iC-RC1000

SIN/COS MONITORING IC FOR FUNCTIONAL SAFETY

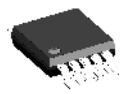
FEATURES

- Sine/cosine encoder signal monitoring for SIL applications
- Suitable for differential encoder signals of 1 Vpp (250 mV amplitude per line)
- Suitable for single-ended input signals (500 mV amplitude per line)
- Verification of common mode range per signal line (from DC to 500 kHz)
- Lissajous figure monitoring with min/max limits (from DC to 100 kHz)
- Cable fracture detection
- Source decoupling and overvoltage clamping per pin by external resistors
- Single-failure-proof dual channel concept
- Independent diagnostic outputs: signal OK message and signal error message
- Approved for safety applications

APPLICATIONS

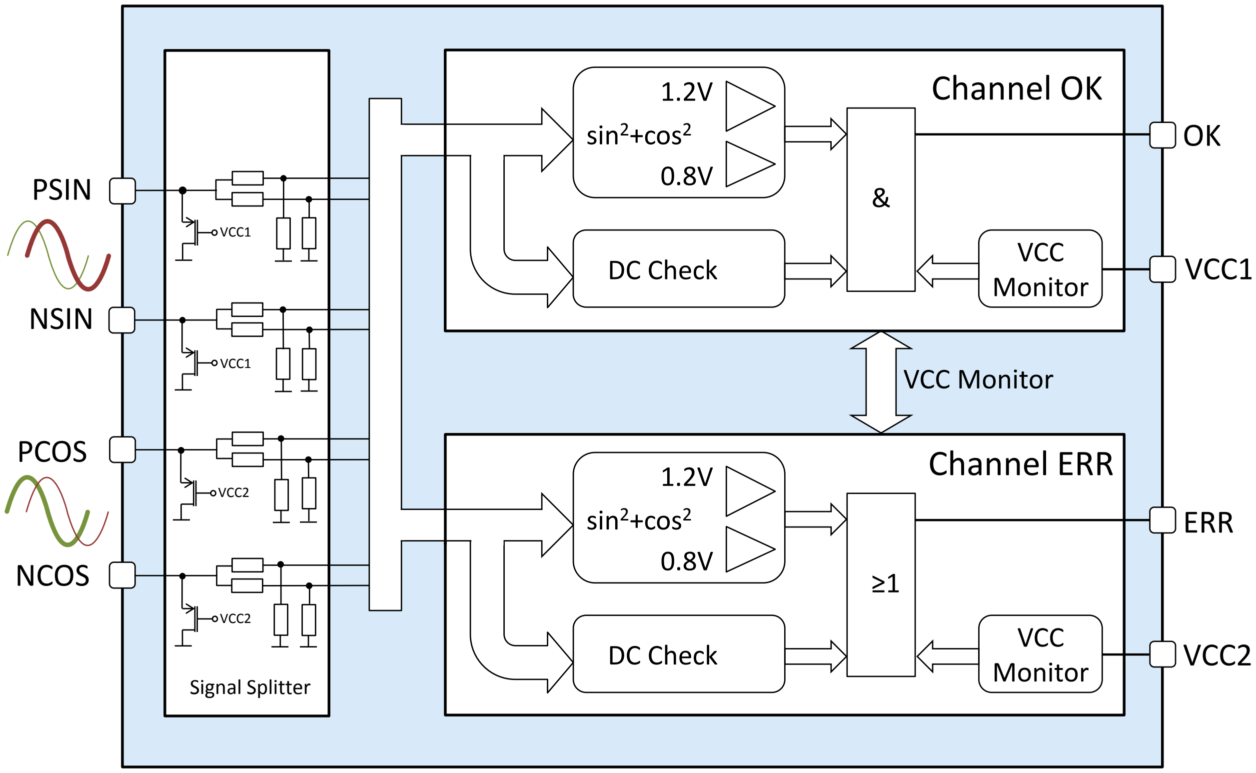
- Sensor monitoring
- Motion control
- Functional safety

PACKAGES



MSOP10
3 mm x 3 mm x 0.9 mm
RoHS compliant

BLOCK DIAGRAM



DESCRIPTION

iC-RC1000 acts as an independent monitoring device for industrial safety controllers and drive systems in the evaluation of sine encoders for SIL applications.

In this function the IC checks that four analog signal lines have the correct DC voltage range (DC range: 30 to 80 % from VCC1 or VCC2) and that two respective paired lines have the correct differential 1 Vpp signal amplitude in real time (amplitude range: 200 to 300 mV). Single-ended signals referenced to ground with twice this amplitude (400 to 600 mV) can also be monitored; here, the negative input must be kept within the permissible DC range (e.g. VCC/2).

iC-RC1000 has intrinsic safety, enabling single errors to be securely identified through redundancy; independent of one another, two different diagnostic channels monitor the input signals, and output separate messages.

iC-RC1000 confirms valid input signals by a signal OK message of OK = 1 and a signal error message of ERR = 0.
iC-RC1000 confirms invalid input signals by a signal OK message of OK = 0 and a signal error message of ERR = 1.
If the messages are not complementary to one another, the inputs signals are at range limits or a circuit error does exist.

