies.

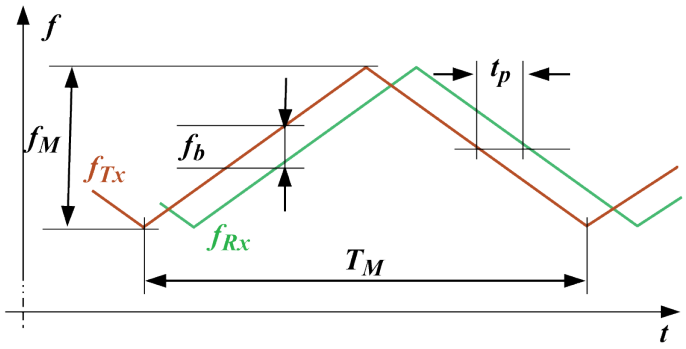


Fig. 3a – Triangle modulation – stationary object

Returned echo from stationary object

f_M	Modulation depth
T_M	Modulation period
f_{Tx}	Transmitted frequency
f_{Rx}	Received frequency
t_p	Signal propagation time (time of flight)
f_b	Beat frequency f_{Tx} - f_{Rx}
f_d	Doppler frequency

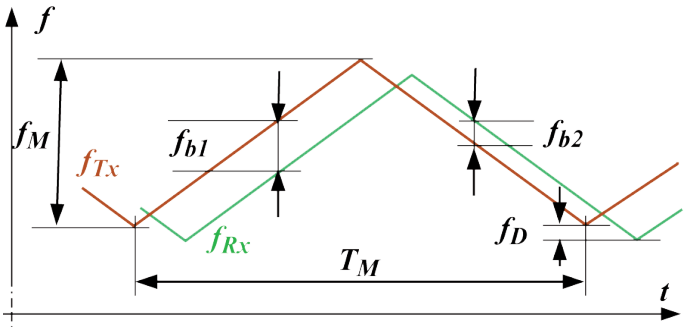


Fig. 3b – Triangle modulation – moving object

Returned echo from moving object

The received frequency f_{Rx} is shifted by f_d. This is the Doppler frequency caused by a receding object moving at a constant speed.

By measuring during up and down ramp, the Doppler frequency f_d is the diffence between f_{b1} and f_{b2}.

Distance can be calculated as follows

$$R = \frac{c_0}{2} \cdot \frac{f_b}{f_M} \cdot \frac{T_M}{2}$$

For legend refer to Fig. 3a

R = Range, distance to target

c_0 = Speed of light (3×10^8 m/s)

Maximum unambiguous range

$$R_{max} = \frac{c_0}{2} \cdot \frac{T_M}{2}$$

For legend refer to Fig. 3a
R_{max} = Max. unambiguous target distance
c_0 = Speed of light (3×10^8 m/s)

Distance and resolution

In K-Band (24 GHz), the maximum allowed frequency modulation depth f_M is <250 MHz. We also have to take in account tolerances and temperature influences. This limits the usable frequency shift f_M to typically 150 MHz.

For measuring f_b to evaluate distance we need at least one period of f_b during T_M, the range resolution is limited to

$$R_{min} = \frac{c_0}{2 \cdot f_M} = \frac{3^8 \text{ m/s}}{2 \cdot 250 \text{ MHz}} = 0.6 \text{ m}$$

This is a theoretical value, because we have to consider drifts and tolerances in order to stay in the allowed frequency band. Working with the more realistic value of f_M = 150 MHz, we get a minimum distance and resolution of R = 1 m.
Resolution may be enhanced by using phase conditions, correlation and other sophisticated algorithms.

About FSK mode

FSK stands for Frequency Shift Keying. FSK uses two discrete carrier frequencies f_a and f_b, (Fig. 4) while FMCW uses linear ramps.

For each carrier frequency, separate IF signals must be sampled in order to get 2 buffers for separate FFT processing. Due to the very small step f_a-f_b a moving target will appear nearly with the same Doppler frequency at both carriers, but with a different phase (Fig. 5). Phase shift due to the modulation timing and sampling must also be taken into account.

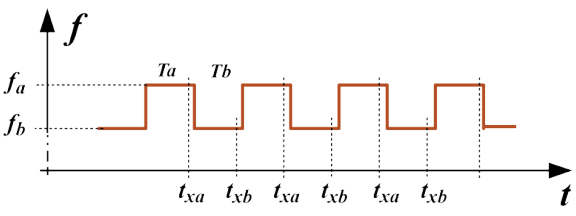


Fig. 4 - FSK modulation scheme

f_a Carrier Frequency a
f_b Carrier Frequency b
t_{xa} Sampling point for Doppler a
t_{xb} Sampling point for Doppler b

Switching must be performed at a sampling rate high enough to meeting the Nyquist criteria for the Doppler signal acquisition.

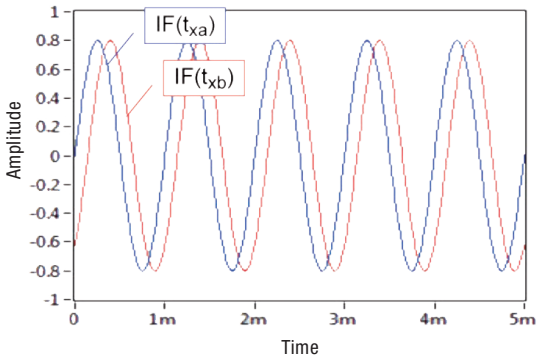


Fig. 5 - Resulting Doppler frequencies

$IF(t_{xa})$ Sensor output signal at carrier frequency f_a
$IF(t_{xb})$ Sensor output signal at carrier frequency f_b

Doppler signals of the same moving target have thesame frequency, but are phase shifted by $\Delta\varphi$.
For both IF signals, phase must be determined at the spectral peak of the object.

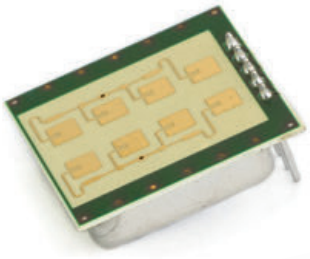
$$R = \frac{c_0 \cdot \Delta\varphi}{4\pi \cdot (f_a - f_b)}$$

$\Delta\varphi$ = Phase shift of $IF(t_{xa})$ and $IF(t_{xb})$

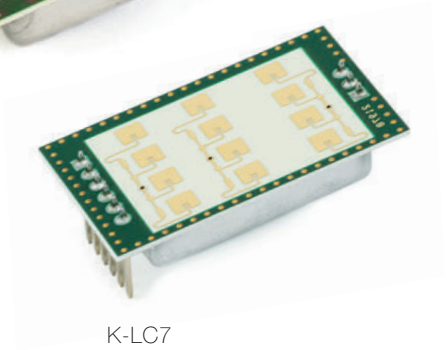
The smaller the frequency step, the higher the maximum range. To achieve an unambigous distance range of 150 m, a frequency step of 1MHz is required.

Remarks

- FSK can only be used for moving objects
- Multiple objects at different speeds may be detected
- Distance resolution depends mainly on signal processing and is not limited by the carrier bandwidth limitations
- FSK has the advantage of simple modulation and does not suffer from linearity problems
- VCO signal generation is simple, but sampling and phase measurement is challenging

