Technical documentation

Frequently asked questions for 24 GHz industrial radar

What is radar?

Radar is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, an emitting antenna, a receiving antenna (separate or the same as the previous one) to capture any returns from objects in the path of the emitted signal, a receiver and processor to determine properties of the object(s).

What product family is available?

The BGT24M/L family is the largest and highest integrated 24 GHz ISM band radar transceiver family currently in the market. It saves ~30 percent board space compared to discrete line ups. Infineon offers 4 different components, the BGT24MTR11 which combines one transmit and one receive channel, the BGT24MTR12 which comprises one transmit and two receive channels, and the BGT24MR2, a chip with 2 receive channels, combinable with both chipsets. Infineon recently released a new lower power, smaller form factor radar transceiver called BGT24LTR11 which comprises of one transmit and one receive channel.

What applications can radar be used in?

- Drones-soft landing and collision avoidance
- Street lighting projects
- Intelligent door openers
- Home automation
- Speed meters
- Robotics
- Internet of things

What are the radar processing technologies?

Technique	Complexity	Movement	Speed	Distance of moving objects	Distance of static objects	Angle of moving objects
Doppler	Low	✓	✓			
FSK	Medium	✓	✓	✓		
FMCW	High	✓	✓	✓	✓	
Monopulse	Medium					✓

Monopulse is an additional option for all the above operating modes

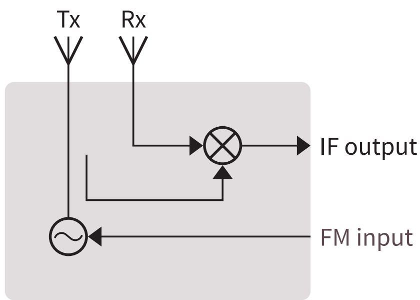
What are some of the main features of the products available?

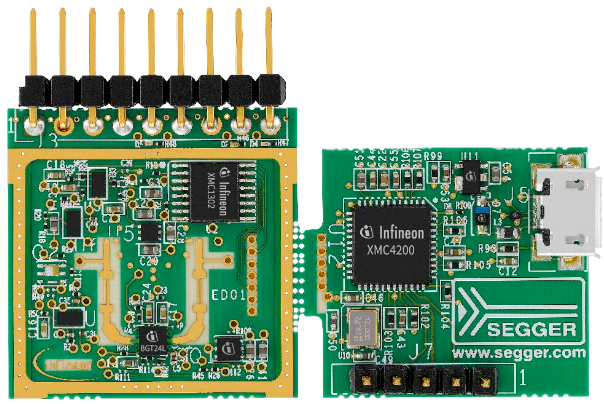
- Highest integration currently in the market
- Multiple combination Tx/Rx configurations available
- Fully packaged solution
- Low cost TSNP-16-9 package
- Distance detection up to 100 m
- Smallest packaged radar chip on the market

What is radar transceiver?

Radar transceiver (**trans**mitter re**ceiver**)

- Transmits low energy radio frequency signal over Tx antenna (24 GHz, max. 100 mW)
- Receives reflected signal over Rx antenna
- Moving target generates low frequency Doppler output signal (so called IF)

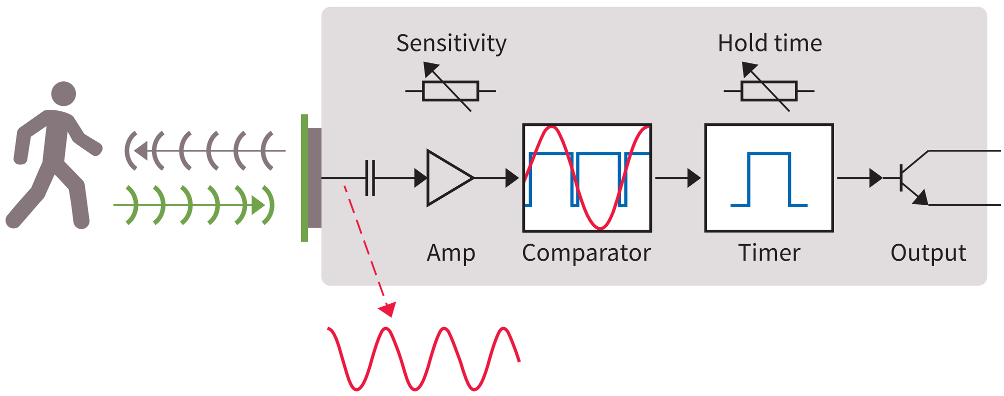




How does radar detect movement?

