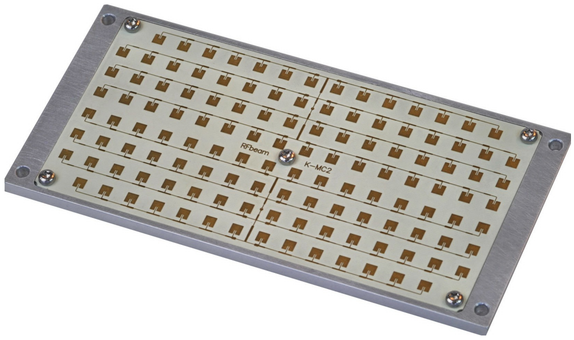
K-MC2 RADAR TRANSCEIVER

Replaced by K-MC3 Datasheet

Features



- 24 GHz short range transceiver
- 90MHz sweep FM input
- High sensitivity, integrated RF/IF amplifier
- Dual 62 patch narrow beam antenna
- Buffered, gain adjustable I/Q IF outputs
- Additional DC IF outputs
- Beam aperture **25°/7°**
- RSW Rapid Sleep Wakeup
- Extremely compact:138x65x6 mm^3 construction

Applications

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

Description

K-MC2 is a 124 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 multistep FSK ranging applications.

The unique "RSW" *R*apid *S*leep *W*akeup function with <7us wakeup time makes this module ideal for battery operated equipment. Typical duty cycle in RWS mode may be < 1% 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.

A powerful starterkit with signal conditioning and visualization is also available. (see www.rfbeam.ch Download Section)

Blockdiagram

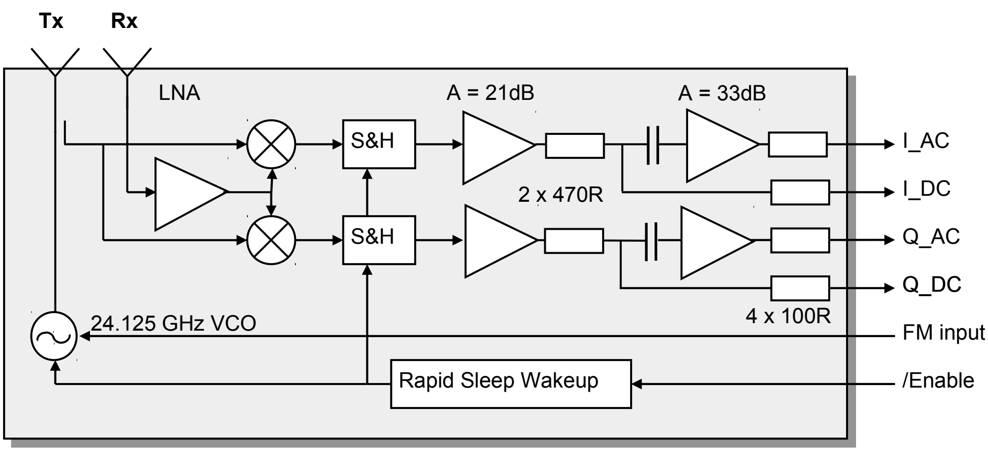


Fig. 1: K-MC2 Blockdiagram

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}		80	100	mA
	Module RSW mode (Pin 1 = V_{IH})			5	7	mA
VCO input voltage		U_{vco}	0		5.0	V
VCO pin resistance	Internal pulldown 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}	7			µs
Maximum hold time	S&H error <10%	t_{off}			2	ms
Transmitter						
Transmitter frequency	U_{VCO}= 2V, 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}		89		MHz
VCO sensitivity		S_{vco}		22		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}		570		Ω
IF Amplifier gain	_AC outputs	G_{IF_AC}		54		dB
	_DC outputs	G_{IF_DC}		21		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		300	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

