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filename: MW sensor - spec tenderCobra0.1

MW sensor 5481

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Document History

Version	Revision	Date	Paragraph	Modification description
0	**0**	**27/02/08**		First issue
0	**1**	**17/03/2008**		

1 Abstract

This document describes the functional characteristic of the MW sensor module 5481.
The module 5481 is a volumetric sensor designed to detect intrusion into the passengers compartment of vehicles, by means of measuring the Doppler effect caused by moving objects inside the vehicle.

2 General description

The MW sensor 5481 is an intrusion sensor unit based on 5.8 GHz range microwaves. It uses the Doppler principle for motion detection in a vehicle compartment. Depending on car variants and vehicle packaging strategies, the system configuration is either a single Master MW sensor or a Master and slaves MW sensors.
The MW sensor is range gated, which means that it will detect motions within a certain range. The maximum range is SW adjustable from 83 to 107cm (or 65 to 87cm). It also has a clutter suppression function for near echoes within a radius of approximately 20cm.
Data serial communication is on Cobra bus and compatible with Cobra 787x siren platform.
Comprehensive on board tests are built in including limits for manufacturing, field, initialization and continuous tests. The only test parameters that require external measurement equipment are the microwave frequency and transmitted pulse power level.

2.1 Electrical specification

The MW sensor module operates within full specification when connected to the vehicle battery within a voltage range of 9V to 16V Volts DC (measured at controller terminals).

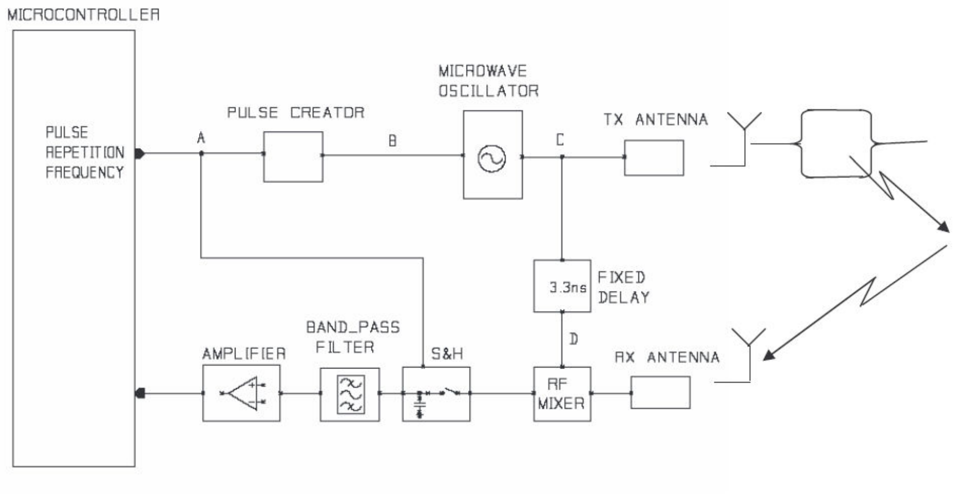
The average current consumption should be no greater than 2.5 mA at 12.0±0.5V in an ambient temperature of 25±5 °C.

State	Typ.	Max.
SLEEP		100 µA
UNSET		1 mA
SET	2.5 mA	2.7 mA
OPERATING FREQ. (CW)	5.8 or 5.95 GHz (depends on country)	--
ERP	--	< 1 mW