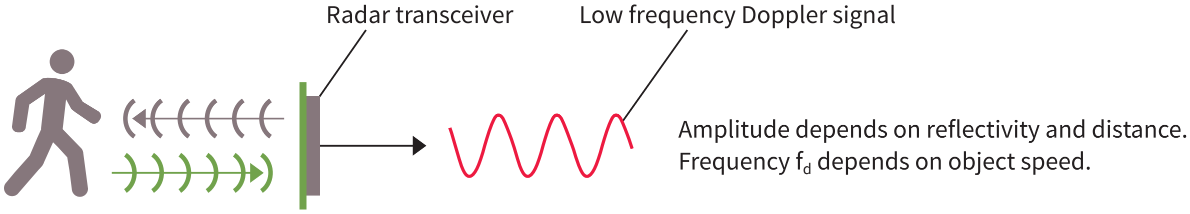
Basic movement detector

- Output becomes active as soon as Doppler signals are present
- Implemented with discrete components or simple microcontroller



What is the Doppler effect?

Doppler effect



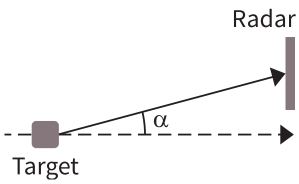
Calculating the Doppler frequency

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

or

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

f_d Doppler frequency
f_{Tx} Transmit 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



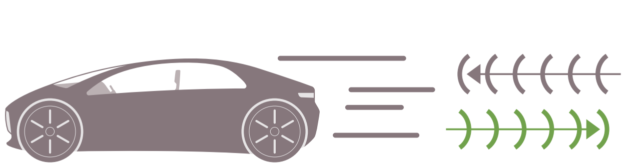
At a transmit frequency of f_{Tx} = 24.125 GHz we get a Doppler frequency for a moving object at the IF output of

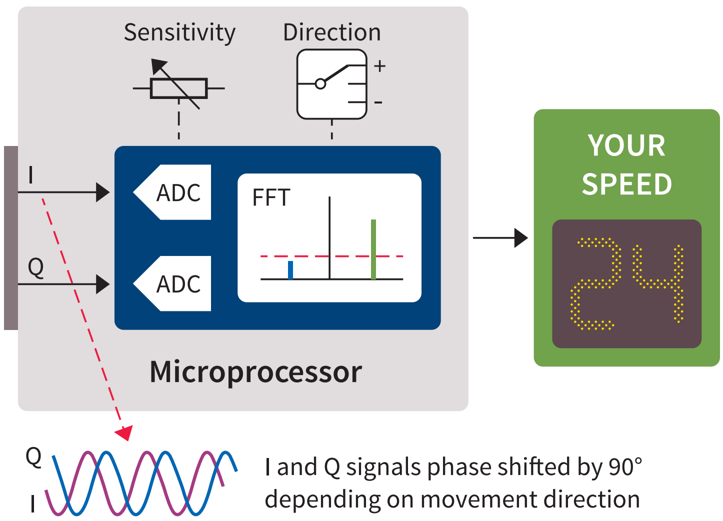
$$f_d = v\,[\text{km/h}] \times 44\ \text{Hz} \times \cos\alpha \quad \text{or} \quad f_d = v\,[\text{m/s}] \times 161\ \text{Hz} \times \cos\alpha \qquad (3)$$

How does Doppler processing calculate speed?

Speed display

› Frequency (= speed) and direction are detected by complex FFT
› Implemented with FFT (Fast Fourier Transform)





$$\text{Speed [km/h]} = \frac{f_d}{44\ \text{Hz} \times \cos\alpha}$$

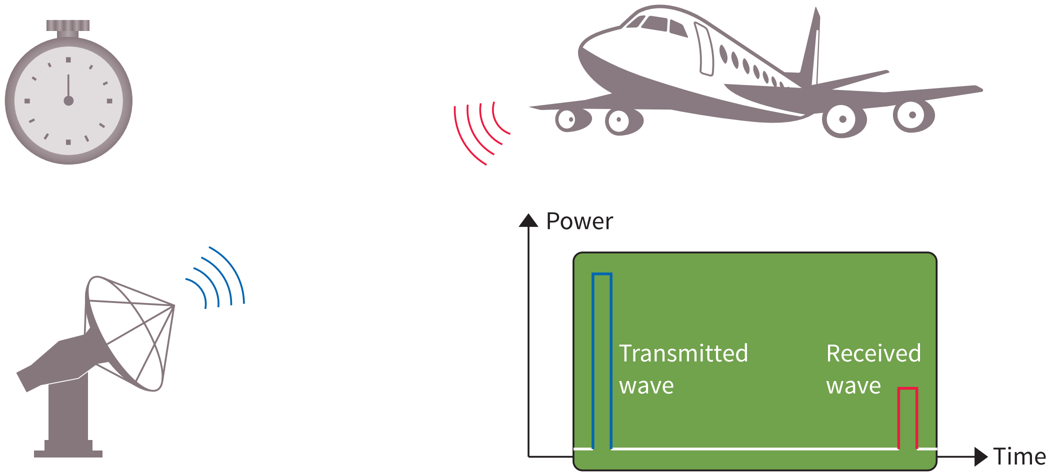
How does radar measure distances?

