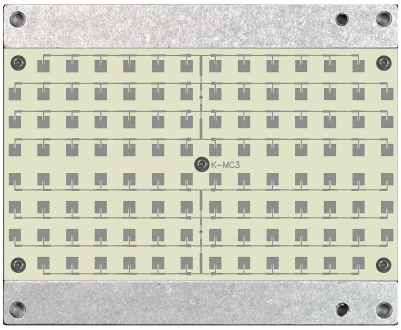
K-MC3 RADAR TRANSCEIVER

Datasheet

Features

- 24 GHz short range transceiver
- Beam aperture **25°/7°**
- Electrically compatible to RFbeam K-MC2
- 180MHz sweep FM input
- High sensitivity, integrated RF/IF amplifier
- Dual 54 patch narrow beam antenna
- Buffered I/Q IF outputs
- Additional DC IF outputs
- RSW Rapid Sleep Wakeup
- Extremely compact:105x85x5 mm^3 construction



Applications

- Traffic supervision and counting
- Object speed measurement systems
- Ranging and distance detection
- Industrial sensors

Description

K-MC3 is a 108 patch doppler module with an asymmetrical narrow beam for long distance sensors. It is ideally suited for traffic supervision.
This module includes a RF low noise amplifier and two IF preamplifiers for both I and Q channels. The need for external analogue electronics will be significantly reduced by this feature. For special signal condition applications, an additional buffered Mixer DC output is provided. This greatly improves flexibility in FSK ranging applications.

The unique "RSW" *R*apid *S*leep *W*akeup function with <4us wakeup time makes this module ideal for battery operated equipment. Typical duty cycle in RWS mode may be < 5% with full movement detection capability by sampling the IF signals.
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](http://www.rfbeam.ch))