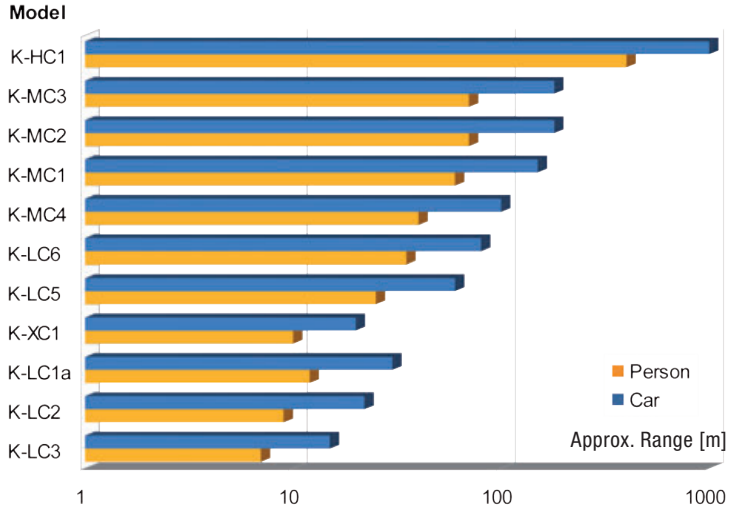


K-LC1a



K-LC7

Selection by detection range



PART NUMBER	TYP. DETECT. RANGE PERSON [m] (1)	TYP. DETECT. RANGE CAR [m]	HORIZ. -3 dB BEAMWIDTH / E-PLANE [°]	VERT. -3 dB BEAMWIDTH / H-PLANE [°]	VCO	OUTPUT I/Q (2)	IF AMPLIFIER	SUPPLY VOLTAGE [VDC]	SUPPLY CURRENT [mA]	INTEGRATED SIGNAL PROCESSING	SIZE [mm x mm x mm]
Selection by parameters											
K-LC3	7	15	138	132				5	35		25 × 25 × 7
K-LC3_V2	7	15	138	132				3.3	35		25 × 25 × 7
K-LC4	7	15	138	132	✓	✓		5	35		25 × 25 × 7
K-XC1_Ant	8	15	25	12	✓	✓	✓	12 … 24	300	✓	89 × 77 × 19
K-LC2	12	30	80	34	✓	✓		5	35		25 × 25 × 7
K-LC1a	12	30	80	34	✓			5	35		25 × 25 × 7
K-LC1a_V2	12	30	80	34				5	35		25 × 25 × 7
K-LC1a_V4	12	30	80	34	✓			3.3	35		25 × 25 × 7
K-LC1a_V5	12	30	80	34				3.3	35		25 × 25 × 7
K-LC7	12	30	80	34	✓	✓✓		3.3 … 5	75		38 × 25 × 7
K-LD2	15	30	80	34		✓		3.3 … 5	55	✓	25 × 25 × 7
K-LC5	25	60	80	34	✓	✓		5	50		25 × 25 × 7
K-LC5_V2	25	60	80	34		✓		5	50		25 × 25 × 7
K-LC5_V3	25	60	80	34	✓	✓		3.3	50		26 × 25 × 7
K-LC6	35	80	80	12	✓	✓		5	50		66 × 25 × 7
K-LC6_V2	35	80	80	12	✓	✓	✓	5	50		66 × 25 × 7
K-MC4	40	100	30	12	✓	✓✓	✓	5	140 / 5		78 × 78 × 7
K-MC1	60	150	25	12	✓	✓	✓	5	70 / 7		65 × 65 × 7
K-MC1_LP	60	150	25	12		✓	✓	3.3 … 5	8		65 × 65 × 7
K-MC3	70	180	25	7	✓	✓	✓	5	70 / 7		105 × 85 × 7
K-MD2	100	200	30	21	✓	✓✓✓		12	550	✓	120 × 72 × 17
K-HC1	400	1000	25	12		✓	✓	15 … 30	220		110 × 77 × 21

(1) - values with simple comparator detector, (2) ✓ - 2 Channels, ✓✓ - 4 Channels, ✓✓✓ - 6 Channels
Above are indicative values only and cannot be guaranteed. Range depends on many parameters like size of object, direction of movement and data processing method.

ST100 Starter kit, ST200 evaluation system and RSP1/K-LD2 evaluation kit

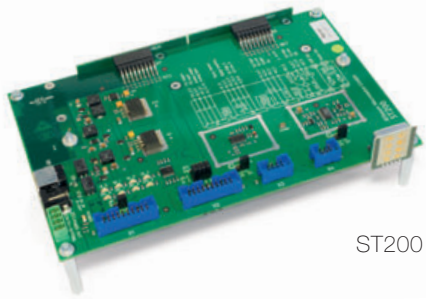
These kits allow to learn radar basics and evaluating radar technology for your specific application. STxxx kits can save a lot of initial time and money in order to get first radar experience. While ST100 and ST200 allow signal analysis in more detail, RSP1 and K-LD2 Evaluation Kits are oriented on practical implementation of movement sensors.

Scope of delivery

- **ST100 Starter kit** is including board, K-LC1a, USB cable, signalViewer software
- **ST200 high performance evaluation system** is including board, K-LC1, K-LC2, K-MC1, USB cable, signal explorer software
- **RSP1 evaluation kit** is including board, K-LC1a, K-LC2, K-LC3, K-LC5, K-LC6, USB-cable, RSP_Scope and RSP_Terminal software
- **K-LD2 evaluation kit** is including board, K-LD2, USB-cable, powerful control panel software & documentation on USB-stick

K-LD2 EVAL

ST100



ST200

PURPOSE	ST100	ST200	RSP1 EVAL / K-LD2 EVAL	COMMENTS
ST100 Starter kit vs. ST200 evaluation system vs RSP1/K-LD2 Evaluation kit				
Learning Doppler basics	✓	✓	✓	
Exploring Doppler sensors	✓	✓	✓	
Developing movement sensors	✓	✓	✓	
Analyzing Doppler frequency spectra	✓	✓	✓	
Working with complex FFT and I/Q sensors	✓	✓	✓	Important for separating multiple objects, suppressing interferences etc.
Recording and playback of Doppler signals	✓	✓		
Analog output of recorded Doppler signals	✓			Very helpful for analyzing real world signals in the laboratory
Exploring FSK ranging		✓		Ranging of moving objects
Exploring FMCW ranging		✓		Ranging of moving and stationary objects
Exploring monopulse principle		✓		Detect direction angle of moving objects
Suppression of false triggering			✓	

3.3 RADAR DOPPLER SIGNAL PROCESSOR RSP1

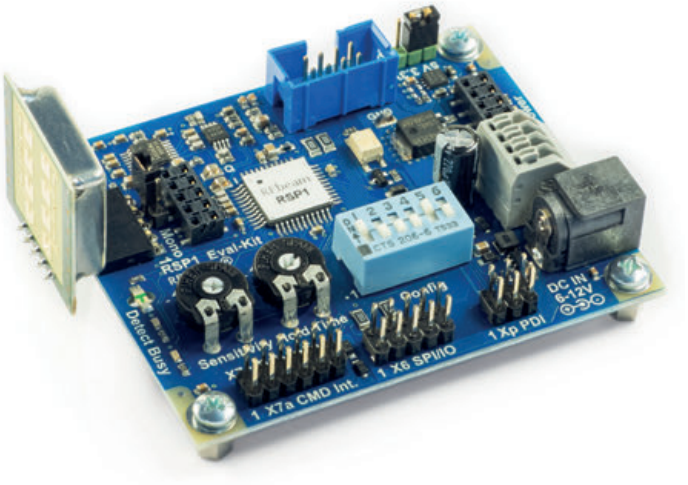
RFbeam

Radar signal processing chip RSP1

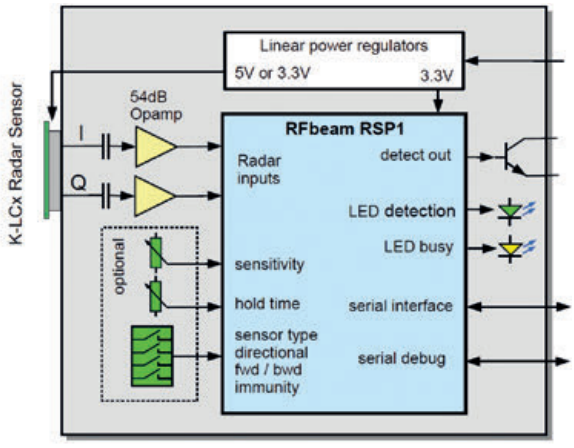
RSP1 is a new microcontroller, which is designed for a smart evaluation of output signals of radar transceivers operating in the Doppler-mode. Speed and presence of moving objects will be detected.

Features

- Universal Doppler radar signal processor
- Complete I/Q radar sensor interface
- Double detection distance compared to traditional solutions
- Object speed and direction detection
- Complex FFT based signal processing
- Efficient adaptive interference suppression
- Inherent object speed detection up to 200 km/h
- Stand-alone or hosted operation
- Serial interfaces to host processor
- Reference design and evaluation board available



Evaluation board for RSP1



RSP1 Typical Application

Stand-alone application circuitry

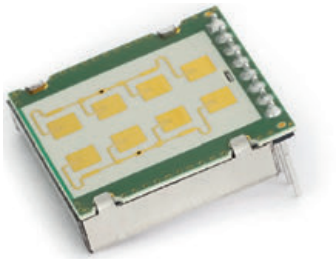
Key Data

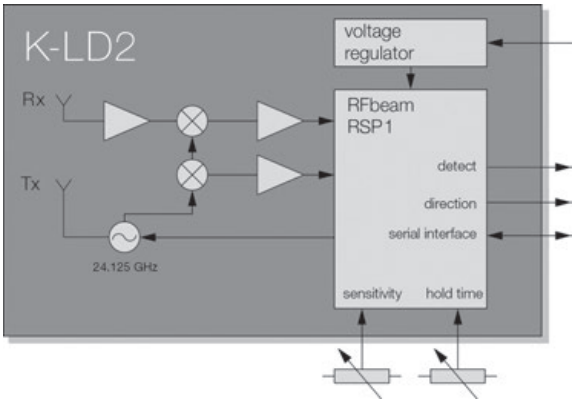
- 12 bit ADC
- Differential analog inputs for I and Q signals
- Internal programmable gain amplifier
- Sampling rates from 1280 Hz ... 22.5 kHz
- Efficient 256 pt complex FFT
- Logarithmic detection algorithms
- Adaptive noise and interference analysis and canceling algorithms
- Serial command and debug/streaming interfaces
- Highly configurable by serial interface and/or digital and analog inputs
- Application settings can be down- and uploaded from chip
- Sophisticated serial outputs like peak magnitude, frequency and sign, noise level and many more

3.4 K-LD2 RADAR TRANSCEIVER

The K-LD2 is an easy to use 2 × 4 patch Doppler module with an asymmetrical beam for low cost short distance applications. This transceiver includes a RFbeam RSP1 signal processor and all necessary circuitry. It outputs a detection signal and also the direction of the movement. Important parameters can be adjusted with external potentiometers. Object speed can be measured using the integrated serial connection.

There is no need to write own signal processing algorithms or handle small and noisy signals. This module contains everything what is necessary to build a simple but reliable movement detector. An extremely slim construction with a thickness of 6 mm depth gives you maximum flexibility in your equipment design. A powerful starter kit with signal visualization on the PC is available.





