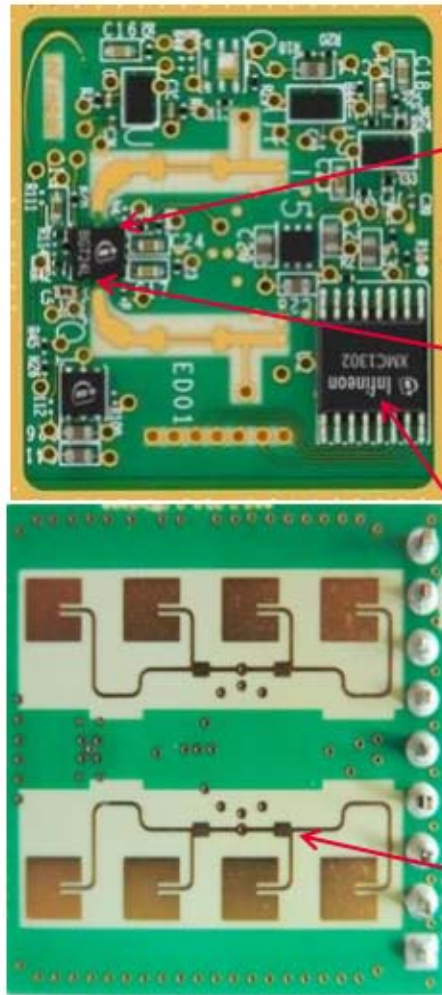


24GHz Motion Detectors and Applications

1. Introduction
2. 24-GHz motion detector applications
3. 24-GHz motion detector modules
4. 24-GHz motion detector design issues
5. Frequency allocations
6. Doppler amplifiers
7. Further applications of 24-GHz radar modules

1. Introduction

- Infineon Sense2GoL



Transmitter

Generates a RF electrical signal

Receiver

Converts the RF electrical signals into low frequency signals

Signal processor

Extracts *distance*, *Speed*, and *angle* information from the signal

Antennas

Converts electrical energy to electro-magnetic waves

Required to operate the radar:

Software algorithm:

- › To provide the Radar with a process or set of rules to follow:

GUI:

- › Required to interact with the Radar

- Modulation and algorithm

Radar operating mode (in order of complexity)	Movement	Velocity	Distance	Presence
<u>Doppler</u> Continuous wave (CW)	✓	✓		
<u>FSK</u> Frequency shift key	✓	✓	✓ moving target only	
<u>FMCW</u> Frequency modulated continuous wave	✓	✓	✓	✓

■ Frequency and wavelength

All radar operates in a specific frequency band ranging from 300 MHz up to 300 GHz

Each frequency bracket can impact the Radar in the following ways:

- › **Physical antenna size**
- › **The range / distance required of the application**
- › **Global band availability**
- › **Interference from other RF**
- › **Wavelength**
- › **Ability to penetrate walls**

Application	f (Frequency)	Wavelength
Diverse	200 GHz	150 μ m
Automotive	77 GHz	3.9 mm
Industrial	60 GHz	5 mm
Industrial, Automotive	24 GHz	1.25 cm
UWB	9 GHz	3.3 cm
LTE advanced	6 GHz	5 cm
Microwave oven	2.4 GHz	12.5 cm

- Detection mode and use cases

	Software	Capability	User case
Simple presence detection	› Doppler	› Motion › Speed › Direction	› Door opener › Security › Lighting › Traffic control › Vital sensing
Intermediate presence detection	› Doppler › FMCW › FSK	› Motion › Speed › Direction › Distance	› Street lighting › Security alarm › Smart home › HVAC › Vital sensing
Advanced obstacle detection / vital sensing	› FMCW › FSK › Micro doppler	› Motion › Speed › Direction › Distance › Angle	› UAV / copter › Robotics › People counting › Vital Sensing

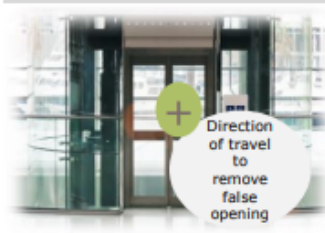
2. 24-GHz Motion Detector Applications

Basic movement detection

Smart appliances



Door opening



Security



Lighting



Traffic



Advanced motion detection & sensing

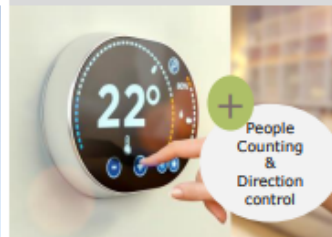
Streetlighting



Multicopter



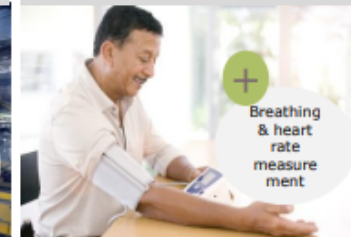
HVAC controls



Robotics



Vital sensing



- Comparison with alternative technologies

Features	24 GHz Sensor	Infrared	Ultrasonic	Laser
Application flexibility	●	●	●	●
Resistance to moisture, dirt and temperature	●	●	●	●
Speed detection	●	●	●	●
Accuracy sensitivity	●	●	●	●
Resolution	●	●	●	●
Direction capability	●	●	●	●
Distance measurement	●	●	●	●
Penetration of materials	●	●	●	●
Size of solution	●	●	●	●
Cost	●	●	●	●

KEY



Best



Good



Weak

- 24-GHz radar advantages

Features	24 GHz	5.8 GHz	PIR	Ultra-sonic	Laser
Speed, direction, and distance information	●	●	●	●	●
Resistance to moisture dirt and temperature	●	●	●	●	●
Sensitivity	●	●	●	●	●
Suitability for Indoor (wall penetration)	●	●	●	●	●
Size of solution	●	●	●	●	●
Penetration of material	●	●	●	●	●
Cost of solution	●	●	●	●	●

KEY	● Best	● Good	● Weak
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■ Indoor lighting

Application requirements	Benefits of Radar
› Suitable range / coverage for given area › Lights to remain on without need for human to move to "wake" PIR sensor › Discrete design aesthetics to fit with surroundings › Energy efficient minimizing wasted electricity	› Detection range of 270 m² compared to 30 m² for Infrared* › Potential to detect presence not just motion with the right software solution › Replace unsightly PIR box with hidden Radar sensor › Lights dimmed down automatically saving electricity



*estimate

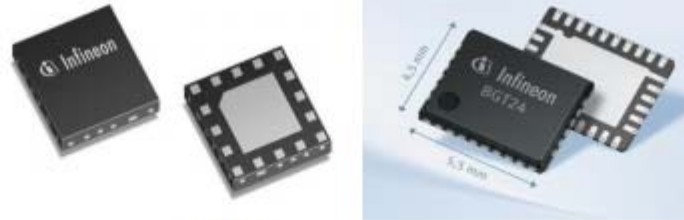
3. 24-GHz Motion Detector Modules

■ Infineon

Features

- > 24 GHz ISM band operation for motion, speed, direction movement and distance measurements
- > 4 MMIC chips available

IFX MMIC



MMIC

Benefits

- > Long range distance detection of moving objects up to 30 m
- > Wide range speed detection up to more than ± 100 km/h

Features

- > 3 system boards available
- > All include 24 GHz radar and XMC™ microcontroller
- > Kit contains user manual, GUI, MATLAB compiler and Gerber files
- > Requires software

IFX development kit



Demokit with SW, reference design

Benefits

- > Capability to detect motion, speed and direction of movement (approaching or retreating), distance and Angle of arrival based on hardware
- > FW/SW available for each radar mode