Each diagnostic channel has signal comparators for DC and square sum monitoring; the monitoring windows have different designs depending on the good/bad diagnosis.

The square sum monitor uses an analog multiplier and evaluates the Lissajous figure derived from the square signal of sine and cosine ($\sin(wt)^2 + \cos(wt)^2$).

In order for the external controller to safely detect an interrupt, the status times are extended to at least 4 ms by retriggerable monoflops. After power-on iC-RC1000 starts in signal error status, and sets the signal OK status at the earliest after the monoflop period has elapsed. The status outputs are configured as push-pull drivers so that optocouplers can be directly connected up to the device (10 mA low side, 4 mA high side).

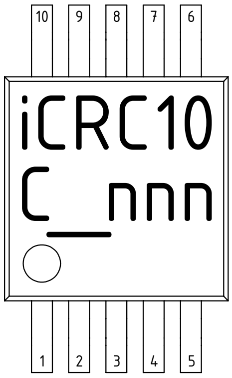
The front end signal splitter isolates the two diagnostic channels from one another. The integrated clamping circuit then reduces the input voltage to a value within the permissible range (supply voltage) and protects against overvoltage with the help of external resistors (18 kΩ at each signal input). At the same time this decouples the signal source so that a controller can simulate an error by loading an input pin. For the detection of signal losses, caused by a fractured cable for instance, integrated pull-down resistors (2.5 MΩ) drag the DC potential into the error range.

iC-RC1000 works at a supply voltage of 5 V. The diagnostic channels can be supplied by one or two separate voltage sources and mutually monitor the applied supply voltages on undervoltage. The device is protected against ESD and in the given circuit is overvoltage-proof at the front end up to 36 V.

Safety Applications
The iC-RC1000 is IFA-certified for safety applications up to SIL 3 according to IEC 61508 and PL e, Cat. 4 according to ISO 13849-1. The instructions of the associated safety manual and referenced documents have to be considered.

PACKAGING INFORMATION

PIN CONFIGURATION
MSOP10 according to JEDEC MO-187BA
(3 mm x 3 mm, lead pitch 0.5 mm)