Applications

- General movement detection applications
- Door opener
- Indoor and outdoor lighting control applications
- Object speed measurement systems
- Industrial sensors

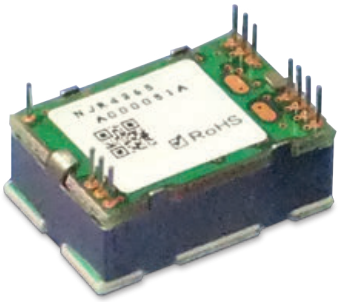
Features

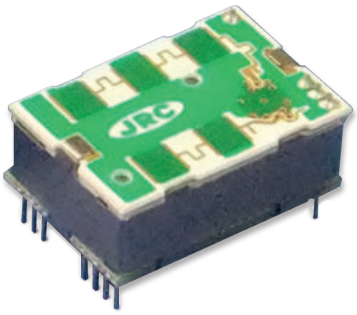
- 24 GHz miniature I/Q transceiver
- Integrated FFT signal processing with digital output
- Low cost design
- Digital outputs for detection and direction
- Sensitivity and hold time can be set using analog inputs
- Additional configuration with serial input possible
- 2 × 4 patch antenna with 80 °/ 34 ° beam aperture
- 25 × 25 mm² surface, thickness < 6.5 mm

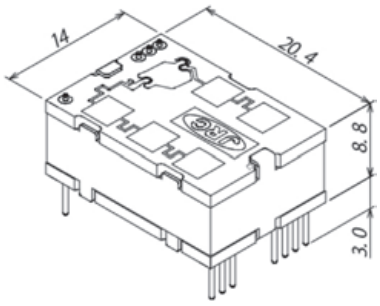
PARAMETER	CONDITIONS / NOTES	SYMBOL	MIN	TYP	MAX	UNIT
OPERATING CONDITIONS						
Supply voltage		V_{CC}	3.15		6.0	V
Supply current		I_{CC}		55		mA
Operating temperature		T_{op}	-20		+85	°C
Storage temperature		T_{st}	-20		+105	°C
SIGNAL PROCESSING						
Velocity processing			256 point FFT			
Sample rate		f_{sample}	1.28		22.5	kHz
Speed range	Depending on sampling frequency	r_{speed}	0		255	km/h
Response time	Depending on sampling frequency	t_{detect}		100		ms

3.5 MOTION SENSOR NJR4265R

Intelligent K-Band Doppler module







NJR4265R is an intelligent motion sensor that is designed for the sensing of short distance low speed moving objects like pedestrians etc. The steady sensing of a moving object is realized by embedded software. The sensor is suitable for the built-in use of the sensing function to various equipments since all functions are integrated in a small package. The NJR4265R can easily be controled from PC/ MCU by UART interface. Furthermore, stand alone operation is also possible.

Features

- Motion sensor based on 24 GHz Microwave Doppler effect
- Antenna, RF circuit, IF amp, MCU and voltage regulator are integrated in a small package (14 × 20.4 × 8.8 mm)
- Signal processing software for the steady sensing
- Enhancing signal from movement object and decreasing random noises
- Decreasing mutual interference between sensors
- Identification of moving direction (approaching and leaving)
- Low voltage operation and low power consumption
- In compliance with EC directive (CE Marking) and FCC certification

Applications

- Energy saving equipment (lighting equipment, air conditioner etc.)
- Room access control system equipment
- Human detection sensor for various devices

Sensing performance

- Speed range of target: 0.25 ... 1 m/s
- Max. distance in the front: 10 m
- Detection angle: ±35°

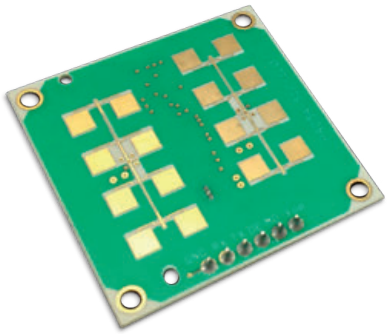
Environmental characteristics

- Operating temp. range: -20°C ... +60°C
- Storage temp. range: -40°C ... +80°C
- Humidity: 0-95% at +30°C

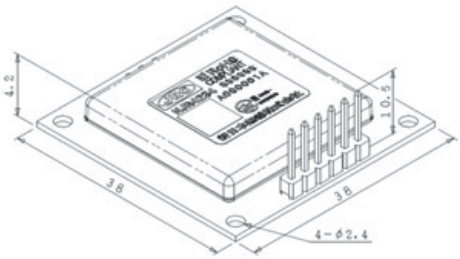
PART NUMBER	FREQUENCY	REGION
Product line-up		
NJR4265RJ1C1	24.05 ... 24.25 GHz	Japan
NJR4265RF1C1	24.05 ... 24.25 GHz	EU except specific regions
NJR4265RF2C1 [1]	24.15 ... 24.25 GHz	All of EU regions
NJR4265RF3C1	24.075 ... 24.175 GHz	United States

[1] - preferential model

3.6 DISTANCE MEASUREMENT SENSOR NJR4234B



Front view



Intelligent K-Band middle distance measurement sensor module for moving objects

NJR4234B is a sensor module that measures the distance of stationary and moving objects such as a pedestrian up to 30 m ahead. It incorporates a 24 GHz band microwave circuit, antenna and signal processing circuit in a low profile package of 38 mm x 38 mm x 4.2 mm. As a sensor capable of distance measurement using microwave, it detects moving objects by innovative proprietary signal processing and contains the function to calculate and output the distance to the objects in indoor and outdoor environments.

Furthermore, it has the unique algorithm to prevent radio interference, and to use multiple sensors in the same location. It can be used as a sensor front end with built-in primary signal processing for distance measurement. Due to the easy connection to other equipment via the UART interface, it can be used in a wide range of applications.

Features

- 24 Ghz microwave distance measurement sensor for moving objects
- Antenna, microwave RF circuit, base-band IF circuit, MCU and also signal processing are integrated in low-profile package (38 mm x 38 mm x 4.2 mm)
- Low-power-consumption
- High sensitivity mobile object detection (patented technology)
- Distance measurement signal processing
- Automatic calibration and gain control
- Radio interference prevention
- UART interface and digital CMOS output

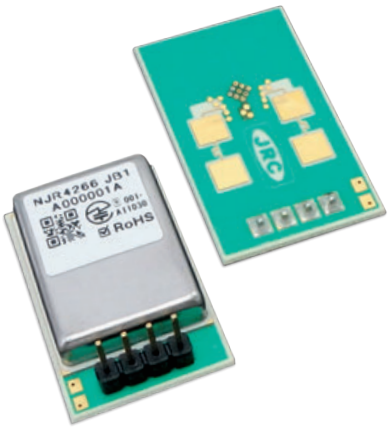
Applications

- Various equipment controlled by moving objects detection and distance measurement
- Security equipment
- Traffic control system
- Industrial drones
- Parking management system

PART NUMBER	CENTER FREQUENCY	REGION	MOVING OBJECT	STATIONARY
Product Line-up				
NJR4234BVF1C1	24.05 ... 24.25 GHz	Japan [MIC Techn. Conf. ARIB STD-T73]	✓	
NJR4234BVF2C1 (1)	24.15 ... 24.25 GHz	All of EU regions [RED 2014/53/EU]	✓	
NJR4234BVF3C1	24.075 ... 24.175 GHz	United States [FCC Part 15.245]	✓	
NJR4234BWF1C1	24.05 ... 24.25 GHz	Japan [MIC Techn. Conf. ARIB STD-T73]	✓	✓
NJR4234BWF2C1 (1)	24.15 ... 24.25 GHz	All of EU regions [RED 2014/53/EU]	✓	✓
NJR4234BWF3C1	24.075 ... 24.175 GHz	United States [FCC Part 15.245]	✓	✓

(1) - preferential model

3.7 DOPPLER SENSOR MODULE SERIES NJR4266



Intelligent low speed K-band motion sensor for short distance

NJR4266 is an intelligent human motion sensor module series that can detect objects moving at low speed like a pedestrian in a short distance range (approx. 7 to 14 m). It incorporates a 24 GHz band microwave circuit, antenna, signal processing circuit and MCU in a low profile package of only 17.2 mm x 27.3 mm x 5.1 mm. Signal processing technology greatly reduces false detection ofo environmental noise and achieves stable detection results.

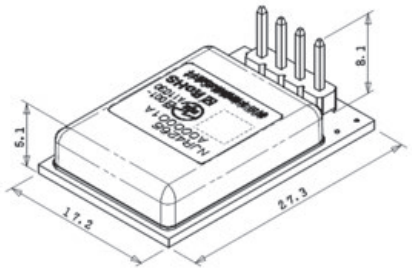
It also reduces power consumption by sensitivity setting. The NJR4266 series is available in multiple antenna versions so that the users can select the ideal detection angle best suitable for their specific application. Moreover, the user can select between UART and stand alone version (digital output / analog range setting) as interface type.

Features

- Motion sensor based on 24 Ghz microwave Doppler effect
- Antenna, microwave RF circuit, IF amplifier, MCU and voltage regulator are integrated in low-profile package (17.2 mm x 27.3 mm x 5.1 mm)
- Low power consumption (intermittent mode 1.9 mA min@3.3 V)
- Sleep mode for power reduction
- Decreasing mutual interference between sensors
- Available in 4 antenna versions to select the optimum detection angle
- Selectable between UART interface or digital output / analog sensitivity setting version
- UART interface version offers identification of direction (approaching and leaving) for moving objects

Applications

- Various control equipment by human sensing
- Lighting sensors
- Safety and Security equipment
- Energy saving management
- Entrance and exit management



PART NUMBER | CENTER FREQUENCY | REGION

Product Line-up		
NJR4266Jxx	24.05 ... 24.25 GHz	Japan [MIC Techn. Conf. ARIB STD-T73]
NJR42366F2xx	24.15 ... 24.25 GHz	All of EU regions [RED 2014/53/EU (CE Marking)]
NJR4266F3xx	24.075 ... 24.175 GHz	United States [FCC Part 15.245]

PART NUMBER | ANTENNA PATCH ARRAY | DETECTION RANGE | DETECTION ANGLE | INTERFACE

Ordering information				
NJR4266F2C1	TX/RX: 4 x 1	15 m	76°/ 32°	C1: UART
NJR4266F2C2	TX/RX: 4 x 1	15 m	76°/ 32°	C2: Analog Threshold / CMOS Output

Note: As 1x1 type, 4x1 type and 2x2 type are being developed, design values are listed for detection angle and detection distance.