Features

- > Complete module, including radar MMIC, antenna options, MCU signal processing options, and SW options (Doppler, FSK and FMCW versions available)

Partner modules using IFX chip



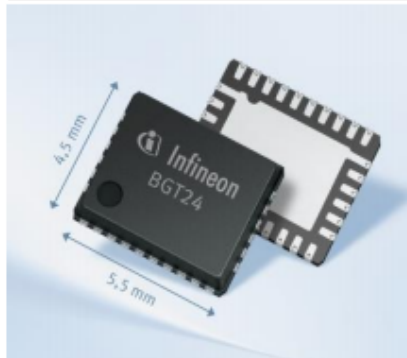
Module (RF module; RF module + MCU including SW)

Benefits

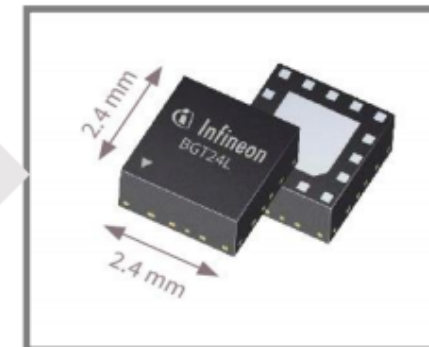
- > Ease of design
- > Turn-key solution for customers with limited radar/RF/SW know-how

■ Infineon

BGT24MTR12	BGT24MTR11	BGT24MR2	BGT24LTR11
› Transceiver 1T_x+2R_x / IQ differential › As TR11 › 700 mW @3.3 V › 4.5x5.5 mm -VQFN-32	› Transceiver 1T_x+1R_x / IQ differential › VCO integrated, SPI › Power/temp sensor › RF_{in} 24.0-26.0 GHz › 500 mW @3.3 V › 4.5x5.5 mm -VQFN-32	› Twin receiver 2R_x / IQ differential › RF_{in} 24.0-26.0 GHz › 300 mW @3.3 V › 4.5x5.5 mm -VQFN-32	› Transceiver (1T_x+1R_x) › Single-ended › BITE tested › RF_{in} 24.0 – 24.25 GHz › 150 mW @3.3 V › 2.4 x 2.4 mm -TSNP-16



Reduced power, lower cost,
smaller footprint

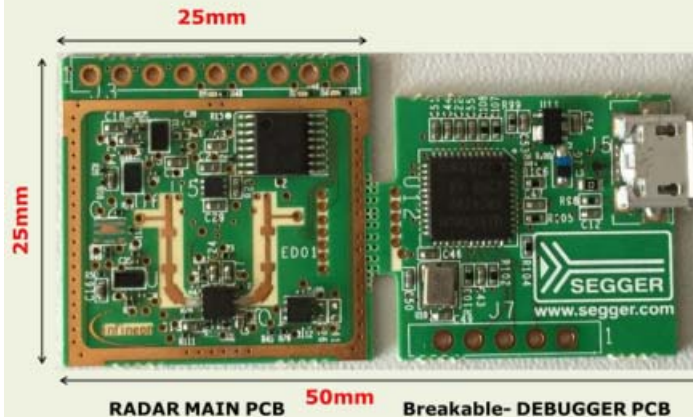


■ Infineon

	BGT24MTR11		BGT24LTR11	
	500 mW	Power consumption	150 mW	Lower power
Adjustable power	11 dBm, adjustable	Output power	6 dBm, fixed	
Longer range	26 dB, adjustable	Conversion gain	22 dB, fixed	
	1.5 GHz and 23 kHz	Prescaler outputs	2.3 MHz (possibly additional 1.5 GHz output)	
	Differential	IF outputs	Single-ended	
	T _x differential R _x single-ended	RF outputs	T _x + R _x single-ended	
	SPI control power sensors	Supporting functions	Temperature sensor	Internal temp sensor
	External frequency control required	Doppler radar	Autonomously inside ISM-band	
	Fine and coarse tuning	FMCW radar	Single tuning pin only	
	5.5 mm x 4.5 mm	Package size	2.4 mm x 2.4 mm	Smaller form factor

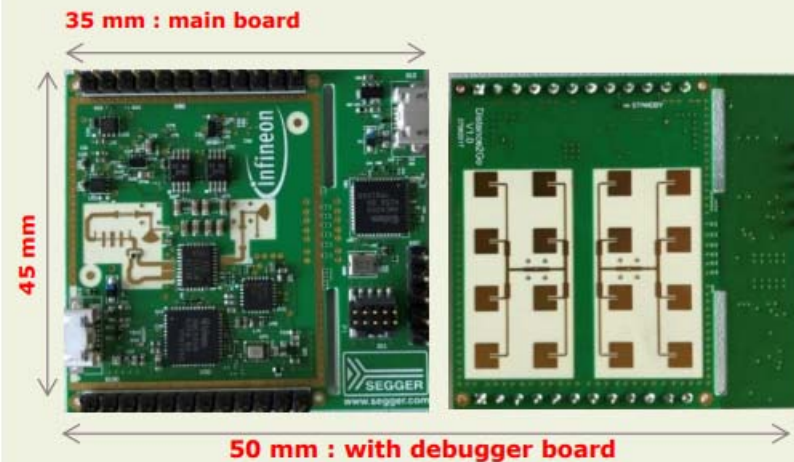
- Infineon

Sense2goL



- › $1T_x-1R_x$: BGT24LTR11
- › CW (doppler only)
- › Speed measurement
- › Presence detection
- › Direction of movement

Distance2Go



- › $1T_x-1R_x$: BGT24MTR11
- › FMCW
- › Distance measurement
- › Speed measurement
- › Presence detection
- › Direction of movement

■ Infineon

Basic motion detection
Motion
Speed
Direction

Boards: Sense2GoL
Products:
 BGT24LTR11 & BGT24MTR11
Operation: Doppler

Applications:

- > lighting, security, door openers, Vital sensing

Key benefits:

- > High sensitivity
- > Small size
- > Can be hidden
- > Robust to environmental conditions
- > Provides speed and direction information
- > Long detection range
- > Adjustable FOV and distance with antenna design

Intermediate
Motion
Speed
Direction
Distance

Boards: Distance2Go
Products:
 BGT24LTR11 & BGT24MTR11
Operation: FMCW & FSK

Applications:

- > Smart toilets
- > Drone soft landing
- > Drone collision avoidance
- > Robotics collision avoidance
- > Level sensing
- > Smart switches
- > Vital sensing (from a distance)

Key benefits:

- Basic Motion PLUS+*
- > Insensitive to vibrations
 - > Resolution not degrading with target distance

Advanced 3D sensing
Motion
Speed
Direction
Distance
Angle

Boards: Position2Go
Products:
 BGT24MTR11, BGT24MR2, BGT24MTR12
Operation: FMCW & FSK

Applications:

- > Drone collision avoidance
- > Robotics collision avoidance
- > Vital sensing (from a distance)
- > HVAC, SMART Home, IOT

Key benefits:

- Intermediate PLUS+*
- > Ability to track people
 - > Positioning of target(s)

- Other sources:

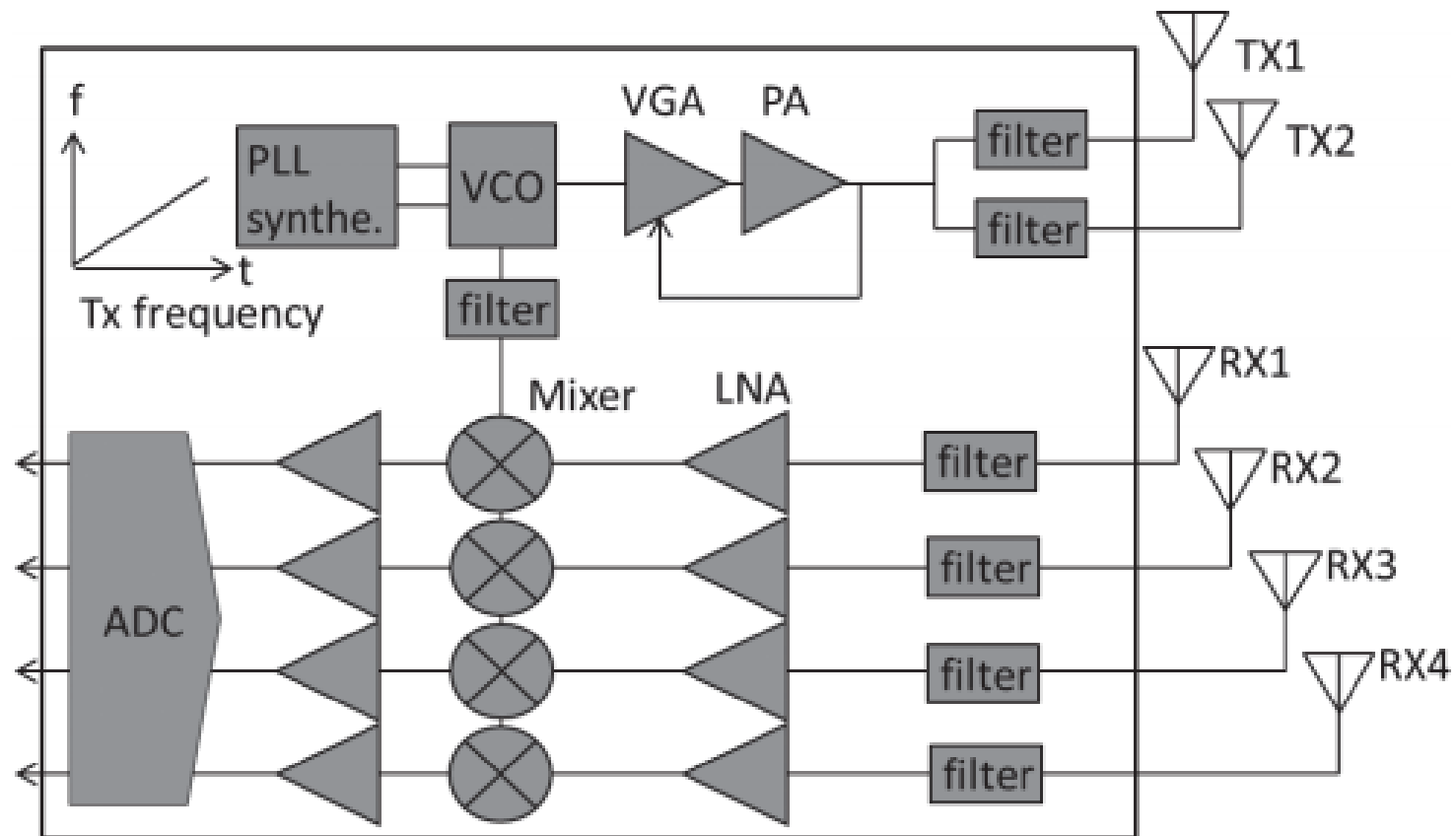
- Aliexpress: YH-24G01, IMD2411A2, IFL2411A2, RD2411A, DM-39, DM-19, DB-16, FM-42, FM-49, 182MOD, USRP187, TD-24G-B-002, YH-K24-G01, HLK-LD303-24G, CFK024-5A, FMK24-A
- AMG AMG072-001, AMG072-002, DOS048-004
- Analog Devices TinyRad Demonstration Platform
- B+B Thermo-Technik RSM2650, IPM-165
- DFRobot SEN0395
- Fujitsu FWM7RA01-200002
- Icstation CDM324
- Impulse Technologies uRAD
- Infineon Xensiv 24 GHz radar demo kits
- Innosent IVS-362, IMD-2000, IMD-3000

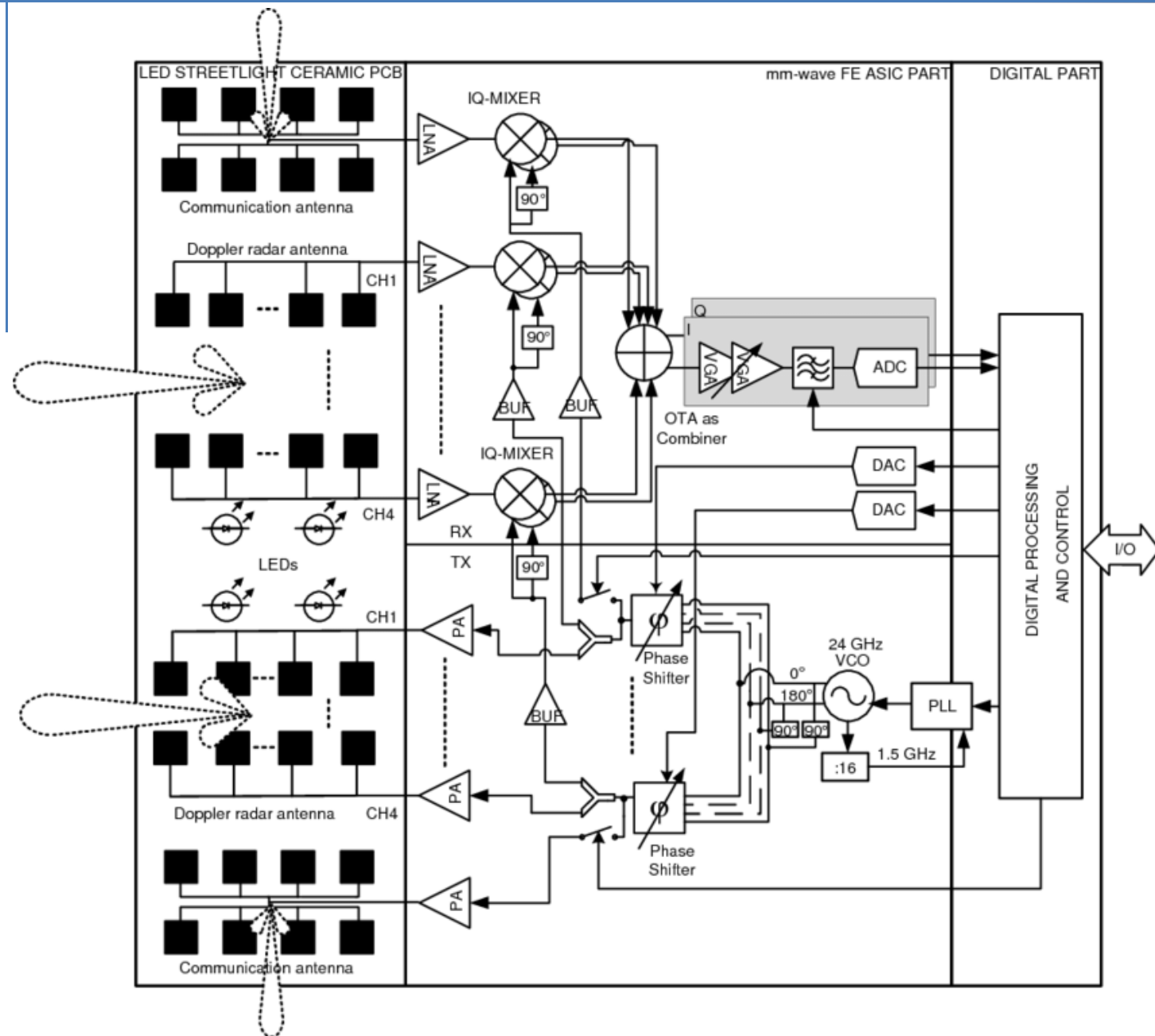
- Other sources:
 - MikroElektronika MIKROE-2781
 - NJR NJR4234BV, NJR4265, NJR4266
 - Novelic NoraSens Radars
 - NXP TEF810X
 - OmniPreSense OPS243-A-CW-RP
 - RFbeam K-LC7
 - SeedStudio MW2401TR11, BGT24LTR11
 - Silicon Radar TRX_024_006, TRX_024_007
 - Smartmicro
 - Socionext SC1232AR3
 - ST STRADA431
 - TiOne TRM-121A, IPM-65, SMR-333
 - Yanwu-Tech FM24-NP100