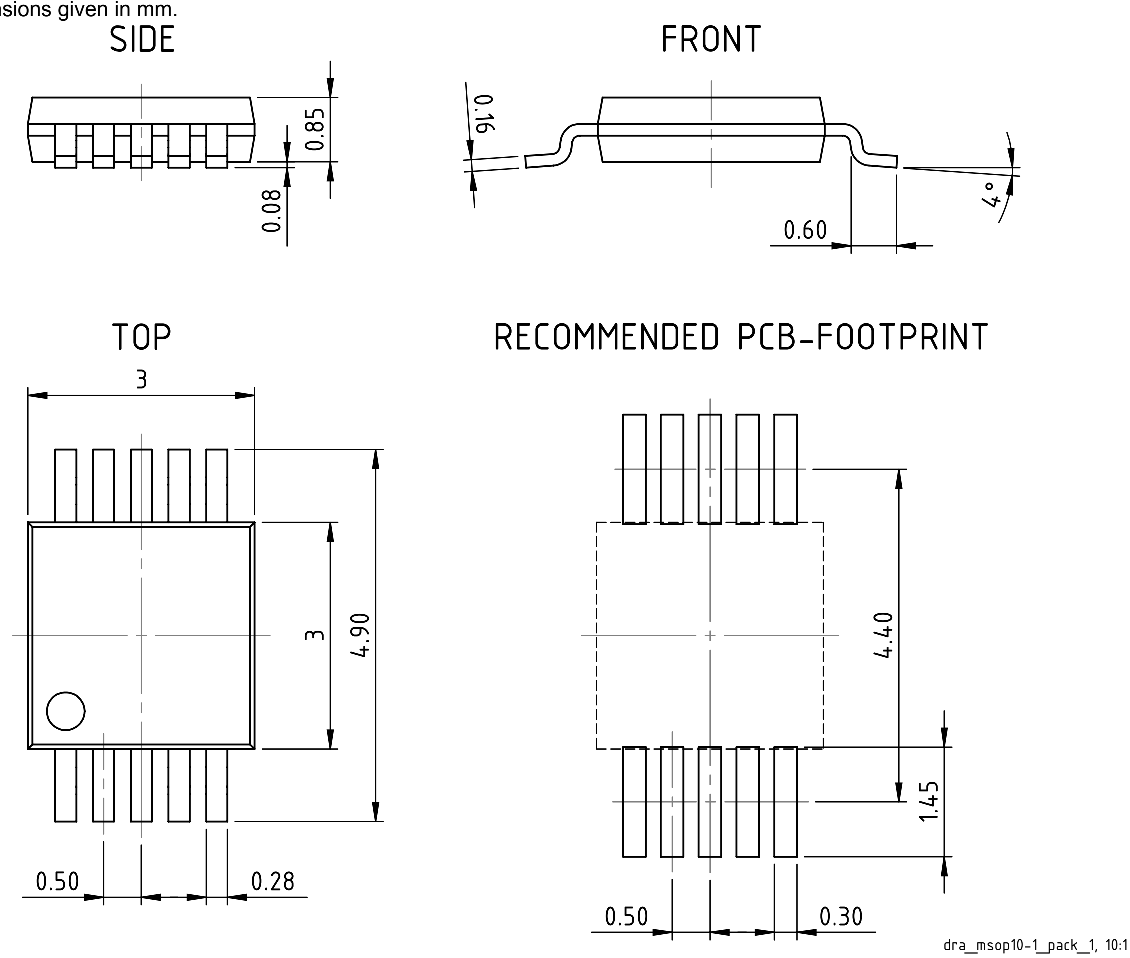
PIN FUNCTIONS

No.	Name	Function
1	NSIN	Inverted Sine Input
2	PSIN	Sine Input
3	GND	Ground
4	PCOS	Cosine Input
5	NCOS	Inverted Cosine Input
6	OK	OK Indication Output
7	VCC1	+5 V Supply Voltage Channel OK
8	GND	Ground
9	VCC2	+5 V Supply Voltage Channel ERR
10	ERR	ERROR Indication Output

Ground can be connected to pin 3 or pin 8.

PACKAGE DIMENSIONS MSOP10 3x3

All dimensions given in mm.



ABSOLUTE MAXIMUM RATINGS

These ratings do not imply permissible operating conditions; functional operation is not guaranteed.
Exceeding these ratings may damage the device.

Item No.	Symbol	Parameter	Conditions	Min.	Max.	Unit
G001	V(VCC)	Voltage at VCC1, VCC2		-0.3	7	V
G002	I(VCC)	Current in VCC1, VCC2		-10	25	mA
G003	Vin()	Voltage at PSIN, NSIN, PCOS, NCOS		-0.3	7	V
G004	Iin()	Current in PSIN, NSIN, PCOS, NCOS		-10	10	mA
G005	Vout()	Voltage at ERR, OK		-0.3	7	V
G006	Iout()	Current in ERR, OK		-10	25	mA
G007	Ilu()	Pulse Current in all pins (latch-up susceptibility)	according to Jedec Standard No. 78; Ta = 25 °C, pulse duration to 10 ms, VCC1 = $VCC1_{max}$, VCC2 = $VCC2_{max}$, Vlu() = (-0.5...+1.5) x $Vpin()_{max}$	-100	100	mA
G008	Vd()	ESD Susceptibility at all pins	HBM 100pF discharged through 1.5 kΩ		2	kV
G009	Tj	Chip Temperature		-40	150	°C
G010	Ts	Storage Temperature		-40	150	°C

THERMAL DATA

Operating conditions: VCC1 = 5 V ±10 %, VCC2 = 5 V ±10 %

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
T01	Ta	Operating Ambient Temperature Range		-40		110	°C
T02	Rthja	Thermal Resistance Chip to Ambient			30		K/W

All voltages are referenced to ground unless otherwise stated.
All currents flowing into the device pins are positive; all currents flowing out of the device pins are negative.

ELECTRICAL CHARACTERISTICS

Operating conditions: VCC1 = 5 V ±10 %, VCC2 = 5 V ±10 %, T_j = -40 ... 125 °C, unless otherwise stated