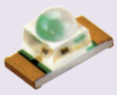
4.1 INFRARED-LED

EVERLIGHT

Infrared-LEDs are used as infrared light source for many optosensor applications. In most cases the emitted infrared beam is reflected or interrupted by barrier objects, and the presence of the object is detected by a phototransistor or photodiode. Very often, infrared LEDS are also used for optical data transmission.

Features

- Different types of housings
- All devices are available in optical wavelength 850 nm, 880 nm and 950 nm (most popular one)
- Emission angle 2φ between 10° and 160°
- Radiant intensity (in mW/sr)

SHAPE	PART NUMBER	DESCRIPTION	EMISSION ANGLE 2 φ [°]	EMISSION DIRECTION, u = up, d = down, s = side	RADIANT INTENSITY TYP. [mW/sr]
Specifications of IR-LEDs					
	IR204-A	ø 3 mm	35	u	5.6 @ 20 mA
	IR333-A	ø 5 mm	20	u	20 @ 20 mA
	IR908-7C	rectangular housing	60	s	n. a.
	IR19-21C/TR8	SMD size 0603	150	u	0.7 @ 20 mA
	IR11-21C/TR8	SMD 1206 with inner lens	100	u	1.6 @ 20 mA
	IR26-21C/L110/TR8	SMD with lens	20	u, d	3.5 @ 20 mA
	IR26-51C/L110/TR8	SMD with lens	20	s	3.5 @ 20 mA
	IR91-21C/TR7	SMD, with lens small angle	25	u, d	5 @ 20 mA

Many other types of housings and other parameters are available on request.

4.2 PHOTOTRANSISTORS

EVERLIGHT

In many simple optical sensor applications phototransistors are used as a detector for the infrared radiation which is emitted by the IR-LEDs. Phototransistors can be connected directly to a microcontroller and do not need any additional amplifier. This is, besides the low cost of phototransistors, one of the most important advantages compared to photodiodes.

Features

- Sensitive wavelength between 400 nm and 1100 nm without daylight filter
- Sensitive wavelength between 800 nm and 1100 nm with daylight filter
- Same housings available as for IR-LEDs
- Low cost

SHAPE	PART NUMBER WITHOUT DAYLIGHT FILTER	PART NUMBER WITH DAYLIGHT FILTER	DESCRIPTION	RISE/FALL TIME	SENSITIVITY DIRECTION, u = up, d = down, s = side	LIGHT CURRENT
Specifications of phototransistors						
	PT204-6C	PT204-6B	3 mm	15 µs	u	2 mA (typ.)
	PT333-3C	PT333-3B	5 mm	15 µs	u	3 mA (typ.)
	PT908-7C	PT908-7B	rectangular	15 µs	s	0.8 mA (min.)
	PT15-21C/TR8	PT15-21B/TR8	SMD size 1206	15 µs	u	0.3 mA (typ.)
	PT26-21C/TR8	PT26-21B/TR8	SMD size 1206 with lens	15 µs	u, d	2.6/1 mA (typ.)
	PT26-51C/TR8	PT26-51B/TR8	SMD with lens	15 µs	s	1 mA (typ.)
	PT91-21C/ TR7/9/10	PT91-21B/ TR7/9/10	SMD with lens	15 µs	u, d	1.5 mA (typ.)

Other types of housings and other parameters are available on request.

4.3 PHOTODIODES

EVERLIGHT JRC

Photodiodes are used to quantitatively measure the amount of light, whereas phototransistors are mainly used to distinguish whether the light level is above or below a certain threshold. The size of the photodiode chips is usually bigger than the size of phototransistor chips, which limits the number of housings available for SMD-photodiodes.

Features standard photodiodes

- Much faster response time than phototransistors
- Housings for down-view and side-view available
- Leaded types available on request

SHAPE	PART NUMBER WITHOUT DAYLIGHT FILTER	PART NUMBER WITH DAYLIGHT FILTER	DESCRIPTION	RISE/FALL TIME	SENSITIVITY DIRECTION, u = up, d = down, s = side	LIGHT CURRENT
Specifications of photodiodes						
	PD15-22C/TR8	PD15-22B/TR8	SMD size 2 mm × 2 mm	10 ns	u	6.5 µA (typ.)
	PD70-01C/TR7/10	PD70-01B/TR7/10	SMD size 3 mm × 3 mm	50 ns	u, d	25 µA (typ.)
	PD95-21C/TR7/10	PD95-21B/TR7/10	SMD with lens	6 ns	u, d	4 µA (typ.)
	PD12-21C/L458/TR8	PD12-21B/L458/TR8	SMD with lens 3 × 2 × 1 mm	6 ns	s	1.5 µA (typ.)

Photodiodes with special features

- High sensitivity for blue light
- High sensitivity
- Small package

PRODUCT	FUNCTION – RECEIVER	FUNCTION – RECEIVING LIGHT WAVELENGHT RANGE [nm]	FUNCTION – PEAK SENSITIVETY WAVELENGHT RANGE [nm]	FUNCTION – ACTIVE AREA [nm]	FUNCTION – OTHER	PACKAGE – COBP [nm]
Specifications						
NJL6401R-3	PD	350 ... 1000	800	0.7 x 0.7	Sensitivity 0.28A/W@405nm 0.42A/W@660nm 0.47A/W@780nm	1.2 x 1.7 x 0.8
NJL6402R-2	PD	350 ... 1000	800	1.0 x 1.0		1.6 x 2.4 x 0.8
NJL6407R	PD	350 ... 1000	800	1.3 x 2.0	Sensitivity from blue light to IR light	2.0 x 2.9 x 0.8
NJL6414R	PD	350 ... 1000	900	1.5 x 1.5		2.1 x 2.6 x 0.8
NJL6191R	PD	400 ... 1100	880	2.4 x 2.8	Sensitivity from visible light to IR light	3.5 x 5.0 x 1.5
NJL6193R-3	PD	400 ... 1000	850	0.7 x 0.7	Thin package	1.2 x 1.7 x 0.5
NJL6195R	PD	700 ... 1100	900	2.98 x 2.98	Sensitivity of IR range	3.55 x 3.95 x 0.8

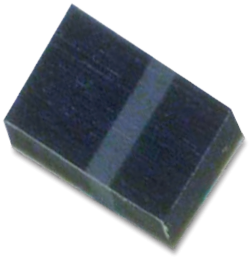
4.4 PHOTOREFLECTORS

Photoreflectors are very convenient to build optical switches. The emitted radiation of the infrared LED is reflected by an object and the reflected radiation is measured by a phototransistor. The decision, whether the object is present or not, can be made by comparing the photocurrent with a preset threshold value. To measure the distance of the objects is associated with some effort.

Features

- SMD: very small sizes available
- Leaded types are available on request
- Photoreflector with inner lens: long focal distance of 4 mm
- Easy mechanical implementation

NJL5909RL-4



NJL5901R-2

PRODUCT	PACKAGE SIZES [mm]	OUTPUT CURRENT [µA]	OPERATION DARK CURRENT [µA]
Specifications			
NJL5901AR	2.4 x 1.6 x 0.8	180 ... 450	2.0 max.
NJL5901AR-1	1.6 x 1.3 x 0.6	280 ... 700	5.0 max.
NJL5901R-2	1.4 x 1.0 x 0.6	165 ... 412	5.0 max.
NJL5902R	2.6 x 1.9 x 0.8	90 ... 250	0.2 max.
NJL5902R-1	2.0 x 1.6 x 0.6	160 ... 400	0.5 max.
NJL5902R-2	1.7 x 1.2 x 0.6	62 ... 155	0.5 max.
NJL5905R (Location detection type)	2.3 x 1.8 x 0.6	270 ... 675	0.5 max.
NJL5908AR (Thin package)	1.46 x 1.06 x 0.5	92 ... 230	2.0 max.
NJL5909RL-4 (Long focal: 4 mm)	2.6 x 1.9 x 1.6	35 ... 175	0.2 max.
NJL5911R (Thin package)	1.66 x 1.24 x 0.35	42 ... 105	5.0 max.
■ Digital output type			
NJL5820R (Rotation detection type)	2.6 x 2.5 x 0.8	2 Phase digital output (50.8 LP)	

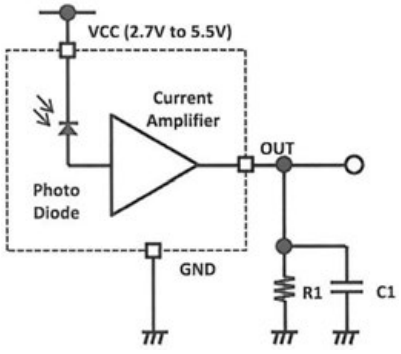
4.5 AMBIENT LIGHT SENSORS

Standard silicon phototransistors and photodiodes are sensitive for radiation with wavelengths between 400 and 1100 nm. Especially in the infrared range between 800 and 1100nm the sensitivity of silicon devices are quite high compared to the sensitivity in the visible range between 400 and 800 nm. As a consequence such detectors output a relatively high signal under twilight condition, because in this case there is much more infrared radiation present than visible light. This renders the standard silicon photodetectors unusable as (visible) light sensors. Ambient light sensors are optical sensors (photodiodes, phototransistors or photo-ICs) which show a very similar sensitivity spectrum compared to the human eye.
This ensures that the signal of the ambient light sensor correlates with the subjective impression of the human eye.

