3 - Audio System

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Introduction

This Chapter specifies the Audio hardware for the NPL-1 program.

Abbreviations

UEM	Universal Energy Management
UPP	Universal Phone Processor
UIF codec	User InterFace Codec in UPP
VBAT	Main battery voltage
PWM	Pulse Width Modulated (signal)
MUX	MUltiPlexer
GND	Phone ground
LGND	GND abbreviation in System connector
SGND	Signal ground – reference for microphone
MCU	MicroController Unit
PWB	Printed Wire Board
ERP	Ear Reference Point
MRP	Mouth Reference Point
SPL	Sound Pressure Level (reference value 20 uPa)
BT	BlueTooth
AGC	Adaptive Gain Control
DRC	Dynamic Range Compressor
ALWE	Noise suppressor algorithm
AEC	Acoustic Echo Canseler
IMD	Insert Moulded Decoration
SCO	Syncronous Connection Oriented
LPRF	Low Power Radio Frequency (BlueTooth)
PWM	Pulse Width Modulated

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Technical overview

Block Diagram

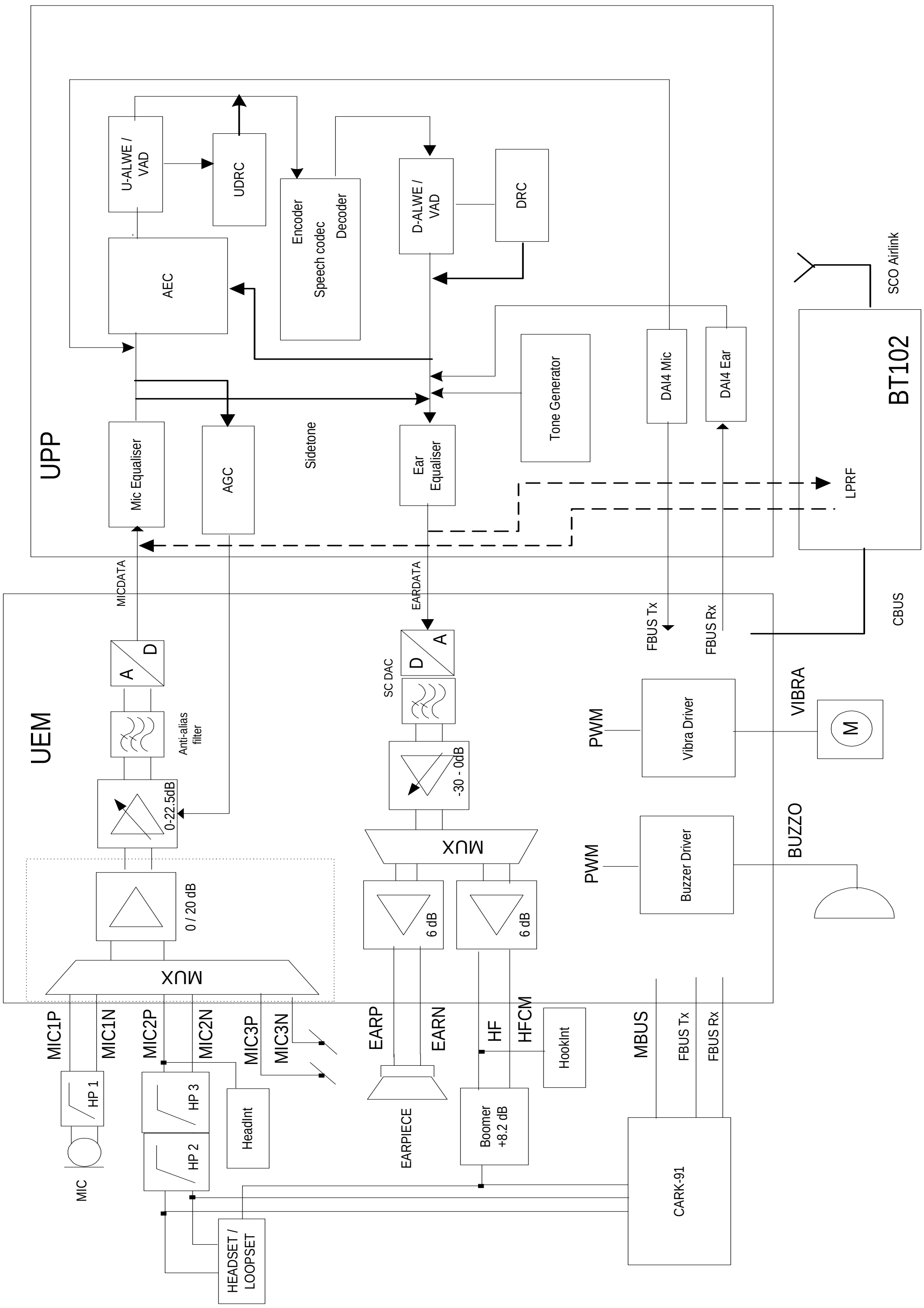

Figure 1. Audio Block diagram

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Part List

All involved key parts are listed in the following table. As seen in the table there is only one vendor for some of the audio and vibration key components.

Table 1: Parts list

NAME OF THE SUB-MODULE	COMPONENT DESIGNATION	VENDOR	MATERIAL CODE
Buzzer 1	MCC-03ACS	STAR	5140209
Earpiece 2	TYPE: WD 00518/32 U CODE: 2403 252 08108	PHILIPS Earpiece Systems	5140067
Earpiece 1	LT 201	KIRK Acoustics	5140233
Microphone assy 1	WM-64-HNY-310	MATSUSHITA	5140225
Vibrator 1	KHN4NB1H	MATSUSHITA	6800043
Headset	HDC 9P	NMP	
Loopset	LPS-1	NMP	
Carkit - Handsfree unit - Handsfree earpiece - Microphone - Handset unit	CARK-91 - HFU-2 - HFS-12 - HFM-8 - HSU-1	NMP	
Bluuetooth Carkit - Junction box - Remote control button - Handsfree earpiece - Microphone - Handset unit	CARK-112 - HFW-1 - CUW-2 - HFS-12 - HFM-8 - HSU-1	NMP	0750135
Bluetooth headset	HDW-1	NMP	0694064
UEM			4370805
UPP			4370815
Boomer	LM4890	National semiconductors	4341221
System connector			5469061

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DC Characteristics

The audio relevant supply voltages are shown in the following table:

Table 2: Supply Voltages

Line Symbol	Minimum	TYP. / Nominal	Maximum	Unit	Notes
Vana	2.7	2.78	2.86	V	(Mic bias buffer)
	0,005		80	mA	Min. due to regulator stability
VBAT	3.1 (SW) (2.9 (HW))	3.6	5.1 (SW) (5.4 (HW))	V	(Buzzer and Vibra driver). Min and max due to SW cut off.
Vflash1	2.7	2.78	2.86	V	(DLR3, HEADINT and HOOKINT pull up)
	0.005		70	mA	Min. due to regulator stability
	0.005		1.5	mA	Sleep
Vflash2	2.7	2.78	2.86	V	(DLR3)
	0.005		40	mA	Min. due to regulator stability
VIO	1.72	1.8	1.88	V	(HOOKINT level shifter)

Audio Function Description

Audio control

The audio control and processing is done by the UEM, which contains the audio codec and the UPP contains DSP blocks, handling and processing the audio data signals.