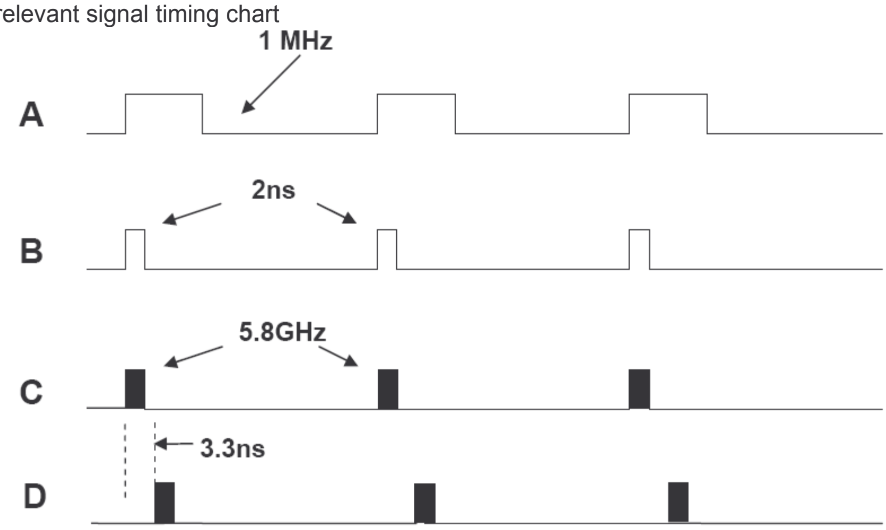
2.2 Movement detection concept

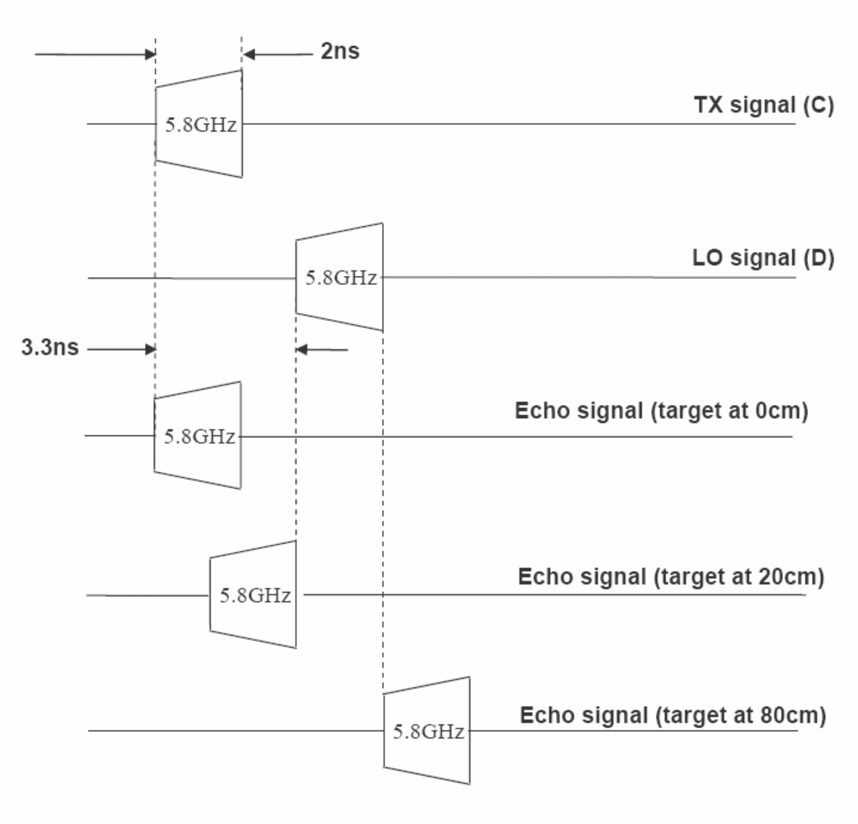
The movement detection is based on conventional pulse Doppler radar principle, with 2 separate tx / rx antennas; also it has a near echo attenuation that lower down the close echo amplitude to filter the effect of small reflecting objects near to the sensor. The detection range is gated and adjustable between 83 to 107cm (or 65 to 87cm).

Functional diagram:



relevant signal timing chart



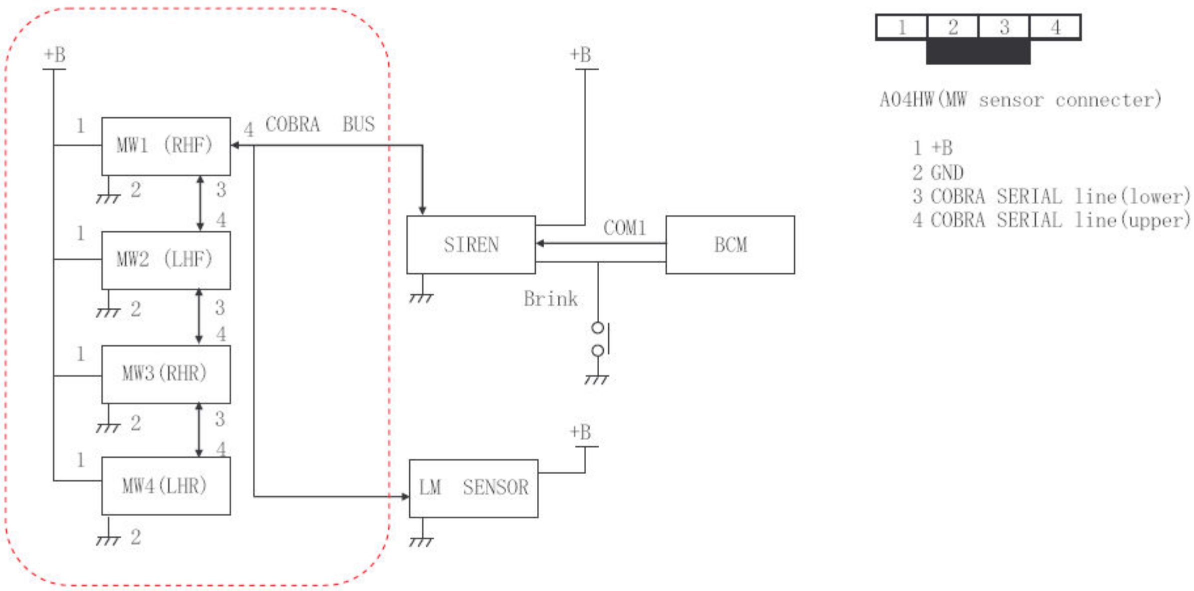


Only targets positioned between 20cm (3.3 ns delay) and 80cm (5.3 ns delay) can give an echo signal that can mix with the LO signal.