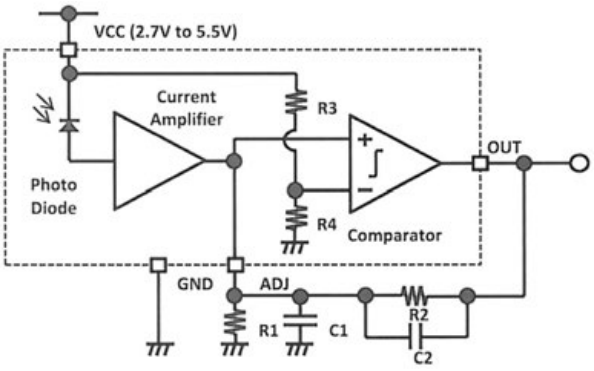
Features

- Faster response time than phototransistors
- SMD: very small sizes available
- Leaded types are available on request
- Photo-IC: with internal amplifier (NJL3301FV1) and comparator available (NJL3302FV1)

PRODUCT TYPE	PRODUCT	PHOTOCURRENT [µA] @EV=1,000 LUX, WHITE LED	HALF ANGLE [deg.]	PACKAGE
Specifications				
Photo diode	NJL6502R-1	0.42	–	COBP (1.7 x 1.2 x 0.8 mm)
Photo transistor	NJL7502R	45	+/-60	COBP (1.8 x 1.3 x 0.65 mm)
	NJL7502L	330	+/-20	Lead pin type (3ϕ)
	NJL7302L-F3	2000	+/-55	Lead pin flat lens (3ϕ)
	NJL7302L-F5	2000	+/-45	Lead pin flat lens (5ϕ)
Photo IC	NJL3301FV1	1000	+/-40	PLCC (5.0 x 5.3 x 0.95 mm)
	NJL3302FV1	–	+/-40	



NJL3301FV1 with amplifier



NJL3302FV1 threshold setting by external resistors

Pyrosensors were used in the past as detectors for non-contact temperature measurement. The basic principle behind this is the fact, that a black, solid body with temperature T emits electromagnetic radiation with an energy distribution that depends only on the temperature of the body. The wavelength where the energy distribution shows a maximum, is given by λ_{max} (unit µm)= 2899 / T(unit K). For a human body with a temperature of 37°C the emitted radiation has its maximum at a wavelength of 9.4 µm.

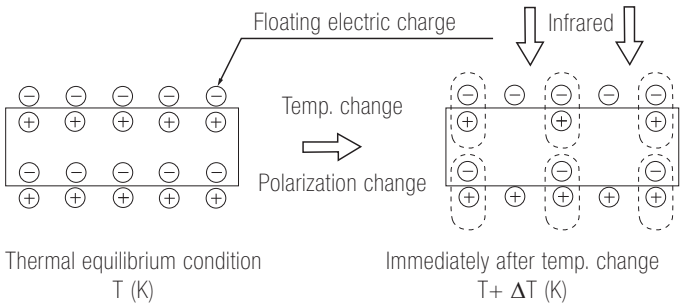
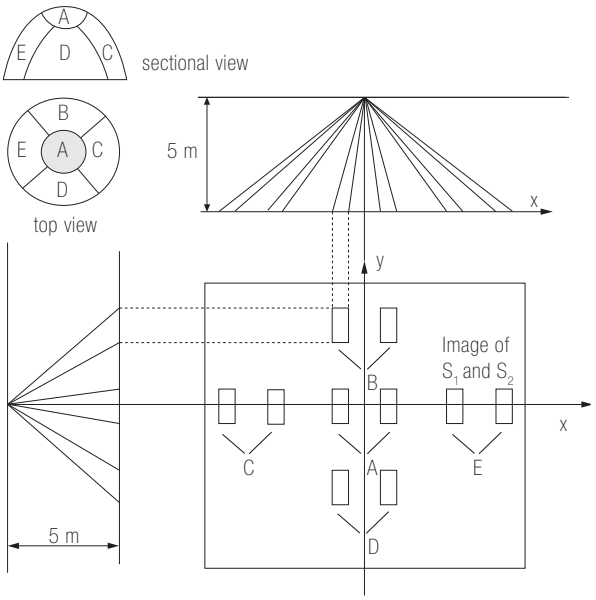


Fig. 1 - Pyroelectric principle

In the last years it became very popular to use pyrosensors to detect the presence (or more precise the movement) of a human body. These sensors consist of two or four pyroelectric elements in a hermetic housing with a silicon window which is transparent in the range of 5 to 10 µm. The pyroelectric elements show ferroelectric behaviour and are characterized by some permanent electrical polarization on the surface of the elements, see Fig.1. However, the polarization is not detectable because the surface charges are compensated by some charged ions in the environment of the surface. If infrared radiation hits the pyroelectric elements their temperature increases by a very small amount. Due to the thermal expansion, the crystal structure has to rearrange and thus the polarization on the surface of the elements changes. This change in polarization can be detected by electrodes on the top and bottom side of the pyroelectric elements. The electrical charge necessary to compensate the change in electrical polarization is detected and amplified by an internal FET, see Fig.3. Each temperature change of the elements leads to a short spike in the output signal of the FET which is used to detect the presence of a human body. The changes in polarization are very small and therefore it is necessary that the changes are fast enough in order to be detectable by the FET.

As a consequence, only moving infrared emitting sources can be detected. In order to cancel false signals due to temperature change of the environment there are at least two pyroelectric elements connected in series with antiparallel polarization (Fig. 3).

For movement sensors usually a Fresnel lens (sometimes also a mirror) is used to focus the infrared radiation onto the detecting elements of the pyrosensor. In most cases the Fresnel lenses are divided into several zones and each zone acts as a separate lens. As soon as the infrared radiation source starts to move there are many images of the infrared source in the plane of the sensing elements which pass the pyroelectric element. Each time one of the images passes the elements a spike in output voltage is created. The more zones the lens has, the more



Field of view pattern for a lens with 5 zones A ...E in a distance of 5 m (pyrosensor with two elements S_1 and S_2)

Fig. 2 - Field of view pattern

NICERA lenses	TYPE	ZONE	TOTAL HEIGHT [mm]	TOTAL DIAMETER [mm]	RECOMENDED MOUNTING	ANGLE
NCL-10(S) (1)	1	9.5	10.4	wall/ceiling	19°
NCL-10(IL) (1)	3	9.5	10.4	wall	90°
NCL-3(B) (1)	4	8.65	10.4	wall/ceiling	61°
NCL-3(R) (1)	7	8.65	10.4	wall/ceiling	90°
NCL-8 (1)	9	10.0	14.8	ceiling	100°
NCL-9(S) (1)	1	14.45	17.0	wall/ceiling	16°
NCL-9(10) (1)	10	11.5	17.0	wall	120°
NCL-9(26) (1)	26	12.37	17.0	ceiling	100°
NCL-11 (2)	16	12.7	23.0 x 11.0	wall	105°
SAA-Pe.cover lens-4 (2)	16	12.0	24.0 x 15.0	wall	110°
NCL-13 (2)	20	15.75	24.2	wall	100°
NL-11 (2)	17	17.2	24.0	wall/ceiling	107°
SL-7512 (3)	12	16.3	15.7	ceiling	110°
NCL-14 (2)	18	15.0	22.7 x 15.0	wall	120°

(1) = Cap style; (2) = PCB catch style; (3) = PCB catch style, sensor has be to set on a spacer

images are created. This makes it possible to detect even slowly moving objects. To describe the optical properties of a Fresnel lens it is convenient to look at the field of view pattern, see Fig. 2. In this drawing the sensing elements are facing to the plane of the moving object. The rectangular images of the two sensor elements created by the 5 zones of the lens are shown in a plane at a distance of z=5 m from the sensor. Whenever an object is moving from one rectangular area to its neighbouring area, the sensor will detect the moving object. If the object is moving only in the x-direction (e.g. for wall mounted pyrosensor modules) a pyrosensor with two elements is sufficient. If the object is moving in x- and y-direction (e.g. for ceiling mounting of the sensor module) a four element pyrosensor is recommended.

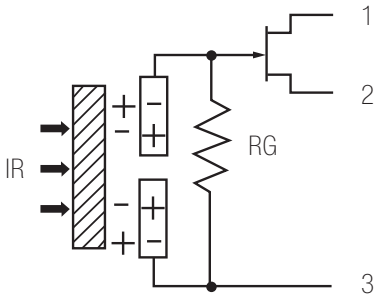
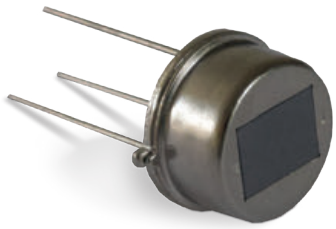


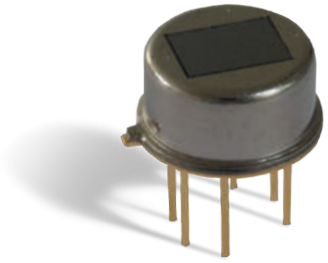
Fig. 3 - Equivalent circuit

Other pyrosensors, pyrosensor modules and lenses are available on request

4.7 DIGITAL PYROSENSORS

NiCeRa





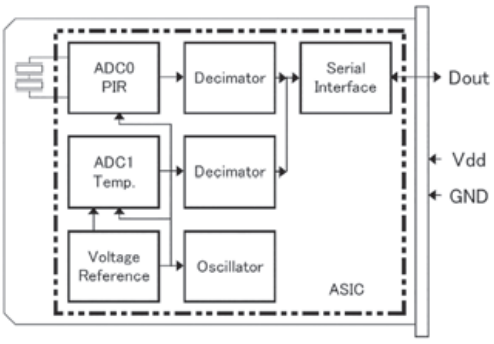
The new generation of pyrosensors contains the pyroelectric elements, amplifier and a microcontroller chip inside the same housing. The signals generated by the pyrosensor elements are converted into a digital signal. These pyrosensors are therefore called digital pyrosensors. Their main advantages are an easy signal evaluation with only a few external devices and a high immunity to electromagnetic interference (EMI).