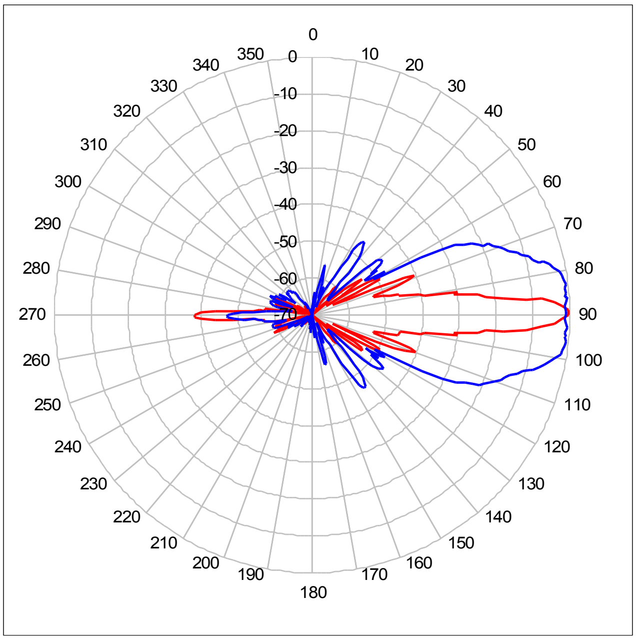
Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Unit
Antenna						
Horizontal -3dB beamwidth	E-Plane	W_φ		7		°
Vertical -3dB beamwidth	H-Plane	W_θ		25		°
Horiz. sidelobe suppression		D_φ		-20		dB
Vert. sidelobe suppression		D_θ		-18		dB
Body						
Outline Dimensions	connector left unconnected			138x65x6		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 when the VCO pin is set to 2VDC

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

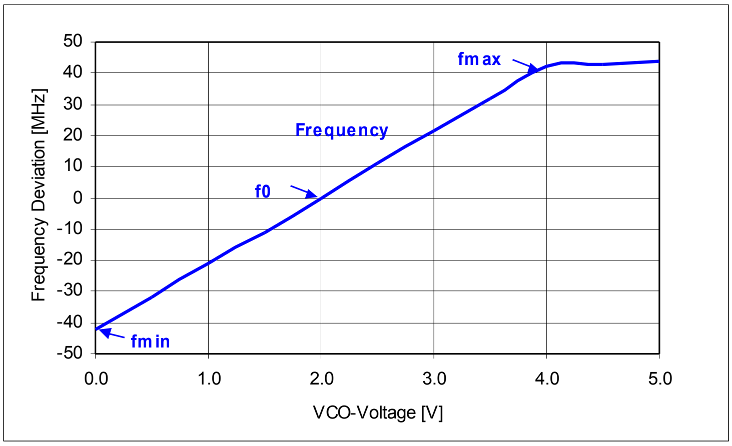
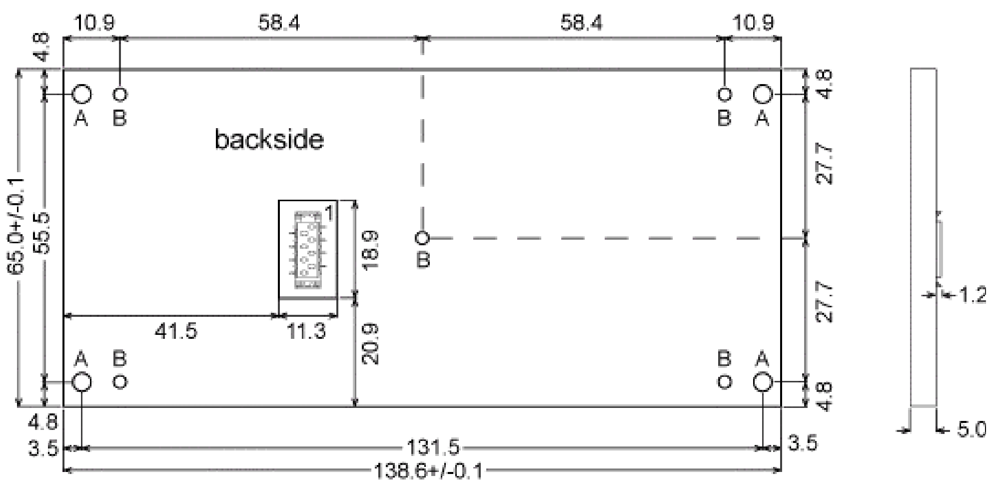