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Total Device							
001	Vin()	Permissible Input Voltage at PSIN, NSIN, PCOS, NCOS	referred to Figure 1; acceptable DC range (no error by DC check)	0 38		100 73	%VCC %VCC
002	Vc()hi	Clamp Voltage hi at PSIN, NSIN, PCOS, NCOS	Vc()hi = V() – VCC1 or VCC2, I() = 10 mA	0.7		2	V
003	Iin()	Permissible Input Current	indefinite			2	mA
004	Vc()lo	Clamp Voltage lo at all Pins	I = - 1 mA	-1.2		-0.3	V
005	fin()	Permissible Input Frequency	DC check operational Lissajous monitoring operational	0 0		500 100	kHz kHz
006	Rpd()	Pull-down Resistor at PSIN, NSIN, PCOS, NCOS			2.5		MΩ
007	Vin()	Magnitude Error Tolerance	ERR = 0, OK = 1 (no error message)	0.8		1.2	V
008	ΔPHI	Phase Error Tolerance	f = 0 ... 100 kHz 1 Vpp, 1 kHz (see also table 2 on page 11)	±7 	 ±30		° °
Channel OK, Channel ERR							
301	VCC	Permissible Supply Voltage at VCC1, VCC2		4.5		5.5	V
302	I(VCC)	Supply Current in VCC1, VCC2	T_j = 27 °C, no Load		0.7		mA
303	VCCon	Turn-on Threshold VCC1, VCC2 (power-on release)	increasing voltage VCC	4.1		4.4	V
304	VCCoff	Turn-off Threshold VCC1, VCC2 (power-down reset)	decreasing voltage VCC	3.9		4.2	V
305	VCChys	Hysteresis at VCC1, VCC2	VCChys = VCCon – VCCoff	100		400	mV
306	Vpp()max	Differential Voltage Threshold Maximum-Alarm	referred to Fig. 2, ΔPHI = 0 (phase |90°|); OK = Hi and ERR = Lo OK = Lo or ERR = Hi for $(V(PSIN-NSIN))^2 + (V(PCOS-NCOS))^2$ > Vpp()max for at least 3 µs	 1.2	 1.5		 Vpp Vpp
307	Vpp()min	Differential Voltage Threshold Minimum-Alarm	referred to Fig. 2, ΔPHI = 0 (phase |90°|); OK = Hi and ERR = Lo OK = Lo or ERR = Hi for $(V(PSIN-NSIN))^2 + (V(PCOS-NCOS))^2$ < Vpp()min for at least 3 µs	 0.5		 0.8	 Vpp Vpp
308	Vdc()max	DC-Check Maximum Voltage Threshold	referred to Figure 1	73	76	79	%VCC
309	Vdc()min	DC-Check Minimum Voltage Threshold	referred to Figure 1	30	33	38	%VCC
310	Vs()hi	Saturation Voltage hi at OK, ERR	Vs(OK)hi = VCC1 - V(); I() = -4 mA Vs(OK)hi = VCC1 - V(); I() = -1.6 mA Vs(ERR)hi = VCC2 - V(); I() = -4 mA Vs(ERR)hi = VCC2 - V(); I() = -1.6 mA		0.7 0.7 	1 0.5 1 0.5	V V V V
311	Vs()lo	Saturation Voltage lo at OK, ERR	I() = 10 mA I() = 4 mA		0.7 	1 0.5	V V
312	Isc()hi	Short-Circuit Current hi at OK, ERR	V(OK) = 0 V ... VCC1 - 1 V V(ERR) = 0 V ... VCC2 - 1 V	-11		-4	mA
313	Isc()lo	Short-Circuit Current lo at OK, ERR	V(OK) = 1 V ... VCC1 V(ERR) = 1 V ... VCC2	12		30	mA
314	td()	Minimum Duration of Lo-Signal at OK Hi-Signal at ERR		4		20	ms
315	Ir()	Reverse Current in OK, ERR	VCC1 = 0 or open, V(OK) = 5.5 V VCC2 = 0 or open, V(ERR) = 5.5 V			500 400	µA µA
316	Vr()	Back Bias Voltage at VCC1, VCC2	VCC1 open, V(OK) = 5.5 V VCC2 open, V(ERR) = 5.5 V	0 0		1.0 2.5	V V

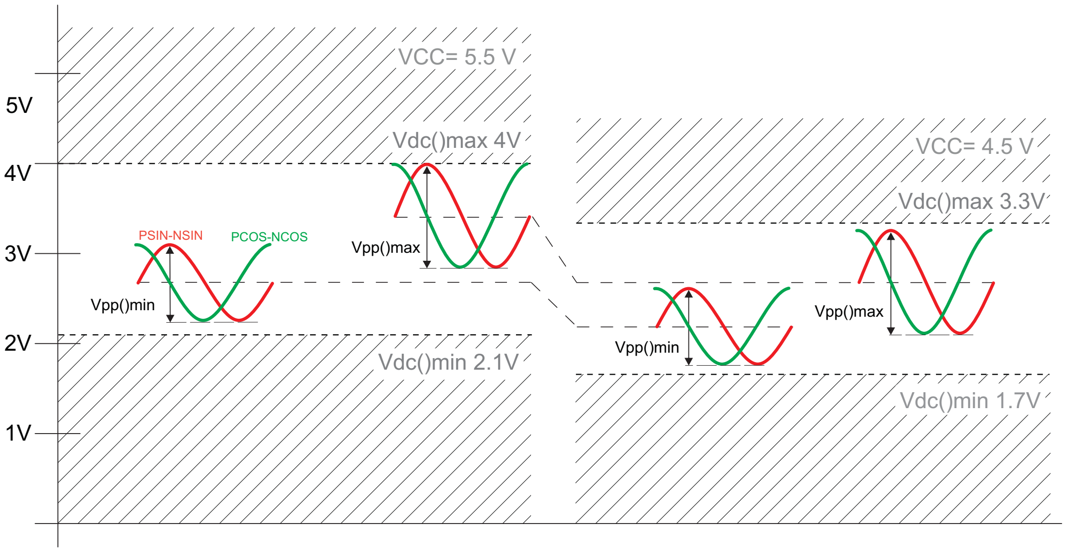


Figure 1: Examples of monitored input signals (no error messaging)