The audio block diagram is presented in , page 3-6.

The UEM supports three microphone inputs and two earphone outputs. The inputs can be taken from an internal microphone, a headset microphone or a handsfree-unit / Carkit microphone. The microphone signals from different sources are connected to separate inputs at the UEM ASIC. Inputs for the microphone signals are differential type.

MIC1 and EAR in/output are used for the internal microphone input and Earpiece output. The Headset or handsfree unit / Carkit audio is connected to the MIC2 input / HF (single ended) output. The MIC3/XEAR is connected to GND and not used in the NPL-1 project.

Input and output selection and gain control is performed inside the UEM ASIC (register AudioCtrl (Gain and routing) and MicBias (microphone bias selection).

Additional gain is added in the DSP SW. This gain is controled by adaptive algorithms (AGC, DRC, ALWE and AEC) and set as a function of background noise, signal level and echo canceling.

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In case of BT audio the BT accessory and the phone is connected by both an ACL and SCO air link. ACL is used for connection commands and SCO for the actual audio transmission. In both cases the BT module (in accessory and phone) receives the audio signal. In the phone this signal is routed from BT module over LPRF to DSP where it follows the regular audio path through out the rest of the system. The BT module and MCU is connected by the CBUS for exchanging low level information.

All BT Gain adjustments are done in the accessory. DSP tuning is done in UPP, completely as usually.

Gain Table

The possible gain for each input and output is shown in The gain settings are controlled in the 16 bit AudioCtrlR register. Note * MIC3 only used for test purposes in NPL-1.. Table 4: Total UEM gain for each input and output in different audio paths (modes). contains the total gain for each input and output in different audio modes.

The gain settings are controlled in the 16 bit AudioCtrlR register.

Table 3: Possible UEM gains for each input and output

UEM Pins	Gain (dB)		
Input / Output	Programmable	Fixed UEM	Total
MIC1	0 to 22.5, step 1.5dB	20	20 to 42.5, step 1.5dB
MIC2	0 to 22.5, step 1.5dB	0 or 20	0 to 22.5 or 20 to 42.5, step 1.5dB
MIC3*	0 to 22.5, step 1.5dB	0 or 20	0 to 22.5 or 20 to 42.5, step 1.5dB
HF (single ended)	-30 to 0, step 2dB	6	-24 to 6, step 2dB
EAR	-30 to 0, step 2dB	6	-24 to 6, step 2dB

Note * MIC3 only used for test purposes in NPL-1.

Table 4: Total UEM gain for each input and output in different audio paths (modes)

Gain Table		Normal Mode - Gain dB		
	UEM Signals ↓	Handportable	Headset	Handsfree (Carkit)
INPUTS	MIC1	20 to 42.5, step 1.5dB		
	MIC2		20 to 42.5 step 1.5dB	0 to 22,5 step 1.5dB
	MIC3			
OUTPUTS	EAR	-24 to 6, step 2dB		
	HF		-24 to 6, step 2dB	-24 to 6, step 2dB

Deviations in gain performance:

Transmit gain absolute accuracy: -1.0 / 0.0 dB

Transmit gain variation (temperature, supply): +/- 0,7 dB

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Transmit gain variation with frequency (300 – 3000 Hz):	+/- 0,5 dB
Transmit gain variation with signal level (> -50 dBm0):	+/- 0,5 dB
	(<-50 dBm0: +/- 1.2 dB)
Receive gain absolute accuracy:	+/- 0,5 dB
Receive gain variation (temperature, supply):	+/- 0,7 dB
Receive gain variation with frequency (100 – 3000 Hz):	+/- 0,5 dB
Receive gain variation with signal level (> -50 dBm0):	+/- 0,5 dB
	(<-50 dBm0: +/- 1.2 dB)

DSP Gain:

Initially the DSP gain uplink (Mic) is set to 12 dB and 0 dB downlink. This is done in the Equaliser.

The AGC controled by the DSP is able to reduce the Uplink gain in the UEM by 18 dB maximum in steps of 1.5 dB.

The DRC can either attenuate the signal or enhance in it in DSP by up to 10 dB.

Note: Local mode gains are uptimised for production testing and are not the same as in normal mode.

Internal Audio Devices

NPL-1's internal audio design is described in the following sections.

Earpiece

Receiver solution is selected to be a Kirk Acoustic earpiece. Earpiece design is leak tolerant with a front protection cover directly on the earpiece component. The Earpiece will be placed in a moulded rubber gasket which seals the front cavity to the IMD Window.

In front of the earpiece and leakholes a shielding material will be placed to prevent dust particles to migrate onto the earpiece diaphragm. This material consists of a grid material type Saati PES 120/41 from Tradex (It is the same material as in Nokia 8210).

The earpiece is designed to be approved in type approval by type 3.2, low leak artificial ear (Ear Simulator Type 4195, Low Leakage). No support for type 1 artificial ear is made (Ear Simulator Type 4185).

Earpiece Acoustic Design

The earpiece is sealed to the front cover (IMD window) with a rubber gasket. The gasket is fixed inside the A-cover by the vibra motor assembly.

The Earpiece and gasket is designed to seal perfectly against the front cover. There is no

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well defined leakage as known from the NPE-3 project. This is done to have a better performance in the frequency area from 2 – 3.4 kHz and to prevent the possibility of an acoustic feedback loop inside the phone mechanics.

There is no sealing between the earpiece and the PWB.

There are also holes through the PWB to make the design more leak tolerant by using the volume between PWB and the B-cover.

A-Cover or window contains front and leakage holes. On the inside of the A-cover a dust shield is placed. This shield covers both front and leakage holes.