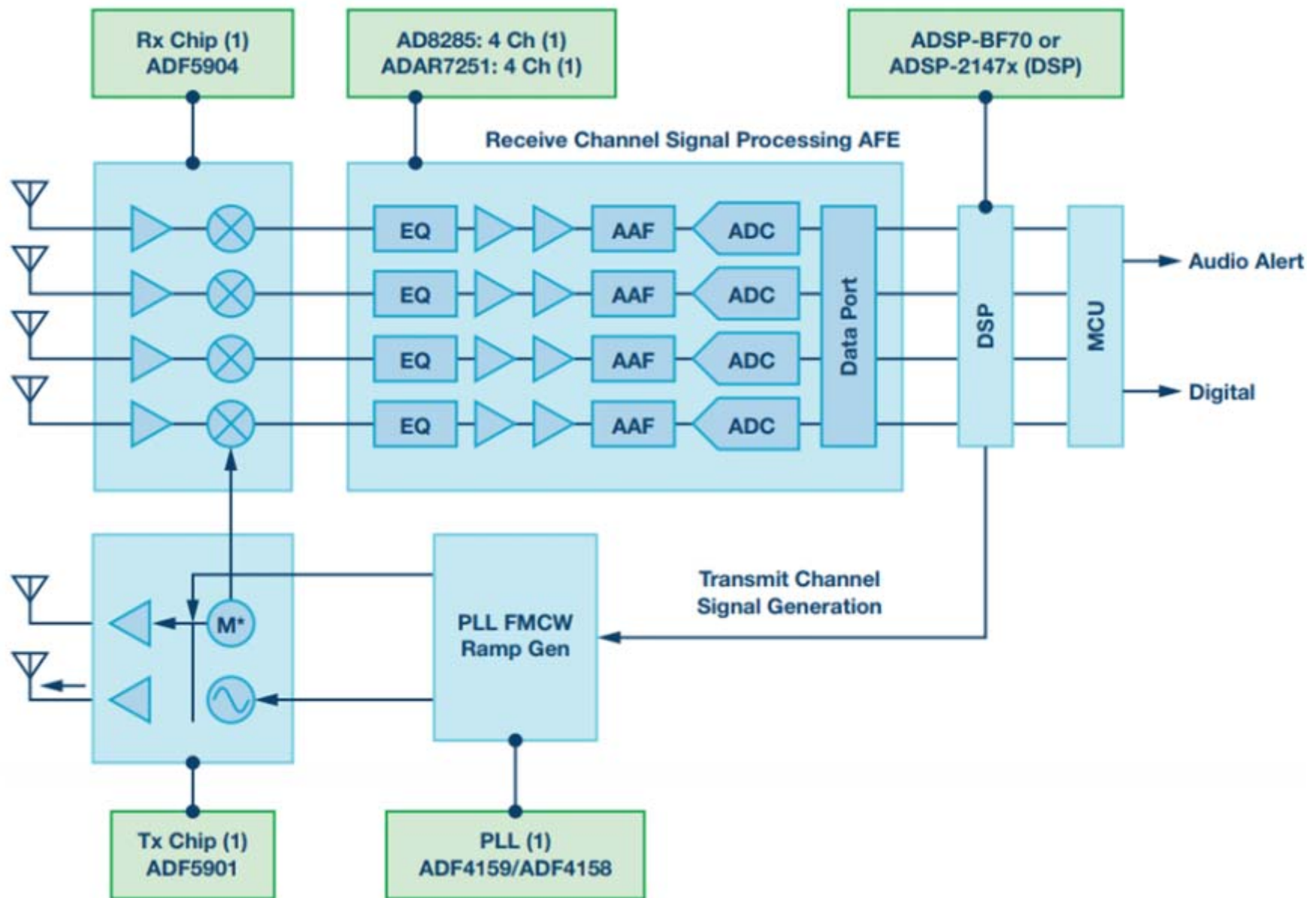
4. 24-GHz Motion Detector Design Issues

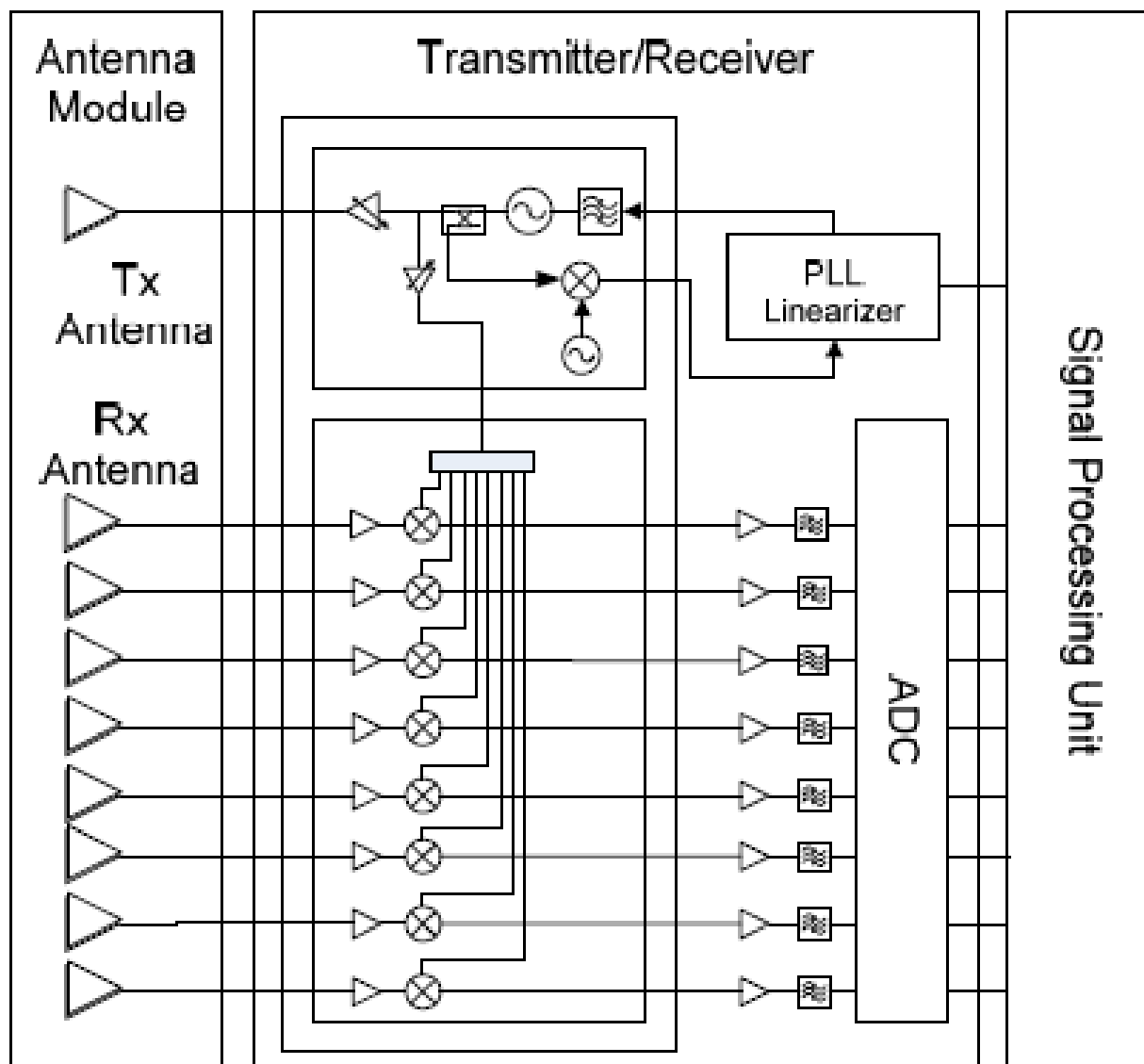
- Motion detector architecture
- Antenna gain
- Signal processing