There are two different types of digital pyrosensors available

PSH3-323-36AA: Communication type

This type communicates with a host controller by a one-wire interface (via Dout-pin). The IR signal of the two pyroelectric elements as well as the temperature data of a built-in temperature reference are transferred with a resolution of 14 bit. The PSH3-323-36AA is assembled in a TO5-housing.

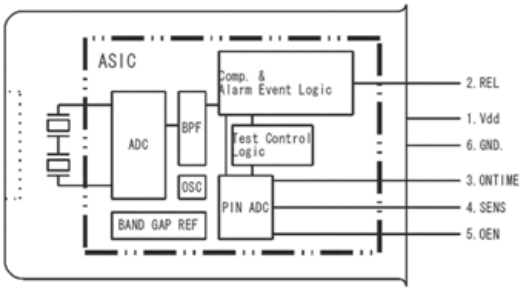
PSH3-323-36AA



PSH2-323-66AA: "all-inclusive"- type

This type includes all the electronics of a movement detector in one housing. The signal of the pyroelectric elements is converted into a digital signal and processed by some internal logic. It may communicate with a host controller, but the device can also be used as "stand-alone" with the ouput signal at pin 2 driving an amplifier with e.g. relay-output. The sensitivity and hold time are fixed by an appropriate voltage divider at the SENS and ONTIME pin. There are also types available with fixed values for the sensitivity and hold time and types with four pyroelectric elements.

PSH2-323-66AA



Applications

- Intrusion alarm
- Automatic light switching
- Automatic backlight control of LCD panels
- Door opener

4.8 SUMMARY PYROSENSORS

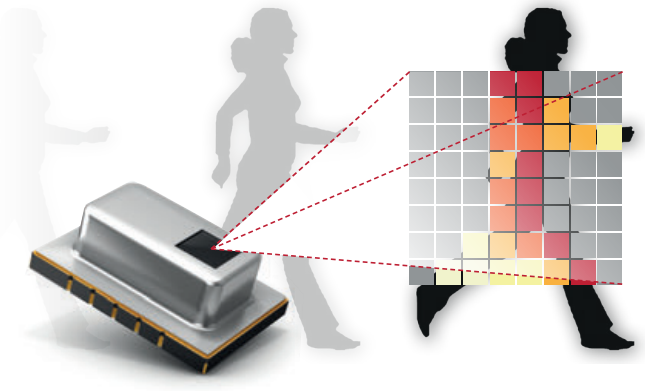
MODEL	COMMENTS	EMC	AMPLIFIED SIGNAL OUTPUT VP-P	FIELD OF VIEW [DEG.]	BALANCE OUTPUT [%]	NOISE OUTPUT MVP-P
NICERA Pyrosensors						
RE200G	General, low cost, low noise	Good	3,3	138	15	70
RE200GE	General, low cost, low voltage	Good	3,3	138	15	90
SBG323-671	Standard,low noise,wide window	Good	4.0	134	10	70
SBG323-611	Standard, low voltage, wide window	Good	4.0	134	10	90
SBG342-671	High sensitivity	Good	5,8	134	15	100
SFG323-671	High security, excellent EMC, low noise	Excellent	3,5	134	10	70
SBA02L2-81RC2-P	Low profile, TO-39	Good	3,4	159	15	90
SBG446-671	Quad element for ceiling	Good	6,5	132	15	120
Special types						
SFG323-771	low noise	Good	3,8	134	10	70
SBG323-711	high output voltage, high sensitivity	Good	5,5	134	10	90
Built-In amplifire						
SW-IVC-15G	High speed response, low cost	Fair	0,005	134	n/a	n/a
SW-ULP23-20	Ultra low power consumption	Fair	1,5	134	n/a	160

DIGITAL PYROSENSORS MODEL	COMMENTS	EMI	SIGNAL OUTPUT AMPLIFIED VP-P	FIELD OF VIEW [DEG.]	BALANCE OUTPUT [%]	OUTPUT
NICERA Pyrosensors						
PSH3-323-36AA	digital communication	Fair	n/a	134	n/a	digital communication
PSH2-323-66AA	digital motion sensor	Good	n/a	134	n/a	switching output
PSH2-446-3	digital motion sensor, four elements	Good	n/a	132	n/a	switching output

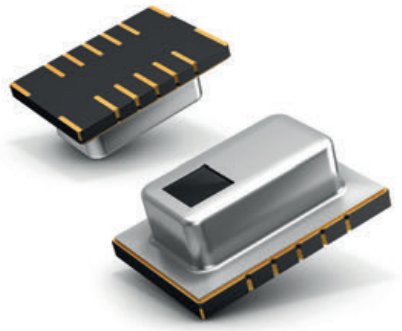
4.9 THERMOPILE ARRAY SENSOR – GRID-EYE

Panasonic

GRID-EYE is a thermopile array sensor that features 64 thermopile elements in an 8x8 grid format. Contrary to conventional thermal sensors which only measure the temperature of a certain point-of-contact, Grid-EYE, based on Panasonic's MEMS technology, can measure the temperature of the entire specified area without any contact; in other words, it is a "contactless thermopile array sensor". 64 pixels yield accurate temperature measurement over a viewing angle of 60° provided by a silicon lens. Grid-EYE uses an I2°C communication interface, enabling temperature measurements at speeds of 1 or 10 frames/sec. An interrupt function is also available.
With an array of detection elements Grid-EYE can use passive infrared detection to determine temperature differentiation allowing it to detect multiple objects simultaneously. Grid-EYE is able to measure actual temperature and temperature gradients, providing thermal images and identifying direction of movement. Compared to single thermopile sensors or pyroelectric sensors, Grid-EYE offers immense benefits:



- Digital output (I2C)
- SMD package (reflow compatible)
- 8×8 (64) pixel range
- Frame rate: 10 frames/s or 1 frame/s



Evaluation board

We offer a Grid-EYE evaluation kit that combines its "nanopower" PAN1740 bluetooth smart module and a microcontroller together with the Grid-EYE sensor on one PCB. By combining its new IR sensor technology with Bluetooth technology and using a special software for IR detection of people and objects on one board, Panasonic enables customers to develop rapid prototypes and quickly build their own wireless sensor "Internet of Things" applications.

Features

- Dimensions:
  11,6 mm×4,3 mm×8,0 mm (L×H×W)
- Operating voltage: 3,3 V or 5,0 V
- Current consumption: Typ.
  4,5 mA (normal mode);
  0,8 mA (stand-by mode),
  0,2 mA (sleep mode)
- Temperature range of measuring object:
  With amplification factor high gain: 0°C ... 80°C,
  Low gain: -20°C ... 100°C
- Field of view: 60° (vertical and horizontal)
- Number of thermopiles:
  64 (8 vertical x 8 horizontal)
- External interface: I²C (fast mode)
- Frame rate: 1 or 10 picture/s
- Absolute temperature accuracy: Typ. ±2,5 °C

Applications

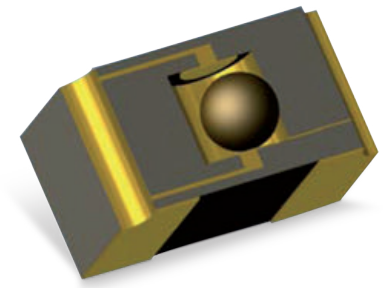
Grid-EYE opens the door to a whole world of applications, ranging from energy savings in the lighting industry (commercial and public places as well as residential spaces) to household applications (air conditioners, microwave ovens, etc.), from security systems (automatic doors, elevators, ATMs, kiosks, etc.) to the medical industry (patient detection and positioning), and many more.

- Security: occupancy detection, people counting, multiple person detection
- Household: cooking stoves, microwave ovens, air conditioners, heating systems
- Medical: patient detection, movement detection, thermal imaging, position detection
- Lighting control: energy savings, detection without movement
- Industrial temperature measurement: industrial process management and control, preserving maintenance, contactless temperature measurement

5.1 VIBRATION SENSORS VS1 AND VS2

SENSOLUTE

Energy saving aspects of products (‚green products') get more and more important. A common method to achieve this, is to put the system in a low power state as long as the system is not used (sleep mode), and to wake up the system as soon as it is used.



SECTIONAL VIEW VS2
2 CONTACT AREAS

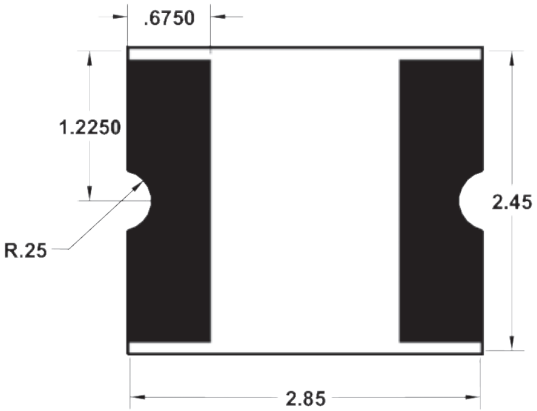
Normally a sensor is needed to switch from sleep mode to normal operation. Our VS1 and VS2 are perfectly suited to detect movements of handheld devices and to trigger the wake up of the system.