Blockdiagram

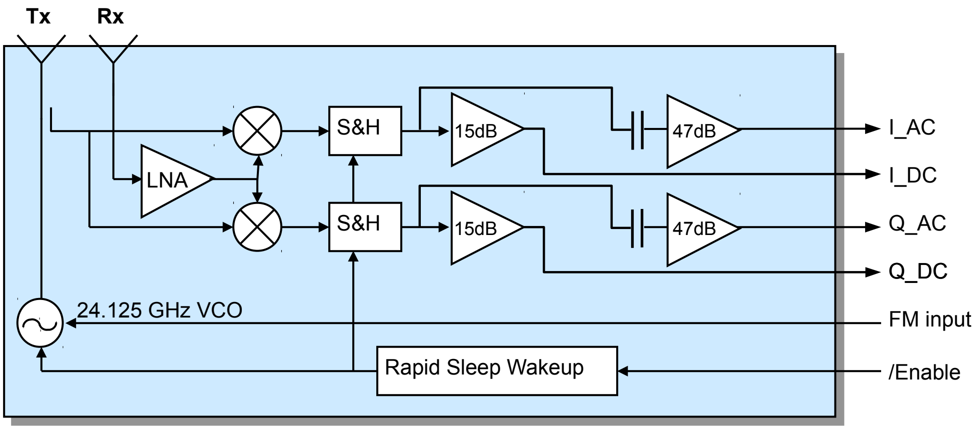


Fig. 1: K-MC3 Blockdiagram

Characteristics

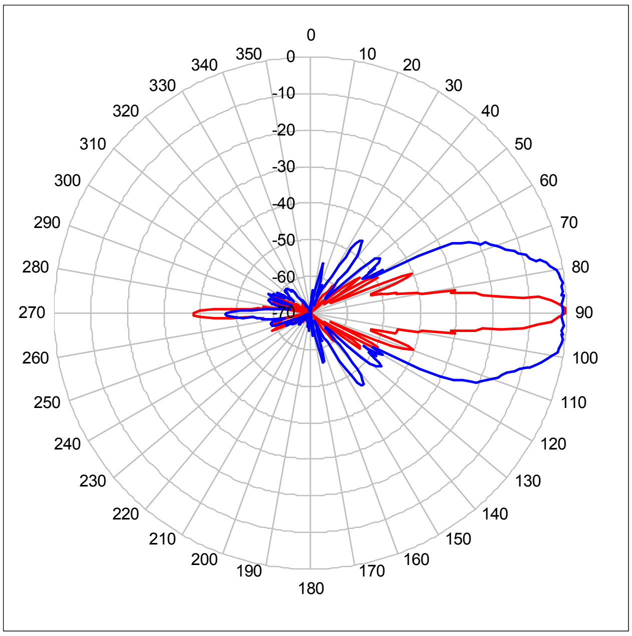
Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Unit
Operating conditions						
Supply voltage		V_{cc}	4.75	5.0	5.25	V
Supply current	Module enabled (Pin 1 = V_{IL})	I_{cc}		70	100	mA
	Module RSW mode (Pin 1 = V_{IH})			7	10	mA
VCO input voltage		U_{vco}	1		10	V
VCO pin resistance	Internal pullup 10k	R_{vco}		10k		Ω
Operating temperature		T_{op}	-20		+80	°C
Storage temperature		T_{st}	-20		+80	°C
Power down/Enable						
Module power down	Input tied high with pullup 10k	V_{IH}	V_{cc}-0.7		V_{cc}+ 0.3	V
Module enable		V_{IL}	-0.2		2	V
Minimum enable time	Sample&Hold capacitor charged	t_{on}	4			µs
Maximum hold time	S&H error <10%	t_{off}			2	ms
Hold Step	Charge injection visible at DC output	V_{step}		6		mV
Transmitter						
Transmitter frequency	U_{VCO}= 5V, T_{amb}=-20°C .. +60°C	f_{TX}	24.050	24.150	24.250	GHz
Frequency drift vs temp.	V_{cc}=5.0V, -20°C .. +60°C Note 1	Δf_{TX}		-1.0		MHz/°C
Frequency tuning range		Δf_{vco}		180		MHz
VCO sensitivity		S_{vco}		18		MHz/V
VCO Modulation Bandwidth	Δf=20MHz	B_{VCO}		3		MHz
Output power	EIRP	P_{TX}	+16	+19	+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}=24.125GHz Note 2	G_{Ant}		21		dBi
LNA gain	F_{RX}=24.125GHz	G_{LNA}		16		dB
Mixer Conversion loss	f_{IF} =500Hz	D_{mixer}		-6		dB
Receiver sensitivity	f_{IF} =500Hz, B=1kHz, S/N=6dB	P_{RX}		-126		dBm
Overall sensitivity	f_{IF} =500Hz, B=1kHz, S/N=6dB	D_{system}		-145		dBc
IF output						
IF output impedance	_AC outputs	R_{IF_AC}		100		Ω
	_DC outputs	R_{IF_DC}		100		Ω
IF Amplifier gain	_AC outputs	G_{IF_AC}		47		dB
	_DC outputs	G_{IF_DC}		15		dB
I/Q amplitude balance	f_{IF} =500Hz, U_{IF}=100mV_{pp} (_AC outputs)	ΔU_{IF}		3		dB
I/Q phase shift	f_{IF} =500Hz, U_{IF}=100mV_{pp} (_AC outputs)	φ	80	90	100	°
IF frequency range	-3dB Bandwidth (_AC outputs)	f_{IF_AC}	40		15k	Hz
	-3dB Bandwidth (_DC outputs)	f_{IF_DC}	0		500	kHz
IF noise voltage	f_{IF} =500Hz	$U_{IFnoise}$		22		µV/√Hz
	f_{IF} =500Hz	$U_{IFnoise}$		-93		dBV/Hz
IF output offset voltage	V_{cc} = 5V, _AC outputs	U_{os_AC}	2.0	2.5	3.0	V
	no object in range,VCO pin open,_DC outputs	U_{os_DC}	0.5	2.5	4.5	V
Supply rejection	Rejection supply pins to _AC outputs, 500Hz	D_{supply}		-24		dB