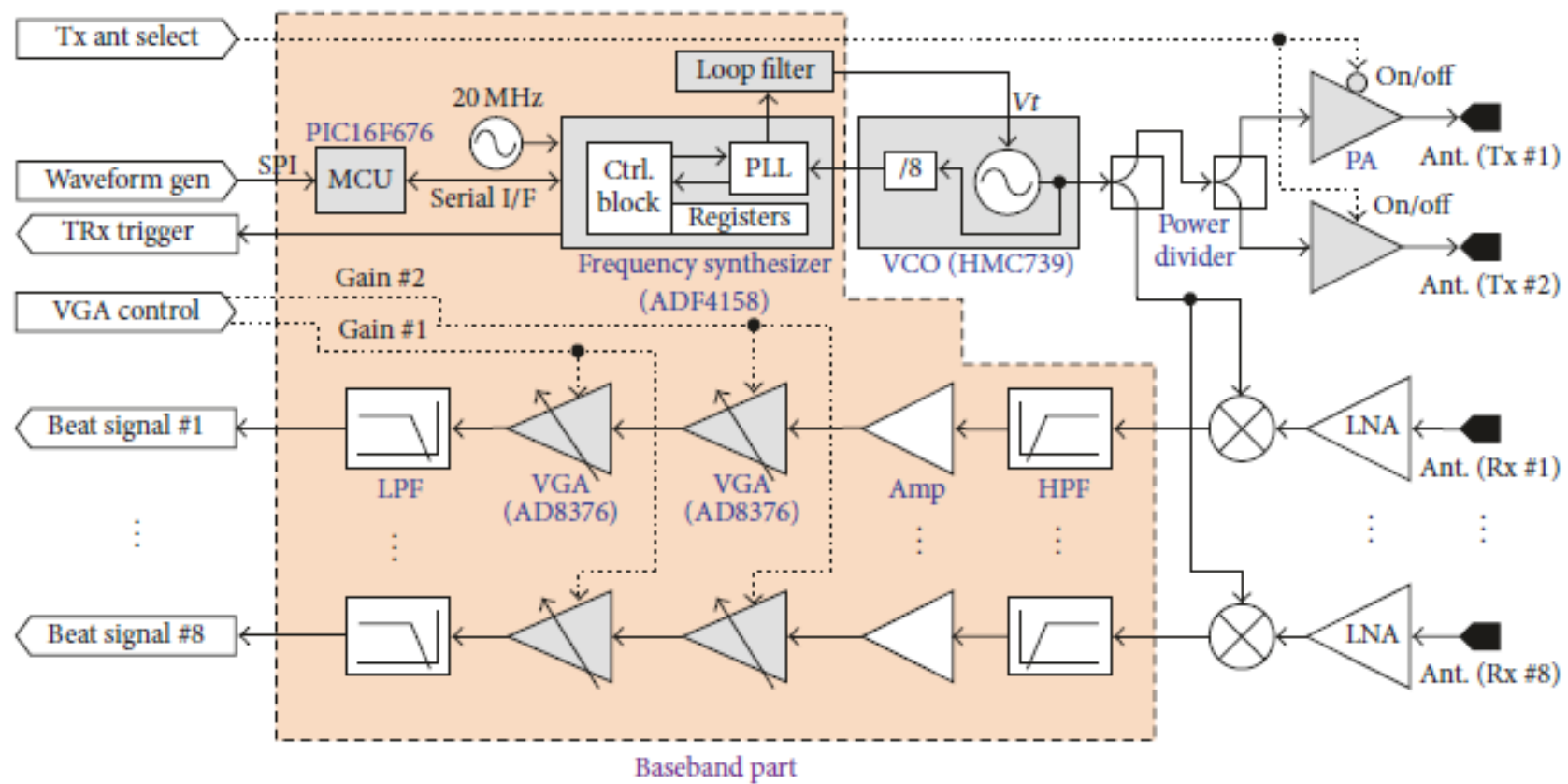
- 2-Tx & 4-Rx structure

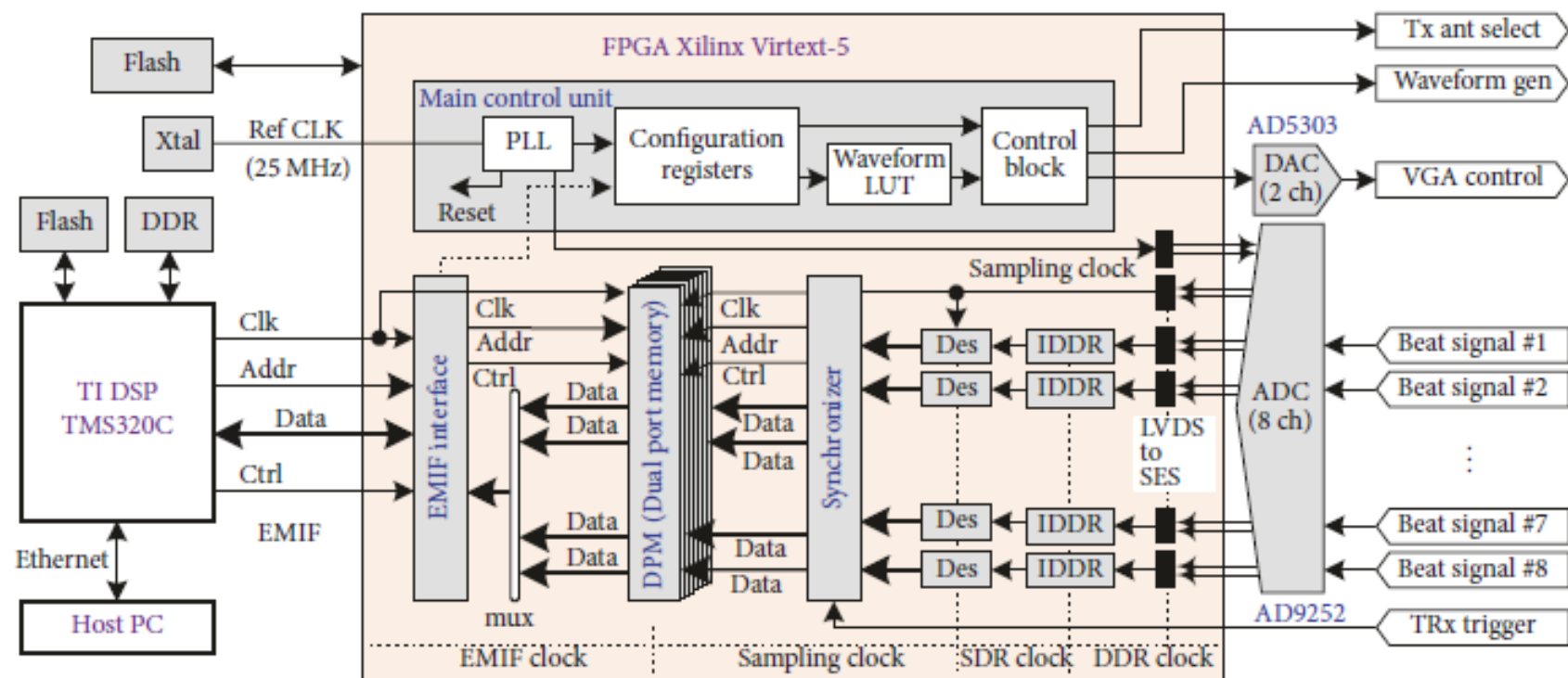


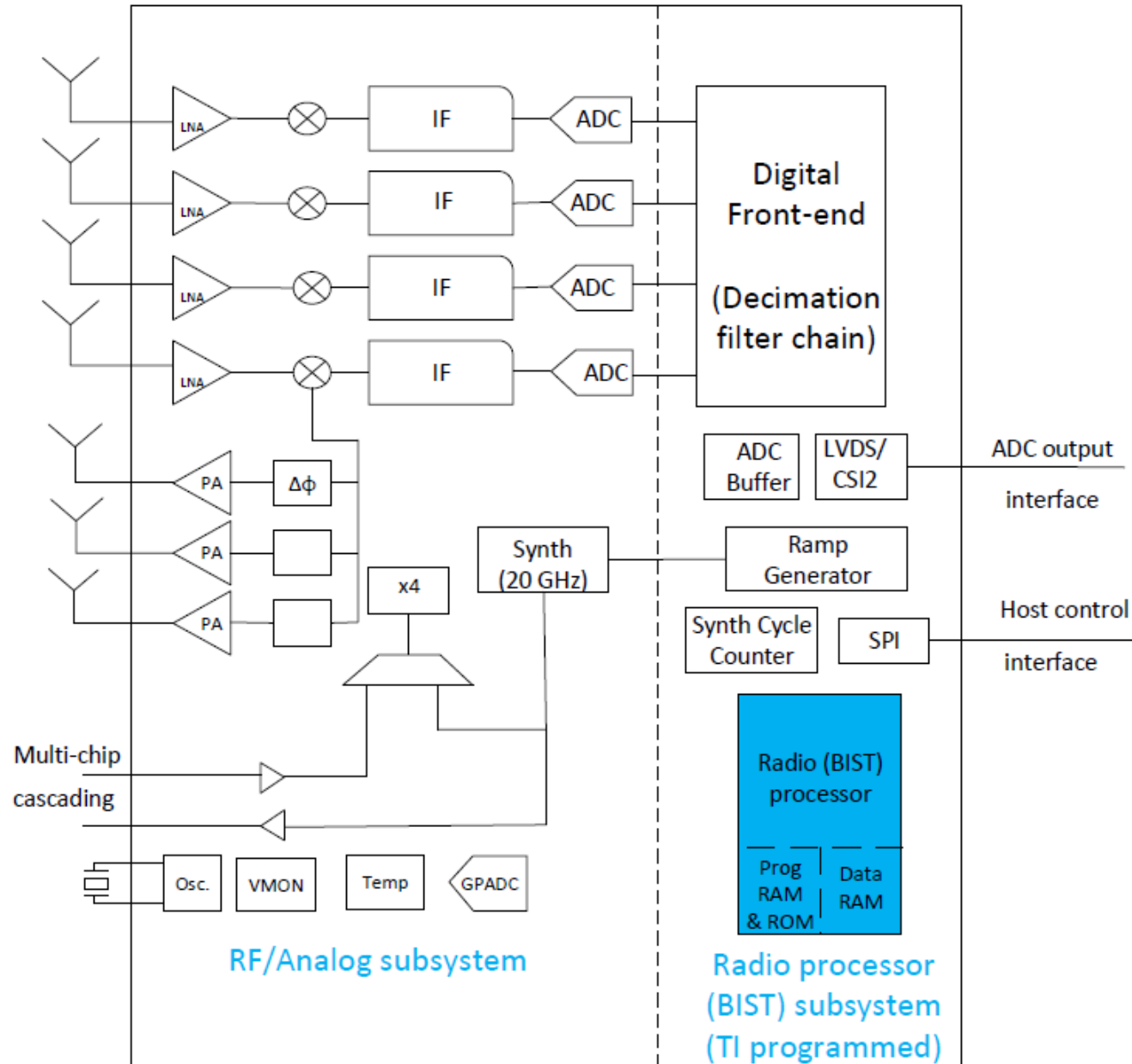


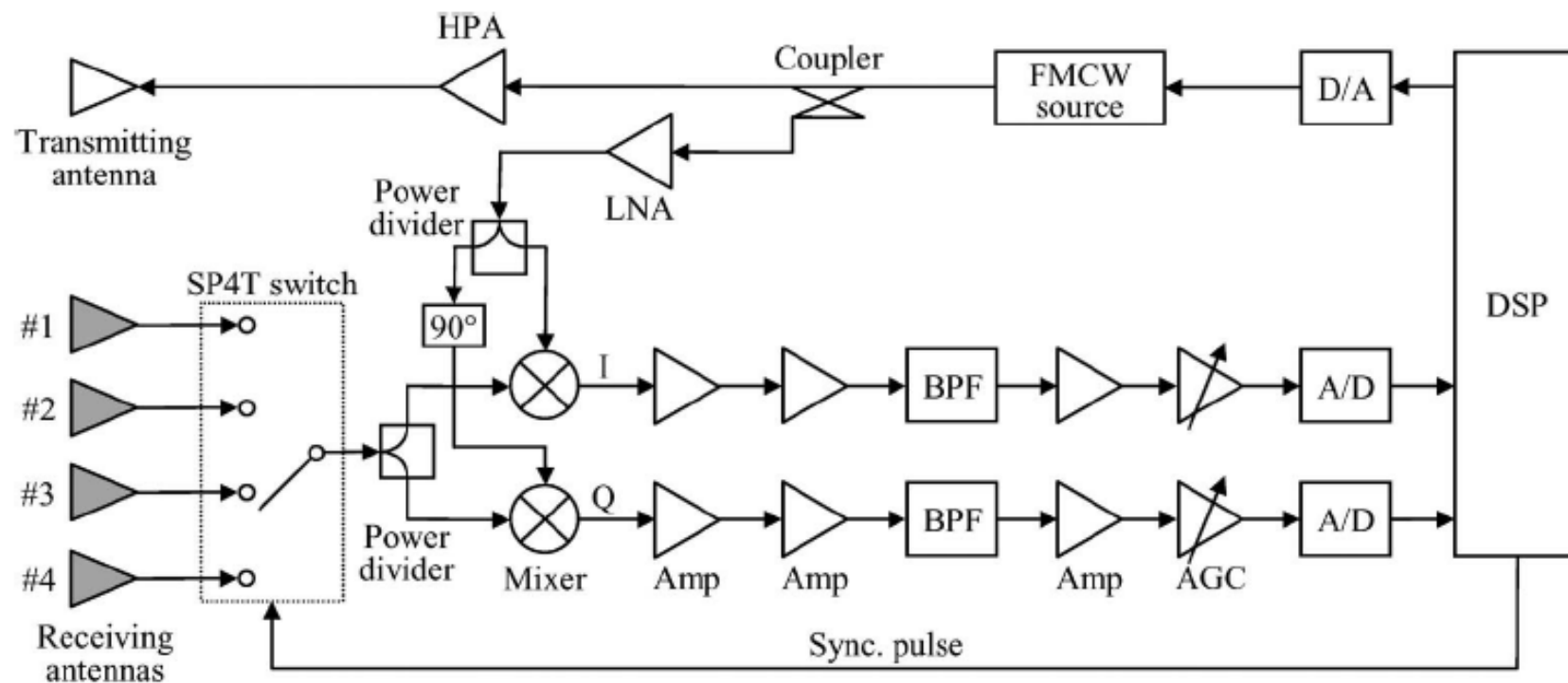












5. Motion Detector Frequency Allocations

[표 2-1] 국내 물체감지센서 현황

주파수 대역	복사전력	인증 건수	비고
10.50~10.55GHz	25mW	66	옥내사용 한정
24.05~24.25GHz	100mW	75	

[표 2-8] 일본 물체감지센서 기술기준

주파수 대역	안테나 공급전력	불요파 전력	점유 대역폭	비고
10.5~10.55GHz	10mW	2.5 μ W	40MHz	실내사용 한정
