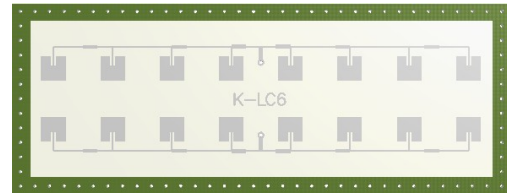


Features

- 24 GHz short range transceiver
- Narrow - wide asymmetrical field pattern
- Beam aperture 80°/12°
- High sensitive LNA receiver
- 250MHz wide sweep FM input
- I/Q IF outputs
- Optional IF amplifier (K-LC6_V2)
- Compact size: 66mm x 25mm x 6mm



K-LC6 actual size

Applications

- Indoor and outdoor lighting control applications
- Traffic supervision and counting
- Object speed measurement systems
- Ranging and distance detection
- Industrial sensors

Description

K-LC6 is a dual channel Doppler Radar module with an asymmetrical narrow beam for short to medium distance sensors. It is ideally suited for person and vehicle movement and presence sensors.

This module includes an RF low noise amplifier (LNA) for best signal to noise performance. Dual IF I and Q allow movement direction detection and high performance signal processing.

The optional internal IF amplifier is available in version K-LC6_V2.

An extremely slim construction with only 6mm depth gives you maximum flexibility in your equipment design.

Powerful starterkits with signal conditioning and visualization are also available. (see www.rfbeam.ch Download Section)

Blockdiagram

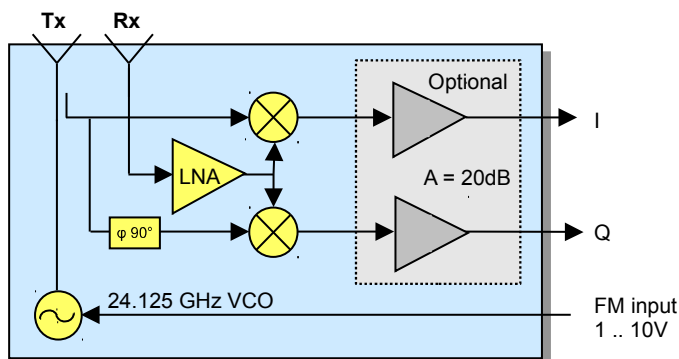


Fig. 1: K-LC6 Blockdiagram

Optional amplifier is present in the K-LC6_V2 version.