Fig. 3: Typical Frequency vs. VCO voltage

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	2.0V = f_0
7	IF output I_DC	low gain output
8	IF output Q_DC	Low gain output

Outline Dimensions



A 4x bore hole 3.5mm Module mounting B 5x bore hole 2.3 +/-0.03 mm PCB mounting

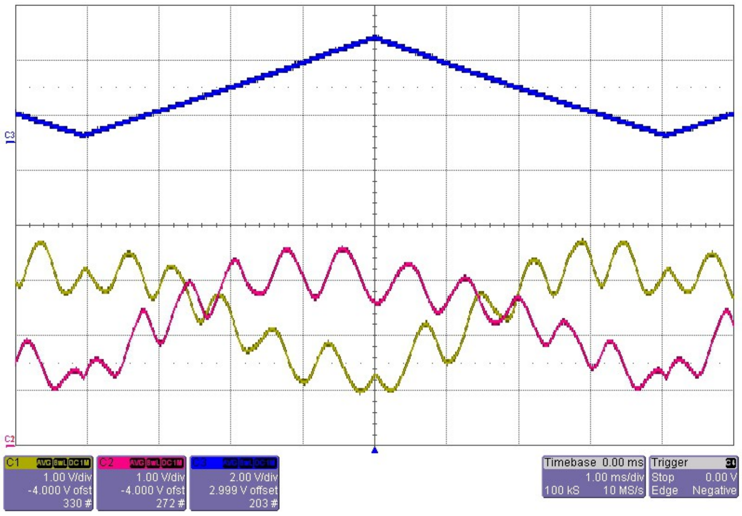
All Dimensions in mm All values given are typical unless otherwise specified.

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.



Triangle VCO Voltage with A=3.8Vpp and f=125Hz. Resulting transmit frequency deviation of approx. 100MHz

I_AC and Q_AC outputs show a low frequency caused by local carrier feedthrough.
The superposed higher frequency with 1.25kHz is caused by a target.
The peak-peak amplitude of 2.8Vpp is no problem, because the x_AC outputs are limited at 4.5Vpp approx.

Fig. 5: x_AC Output FMCW signals with triangle VCO and df = 100MHz

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.
There is also a possibility to adjust output levels by using a resistor at the x_DC outputs. (see chapter Adjusting IF Gain).

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 300kHz. Using ADCs with resolutions of 12Bits and more and processing with DSP processors allow versatile and flexible radar applications.

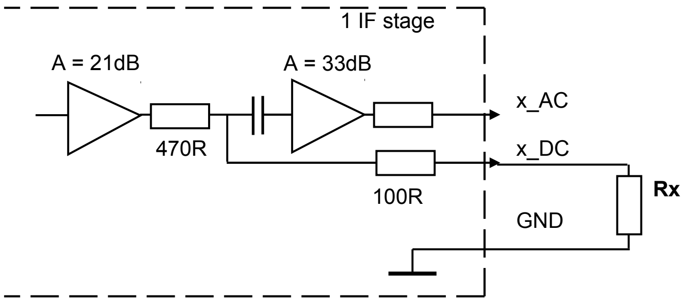
Adjusting IF Gain

If there is a risk of overdriving the 2nd amplifier, you may use the low gain x_DC outputs or attenuate the input signals of the 2nd stage amp.
Gain of the 2nd stage amplifier may be lowered by adding an external resistor at pins I_DC and Q_DC connected to GND. Please refer to Fig. 1: K-MC2 Blockdiagram to understand the resistive attenuator.

2nd stage gain A_R may be adjusted between 18dB and 33dB resp. attenuated by max. 15dB.