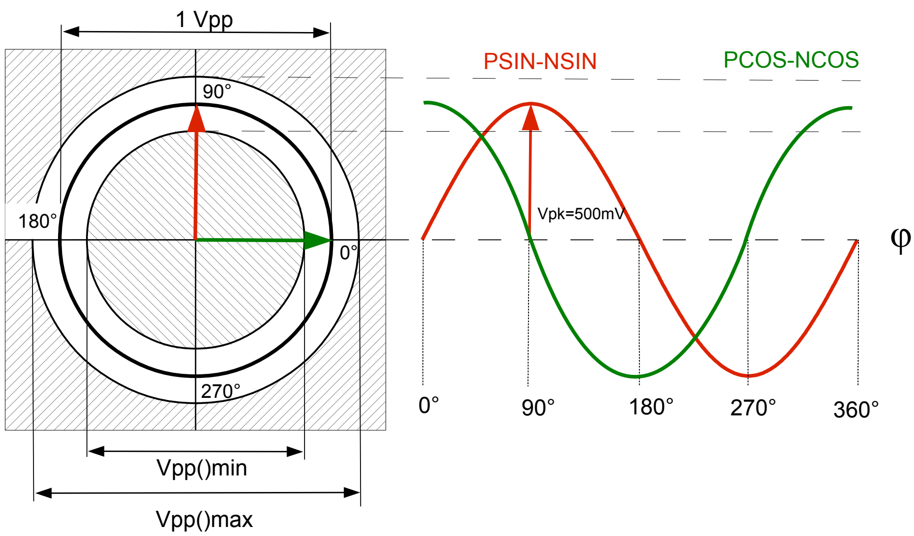


Figure 2: Differential voltage thresholds for maximum and minimum alarm

APPLICATION NOTES ON SAFETY APPLICATIONS

For safety-related applications according to IEC 61508-1 and -2 (Edition 2.0: 2010), as well as DIN EN 61800-5-2:2008 if applicable for the device under consideration, the following instructions must be considered for circuit implementation:

Functional Safety: The subsequent evaluation circuit must be able to process signals at least down to the lowest monitoring thresholds:
Minimum value of Elec. Char. 307 and 309

(concerns the switching threshold of a pulse counter and direction detector, for instance)

Circuit Note #1

Functional Safety: The subsequent evaluation circuit must be able to process signals at least up to the highest monitoring thresholds:
Maximum value of Elec. Char. 306 and 308

Circuit Note #2

Functional Safety: The subsequent evaluation circuit must be able to react on the shortest indication signal:
Minimum value of Elec. Char. 314

Circuit Note #3

Functional Safety: Exceeding the permissible input frequency can be safety critical:
Maximum value of Elec. Char. 005

Circuit Note #4

Functional Safety: Category 4 requires the correct and dual evaluation of both channel outputs, OK and ERR.
For category 3 the correct evaluation of a single channel output, either OK or ERR, can be sufficient.

Circuit Note #5

Functional Safety: The subsequent evaluation circuit must reach and lock a safe state after the detection of an error (inhibition of operation).

Circuit Note #6

APPLICATION NOTES

Application with Series Resistors

The input pins can be loaded permanently with up to 2 mA, and this permissible maximum current determines the resistor value of Rv. The input pins are limited to the supply voltage plus the clamp voltage Vc()hi by the integrated clamping circuit (see Elec.Char. No. 002).

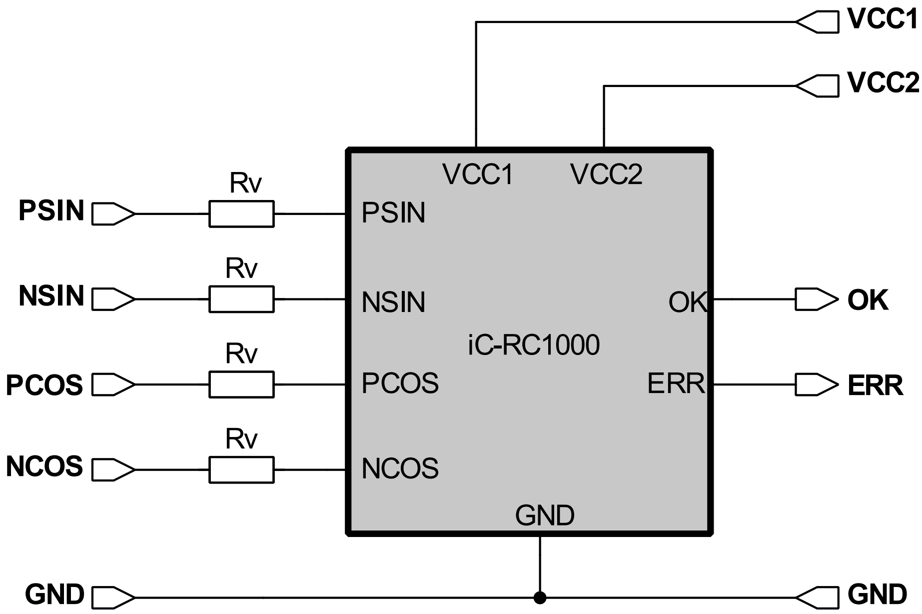


Figure 3: Overvoltage protection with external resistors

In this application, the following must be paid attention to:

1. The power loss in the series resistor
2. The cut-off frequency at the input pins

The following example refers to the measurings with the evaluation board RC1D. For an overvoltage capability of up to 36 V resistors of for instance 39 kΩ or 18 kΩ can be used. On the evaluation board the capacity of each input pin is approximately 10 pF. The cut-off frequency can be calculated using the capacity and the selected series resistor (Table 1).

39 kΩ	408 kHz
18 kΩ	880 kHz

Table 1: Cut-off frequency (-3 dB) with series resistor

A -3 dB cut-off frequency of 880 kHz means that the input amplitude at 500 kHz is already approximately 1 dB lower. Concerning the amplitude monitoring this means that the error message at 500 kHz is only carried out at a 10 % higher input amplitude.

Note: The iC's pin capacity is approximately 5 pF; additional capacitances should be kept as low as possible if higher frequency input signals are to be monitored.

Single-ended application
Signals referring to ground with double amplitude (400 bis 600 mV) can also be monitored; for this purpose the negative input must be kept in the permissible common mode range (e.g. at VCC/2).

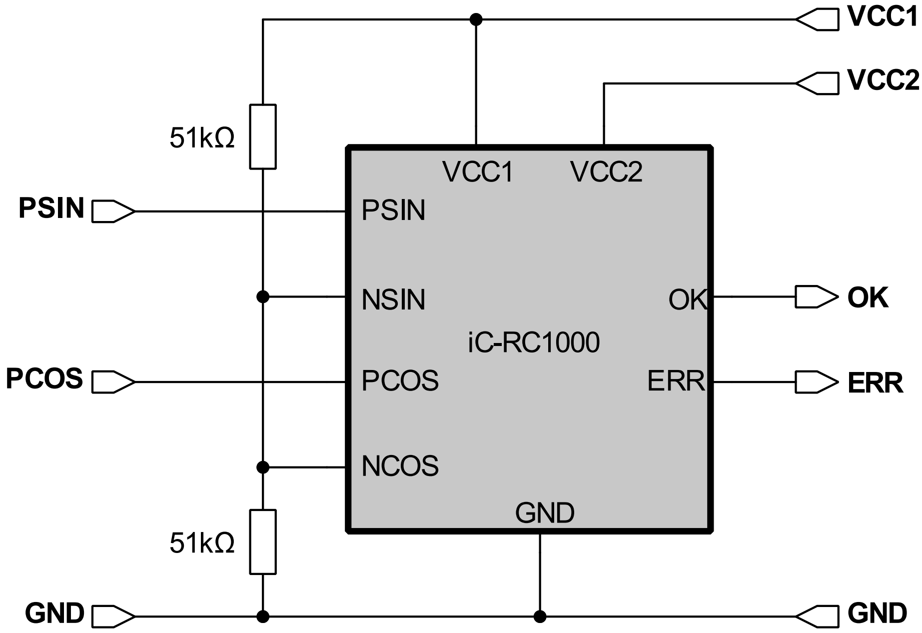


Figure 4: Single-ended application

Monitoring of phase shift

The phase shift between SIN (PSIN-NSIN) and COS (PCOS-NCOS) can be monitored only indirectly, what leads to limitations. The following table shows the phase error tolerance for different input frequencies. Any larger phase shift results in an error message.

	1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	200 kHz	300 kHz	400 kHz	500 kHz
0.8 Vpp	±18 °	±18 °	±18 °	±18 °	±20 °	±33 °	±48 °	±75 °	*	*
1.0 Vpp	±34 °	±34 °	±34 °	±34 °	±36 °	±50 °	±65 °	*	*	*
1.2 Vpp	±9 °	±9 °	±9 °	±9 °	±10 °	±15 °	±22 °	±25 °	±35 °	±45 °

Table 2: Permissible phase error ΔPHI between SIN and COS for different input frequencies (without series resistors); *) No error message (OK = 1 and ERR = 0)

The following figure shows a SIN signal (PSIN-NSIN) and a COS signal (PCOS-NCOS) leading by just 45°, as well as the Lissajous figure resulting from this phase shift. Additionally, the result of square sum generation is also shown, here exceeding the monitoring thresholds for the maximum and minimum amplitudes.