K-LC6 RADAR TRANSCEIVER

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Characteristics

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Unit
Operating conditions						
Supply voltage		V_{cc}	4.75	5.0	5.25	V
Supply current		I_{cc}		50	70	mA
VCO input voltage		U_{vco}	1		10	V
VCO pin resistance	Internal pullup 10k to 5V	R_{vco}		10k		Ω
Operating temperature		T_{op}	-20		+80	$^{\circ}\text{C}$
Storage temperature		T_{st}	-20		+80	$^{\circ}\text{C}$
Transmitter						
Transmitter frequency	$U_{vco}=5\text{V}$, $T_{amb}=-20^{\circ}\text{C} \dots +60^{\circ}\text{C}$	f_{TX}	24.050	24.150	24.250	GHz
Frequency drift vs temp.	$V_{cc}=5.0\text{V}$, $-20^{\circ}\text{C} \dots +60^{\circ}\text{C}$ <small>Note 1</small>	Δf_{TX}		-1.0		MHz/ $^{\circ}\text{C}$
Frequency tuning range		Δf_{vco}		250		MHz
VCO sensitivity		S_{vco}		25		MHz/V
VCO Modulation Bandwidth	$\Delta f=20\text{MHz}$	B_{vco}		10		MHz
Output power	EIRP	P_{TX}	+16	+18	+20	dBm
Output power deviation	Full VCO tuning range	ΔP_{TX}		+/- 1		dBm
Spurious emission	According to ETSI 300 440	P_{spur}			-30	dBm
Receiver						
Antenna gain	$F_{TX}=24.125\text{GHz}$ <small>Note 2</small>	G_{Ant}		12.5		dB
LNA gain	$F_{RX}=24.125\text{GHz}$	G_{LNA}		10		dB
Mixer Conversion loss	$f_{IF}=500\text{Hz}$	D_{mixer}		-6		dB
Receiver sensitivity	$f_{IF}=500\text{Hz}$, $B=1\text{kHz}$, $S/N=6\text{dB}$	P_{RX}		-108		dBm
Overall sensitivity	$f_{IF}=500\text{Hz}$, $B=1\text{kHz}$, $S/N=6\text{dB}$	D_{system}		-126		dBc
IF output K-LC6						
IF output impedance		R_{IF}		50		Ω
I/Q amplitude balance	$f_{IF}=500\text{Hz}$	ΔU_{IF}		3		dB
I/Q phase shift	$f_{IF}=500\text{Hz}$	φ	80	90	100	$^{\circ}$
IF frequency range	-3dB Bandwidth	f_{IF}	0		50	MHz
IF noise voltage	$f_{IF}=500\text{Hz}$	$U_{IFnoise}$		45		nV/ $\sqrt{\text{Hz}}$
	$f_{IF}=500\text{Hz}$	$U_{IFnoise}$		-147		dBV/Hz
IF output offset voltage		U_{os}	-0.2		+0.2	V
Supply rejection	Rejection supply pins to outputs, 500Hz	D_{supply}		-26		dB
IF output K-LC6_V2						
IF output impedance		R_{IF}		100		Ω
IF Amplifier gain	Only present in version K-LC6_V2	G_{IF}		20		dB
I/Q amplitude balance	$f_{IF}=500\text{Hz}$	ΔU_{IF}		3		dB
I/Q phase shift	$f_{IF}=500\text{Hz}$	φ	80	90	100	$^{\circ}$
IF frequency range	-3dB Bandwidth	f_{IF}	10		15k	Hz
IF noise voltage	$f_{IF}=500\text{Hz}$	$U_{IFnoise}$		450		nV/ $\sqrt{\text{Hz}}$
	$f_{IF}=500\text{Hz}$	$U_{IFnoise}$		-127		dBV/Hz
IF output offset voltage		U_{os}	2.25	2.5	2.75	V
Supply rejection	Rejection supply pins to outputs, 500Hz	D_{supply}		-26		dB

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Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Unit
Antenna						
Horizontal -3dB beamwidth	E-Plane	W_e		12		°
Vertical -3dB beamwidth	H-Plane	W_a		80		°
Horiz. sidelobe suppression		D_e		-20		dB
Vert. sidelobe suppression		D_a		-18		dB
Body						
Outline Dimensions	connector left unconnected					mm ³
Weight				6		g
Connector				5		pins

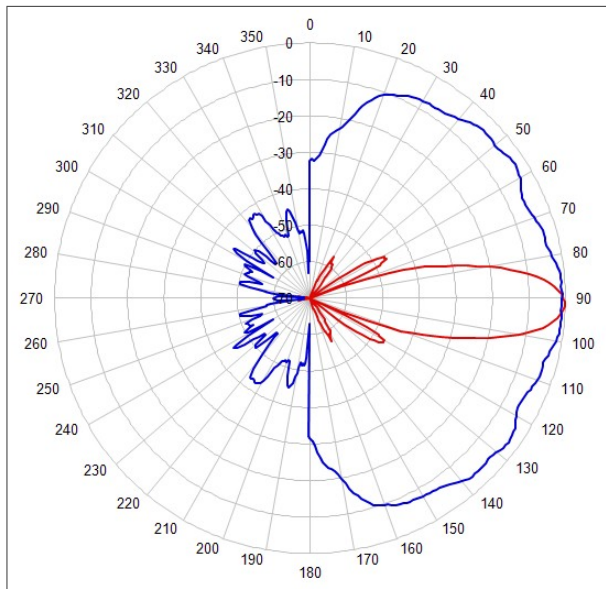
Note 1 Transmit frequency stays within 24.050 to 24.250GHz over the specified temperature range if VCO pin is left open
 Note 2 Theoretical value, given by design



Do not touch open connector pins. RFbeam K-LC6 radar module is susceptible to electrical discharge as long as it is not placed in the circuit.

Antenna System Diagram

This diagram shows module sensitivity (output voltage) in both azimuth and elevation directions. It incorporates the transmitter and receiver antenna characteristics.
 Please note: broad side of the module results in 12° narrow beam because of the 8 antenna elements.