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Unit
Antenna						
Horizontal -3dB beamwidth	E-Plane	W_φ		7		°
Vertical -3dB beamwidth	H-Plane	W_θ		25		°
Horiz. sidelobe suppression		D_φ		-20		dB
Vert. sidelobe suppression		D_θ		-18		dB
Body						
Outline Dimensions	connector left unconnected			105x85x5		mm^3
Weight				102		g
Connector	Module side: AMP X-338069-8			8		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

Antenna System Diagram

This diagram shows module sensitivity (output voltage) in both azimuth and elevation directions. It incorporates the transmitter and receiver antenna characteristics.



Azimuth 7° , Elevation 25°
At IF output voltage -6dB
(corresponds to -3dB Tx power)

Fig. 2: Anntenna system diagram

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.

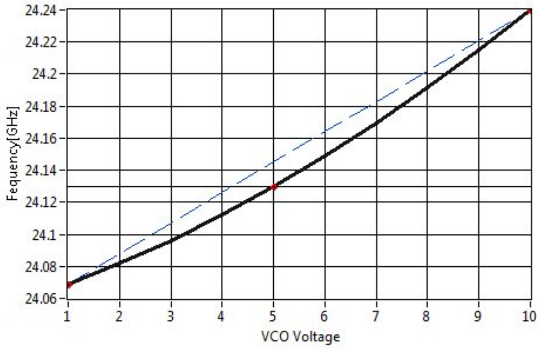
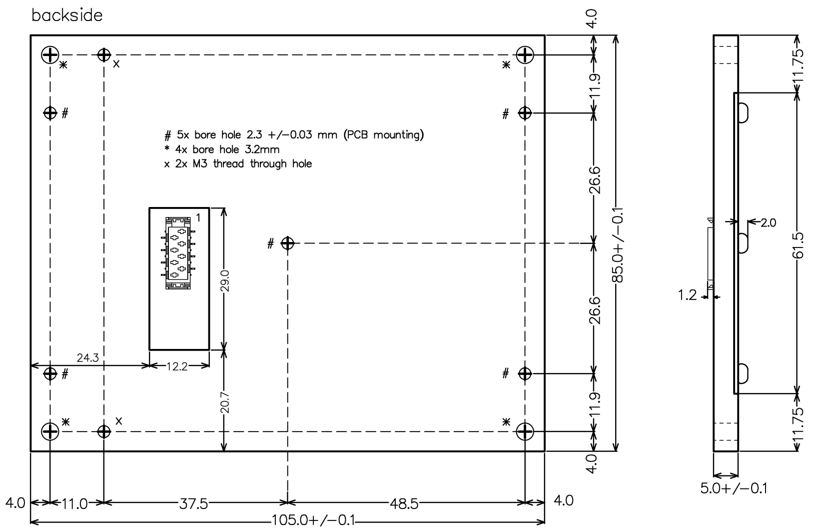


Fig. 3: Typical Frequency vs. VCO voltage

Pin Configuration

Pin	Description	Typical Value
1	/Enable	GND: module active
2	VCC	5V supply
3	GND	0V supply
4	IF output Q_AC	high gain output
5	IF output I_AC	high gain output
6	VCO in	5.0V = f_0 (Range 0 .. 10V)
7	IF output I_DC	low gain output
8	IF output Q_DC	Low gain output