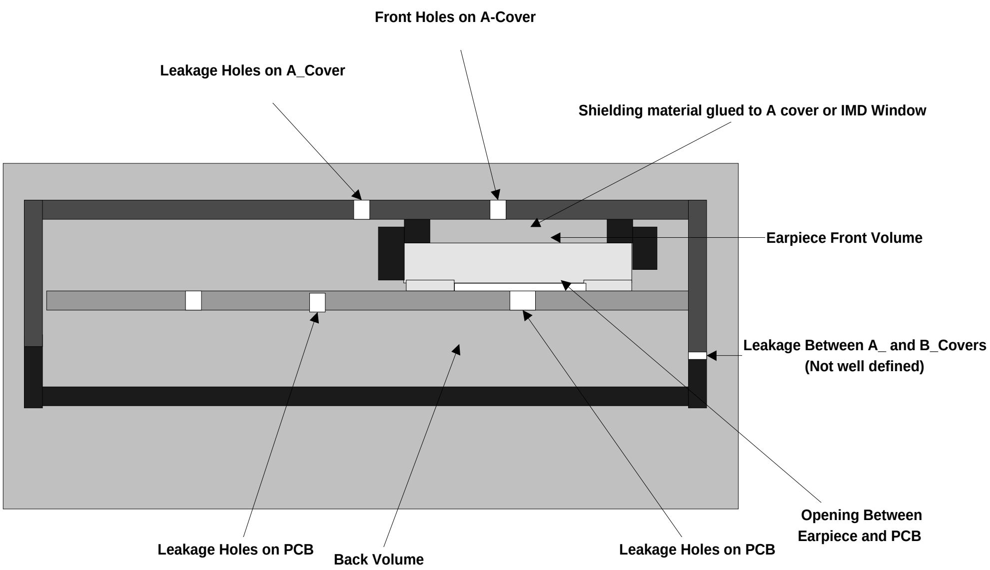

Figure 2. Sketch of Earpiece Acoustic Design

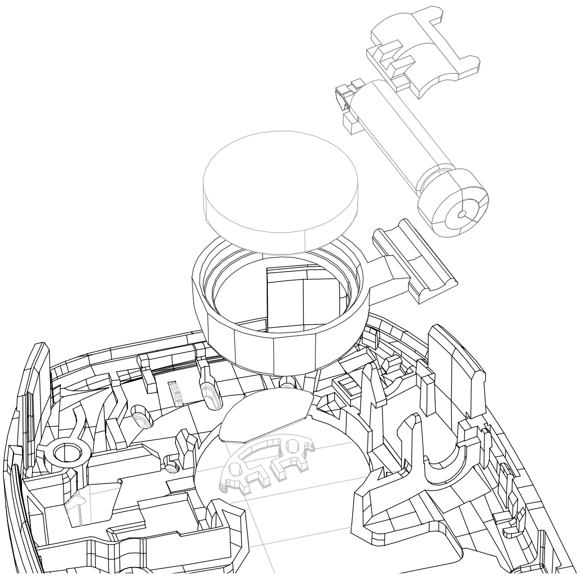

Figure 3. Mechanical assembly of Earpiece and Vibra

Specified frequency response curve for the NPL-1 design (mechanics and Audio):

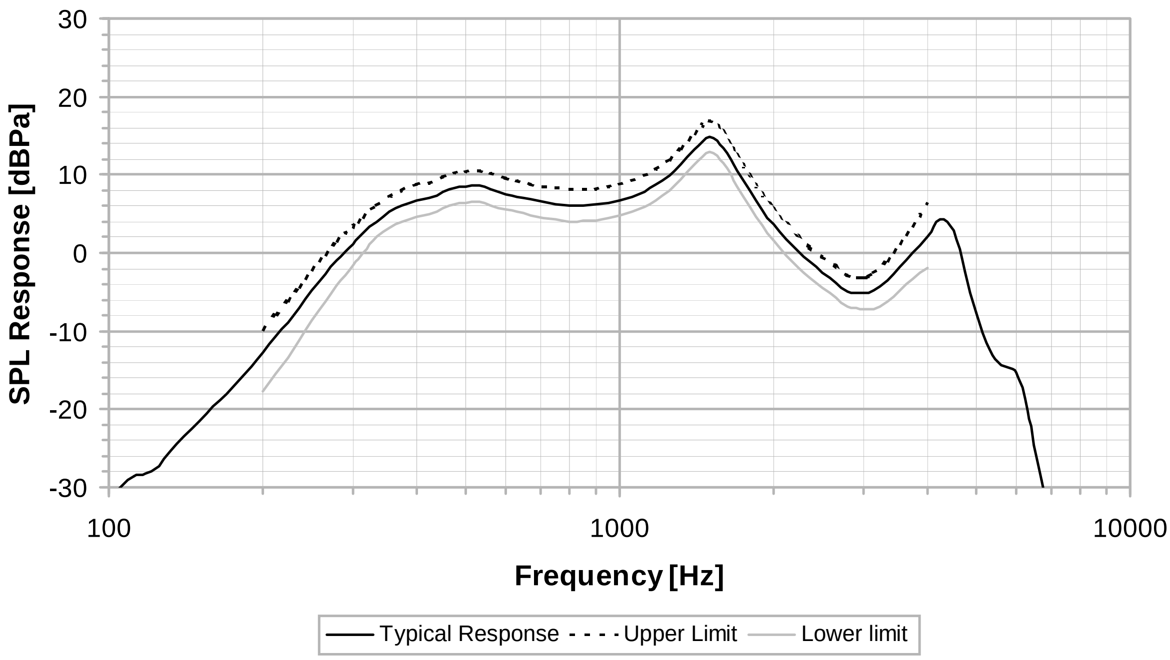

Figure 4. Earpiece frequency response - ERP corrected – non DSP corrected

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Absolute Sensitivity (Low leak): 26 dBPa/V ±3dB @ 1kHz. (0 dB on Figure 4. Earpiece frequency response - ERP corrected – non DSP corrected)