Without additional Resistor:	A_R = 33dB = 45	resulting total IF gain: 54dB = 500
With short circuit at x_DC to ground	A_R = 18dB = 8	resulting total IF gain: 39dB = 89

$$A_R = 45/(1+\frac{470}{100+Rx}) \quad \text{or} \quad Rx = \frac{470}{(45/A_R)-1} - 100$$



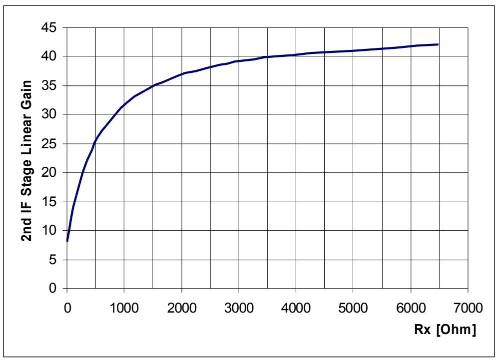
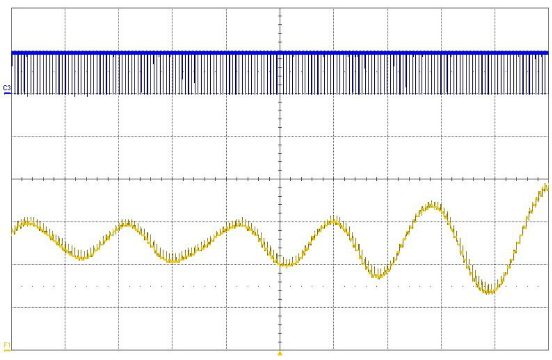


Fig. 6: Attenuating xAC outputs via x_DC pins

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



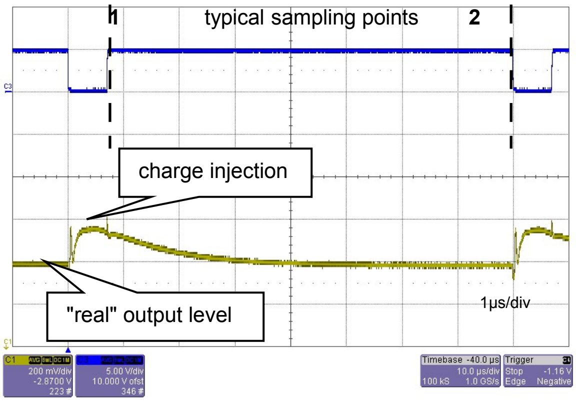
This graph shows the sampling signal at pin */Enable* and a resulting output signal at an *x_AC pin* caused by an approaching object.
This signal may be processed 'as is' or used as trigger to start continuous acquisition.
If RSW mode is used only to detect any movement, aliasing effects are not important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

Fig. 7: 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-MC2 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.

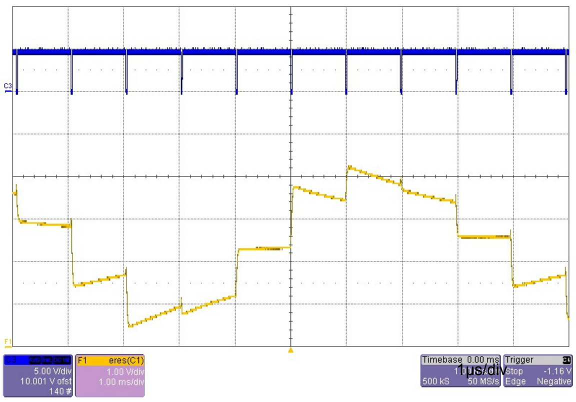
Fig. 8: x_AC output is influenced by charge injection caused by switching signal

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. 9: 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]:	$1m^2$ 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
- > 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.
Maximal distance is also limited by the phase noise of the oscillator. With K-MC2, you get an absolute maximum range of about 200m.

Datasheet Revision History

Version	Date	Changes
1.0	10-June-2009	initial release
1.1	09-Nov-2009	Operating temperature corrected to +80°C
1.2	17-Dec-2009	VCO tuning range corrected to 90MHz