Outline Dimensions



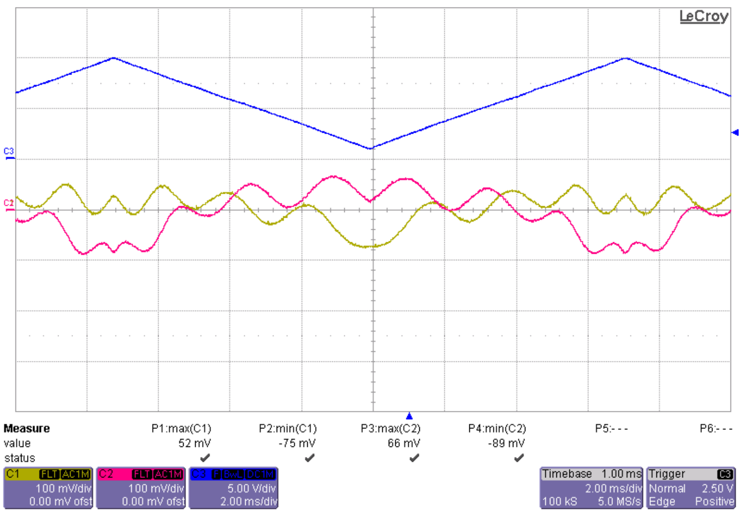
All Dimensions in mm All values given are typical unless otherwise specified.

Fig. 4: Mechanical dimensions

Application Notes

Using VCO and Internal 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 (imaginary) and Q (real) mixer signals are available. The I and Q signals are phase shifted by +90° 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 the 2nd stage (x_AC outputs) of the IF amp under certain circumstances.



Example showing a single target:
Triangle VCO Amplitude: 8Vpp
Triangle period T_M = 14ms.
Modulation depth f_M = 160MHz
IF output freq. f_b = 450Hz

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 3m.

Fig. 5: x_AC Output FMCW signals with triangle VCO and df = 85MHz

Distance calculation

$$R = \frac{c_0}{2} \cdot \frac{f_b}{f_M} \cdot \frac{T_M}{2}$$ = 3m approx

For legend refer to Fig. 5
R Range, distance to target
*c_0 Speed of light (3 * 10^8 m/s)*

Please contact RFbeam Microwave GmbH for more informations on FMCW and also on FSK applications.

I_AC and Q_AC High Gain Outputs

These outputs provide high gain/low noise signals generated by doppler effects or FMCW. They directly can drive ADC input stages of microprocessors or DSPs. Even with 10Bit of resolution only, sensitive and relatively long range Doppler detections are possible. The outputs cover a frequency range of 40Hz ... 15kHz.
However, these outputs may saturate and clip because of too high input signals. In these cases you may use the x_DC outputs described below.

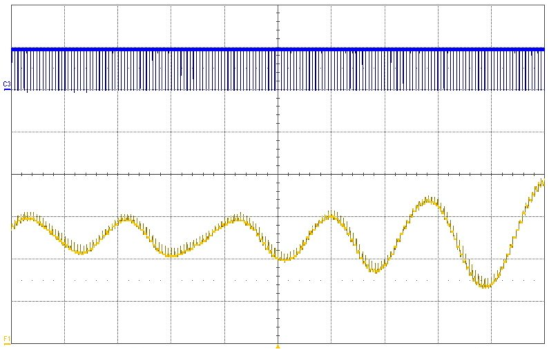
I_DC and Q_DC Low Gain Outputs

The low gain DC outputs (I_DC and Q_DC) hardly enter into a saturation state and may be used in cases, where the high gain outputs (I_AC and Q_AC) are clipped because of high input signals. Saturation and clipping typically arise in conjunction with FMCW and may be caused by objects nearby the sensor, non-compensated radoms etc.
These outputs carry more signal information than the x_AC outputs because of their bandwidth ranging from DC to 500kHz. Using ADCs with resolutions of 12Bits and more and processing with DSP processors allow versatile and flexible radar applications.

Rapid Sleep Wakeup (RSW)

RFbeam's unique rapid sleep wakeup feature allows power savings of more than 90% during 'silent' periods. The module may be used in a relaxed sampling mode as long as no movements are detected. RSW also helps saving power, if not the full IF bandwidth of 15kHz is needed.
In battery operated equipment such as traffic control, RSW may significantly lower battery and equipment volume and cost.