Typical measurement methods

Distance measurement always needs bandwidth/modulated carrier

Pulse radar

- Sends out a very short, powerful pulse
- Measures time of flight of reflected pulse
- Needs high bandwidth → not usable in K-band



Continuous wave methods

No pulse, but a continuous, frequency modulated carrier is sent

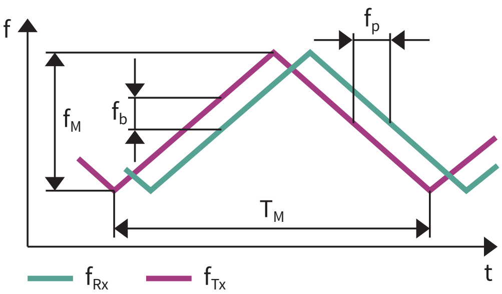
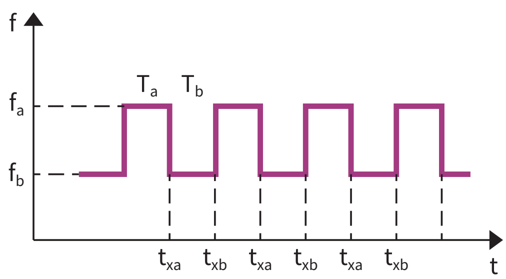
- **FMCW:** used to detect stationary and moving objects.
  A so called chirp is sent and mixed with the received signal.
  Low frequency output represents distance.

- **FSK:** used to get distances of moving objects.
  2 frequencies are sequentially sent.
  2 phase shifted Doppler signals represent distance.

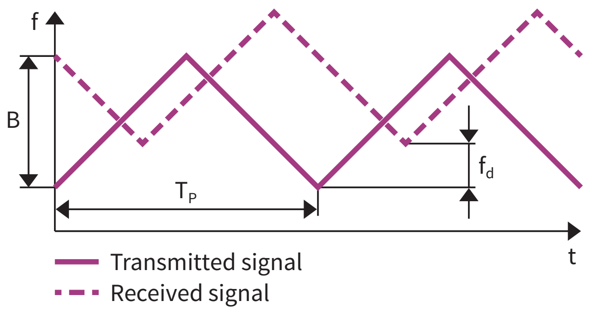
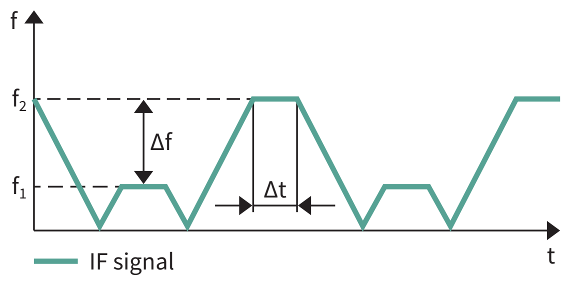
What is the difference between FMCW and FSK?