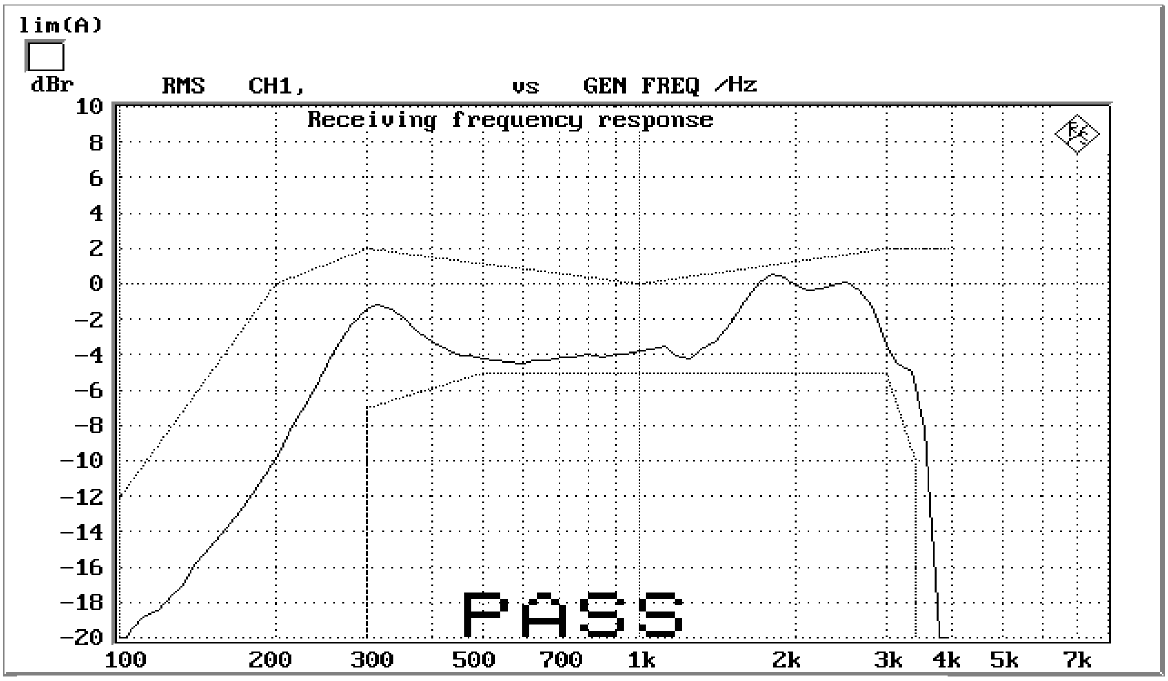

Figure 5. DAI receiving frequency response, B4.0

Earpiece Electrical Interface

Earpiece circuit includes pads for earpiece together with 2 ferrite beads (Common mode filter), 2 capacitors (900 MHz cut-off filter) and two varistors for ESD protection placed near the Earpiece.

The low impedance, dynamic type earphone is connected to the differential output (EAR) in the UEM audio CODEC. On the differential output 2 * 22 Ohm (R171) is placed for noise reduction and to compensate for the high capacitance of the varistors (1 nF), which could lead to instability in the UEM.

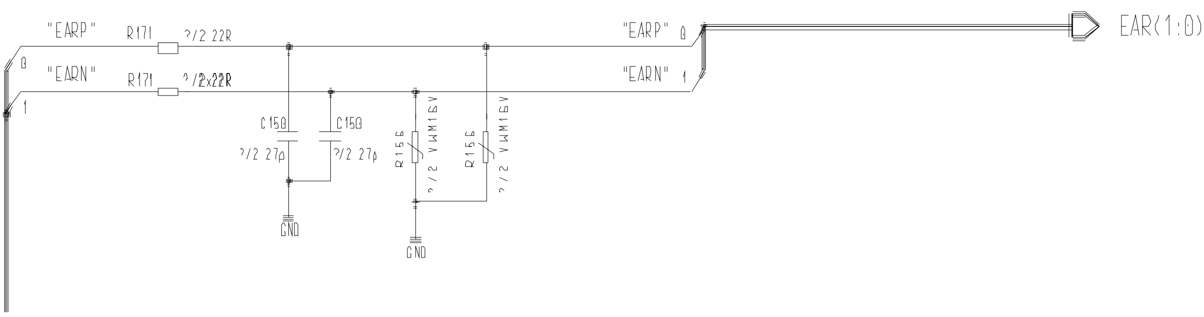

Figure 6. Internal Earpiece Electrical Interface

Ear output specifications from the UEM specifications:

Table 5: UEM Ear output specification

Parameter	Test condition	Min	Typ	Max	Units
Output swing @ 0dBm0, GR=-6 dB	V_{ASwing}	2.36	2.5		V_{pp}
Output voltage swing	With 60 dB signal to total distortion ratio	4.0			V_{pp}
Output resistance	PDM data with 50 % pulse ratio in the DAC input			1.0	Ω
Load capacitance	EARP to EARN			50	nF
Load resistance	EARP to EARN	26	32		Ω
Load capacitance	EARP to GND			200	pF
Differential offset voltage		-50		50	mV
Common voltage level for EAR output (EARP & EARN)	VCM_{EAR}	1.3	1.35	1.42	V

Microphone

An omni directional microphone (DCT3 type) is used. The microphone is placed in the system connector sealed in its rubber gasket. The sound port is provided in the system connector.

The microphone is delivered from Matsushita with the microphone mounted in the rubber gasket.

A new rubber boot (Microphone gasket) with a harder shore (shore 80 versus shore 50) will be used, to increase production ease and subsequently the production yield.

The microphone is connected to the differential input (MIC 1) of the UEM.

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Sketch of Microphone Acoustic Design

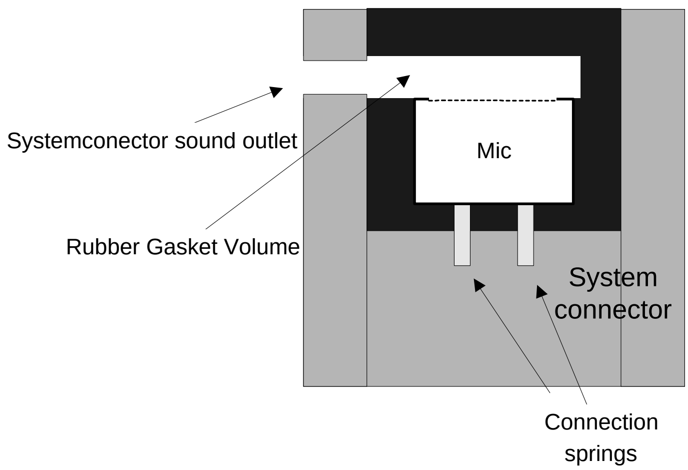

Figure 7. Microphone Acoustical Design

Absolute Sensitivity: -42 dBV/Pa ±3dB @ 1kHz.