Endrich provides these surface mountable micro vibration sensors VS as replacement for mercury switches. The sensors detect vibrations by bridging a high ohmic gap in a P.C.B. with a micro ball (ø 0.8 mm). During vibration the resistance between both contact areas changes from some MΩ to less than 100 Ω.

Compared to VS1 type, VS2 has contacts on both sides (top and bottom) of the cylindric tube, whereas VS1 only has a contact at the bottom side. Therefore VS2 has nearly omnidirectional sensitivity characteristics.

Features

- Small size 2.45 mm × 2.85 mm × 1.7 mm
- Mercury-free, RoHS compliant
- Low R_{ON}: 100 Ω
- Low noise
- Surface mountable
- Material:
  - housing: reinforced FR4 glass fibre
  - internal switching contact: Cu/Ni/Au
  - ball: steel, gold-plated
- Packaging: 1,000 pcs/reel or 2,000 pcs/reel
- Minimum order quantity: 100 pcs.



Dimensions (mm) Height: 1.7 mm

PARAMETER / SPECIFICATION

Specifications of VS1/2	
Rated voltage	+15 V max.
Reaction point	50 mg approx.
On-resistance	less than 100 Ω
Dimensions	2.45 mm × 2.85 mm × 1.7 mm
Operating temperature	-20 ... +70°C
Rec. soldering conditions	260°C, 10 s

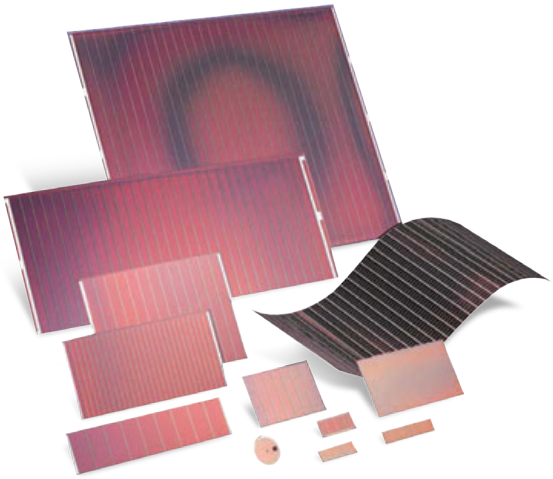
Applications

- Motion detection
- System wake up-low power
- Presence detection

5.2 AMORPHOUS SILICON

SOLAR CELLS – AMORTON

Panasonic



Solar cells are classified according to the material employed, i. e. crystal silicon, amorphous silicon, and compound semiconductor solar cells. Unlike crystal silicon, in which atomic arrangements are regular, amorphous silicon features irregular atomic arrangements as shown in the figures below.

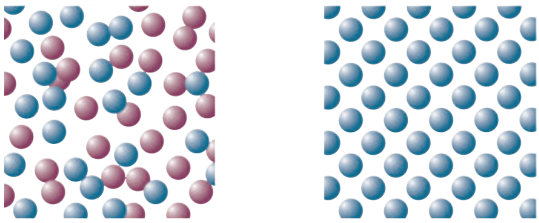
Amorton is an integrated amorphous silicon solar cell which has been developed by SANYO. Amorton uses silane (SiH_4) as its source gas and is fabricated using a plasma CVD method.

Three amorphous silicon layers – p-layer, i-layer, and n-layer – are formed consecutively on a glass substrate. This p-i-n junction corresponds to the p/n junction of a crystal silicon solar cell. In the process of this junction formation, a number of cells are connected in series on a substrate at one time. This allows any desired voltage to be obtained for a variety of equipment operation.

Features

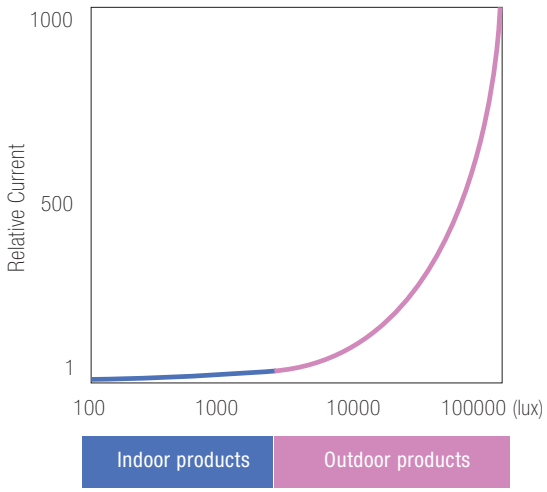
- For indoor and outdoor use
- Glass substrate: low price (basic substrate)
- Stainless steel substrate:
- Thin, light weight, unbreakable, can easily be formed in arbitrary shapes, highly precise dimensions
- Film substrate:
- Thin, light weight, unbreakable, bendable, can easily be formed in arbitrary shapes
- Solar cells with a variety of voltages can be created
- Solar cells with a variety of shapes can be created

Amorphous atomic arrangement

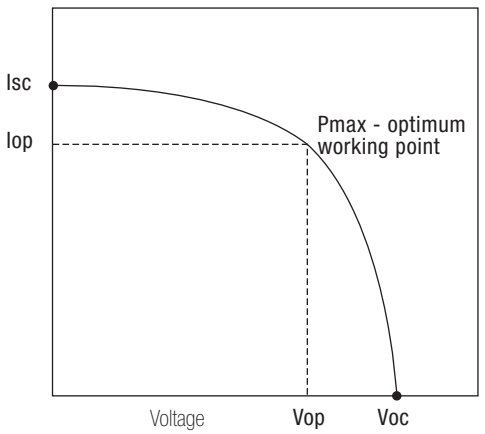


AMORPHOUS CRYSTAL

Relationship between illumination level and output



Current-voltage curve



Voc: open-circuit voltage
Isc: short-circuit current
Vop: optimum operating voltage
Iop: optimum operating current
Pmax: maximum output

Amorton Products for Clocks (Application example)

STAINLESS STEEL

GLASS

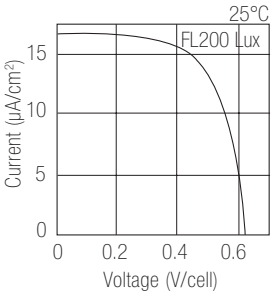
FILM

Applications

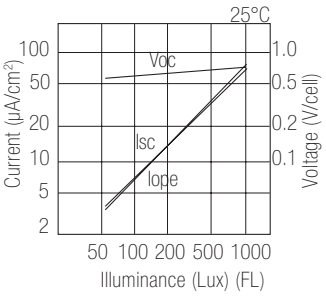
- Wrist watches (solar watches)
- Sensor lights
- Battery chargers
- Clocks
- LED blinkers (curbstone markers)
- Solar driven GSM/GPS modules

Output characteristics

Current - voltage characteristics of a cell

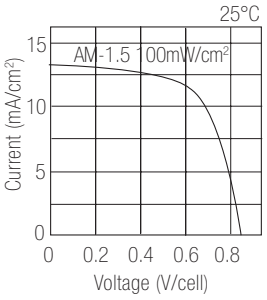


Output illuminance depency characteristics

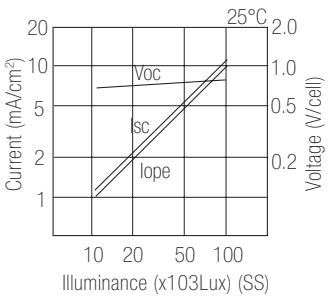


Output characteristics

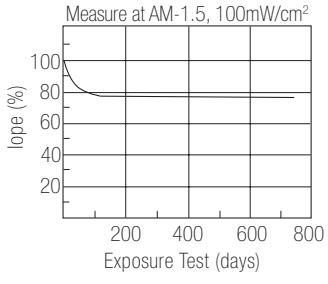
Current - Voltage Characteristics of a Cell



Output Illuminance Depency Characteristics



Lightproof (Leaving Outdoors)



Output characteristics — indoor use Amorton

Indoors, artifical light, such as fluorescent and incandescent light, is used. The illuminance of these light sources ranges from 20 lux to 1,000 lux. Indoors, therefore, Amorton is most suitable for small equipment such as electronic calculators. Please use indoor the Amorton solar cells under 1,000 lux.

Typical cell characteristics	
OPEN-CIRCUIT VOLTAGE	0.63 V/cell
SHORT-CIRCUIT CURRENT	17.0 μA/cm²
MAX. OUTPUT	7.0 μW/cm²
LIGHT SOURCE	FL200 lux

Output characteristics – outdoor use Amorton

Natural light ranges in illuminance from 10,000 lux to 100,000 lux (AM-1.5, 100mW/cm²) or more.