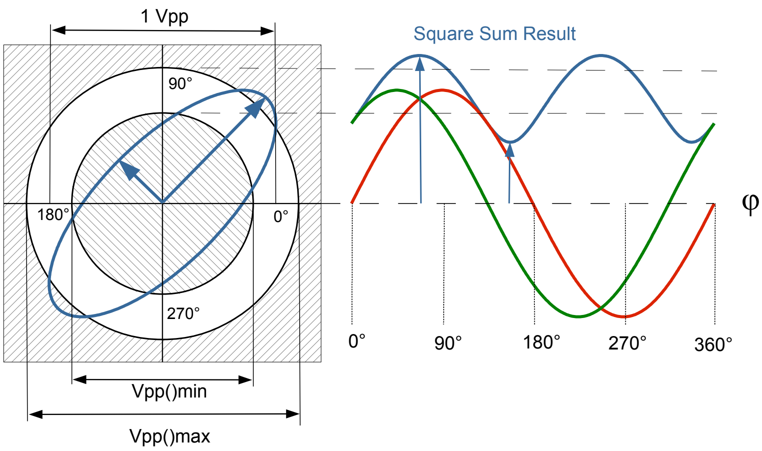


Figure 5: Monitoring of Lissajous figure regarding phase error tolerance

Input Circuits With Operational Amplifiers

For the detection of signal losses, caused by a fractured cable for instance, iC-RC1000 drags its input signals into the DC check's error range using integrated pull-down resistors. If operational amplifiers are connected upstream, cable fracture detection now requires that the external circuit ensures an open external input causes an invalid input signal at iC-RC1000 (violation of DC common mode range).

EVALUATION BOARD

Evaluation board RC1D is available for test purposes. Refer to the following figures for the PCB's schematic diagram and layout.