FMCW and FSK

Measuring distances need modulation of carrier → bandwidth

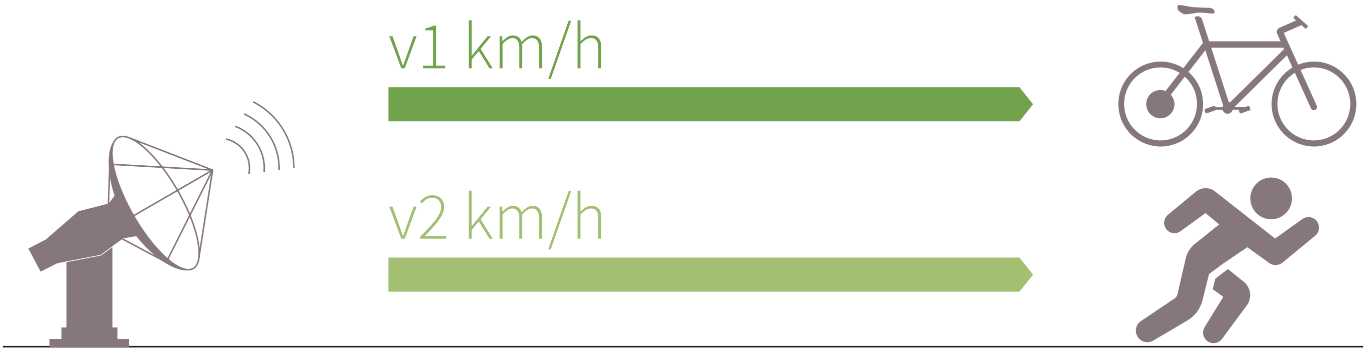
	FMCW (Frequency Modulation Continuous Wave)	FSK (Frequency Shift Keying)
Use	For stationary and moving objects	For moving objects only
Modulation		
Formula	$R = \frac{c_0}{2} \cdot \frac{f_b}{f_M} \cdot \frac{T_M}{2}$	$R = \frac{c_0 \cdot \Delta\phi}{4\pi \cdot (f_a - f_b)}$
Resolution	1 m, limited by K-band bandwidth 250 MHz $R = C/2f_M$	1–100 cm, depending on signal processing Limited by the system SNR and can only detect one target at a given speed

How can we measure speed with single chirp FMCW?

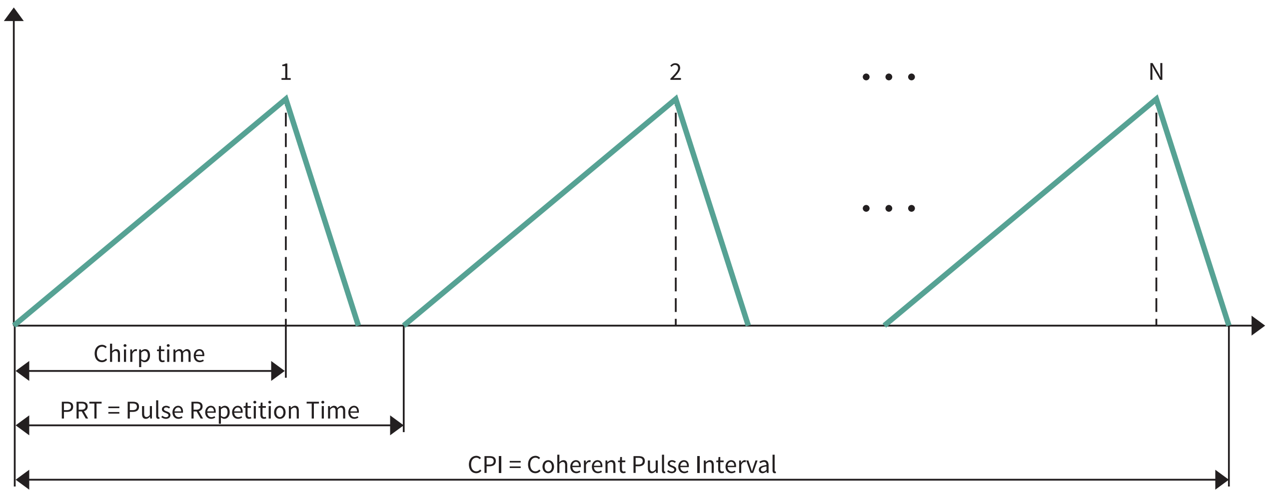
	Transmitted and received FMCW signal	IF signal at the mixer output
Modulation		
Formula	$R = \frac{cT_p}{2B} \times \frac{f_1+f_2}{2}$	$\upsilon_r = \frac{c}{2f_c} \times \frac{f_1-f_2}{2}$

How can we measure speed with multi chirp FMCW?

Multi chirp FMCW is the standard when it comes to detecting and tracking the position and speed of multiple targets.



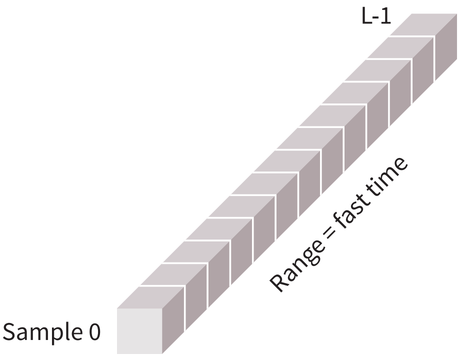
N number of chirps are used to create a frame