When the target is not moving the result of the mixed signal is a continuous signal (d.c.), when the target is moving the resulting mixed signal is a signal of a frequency related to the speed of the movement (Doppler effect).

2.3 System architecture

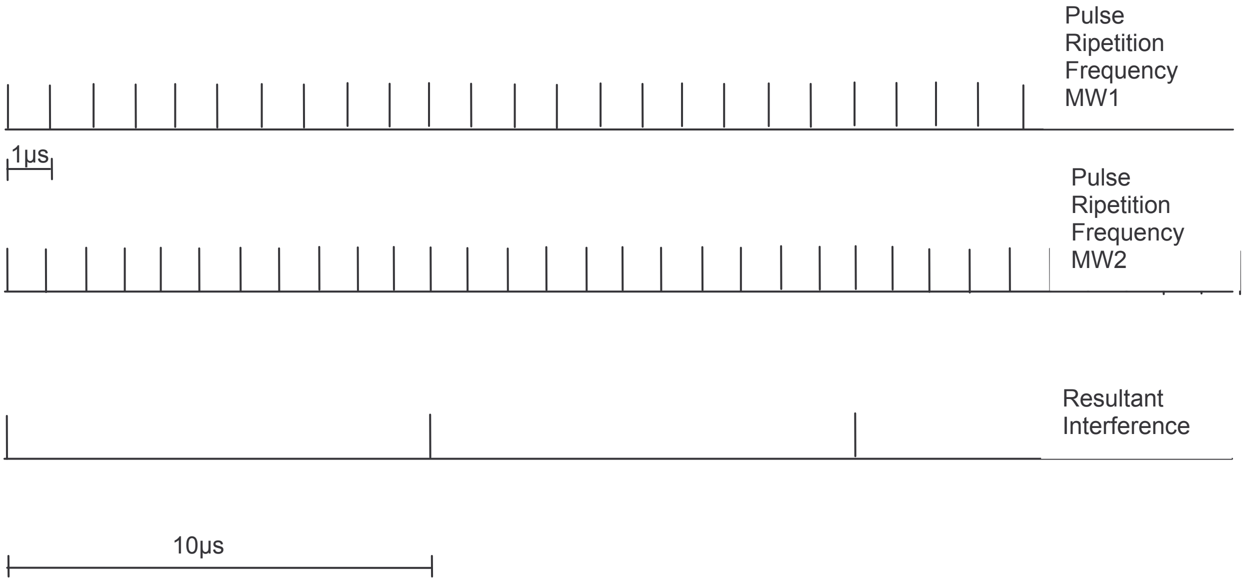
In case more than one MW sensor is required to cover the whole passenger compartment, it is possible to connect additional MW sensors in a daisy chain architecture, as follows:



MW SENSOR ALARM SYSTEM

The design is able to support a system architecture with up to 4 MW sensors.
COBRA SERIAL lines (upper and lower) are 9600 baud.

The four MW are not synchronized but the Pulse Repetition Frequency of each one has a different value in order to avoid that the beat note created by the mutual interferences can bring to a false alarm.



In the drawing above can be explained the effect of the mutual interference between two MW with different Pulse Repetition Frequency: each vertical line in the first two row represents a transmission of 2ns of duration at 5.8GHz.

Vertical line in the third row is the result of the mixing of the pulses of the first two row; a value different from zero is a worst case because it happen only if the two MW have a phase relation (probability practically zero due to the use of free oscillators and to the jitter and also to the fact that the phase relation must be maintained for thousands of samples to build a 50Hz period).
In this example MW1 has a PRF of 1MHz, MW2 has a PRF of 1.1MHz.
Interference is due to a temporal superposition of signal coming from MW1 and MW2 and it happen every 10µs; this interfering signal has a frequency of 100KHz that comes from the difference between the two PRF.
Considering that the MW has a cut off filtering at around 50Hz, this interfering signal is completely filtered out and does not influence the detection performances.
From this point of view is so sufficient that the differences between the PRFs is higher than 150Hz.

In the set of four MW the PRF are set as follow:

PRF1=1 MHz
PRF2=1,00015 MHz
PRF3=1,00045 MHz
PRF4=0,9991 MHz

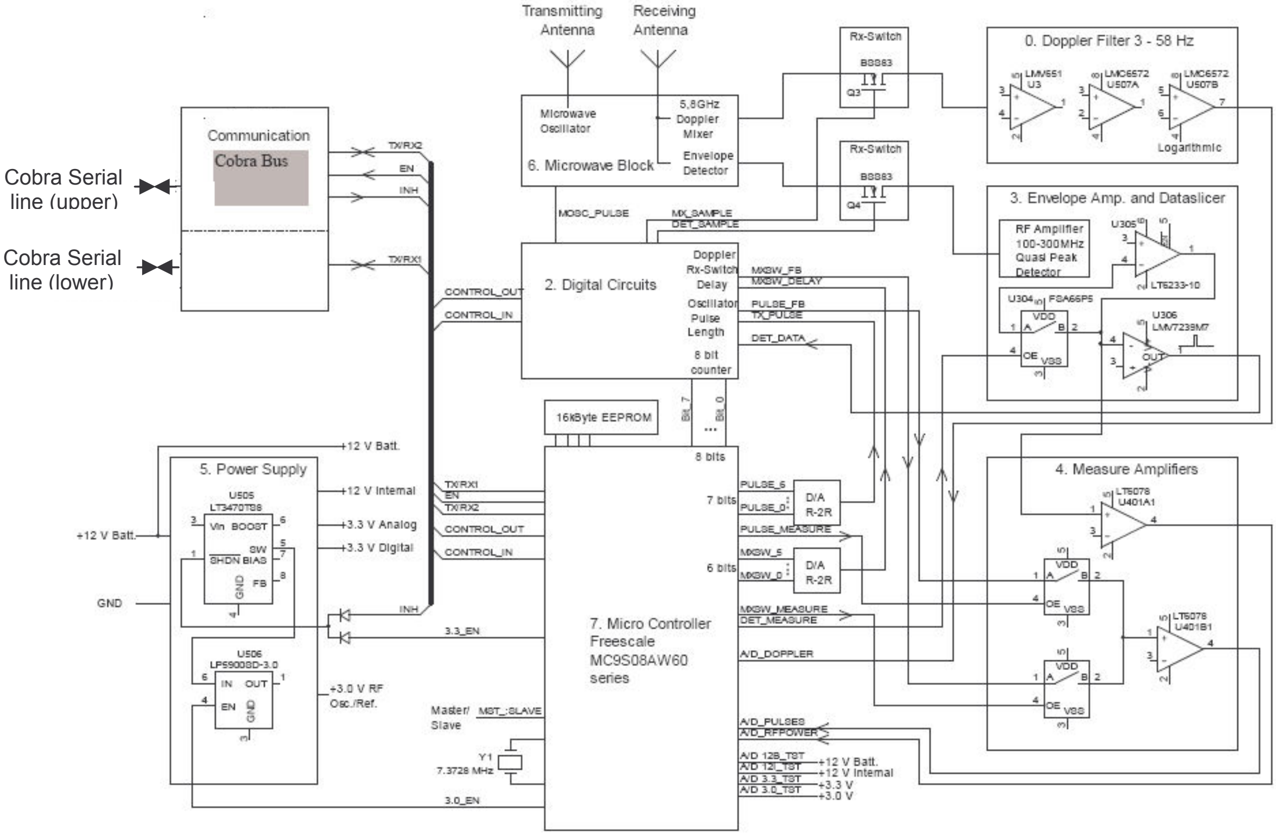
Considering also, as worst case, the calibration tolerances of the crystals (+/-30ppm), the minimum interfering frequency is higher than 150Hz;

Frequency are not equally separate to avoid beat note due to interferences between more than 2 MW: if for example the PRF were as follow:

PRF1=1 MHz
PRF2=1,00015 MHz
PRF3=1,00030 MHz

an interference of PRF1 on PRF 2 creates 150Hz and the same PRF3 on PRF2 and the mixing of the two 150Hz gives a beat note of 0Hz that is filtered as continuous value, but considering tolerances on the crystal frequencies, could be that PRF1 on PRF 2 creates 130Hz and PRF3 on PRF2 create 160Hz and so the mixing creates a 30Hz beat note that is not filtered and so could bring to a false alarm.