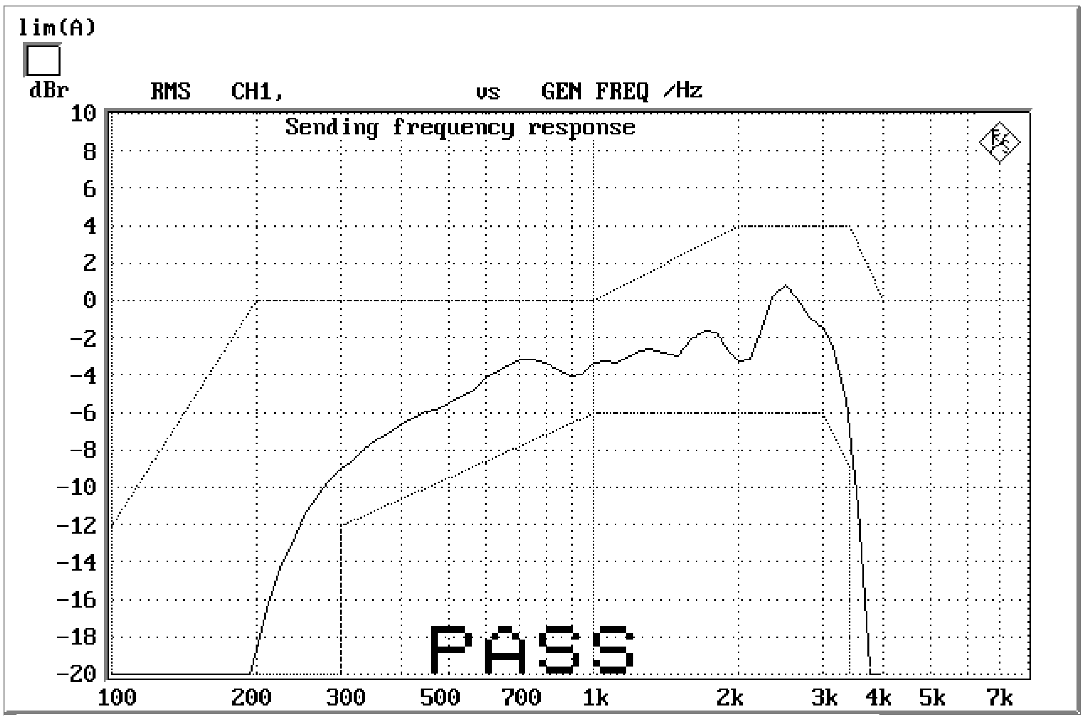

Figure 8. DAI Sending frequency response, B4.0

The desired microphone response is a flat line in 0 dB between 300 Hz and 4 kHz that roles off as much as possibly outside these frequencies.

Since the microphone response is flat, no DSP equalisation is found necessary.

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Microphone Electrical Interface

The microphone electrical circuit includes 2 ferrite beads for common mode noise rejection together with 2 capacitors for filtering the 900 MHz signal and two varistors for ESD protection placed near the microphone PWB spring pads.

The 10 nF (C155) forms a low pas filter together with the microphone impedance to make a steeper role off at high frequencies.

Also an extra High pass filter (R152 + C154) is added to limit audible TDMA-noise (217 Hz + harmonics) and to limit the bumpy road noise.

A transistor circuit (V150) on the bias line from UEM is used as the voltage supplier for minimising the noise level from the UEM bias output.

This gives an decrease in the DC voltage level across the Microphone to typically 1.1 V (1.3 V re. GND). Using Matsushita microphones as single supplier this will not pose any problems as the FET in the microphone have little variation on their Vds curves.

The Microphone bias is controlled in the 8 bit AudioBiasR register. The 1 uF (C171) is lessons learned from NPE-3 and simulations shows that this will give an even higher noise suppression. But it has the risk of oscillating. No difference has been measured on preliminary tests.

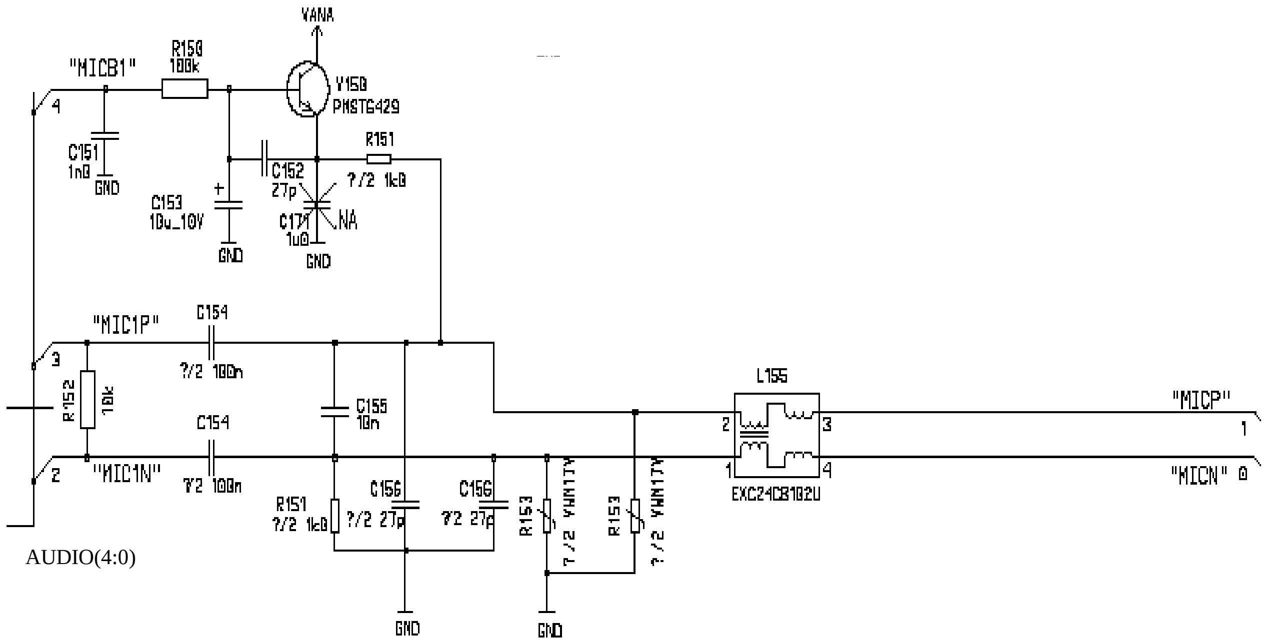

Figure 9. Internal Microphone Electrical Interface

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UEM microphone input specification:

Table 6: **Microphone input specifications**

Parameter	Symbol	Min	Typ	Max	Unit
Microphone amplifier input resistor	R_{M30}	30	50		kOhm
Differential input voltage range for MIC1 input, G =20 dB	V_{IN1}		200	1200	m V_{PP}
Receive Common mode input voltage range for MIC input	V_{HFCM}		100		m V_{PP}
Common mode voltage level	V_{CM}	1.3	1.35	1.4	V
Differential mode voltage range for microphone amplifier, at gain = 20dB	V_{OUT}		2.0		V_{PP}
Differential load resistance for the microphone input stage	R_{OS}	30		450	kOhm
Transmit gain absolute accuracy	GXA	-1.0		0.0	dB
Transmit gain variation with programmed gain, temperature and supply	GXAGTV	-0.7		0.7	dB
Common mode rejection ratio	CMRR	45	60		dB

Buzzer

Alerting tones and/or melodies are generated by a buzzer, which is controlled by a PWM signal from the UEM. The SPL requirement is to be as good or better than the NPE-3 in comparison test. The buzzer is delivered from the supplier with an end of line requirement of 102dB (A) at 5cm and 2.5 kHz.

The actual level is found from a comparison with NPE-3 on specific ringing tones.

The buzzer is designed to have the first resonant peak at 2500 Hz. The ringer melodies will be optimised in DSP so the main frequency of any given melody is shifted to near the resonant peak. For this optimisation a program called BuzzCalc will be used for the calculation of the dominating frequency of a given ringing melody or tone.

The design of the buzzer is a direct copy from the NPE-3 project. The Buzzer is glued to a gasket. This final assembly is delivered by STAR. Sound holes are placed in the A-cover

The A-cover is designed to give an optimal SPL by securing the tightness between buzzer and A-cover.