Azimuth 12° , Elevation 80°
 At IF output voltage -6dB,
 corresponds to -3dB Tx power

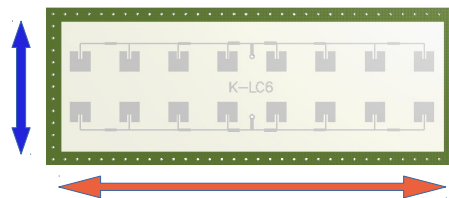


Fig. 2: Antenna system diagram (logarithmic scale)

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FM Characteristics

Carrier frequency can be modulated by means of a voltage applied to the VCO input. This feature can be used for ranging applications using FMCW (see also Fig. 4) or FSK techniques.

FMCW needs good linearity in the frequency ramp. RFbeam provides a downloadable tool "VCO-Lin" that allows calculating the non-linearity using 3 known frequency versus VCO voltage points.

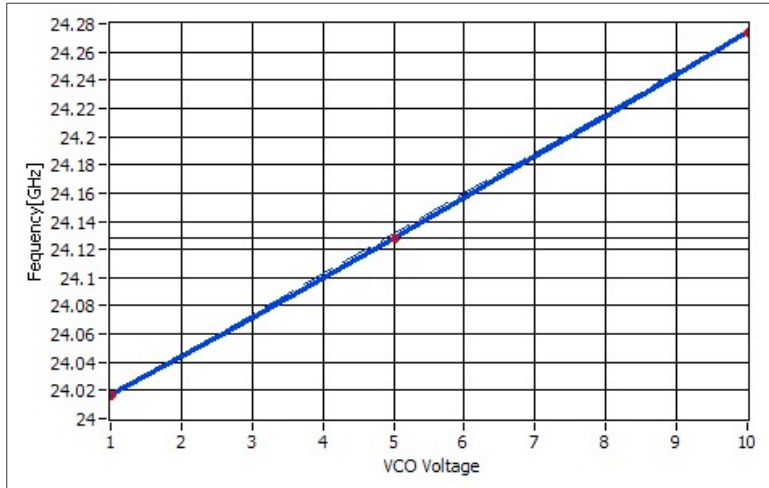


Fig. 3: Typical Frequency vs. VCO voltage

Pin Configuration

Pin	Description	
1	IF output Q	
2	VCC	5V supply
3	IF output I	
4	GND	0V supply
5	VCO in	1V .. 10V, open = 5V