3 HW block diagram



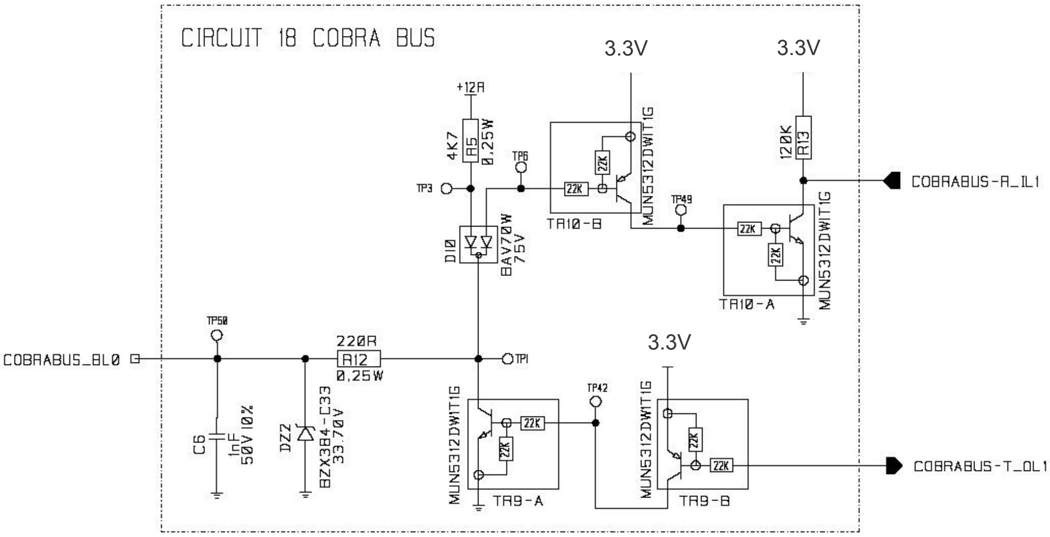
3.1 Block 0 – Doppler filter

The doppler filter is an active filter with a second order high pass link, and a fourth order low pass link, resulting in band pass frequencies from 2,9 to 58 Hz which corresponds to a 0,15 m/s object speed at 60º angle and 1,5 m/s at 0º angle (straight towards the sensor), respectively. Each OpAmp stage has diode feedback, both to make the filter more robust towards transients and for compression of high amplitudes of approximately two times (in the last stage).
The input works as a sample and hold circuit by controlling the timing of ON and OFF.

3.2 Block 1 - Communication

3.2.1 Physical layer

The physical layer for the COBRA SERIAL line (lower, pin 3) uses a standard LIN transceiver.
The physical layer for the COBRA SERIAL line (upper, pin 4) uses the hardware interface schematic reported below: the left connection is the bus itself whereas the right connections is connected to Rx and Tx logic of the microcontroller.



3.2.2 Serial communication format

Single Master, single wire half-duplex bi-directional link

Siren is Master for MW1, MW1 is Master for MW2, MW2 is Master for MW3 and MW3 is Master for MW4.

Transmission is asynchronous with the following parameters:

- ***Baud rate:*** ***9600 +/- 2% bps***
- ***Start bit:*** ***1***
- ***Data bit::*** ***8***
- ***Parity bit:*** ***1(even)***
- ***Stop bit:*** ***1***

The format of a telegram sent by the Master is:

ID	Cmd	Cks

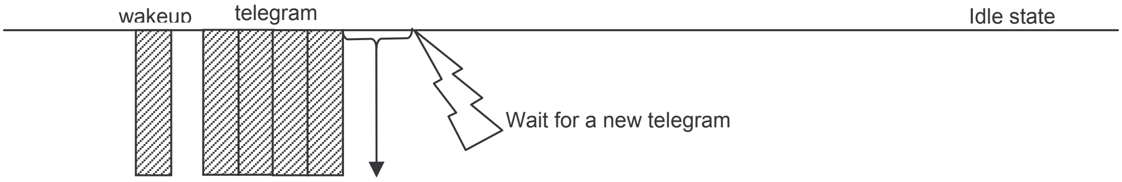
ID = slave device IDentification
Cmd = Command 1 byte
Cks = checksum . Sum without carry of all byte (ID + Cmd)

Each byte is enclosed in an asynchronous 8 bits data frame according to the following convention:

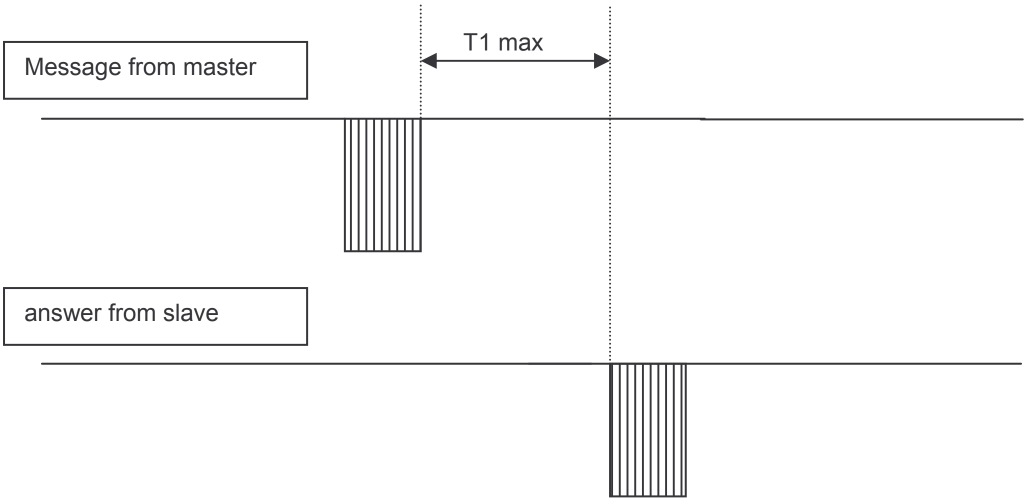
Start Bit	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Parity bit	Stop Bit

Each byte composing the message can be separated from each other by maximum 1 bit time.

A common characteristic of all messages sent by the Master is the start of frame with a wake-up composed by a 0x00 byte.
This byte is necessary to wake-up the addressed (Slave) module; this byte is well separated from the rest of telegram.