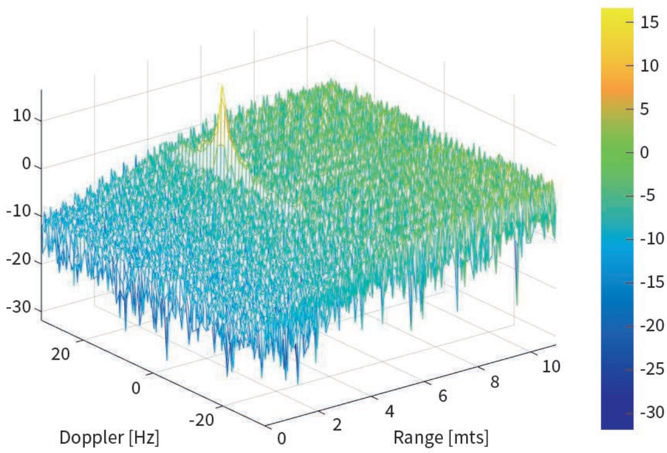
The time between two chirps are refered as Pulse Repetition Time (PRT). The maximum unambiguous Doppler that we can detect is $\pm\frac{1}{2PRT}$. The consecutive chirps/pulses time to estimate velocity is refered to as Coherent Pulse Interval (CPI). The minimum velocity that we can detect is $\pm\frac{1}{2CPI}$.

How is the data processed in a multi chirp FMCW?

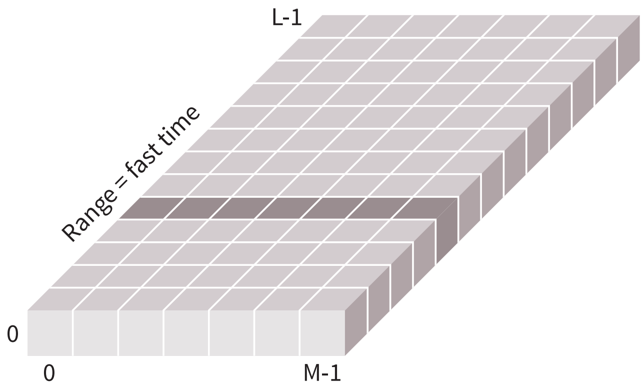
An FFT is applied along the single chirp to provide the different range bins, this is referred to as fast time.



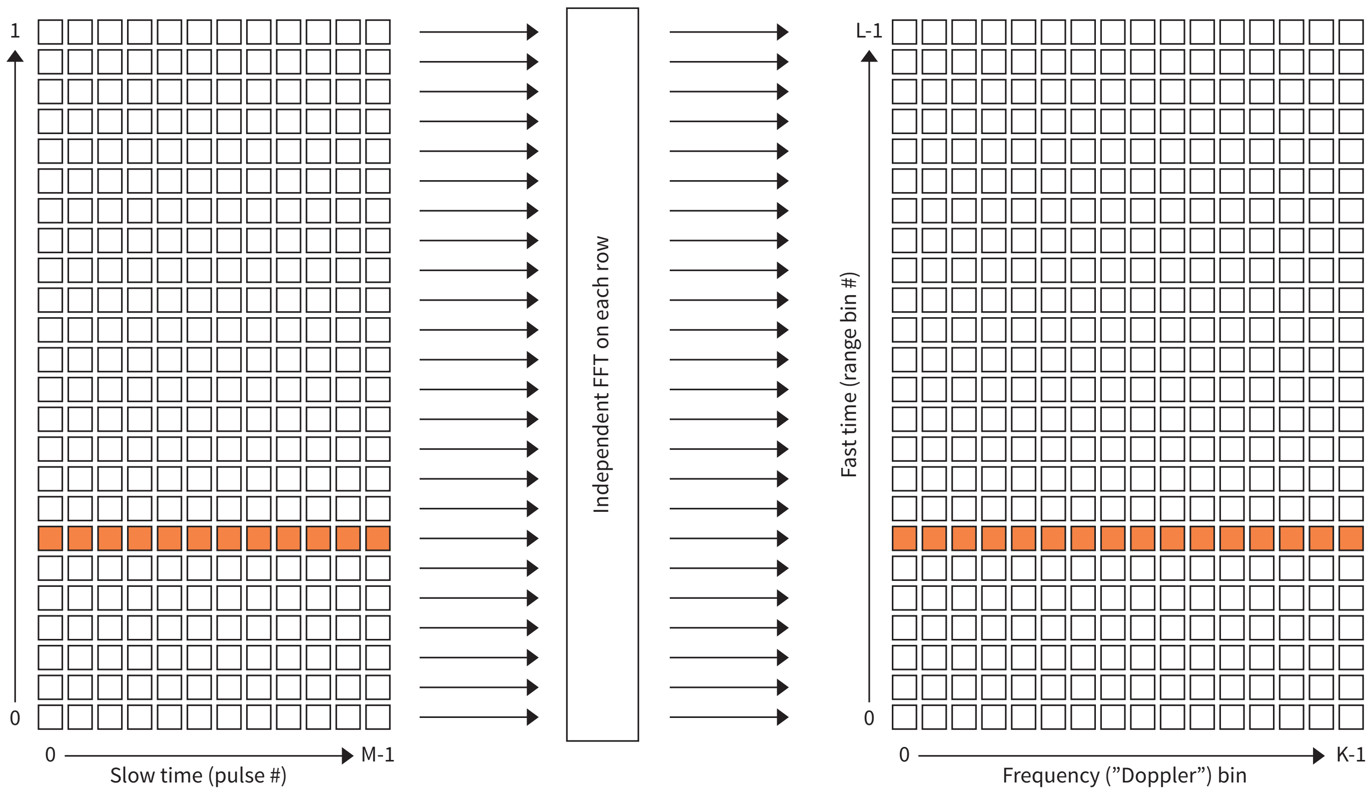
Basic FMCW range-doppler plot with target at 4.5 m range and velocity 5 m/s