Typical cell characteristics	
OPEN-CIRCUIT VOLTAGE	0.84 V/cell
SHORT-CIRCUIT CURRENT	13.3 mA/cm²
MAX. OUTPUT	7.48 mW/cm²
LIGHT SOURCE	AM-1.5, 100 mW/cm²

PART NUMBER	TYPICAL OPERATING CHARACTERISTICS (FL-200 lux)	TYPICAL OPERATING CHARACTERISTICS (Ref:FL-50 lux)	EXTERNAL DIMENSIONS [mm]	WEIGHT [g]
Specifications of Amorton glass substrate – indoor products				
AM-1407	1.5 V / 11.5 µA	1.4 V / 2.85 µA	38.0 × 12.5	1.30
AM-1417	1.5 V / 12.5 µA	1.4 V / 3.10 µA	35.0 × 13.9	1.30
AM-1424	1.5 V / 20.0 µA	1.4 V / 5.00 µA	53.0 × 13.8	2.00
AM-1437	1.5 V / 8.0 µA	1.4 V / 2.00 µA	29.6 × 11.8	1.00
AM-1454	1.5 V / 31.0 µA	1.4 V / 7.75 µA	41.6 × 26.3	3.00
AM-1456	1.5 V / 5.3 µA	1.4 V / 1.30 µA	25.0 × 10.0	0.70
AM-1513	1.8 V / 15.0 µA	1.6 V / 3.75 µA	55.0 × 13.5	2.00
AM-1801	3.0 V / 18.5 µA	2.6 V / 4.60 µA	53.0 × 25.0	3.60
AM-1805	3.0 V / 15.5 µA	2.6 V / 3.85 µA	55.0 × 20.0	3.00
AM-1815	3.0 V / 42.0 µA	2.6 V / 10.50 µA	58.1 × 48.6	7.80
AM-1816	3.0 V / 84.0 µA	2.6 V / 21.00 µA	96.7 × 56.7	15.6

PART NUMBER	TYPICAL OPERATING CHARACTERISTICS (100 mW/cm^2)	TYPICAL OPERATING CHARACTERISTICS (Ref:SS 50 klux)	EXTERNAL DIMENSIONS [mm]	WEIGHT [g]
Specifications of Amorton glass substrate – outdoor products				
AM-5302	1.5 V / 105.0 mA	1.5 V / 47.0 mA	31.2 × 117.8	16.3
AM-5412	2.0 V / 39.0 mA	2.0 V / 17.2 mA	50.1 × 33.1	7.30
AM-5413	2.0 V / 16.3 mA	2.0 V / 7.2 mA	33.0 × 23.9*	2.10
AM-5416	2.0 V / 49.9 mA	2.0 V / 22.0 mA	60.1 × 36.7	9.80
AM-5605	3.0 V / 113.0 mA	3.0 V / 51.0 mA	62.3 × 117.8	32.5
AM-5608	3.0 V / 36.0 mA	3.0 V / 16.0 mA	60.1 × 41.3	11.0
AM-5610	3.0 V / 5.0 mA	3.0 V / 2.2 mA	25.0 × 20.0	2.20
AM-5611	3.0 V / 3.2 mA	3.0 V / 1.4 mA	33.4 × 10.0*	0.90
AM-5613	3.0 V / 31.5 mA	3.0 V / 14.0 mA	60.1 × 36.7	9.80
AM-5706	3.5 V / 45.0 mA	3.5 V / 20.0 mA	70.0 × 60.0	15.5
AM-5710	3.5 V / 32.0 mA	3.5 V / 14.0 mA	62.3 × 37.0*	6.30
AM-5812	4.0 V / 19.5 mA	4.0 V / 8.5 mA	59.0 × 28.7	4.60
AM-5902	4.5 V / 60.0 mA	4.5 V / 27.0 mA	150.0 × 37.5	25.0
AM-5904	4.5 V / 10.0 mA	4.5 V / 4.3 mA	40.1 × 33.1	5.90
AM-5907	4.5 V / 44.7 mA	4.5 V / 19.7 mA	75.0 × 55.0	18.3
AM-5909	4.5V / 22.2 mA	4.5 V / 9.8 mA	60.1 × 41.3	11.0
AM-5910	4.5 V / 88.5 mA	4.5 V / 9.8 mA	60.1 × 41.3	11.0
AM-5912	4.5 V / 15.4 mA	4.5 V / 6.8 mA	42.9 × 47.2*	5.60
AM-5913	4.5 V / 30.1 mA	4.5 V / 13.3 mA	60.1 × 55.1	14.7
AM-5914	4.5 V / 23.2 mA	4.5 V / 10.2 mA	50.1 × 55.1*	7.50
AM-5C03	6.0 V / 28.0 mA	6.0V / 12.5 mA	75.0 × 55.0	18.3
AM-5D01	6.5 V / 11.0 mA	6.5 V / 4.8 mA	100.0 × 18.0	8.00
AM-5E02	7.0 V / 23.3 mA	7.0 V / 10.3 mA	75.0 × 55.0	18.3
AM-5S04	15.0 V / 22.0 mA	15.0 V / 9.7 mA	124.5 × 57.0*	19.3
AM-5S05	15.0 V / 15.0 mA	15.0 V / 6.5 mA	124.5 × 39.3*	13.4
AM-5S06	15.0 V / 11.0 mA	15.0 V / 4.9 mA	124.5 × 29.5*	10.0
AM-7A03	5.3 V / 250.0 mA	5.3 V / 113.0mA	150.0 × 165.0	110
AM-7D08	7.0 V / 190.0 mA	7.0 V / 85.0 mA	150.0 × 165.0	110
AM-7E04	7.5 V / 115.0 mA	7.5 V / 50.0 mA	150.0 × 110.0	74.0
AM-7S03	15.0 V / 77.0 mA	15.0 V / 34.5 mA	150.0 × 165.0	110

Glass thickness with * is 1.1 mm, glass thickness without * is 1. 8 mm

OFFICES IN EUROPE

Germany
Nagold (Headquarters)

Austria

France

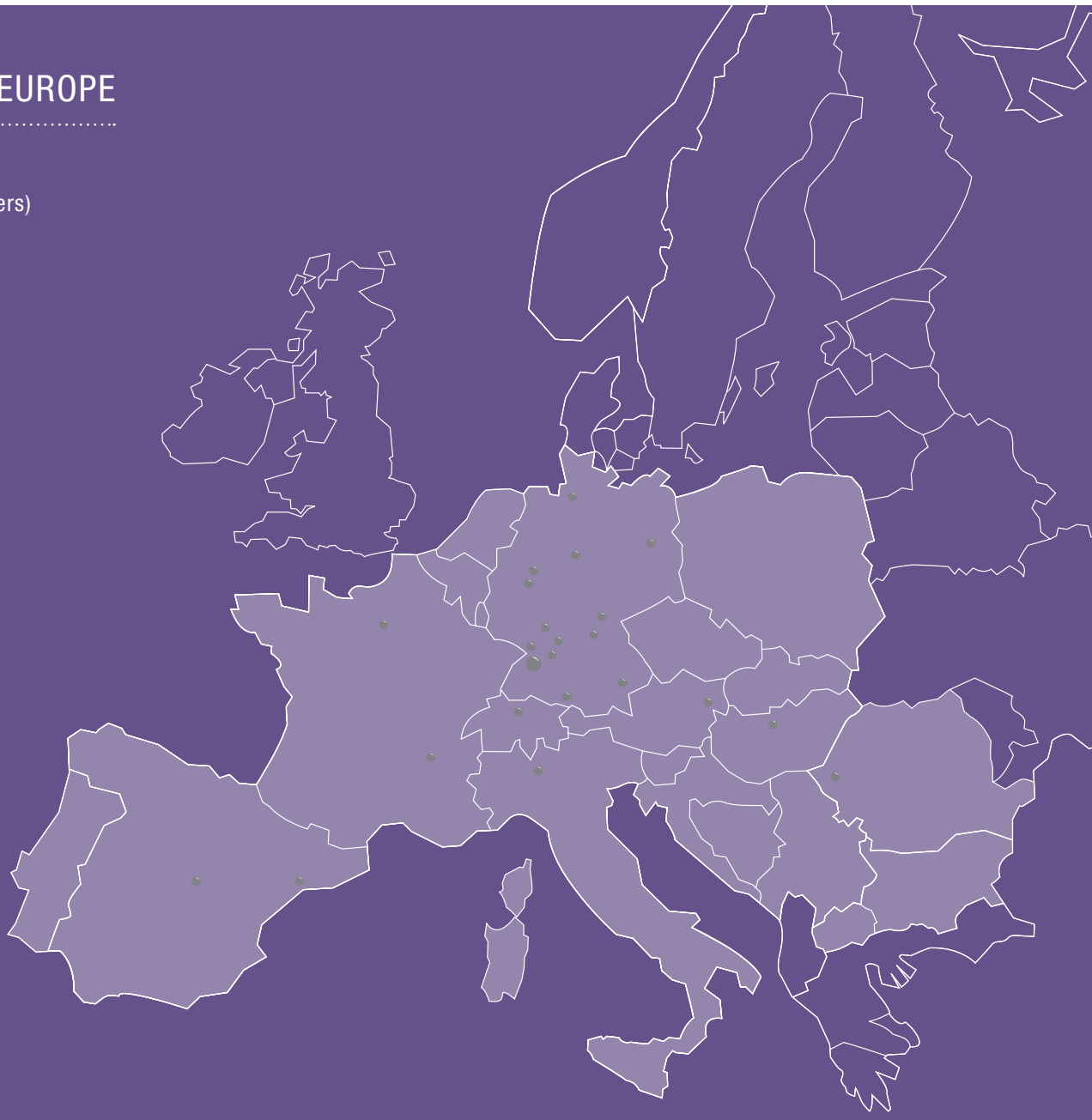
Spain

Italy

Hungary

Romania

Switzerland
novitronic
powered by endrich



ENDRICH Bauelemente Vertriebs GmbH · P.O.Box 1251 · D-72192 Nagold
Tel.: +49 (0) 7452 6007-0 · Fax: +49 (0) 7452 6007-70 · endrich@endrich.com · www.endrich.com

NOVITRONIC AG · Thurgauerstrasse 74 · CH-8050 Zürich
Tel.: +41 (0)44 306 91 91 · Fax +41 (0)44 306 91 81 · info@novitronic.ch · www.novitronic.ch

www.endrich.com

Ausgabe 2019