Slave, after receiving a correct message , must answer within T1.
A telegram is considered finished after an idle state of more than T1.
Answer is composed of only 1 byte (no wake_up byte)



Slave Module	T1 (ms)
MW1	60
MW2	10
MW3	10
MW4	10

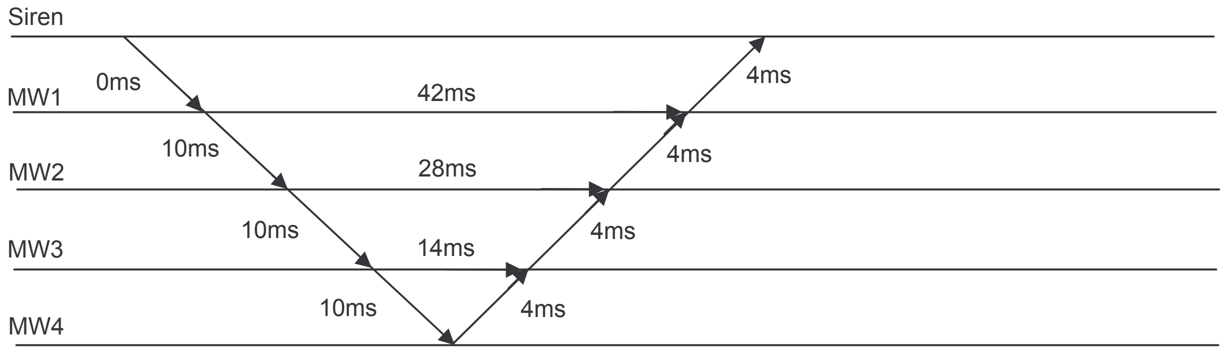
3.2.3 Serial communication

In disarm mode, interrupts on Cobra serial line (lower; pin 3) must be disabled in order to avoid wake_up of MWn by MW(n+1).
All the dedicated telegrams (i.e. with own ID) received by MW1 from its Master are retransmitted (changing format) to MW2 increasing the ID by 1 (ID=ID+1) (for the Polling telegram a bit in EEprom enables or not the retransmission).
Accordingly, the MWn that receives a telegram, must increase the received ID by 1 (ID=ID+1) and must send this updated telegram to its slave module MW(n+1).
In the same way, MW that receives an answer from its Slave, retransmits the answer to its Master filling its own field.
MWn that does not receive an answer in a dedicated timeout, starts the answer itself.
MW4 is the end of line, so it does not send telegram to its Slave and answers without timeout.

Dedicated timeout:

MW ID	Timeout (ms) starting from the beginning of the sent message
MW1	42
MW2	28
MW3	14
MW4	0

Considering a time of 3ms for the MW to manage telegrams and a telegram duration of 7ms, we assume 10ms to transmit command from MWn to MW(n+1); accordingly we assume 4ms for the transmission of the answer from MW(n+1) to MWn.



From the graph above we can see that the Siren get complete answer from MW1 in 46ms independently from the number of MWs.

3.2.4 Commands [Master→Slave]

3.2.4.1 Cmd: 0xA3 "Switch on"

Telegram sent by Master module to start the detection activity (arm).
Master (Siren) sends in sequence this telegram to the following IDs (sequence is repeated two times):

Module	ID	Baud Rate
US	0x20	4800
LM	0x70	4800
ICD	0x51	4800
MW	0x81	9600
SIR	0x41	4800
MONITOR	0x90	4800
EOL TESTER	0x60	4800

Depending on the answers received, the Siren decides the IDs to be managed during the ARM cycle.

Answer
Microwaves answer to "Switch on" command with one byte only, filled as follow:

bit0= Presence MW1 (1=module present ; 0 = module not present)
bit1= Presence MW2 (1=module present ; 0 = module not present)
bit2= Presence MW3 (1=module present ; 0 = module not present)
bit3= Presence MW4 (1=module present ; 0 = module not present)
bit4= Diagnose MW1 (0=module OK ; 1 =failure)
bit5= Diagnose MW2 (0=module OK ; 1 =failure)
bit6= Diagnose MW3 (0=module OK ; 1 =failure)
bit7= Diagnose MW4 (0=module OK ; 1 =failure)

If MW(n+1) does not answer, MW(n) answers its own status verifying the not present status for MW(n+1).

3.2.4.2 Cmd: 0x96 "Polling"

This telegram is sent only in arm mode (after the "switch on" command 0xA3). It is sent cyclically by the Siren module to check the presence of the MWs. This message is sent every 800 msec.
Answer
Microwaves answer the polling command sending only one byte as follow:

bit0= Status MW1
bit1= Status MW2
bit2= Status MW3
bit3= Status MW4
bit4= Presence MW1
bit5= Presence MW2
bit6= Presence MW3
bit7= Presence MW4

for each MW:

Status	Presence	Interpretation
0	0	MW not present
0	1	MW present; no alarm
1	0	MW failure
1	1	MW present; alarm

If MW(n+1) does not answer, MW(n) answers its own status verifying the "not present" status for MW(n+1).
Could be that, depending on the setting, MW1 does not retransmit this telegram to MW2; in this case the other MWs will figure as not present in the answer; this will be managed accordingly by the Siren.