The buzzer is electrically connected to the PWB by spring contacts.

Buzzer Acoustic Design

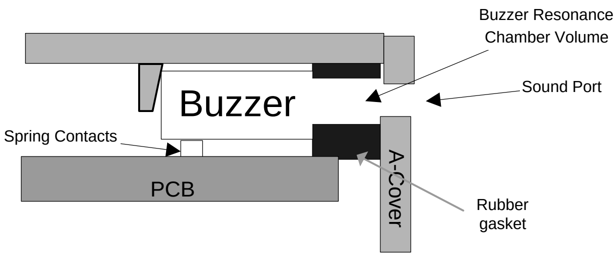

Figure 10. Sketch of Buzzer Acoustic Design

The important parameters in this design are the front cavity and the sound portholes.

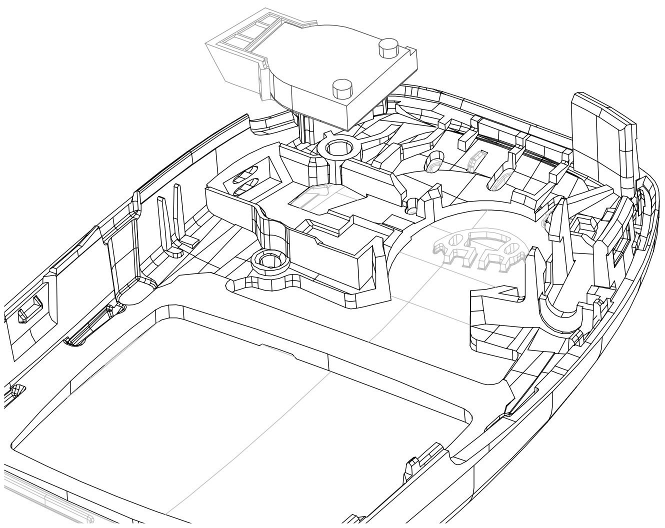

Figure 11. Mechanical buzzer assemply

The expected A weighted frequency response is (50 % Duty cycle). Tested in a simplified testbox. Final result expected to lay 2-4 dB below.

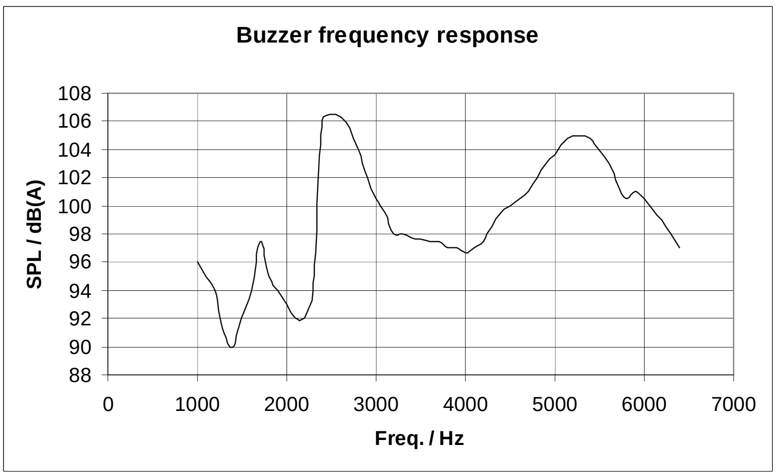

Figure 12. Typical buzzer frequency response

Buzzer Electric Interface

The driver circuit is an integral part of the UEM.

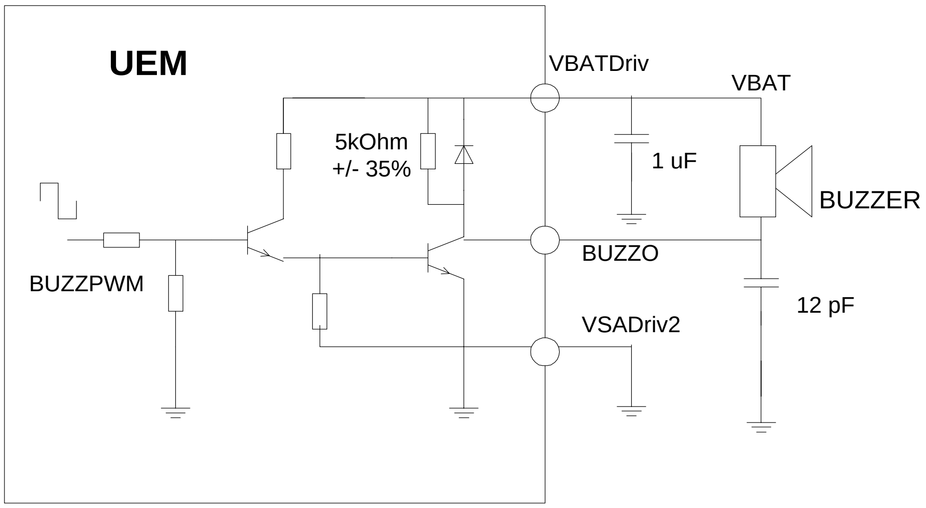

Figure 13. Buzzer driver circuit.

Table 7: Buzzer driver specifications

Parameter	Variable	Min	Typ	Max	Unit
Output switch resistance Rbuzzo		1.0	2.7	4.5	Ohm
Output peak sink current Iout	VBAT	120	180	350	mA
Output peak sink voltage Uout	VBAT		0.5	1.2	V
Output pwm duty cycle Pdcyc				50	%
Buzzer coil resistance Rload		13	16	19	Ohm
Battery voltage VBAT	Ni or Li battery	3.03	3.6	5.2 (Ni) 4.2 (Li)	V
Reverse diode peak current Iforw	tp = 10 us			0.35	A
Output frequency Fout, GSM system		0.48	2500	7751	Hz

The buzzer is controlled from the UEM by a PWM (Pulse Width Modulated) square wave signal.

The frequency is produced by a bitstream on register BUZZFREQR that is counted through a 21 bit accumulator:

$$F_{out} = F_{BuzzClk} /((2^{21} / BuzzFreqR) + 1)$$

BuzzClk has the same frequency as the CBusClk (1 MHz for GSM).

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When buzzer DigEna = 1 then a PWM signal is present at BUZZPWM

The buzzer duty cycle is defined by:

$$Duty\ \mathrm{Cycle} = BPWMDCR(5:0) * 0.78125\%$$

Vibra specification

A vibra alerting device is used to generate a vibration signal for an incoming call. The vibra is placed in the top of the phone. It is fastened to the A-cover by means of a rubber gasket and a lid which are pressed into the A-cover see .

The vibra is electrically connected to the PWB by spring contacts.

The vibra is controlled from the UEM by a PWM (Pulse Width Modulated) square wave signal.

Vibrator Electrical Interface

The driver circuit is an integral part of the UEM.

The two 33 nH inductors are added for decoupling the vibra motor from the RF antenna field. The two 1 nF capacitors are placed for ESD purposes.