24.05~24.25GHz	10mW	2.5 μ W	76MHz	

[표 2-2] 미국 물체감지센서 기술기준

주파수 대역	전계 강도(측정 : 3m)		불요파 강도
	기본파(mV/m)	고조파(mV/m)	
902~928MHz	500	1.6	기본파 신호보다 최소 50dB 낮아야 함
2.435~2.465GHz	500	1.6	
5.785~5.815GHz	500	1.6	
10.5~10.55GHz	2500	25	
24.075~24.175GHz	2500	25	

[표 2-6] 유럽 물체감지센서 기술기준

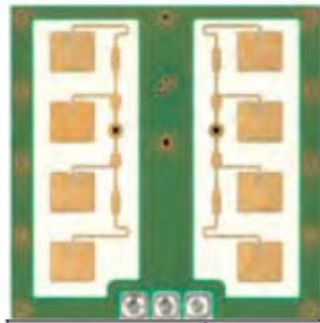
주파수 대역	EIRP	불요파 전력			
		주파수	송신기		수신기
			동작	대기	
2400~2483.5MHz	25mW	1GHz 초과 1GHz 이하	1 μ W 250nW	20nW 2nW	20nW 2nW
9200~9500MHz	25mW				
9500~9975MHz	25mW				
10.5~10.6GHz	500mW				
13.4~14.0GHz	25mW				
24.05~24.25GHz	100mW				

6. Doppler Amplifiers

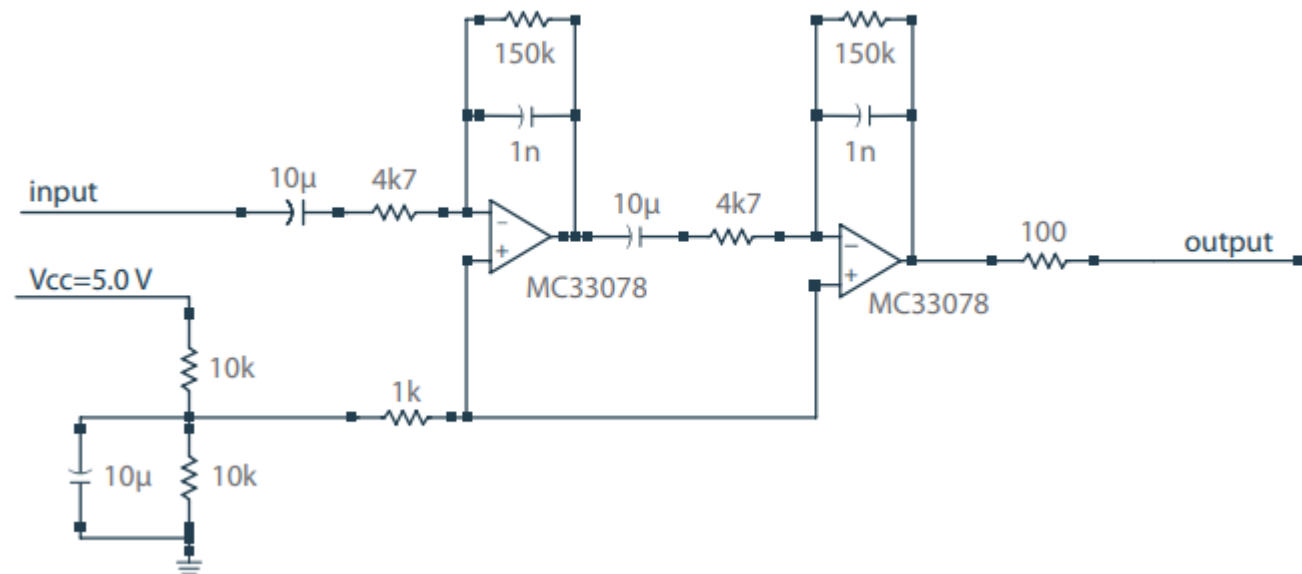
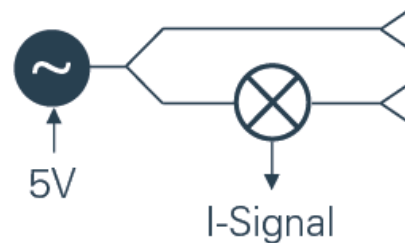
- 24GHz sensor: InnoSenT IPM-165 (or Stenphen Electronics CDM324) launched in 2003

24.05-24.25GHz, 16dBm 10us, -20 to +60°C, 5.5V 30mA, IF -0.3 to +0.3V

<https://www.limpkin.fr/index.php?post/2017/02/22/Making-the-Electronics-for-a-24GHz-Doppler-Motion-Sensor>