3.2.4.3 Cmd: 0x5A "Switch off"

Telegram sent by Master module to stop the detection activity (disarm).
This telegram is sent three times (one every 800ms).

Answer
Microwaves answer to switch off command sending one byte only as follow:

bit0= MW1 status (0=OFF, 1=ACTIVE)
bit1= MW2 status (0=OFF, 1=ACTIVE)
bit2= MW3 status (0=OFF, 1=ACTIVE)
bit3= MW4 status (0=OFF, 1=ACTIVE)
bit4= bit0 complemented
bit5= bit1 complemented
bit6= bit2 complemented
bit7= bit3 complemented

If MW(n+1) does not answer, MW(n) answers its own status but adding an ACTIVE status for MW(n+1).

3.2.5 Diagnostic Commands [Cobra diagnostic tool→MW1]

3.2.5.1 Cmd: 0xD(n) "Read MWn alarm memory"

Diagnostic telegram sent by the Cobra diagnostic tool to read the alarm memory in MWn.
This telegram can be managed only in "disarm state"
In this case, the Cobra diagnostic tool must wait up to 100ms for the answer.

Answer

TBD

3.2.5.2 Cmd: 0x55 "Clear alarm memory"

Diagnostic telegram sent by the Cobra diagnostic tool to clear the alarm memory.
This telegram can be managed only in "disarm state"
In this case, the Cobra diagnostic tool must wait up to 100ms for the answer.

Answer

bit0= MW 1 (0=Clear OK, 1=Clear Fault)
bit1= MW 2 (0=Clear OK, 1=Clear Fault)
bit2= MW3 (0=Clear OK, 1=Clear Fault)
bit3= MW 4 (0=Clear OK, 1=Clear Fault)
bit4= bit0 complemented
bit5= bit1 complemented
bit6= bit2 complemented
bit7= bit3 complemented

3.2.5.3 MW's auto IDentification

MW modules must learn the own ID only after their fixing on the car, as the set of four can be installed in a random way and the ID is related to the positioning.
The MW modules understand their positioning from the ID received by the Master telegram; i.e. if the MW receives a telegram with ID=0x81 it means that it is MW1, if it receives an ID=0x84 it is MW4.

3.2.5.4 MW's alarm

With Polling enabled by MW1 to MW(n+1):

If during an arm period a MW detects an Alarm, it sends the info as an answer to the "polling" telegram.

With Polling not enabled by MW1 to MW(n+1):

If during the arm period a MW detects an Alarm, it sends a Wake_up telegram to its Master.
Wake_up telegram is a 0x00 byte.
MWn (different from MW1) that collects an Alarm wake_up from its Slave must repeat the same procedure to send the Alarm to its Master.
MW1 that collects a Wake up, enables the passing of the Polling telegram to the following MWs in order to get the alarm info in the answer.

3.3 Block 2 - Digital Circuits

The digital circuits generate all fast control signals and have counters and flip-flops for counting. This part of the circuit also control measurements of sampling timings and pulses.

3.4 Block 3 - Envelope Amplifier and Dataslicer

The envelope amplifier and dataslicer amplifies the detector signal with a pre-Amp. band pass 100 – 300 MHz, and through a quasi peak detector, the dataslicer generates pulses of approximately 50 nsec up to a frequency of 10 MHz.

3.5 Block 4 - Measurement Amplifiers

Three parameters are measured:

- Transmitted pulse length
- Time delay from end of a transmitted pulse to start of Doppler Mixer signal sampling
- Transmitted pulse energy, a value where both the pulse length and the power level is considered.

All three signals are amplified, and a sample and hold circuit keeps the value up to half a millisecond after the end of each transmitted burst.

3.6 Block 5 - Power Supply

The main power supply circuit is a DC-DC converter with a 3.3 V output,. This 3.3 V voltage is further stabilized in an ultra low noise 3.0 V circuit for the microwave RF oscillator. Both regulators can be disabled from the micro controller but if the 3.3 V regulator is disabled it can only be enabled either by 12 V feed switching on or a wake up from the LIN transceiver.