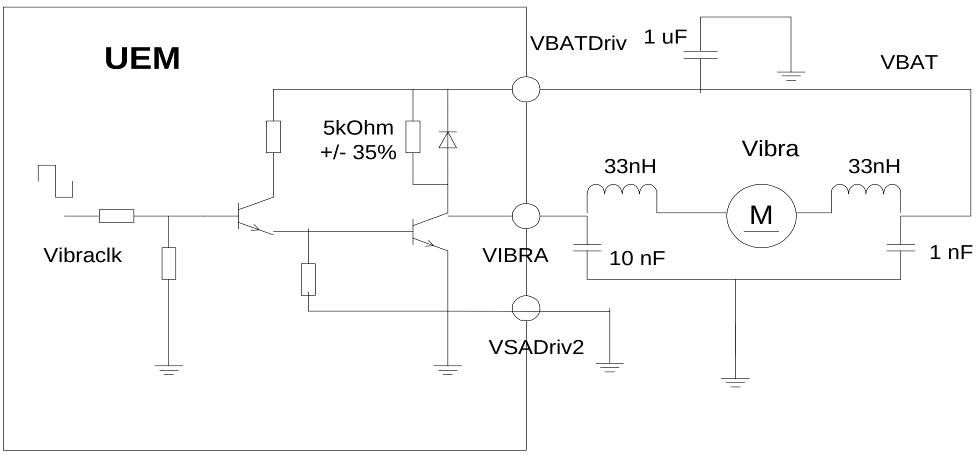

Figure 14. Vibra driver circuit

Vibra electrical specifications

Operating voltage = 1.0 V – 1.2 VDC (Controlled by the Duty cycle)

Starting Current = max 140 mA

Starting voltage = max 1 VDC

Terminal Resistance = 8.8 Ohm (typical)

Coil = 40 uH (typical)

Typical rpm: 9000 at 1.1 VDC.

Table 8: Vibra driver specifications

Parameter	Variable	Min	Typ	Max	Unit
Output swhich resistance Rvibra		1.4	4.2	7.5	Ohm
Output average current Ivibra	VBAT	50	80	135	mA
Output peak current Ipeak	VBAT			300	mA
Output frequency Fvibra		64	129	520	Hz
Output duty cycle Dvibra		2.9	47	96.9	%
Reverse diode peak current Iforw	tp = 10 us			0.30	A
Motor average dc Udc_motor	VBAT=3.0 ... 4.5 V	1.0	1.5	2.3	Vdc
Output current high imp Ihiz	V_ANA, VBAT	-1		1	uA

Valid frequencies are: 64, 129, 258 and 520 Hz

The duty cycle of the vibra output is selected by the VCLKR register bit #7 .. #4. This is 16 accumulated duty cycles from 2.9 % to 96.9 %

The frequency of the vibra is selected by the VCLKR register bit #D1 and #D0, this clock is divided down from the 32.768 Hz clock.

Table 9: Vibra output frequency control

D1	D0	Vibra output frequency
0	0	64,1
0	1	128,5
1	0	258,0
1	1	520,1

External Audio Devices

Audio Accessories

NPL-1 is supporting the following DCT3 and bluetooth audio accessories:

Headsets:

HDC-9P

Headset is the simplest audio accessory to use. It merely only consists of an earpiece, a microphone, and a switch which in technical terms is often referred to as a HOOK-switch or Headset button. The HOOK-switch can be used either to answer in-coming calls, to end a call or to initiate voice dialling calls.

The Hook interrupt is detected by software polling on the UEM hookInt input pin

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HDC-9P is a purely **passive audio accessory.**

Table 10: HDC-9P interface specifications

Object	Specification	Notes
Receiver input impedance	150 Ohm +/- 25 %	@ 390 mV at 1 kHz
Maximum Sound pressure level	106 dB SPL	at 1 mW
Transmitter output impedance	2200 Ohm +/- 30 %	at 1 kHz
Transmitter sensitivity	- 43.5 dBV/Pa +/- 3 dB	at 1 kHz
XMIC bias voltage	1.5 V	Typical
XMIC bias current	1.5 mA	Maximum

HDW-1

Bluetooth headset developed in the Tomahawk project.

The BT headset is containing a microphone, a earpiece, bluetooth module and its own audio codec. HDW-1 is battery supplied

Audio connection is full duplex digital transmission with error correction.

Table 11: Selected specifications for HDW-1 BT Headset

	Min	Typ	Max	Unit
Ear signal in Codec after PCM DAC converter		80	490	mVrms in codec
Ear signal amplifier gain in codec	-18	2	12	dB / setting by 2 dB steps
Electroacoustic transfer function (Rx)		17		dBPa/V/0.5m
Microphone signal level	3	4	6	mV/Pa
Level at AD input in Codec		58	490	mVrms in codec
Mic. amplifier gain in codec	20		42.5	dB
Noise voltage, microphone			5	uVrms

Loopsets:

LPS-1

The Loopset is a hearing aid accessory for hearing impaired persons to use mobile phones.

It consists of a **Wire-loop** and a microphone placed in a collar around the person's neck.

This is detected in the mobile as a Headset. In the UI SW it is possible to change profile from Headset to Loopset enabling the use of Loopset specific DSP tunings.

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The coil amplifier is supplied from MICB2 bias voltage.

No voice dialling from the accessory is possible while there is no hookswhich (voice dialing have to be activated from the phone keypad).

Table 12: LPS-1 interface specifications

Object	Specification	Notes
Receiver input impedance	100k Ohm +/- 5 %	Magnetic loop
Transmitter output impedance	1600 Ohm +/- 30 %	at 1 kHz
XMIC bias voltage	1.3 V	Maximum
XMIC bias current	400 uA	Maximum

Carkits:

CARK-91

The carkit consists of the following components:

MCC-1: Active handset holder with connection for the HFU-2 to mobile

HFU-2: Handsfree unit incl. fast charger, HF – microphone and earpiece amplifiers, interface to handset, datacard and phone and control circuit

HHS-9: Swivel mount

PCH-4J: Mounting cable

HFS-12: Handsfree earpiece, permanently installed in the car.

HFM-8: External handsfree microphone. HFM-8 is an option for the user to have a separate microphone for the carkit-installation. HFM-8 is designed to be permanently installed in a car.

The internal microphone in the mobile is muted by a MBUS message from the HFU-2 when the external microphone is detected in HFU-2.

No data call is possible in HFU-2 while DAU-9 datacable is not supported.

External accessory for Cark-91:

HSU-1: Handset unit with hookswhich. This is a handset used for private conversations without losing the link to the external antenna.

Carkit - 112

The carkit consists of the following components

HFW-1 Bluetooth junctionbox which replaces HFU-2 in the Cark-91 setup

CUW-2 Remote control Button, earpiece volume and hookswhich

And all the components mentioned in Carkit-91 apart from HFU-2 and HSU-1.