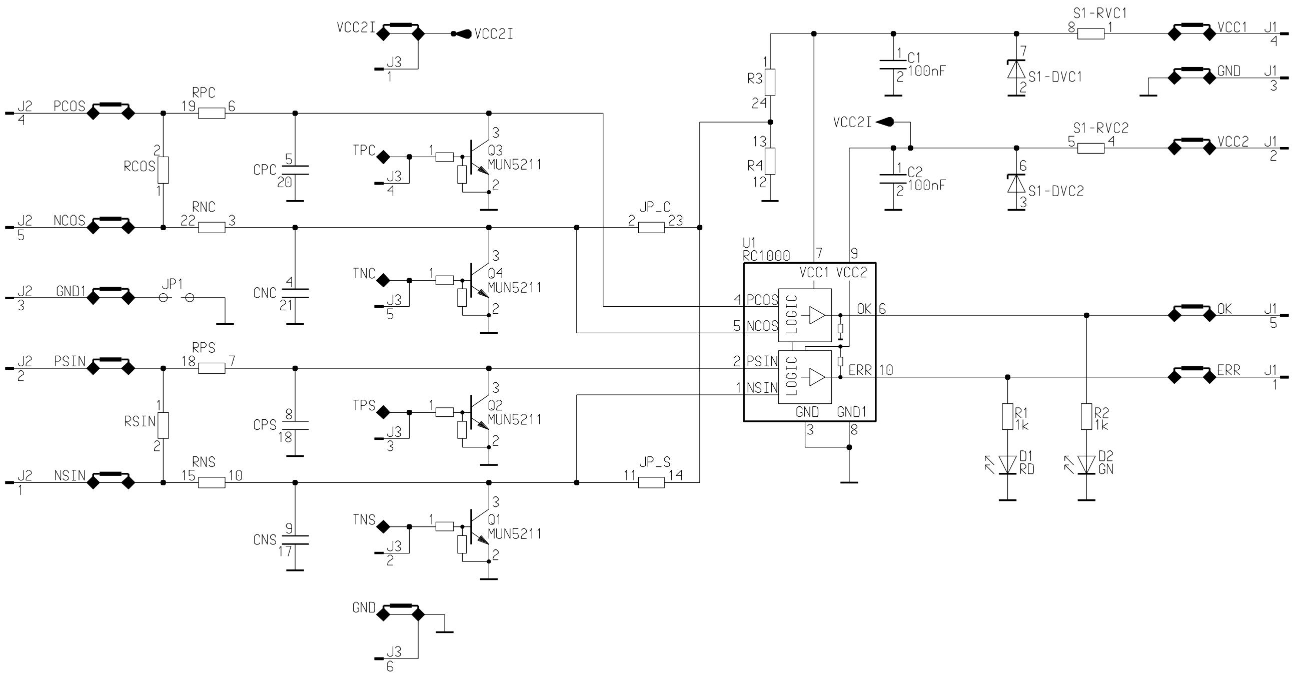


Figure 6: Schematic diagram

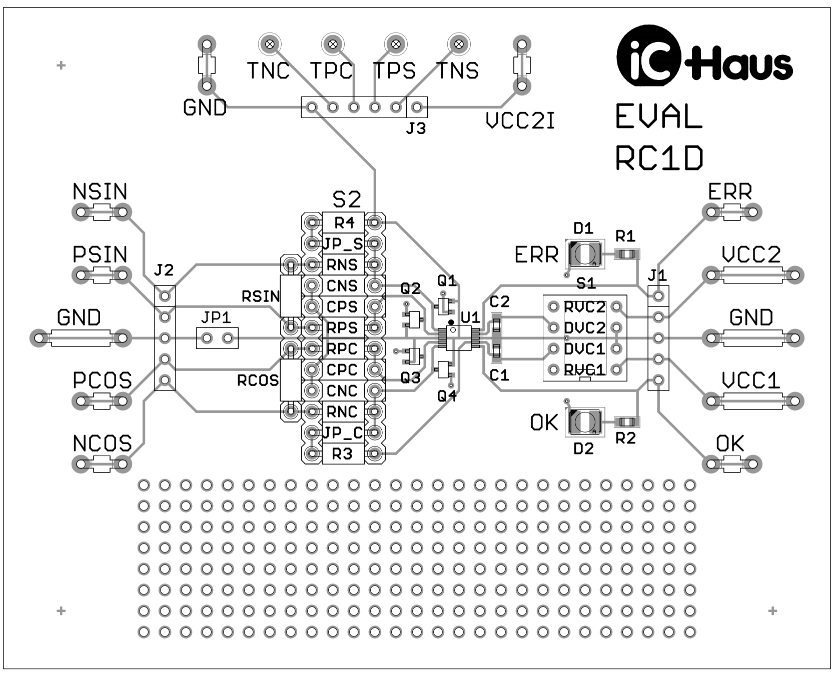


Figure 7: Layout of component side

ASSEMBLY PART LIST

Assembly Part	Value (typical)	Package	Comment
U1	RC1000	SMD MSOP10	
C1, C2	100 nF	SMD 0603	
D1	LS-T67K	SMD PLCC2	Indicator LED (red) of message output ERR
D2	LG-T67K	SMD PLCC2	Indicator LED (green) of message output OK
Q1, Q2, Q3, Q4	MUN5211	SMD SOT323	Analog switch for error simulation
R1, R2	1 kΩ	SMD 0603	
JP1	SLLP10972G	TH W2X1	
S1	DIL8	DIL8	
S2_1, S2_2	MK0112G	TH S12x1	
S3, S4	MK011G	TH S1x1	
S5	MK012G	TH S2x2	
TNC, TNS, TPC, TPS	S1-F	TH W1X1	Control signals for analog switch
RVC1, RVC2	CB 6 G	TH RM7.62	
R3, R4	(51 kΩ)	TH R0207	Optional assembly: resistors for single-ended application
RCOS, RSIN	(120 Ω)	TH R0207	Optional assembly: termination resistor
RNC, RNS, RPC, RPS	(18 kΩ)	TH R0207	Series resistors for application with higher input voltages; shipping is made with a shorting link; a resistor can be used optionally
JP_C, JP_S	(CB 6 G)	TH RM7.62	Optional assembly
CNC, CNS, CPC, CPS		TH RM5.08	Optional assembly: input filter
DVC1, DVC2	(BZX85C5V1)	TH RM7.62	Optional assembly: Zener diodes

DESIGN REVIEW: Function Notes

iC-RC1000 1		
No.	Function, Parameter/Code	Description and Application Notes
1	Elec. Char. No. 314	Maximum limit of up to 30 ms

Table 3: Notes on chip functions regarding iC-RC1000 chip release 1

iC-RC1000 Z1		
No.	Function, Parameter/Code	Description and Application Notes
		—

Table 4: Notes on chip functions regarding iC-RC1000 chip release Z1

REVISION HISTORY

Rel.	Rel. Date*	Chapter	Modification	Page
C1	2014-09-22		See revision history of datasheet release C1	

Rel.	Rel. Date*	Chapter	Modification	Page
C2	2014-10-27	FEATURES	DC check and Lissajous monitoring within frequency limits	1
		DESCRIPTION	Text updated regarding OK and ERR messaging	2
		ELECTRICAL CHARACTERISTICS	Item 001, 005: conditions, correction of max. value	6
		APPLICATION NOTES	New section on using external OP amps.	10

Rel.	Rel. Date*	Chapter	Modification	Page
C2.1	2015-04-30	APPLICATION NOTES	Supplement of safety instructions	8
		ABSOLUTE MAXIMUM RATINGS	Supplement of temperature data	5

Rel.	Rel. Date*	Chapter	Modification	Page
C3	2023-03-15	TITLE, FEATURES	Functional safety added	1
		DESCRIPTION	Note box added on safety applications	2

* Release Date format: *YYYY-MM-DD*

ORDERING INFORMATION

Type	Package	Order Designation
iC-RC1000 Evaluation Board	MSOP10	iC-RC1000 MSOP10 iC-RC1000 EVAL RC1D

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