RSW in Action

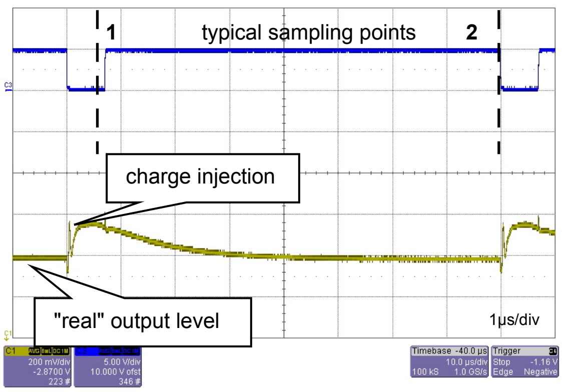


This graph shows the sampling signal at pin */Enable* and a resulting output signal at an *x_AC pin* caused by an approaching object.
This signal may be processed 'as is' or used as trigger to start continuous acquisition.
If RSW mode is used only to detect any movement, aliasing effects are not important (i.e. undersampling is useful).
By choosing a sampling frequency, aliasing must be taken into account, if frequency measurements are intended.

Fig. 6: Sampled Doppler signal at x_AC outputs

RSW principle

RSW combines switching of the RF oscillator and sample&hold of the mixer signals (please refer to Fig. 1: K-MC3 Blockdiagram). During sleep mode (pin /ENABLE = high), only the amplifiers stay switched on to hold the output voltage and coupling capacitor charges. This assures minimum peaks at the outputs when returning to the active state.
Nevertheless, we have to take some important effects into account. An important effect is charge injection, caused by the digital control signal.



/ENABLE signal with t_{on} = 7µs.

x_AC output signal recovers after 80µs approx.

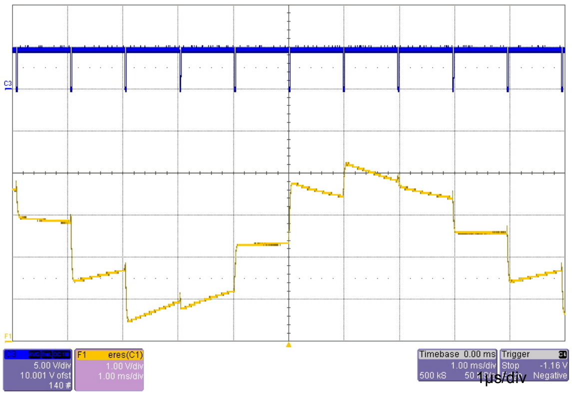
Fig. 7: x_AC output is influenced by charge injection caused by switching signal

Sampling sequence

To simplify signal processing sequence, output sampling may be done immediately after /ENABLE goes high (1) or before next /ENABLE (2).
Both methods have their advantages and disadvantages:

- Sampling point (1) contains a constant overshoot, i.e. sampled output signal becomes shifted by a constant DC component. There is no loss of sensitivity.
- Sampling point (2) corresponds to the real mixer output, as long as sleep time is short enough. But with longer off times, signal amplitude decreases.

As a rule of thumb: with a repeat frequency of 1kHz (duty cycle of 7µs/1ms = 0.7%) amplitude loss is 3dB approx. This situation is shown in the figure below.



Sampling signal (t_c = 1ms, t_{on} = 7us)

Output signal decreases during the off-period with a timeconstant of 4.8ms approx.

Fig. 8: x_AC output amplitude decreases during sleep time.

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:	-145dBc (@1kHz IF Bandwidth)
- Carrier frequency	f_0:	24.125GHz
- Radar cross section RCS ("reflectivity") of the object	σ[1]:	1m² approx. for a moving person >50m² 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
- > 70 meters for a moving person
- > 180 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-MC3, you can achieve a maximum range of more than 500m when using high resolution AD-converters and selective FFT algorithms.

Datasheet Revision History

Version	Date	Changes
1.0	24-Mar-2010	initial release
1.1	13-May-2011	updated mechanical drawing
2.0	14-July-2011	Adapted to new hardware Revision G, valid from lot # LL1108
2.1	02-Nov-2018	Changed footer to new address
2.2	08-Nov-2018	Changed typical value for VCO_In