A second FFT is applied along the chirps for a single range bin, to provide the velocity information; this is referred to as fast time.

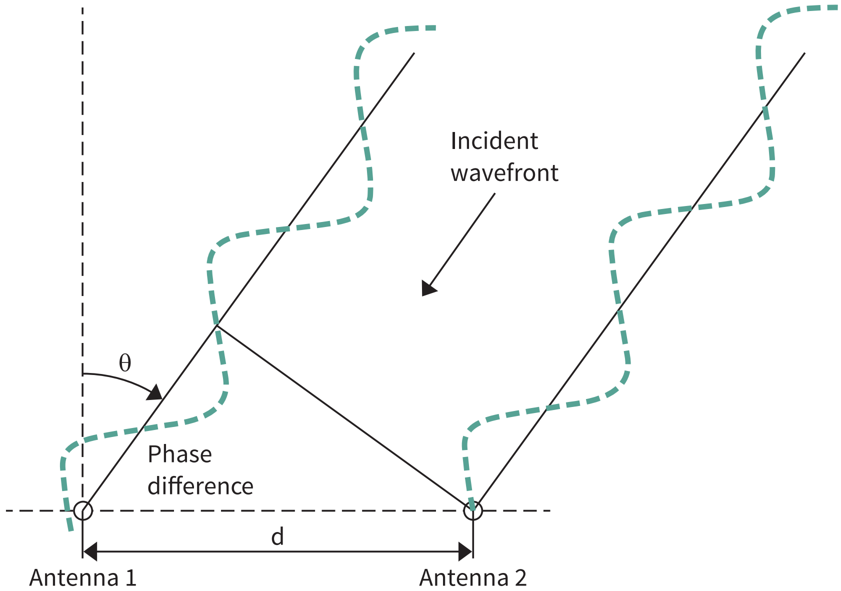


Repeating this for each range bin ultimately provides the range-doppler map.



How can the angle be estimated?

Phase mono-pulse angle estimation



› Two antenna elements separated by a distance d and receiving reflection from angle θ would mean one antenna would incur an additional path length of d sin(θ) which translated to phase difference of

$$\delta\phi = \left(\frac{2\pi}{\lambda}\right) d \sin(\theta)$$

between signals at the two Rx antennas. Hence, the angle of arrival can be estimated as

$$\hat{\theta} = \sin^{-1}\left(\frac{\delta\phi\lambda}{2\pi d}\right)$$

› This is referred as the phase mono-pulse technique

Amplitude monopulse angle estimation

› The sum and difference of the received signal on the two received antennas followed by taking ratio leads to

$$\frac{\Delta}{\Sigma} = -j\tan\left(\frac{\pi d}{\lambda} \cdot \sin(\theta)\right)$$

› So in case of amplitude monopulse the angle estimation becomes

$$\hat{\theta} = \sin^{-1}\left(\frac{\lambda}{\pi d} \cdot \tan^{-1}\left(-\mathrm{imag}\left(\frac{\Delta}{\Sigma}\right)\right)\right)$$

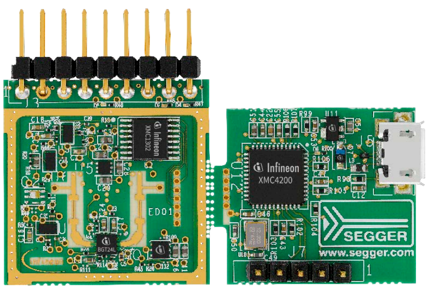
What is current system availability?