Outline Dimensions

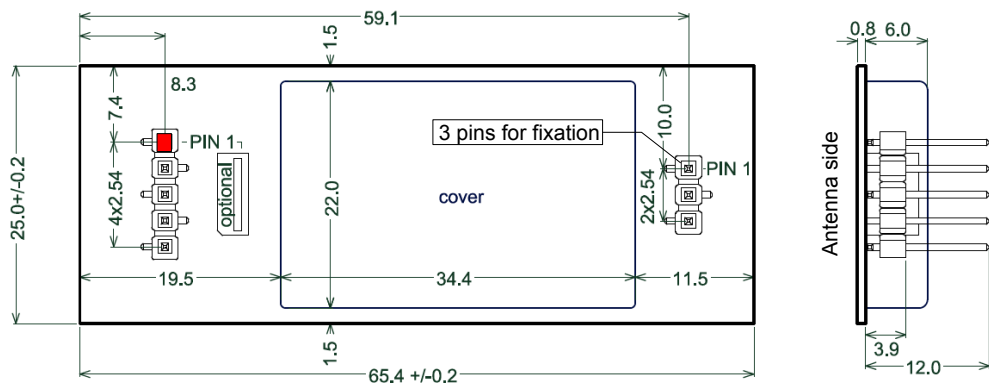


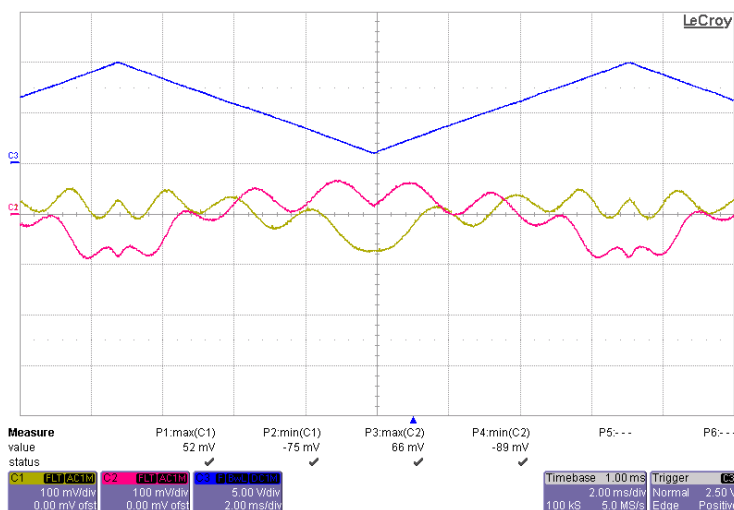
Fig. 4: Mechanical dimensions

Application Notes

Using VCO and IF Amplifier

The IF amplifier provides two outputs per channel according to Fig. 1. These outputs are designed for different requirements in processing radar signals. Both I (in-phase) and Q (quadrature) mixer signals are available. The I and Q signals are phase shifted by $+90^\circ$ or -90° , depending on the moving direction of objects in range.

FMCW generates an output signal even without an object in range because of the finite isolation between transmitter and receiver path. This effect is called self-mixing and leads to a DC signal that depends on the carrier frequency. Using FMCW, these signals move and may overdrive external IF amps under certain circumstances.



Example showing a single target:

Triangle VCO Amplitude: 8Vpp
 Triangle period $T_M = 14\text{ms}$.
 Modulation depth $f_M = 200\text{MHz}$
 IF output freq. $f_b = 450\text{Hz}$

I_AC and Q_AC outputs show a low frequency caused by local carrier feedthrough.

The superposed higher frequency f_b is often called beat frequency, caused by a target at a distance of about 2.4m.

Fig. 5: IF Output FMCW signals with triangle VCO and $df = 200\text{MHz}$

Distance calculation

$$R = \frac{c_0}{2} \cdot \frac{f_b}{f_M} \cdot \frac{T_M}{2} = 2.4\text{m approx}$$

For legend refer to Fig. 5

R Range, distance to target

c_0 Speed of light ($3 \cdot 10^8$ m/s)

For more information on FMCW and also on FSK applications check download area on our website www.rfbeam.ch.

I and Q IF Outputs

The IF outputs provide high bandwidth for use in FMCW and FSK applications. Use external filters to lower bandwidth according your application. The lower the bandwidth, the better the signal to noise (SNR) ratio.

External amplification should be limited in order to prevent saturation. FMCW ramp is visible at the outputs caused by self-mixing effects, near objects and cover (RADOM). With full FMCW sweep, a feed through to IF output of approximately 20mVpp (200mVpp with K-LC6_V2) will exist.

Sensitivity and Maximum Range

The values indicated here are intended to give you a 'feeling' of the attainable detection range with this module. It is not possible to define an exact RCS (radar cross section) value of real objects because reflectivity depends on many parameters. The RCS variations however influence the maximum range only by $\sqrt[4]{\sigma}$.

Maximum range for Doppler movement depends mainly on:

- Module sensitivity	S:	-126dBc (@1kHz IF Bandwidth)
- Carrier frequency	f ₀ :	24.125GHz
- Radar cross section RCS ("reflectivity") of the object	σ ¹⁾ :	1m ² approx. for a moving person >50m ² for a moving car

note ¹⁾ RCS indications are very inaccurate and may vary by factors of 10 and more.

The famous "Radar Equation" may be reduced for our K-band module to the following relation:

$$r = 0.0167 \cdot 10^{\frac{-s}{40}} \cdot \sqrt[4]{\sigma}$$

Using this formula, you get an indicative detection range of

- > 24 meters for a moving person
- > 62 meters for a moving car

Please note, that range values also highly depend on the performance of signal processing, environment conditions (i.e. rain, fog), housing of the module and other factors.

With K-LC6, you can achieve a maximum range of more than 100m when using high resolution AD-converters and selective FFT algorithms.

Datasheet Revision History

Version	Date	Changes
1.0	19-April-2012	initial release
1.1	25-April-2012	Corrected values in chapter Using VCO and IF Amplifier
1.2	02-Nov-2018	Changed footer to new address