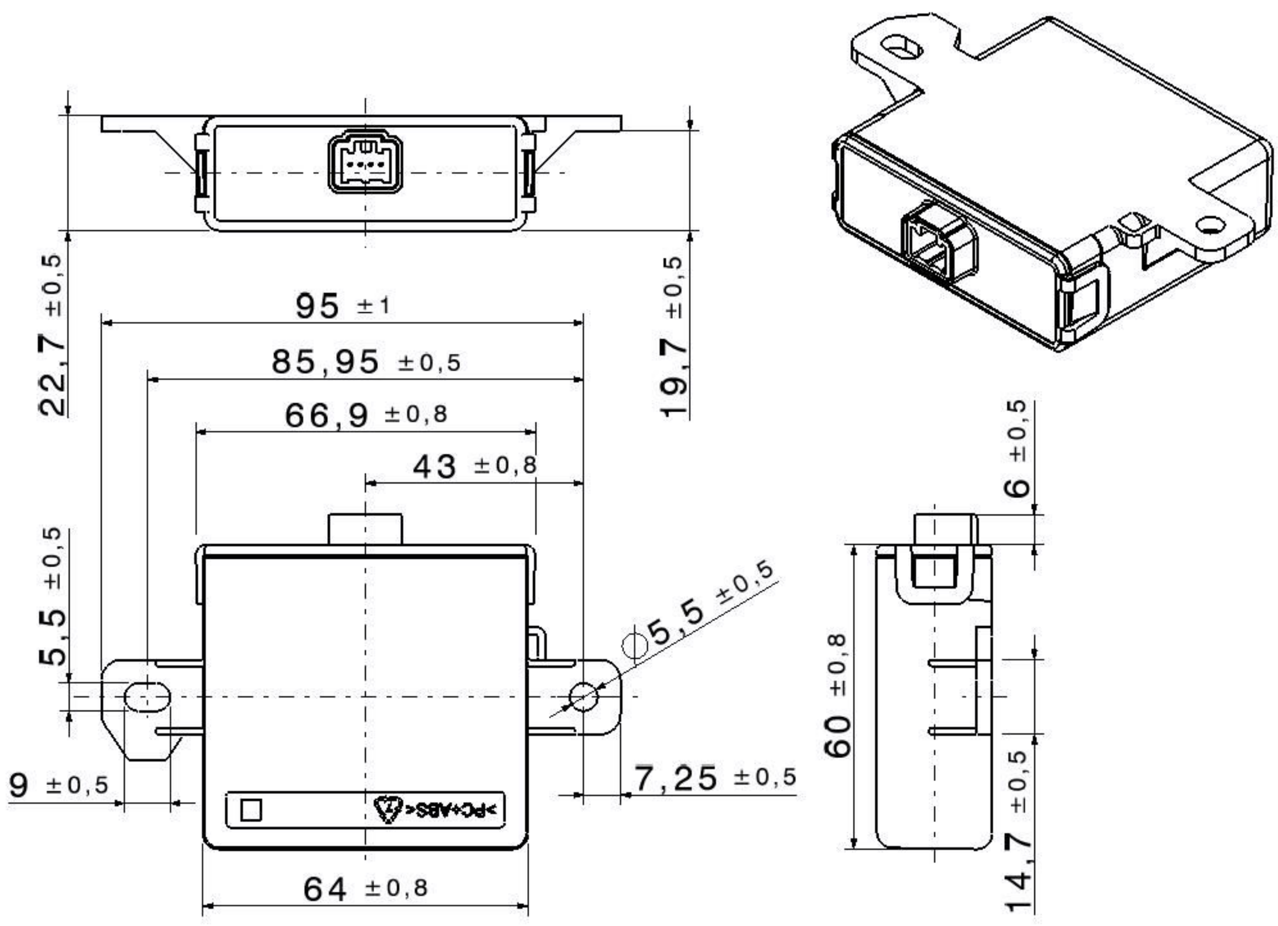
3.7 Block 6 - Microwave stage

The Microwave stage consists of a microwave oscillator, a balanced mixer, an envelope detector, one transmitting antenna, one receiving antenna, a directional coupler and two Wilkinson splitters. Both antennas have λ/4 ESD shortages and low pass filters just above the CW frequency.

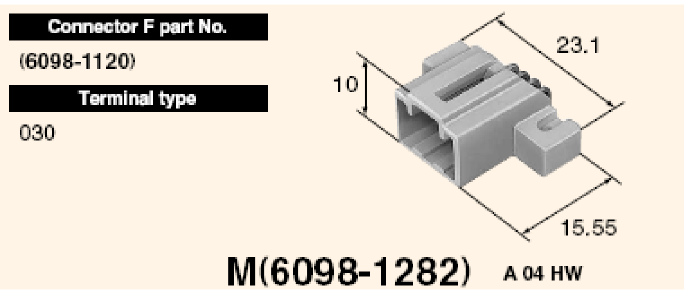
3.8 Block 7 - Micro Controller

The micro controller is based on the Freescale MCS08AW60-series with an external 16kByte EEPROM for diagnostic services. The clock frequency is 7,3728 MHz, and the PRF is generated through a division by 8 which yields 916,2 kHz.
Seven A/D inputs are used, and two D/A conversions is made through R-2R ladders for control of transmitting pulse length and mixer sample delay.

4 Mechanical specification



4.1 Connector type



5 Sensor packaging / vehicle integration

Depending on vehicle type and dimensions, as well as achievable coverage of the passenger compartment in line Technical and Insurance Regulations, sensors could be packaged:

- in the tunnel console, to cover front area
- underneath the rear seat cushion to cover the rear area
- in door panels

Typical detection area and near echo suppression zone are described in pictures underneath.