There are 3 demo boards available now. Please see below description and images.

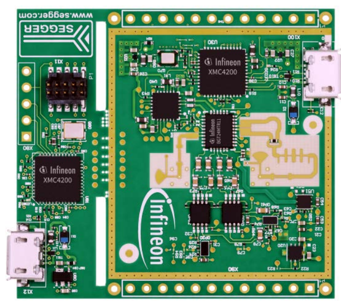
Sense2GoL (BGT24LTR11 + XMC1300)	Distance2Go (BGT24MTR11 + XMC4200)	Position2Go (BGT24MTR12 + XMC4700)[1]
› Capability to detect motion, speed and direction of movement (approaching or retreating) Precise measurement of object detection compared to PIR › Operates in harsh environments and detects through non-metallic materials › Low power mode for enhanced battery life › One of the world's smallest complete radar + MCU development kit › BGT24LTR11 – 24 GHz highly integrated RF MMIC › XMC1300 ARM® Cortex®-M0 – 32-bit industrial microcontroller › Debug over cortex 10 pin debug connector › Integrated multiple element patch antennas	› Capability to detect distance of multiple targets › Capability to detect motion, speed and direction of movement (approaching or retreating) › Operates in harsh environments and detects through non-metallic materials › BGT24MTR11 – 24 GHz highly integrate RF MMIC › XMC4200 ARM® Cortex®-M4 – 32-bit industrial microcontroller › Debug over cortex 10 pin debug connector › Integrated multiple element patch antennas	› Capability to detect position of multiple targets › Capability to detect distance of multiple targets › Capability to detect motion, speed and direction of movement (approaching or retreating) › Operates in harsh environments and detects through non-metallic materials › BGT24MTR12 – 24 GHz highly integrated RF MMIC › XMC4700 ARM® Cortex®-M4 – 32-bit industrial microcontroller › Debug over cortex 10 pin debug connector › Integrated multiple element patch antennas
Main applications › Security › Lighting control › Automatic door opener › Vital sensing	**Main applications** › Drone: soft landing/obstacle avoidance › Smart toilets › Tank level sensing › Intelligent switches	**Main applications** › Drone/robots: obstacle avoidance › Security › People tracking (IoT, smart home) › Vital sensing
Board dimensions › 25 mm x 25 mm (pictured with the Segger Debugger break-off board for reprogramming)	**Board dimensions** › Board 36 mm x 45 mm	**Board dimensions** › Board 50 mm x 45 mm
Kit contents › User's manual › SW GUI to operate kit › Schematic and bill-of-materials of module	**Kit contents** › User's manual › SW GUI to operate kit › FMCW FW and SW [2] › Doppler FW and SW [2] › Schematic and bill-of-materials of module	**Kit contents** › User's manual › SW GUI to operate kit › FMCW FW and SW › Doppler FW and SW › Schematic and bill-of-materials of module

1) Coming soon
2) Usage of the FMCW and/or Doppler FW and SW requires agreeing to Infineon's user's agreement and licensing terms.