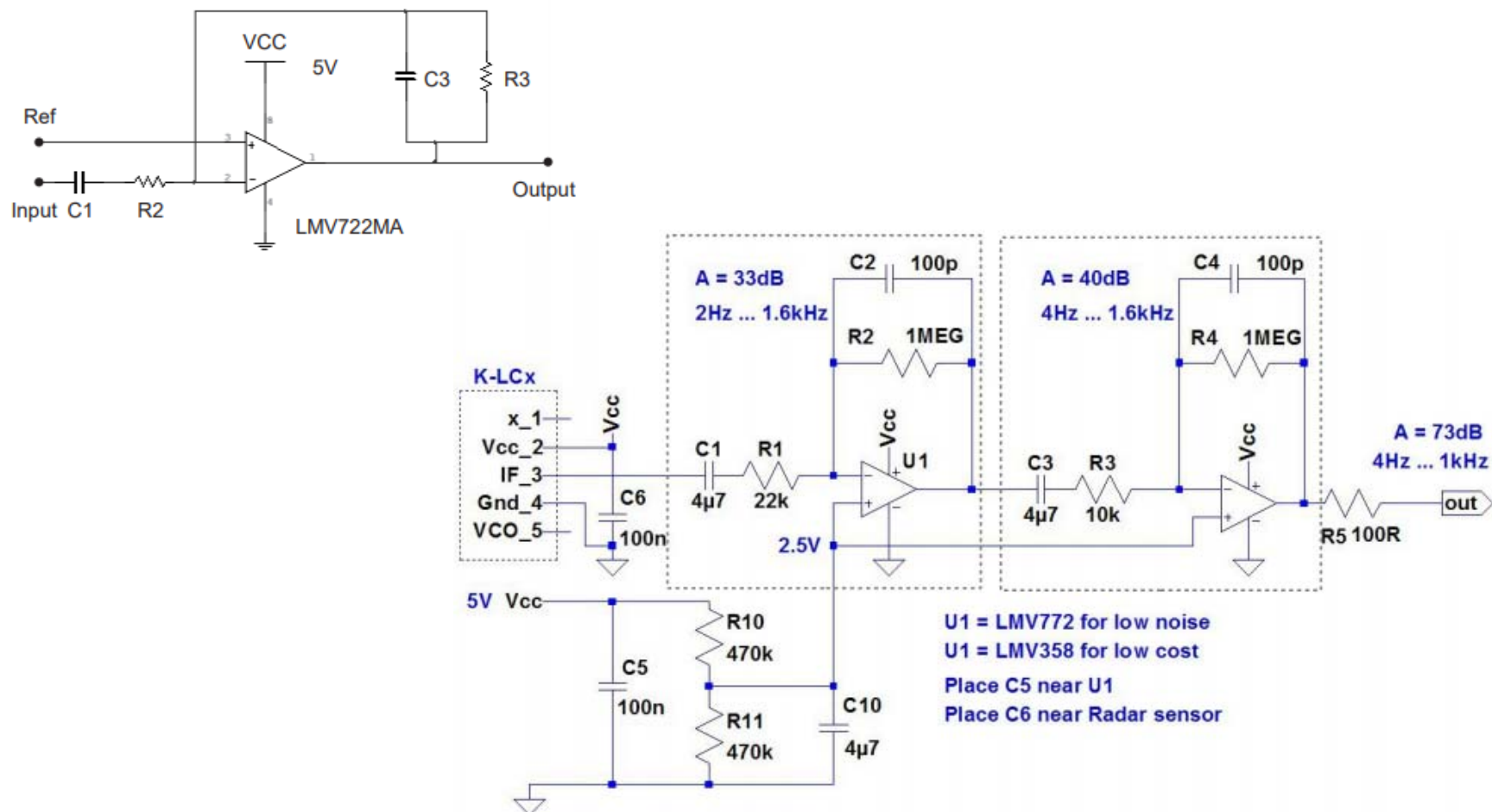
PIN #	DESCRIPTION	IN / OUT	COMMENT
1	V _{cc}	input	supply voltage (4.75 - 5.25V)
2	IF1	output	signal I(nphase)
3	GND	input	analog ground



- Moving objects detector

- 24GHz sensor: RFbeam K-CL7, 5VDC, 8.6dBi antenna gain

- Output amplifier: 52 dB gain, C1-R2 HPF 3.18Hz fc, C3-R3 LPF 3.09kHz fc



- Doppler amp 3

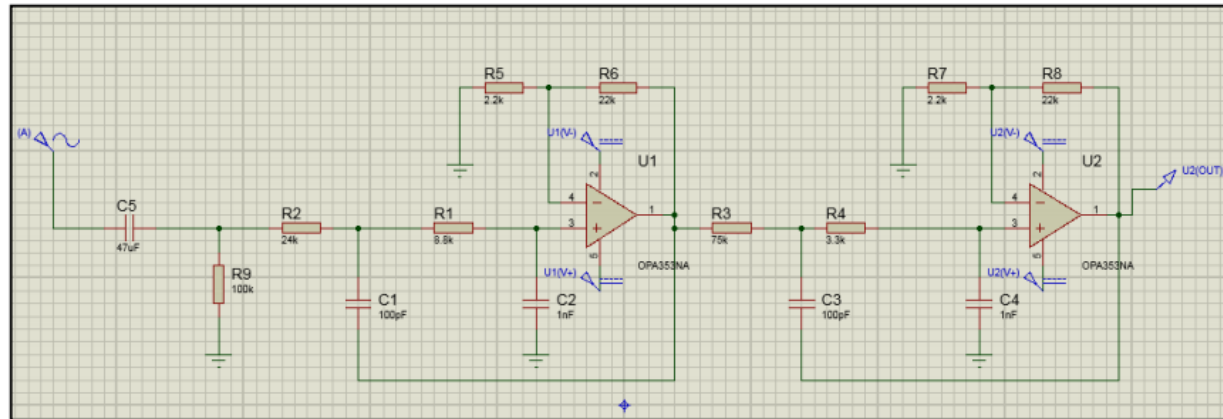
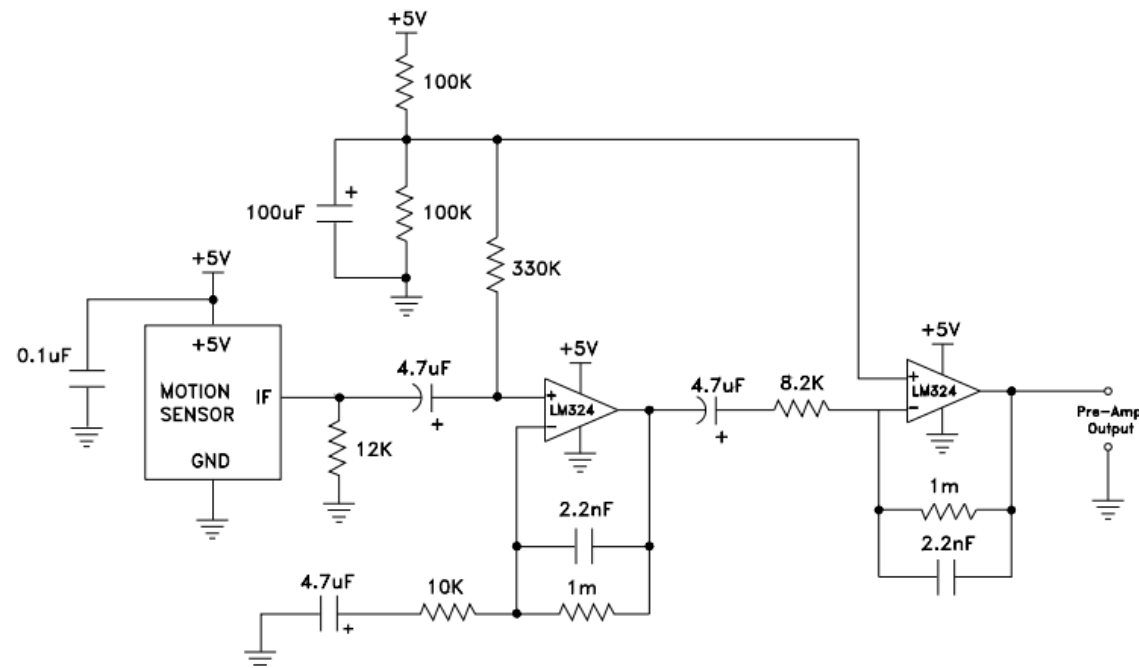


Figure 17. Schematic of the 60dB IF amplifier at 15-500 Hz

- Doppler amp 4



7. Further Applications of 24-GHz Radar Modules

- Long range obstacle detection
- High resolution target angle detection
- Fall detection sensor