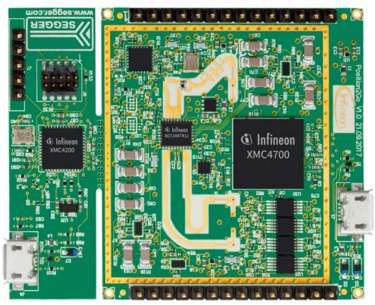
Sense2GoL



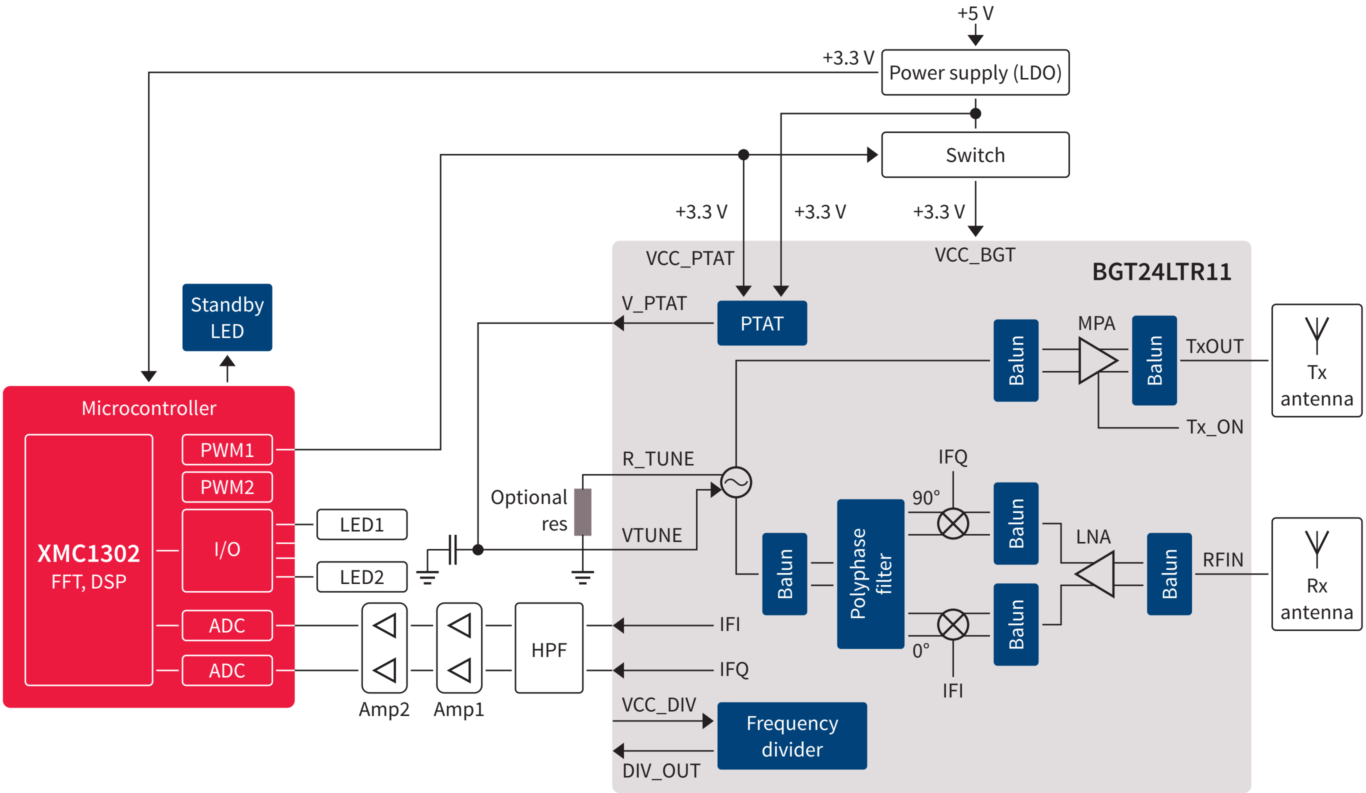
Distance2Go



Position2Go



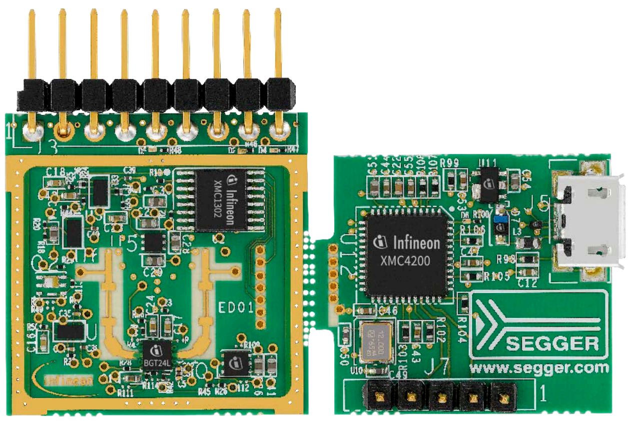
Is there a block diagram available for the Sense2GoL?



What are the key features of the Sense2GoL demo board?

Features

- Capability to detect motion, speed and direction of movement (approaching or retreating)
- BGT24LTR11 – 24 GHz highly integrated low power RF MMIC
- XMC1302 ARM® Cortex®-M0 – 32-bit industrial microcontroller
- Integrated patch antennas
- Segger debugger break off board for reprogramming



Kit contains

- User manual
- SW GUI to operate kit
- Precompiled C libraries provided
- PCB schematic and Gerber files

Is this available as an MMIC or complete module?

Infineon smart sensing solutions

MMIC	Module suppliers using Infineon chip	
Features	Technical benefits	Customer benefits
› Radar-based motion detector operating in the 24 GHz ISM-band › Long range distance detection of moving objects up to 30 m › Wide range speed detection up to more than ±100 km/h	› Large coverage areas such as warehouses, parking lots, ect. › Robust against harsh conditions (rain, dust and temperature) › Precise presence detection › Fast measurement updates	› Excellent movement detection › Fewer false alarms › Energy savings › Concealable › Customized solution › Off the shelf module from market partners

Where do I go for additional information?

www.infineon.com/24GHz

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