Bluetooth carkit developed in the Tomahawk project.

DCH-12

Handsfree Desktop Stand

The Desktop Stand is a desktop charger with integrated handsfree function.

External Audio Interface

The interface is basically a 3-wire solution, which gives two completely separate audio-paths, microphone- and earpiece-signals. The interface is split up into:

External earpiece: **XEAR** (external earpiece, single ended)

External microphone: **XMICP** (external microphone, positive)

XMICN (external microphone, negative)

External Audio Interface — Electrical Interface

The external audio connections are presented in Figure 15. External Microphone Interface and The hookInt is pulled up by 47 kOhm and the detection is being polled by software on GENIO2 via the Inverter circuit. A 100k Ohm resistor is added to the Hookint line to avoid DC-clicks in the Uplink path.. A headset or a handsfree unit can be connected directly to the system connector. The headset microphone bias is supplied from UEM MICB2 output and fed to the microphone through XMICP line.

Note: MIC3 lines will be disconected from MIC2 and grounded near the UEM.

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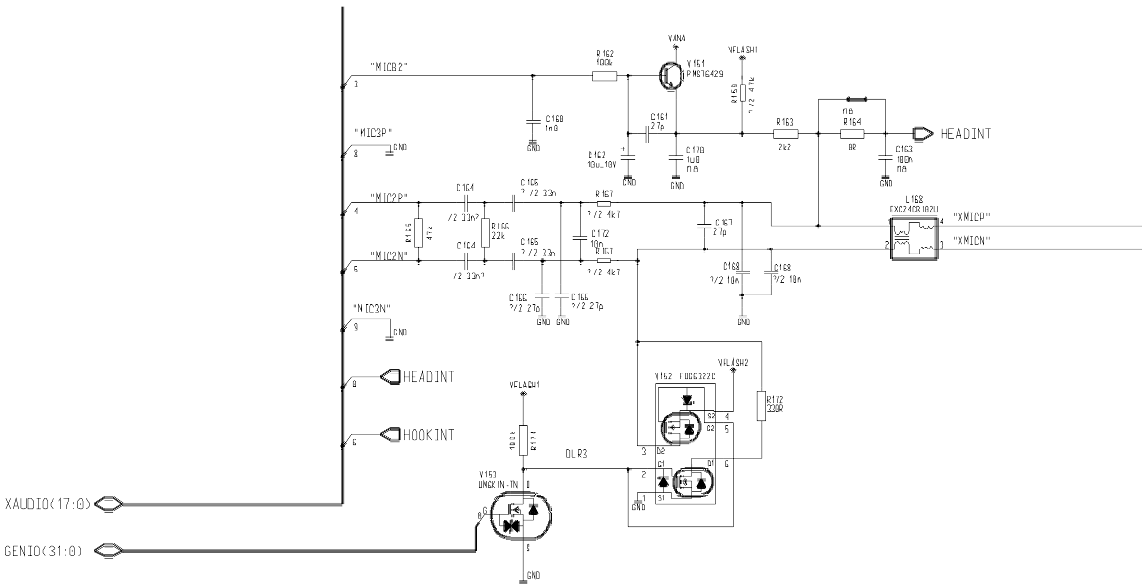

Figure 15. External Microphone Interface

See Table 13. Microphone input specifications, external audio for the input specifications for the external microphone.

The external audio interface microphone electrically circuit includes 2 ferrite beads for common mode rejection together with 2 capacitors for filtering the 900 MHz signal.

An extra Lowpass filter (R167 and C172) for a steeper role-off at higher frequencies and two high pass filters (C165 and R166, C164 and R165) are added to limit the audible TDMA-noise and to improve bumpy road noise suppression.

A transistor circuit on the bias line from UEM is used for a voltage supplier for minimising the noise level from the UEM bias output.

The Microphone bias is controlled in the 8 bit AudioBiasR register.

When DLR-3 cable is not connected there is a 330 Ohm pulldown resistor from SGND (XMICN) to L-GND (R172). When DLR-3 is connected Vflash2 voltage of 2.78 V is used as supply for the data cable on SGND line.

Connections for MIC3 are grounded near the UEM and not as shown in Figure 15. External Microphone Interface connected to MIC2 lines.

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Table 13: Microphone input specifications, external audio

Parameter	Symbol	Min	Typ	Max	Unit
Microphone amplifier gain for MIC 2 / Handsfree	MicG2	0		22,5	dB
Microphone amplifier gain for MIC 2 / Headset	MicG2	22.5		42,5	dB
Microphone amplifier input resistor	R_{MIC}	30	50		kOhm
Differential input voltage range for MIC2 input, G =20 dB	V_{IN2}		200		m V_{PP}
Differential input voltage range for MIC2 input, G =0 dB	V_{IN2}		2.0		V_{PP}
Receive Common mode input voltage range for MIC input	V_{INCMR}		100		m V_{PP}
Common mode voltage level	V_{CM}	1.3	1.35	1.4	V
Differential mode voltage range for microphone amplifier, gain 20 dB	V_{OUT}		2.0		m V_{PP}
Differential load resistance for the microphone input stage	R_{GS}	30		450	kOhm
Transmit gain absolute accuracy	GXA	-1.0		0.0	dB
Transmit gain variation with programmed gain, temperature and supply	GXAGTV	-0.7		0.7	dB
Common mode rejection ratio	CMRR	45	60		dB

From the UEM output a Boomer circuit is added to give enough output swing to the headset. The boomer is coupled as differential input single ended output. The differntial input is using HF / HFCM output from the UEM.

The Boomer is controled by UPP GENIO14. This control signal enables and disables the boomer wich have a internal circuit for uptimal and clickfree startup.

The boomer timing is mostly controled by C176. The nearly clickless operation has been made by timing in the MCU SW (A 12 msec delay between UEM and Bommer startup and a 1 sec delay between boomer and UEM shutdown has be made.)

The Gain of the circuit is controled by R176 / R 180 and R177 / R 178. Leading to a Boomer HW gain of approximately 3 dB.

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Filtering in the boomer circuit:

Highpass: -3dB point = 234 Hz

Lowpass: -3dB point = 3386 Hz

The 15 Ohm with a load of 150 Ohm reduce the output level with approximately 0.8 dB.

XEAR circuit includes 1 ferrite bead HF filter, 1 capacitor (900 MHz cut-off filter) and one 10 nF capacitor (C181) placed near the system connector for EMC purposes.

On the single ended output 15 Ohm (R183) is placed to compensate for the high capacitance of the 10 nF condensator, which could lead to instability in the Boomer.

The hookInt is pulled up by 47 kOhm and the detection is being polled by software on GENIO2 via the Inverter circuit. A 100k Ohm resistor is added to the Hookint line to avoid DC-clicks in the Uplink path.

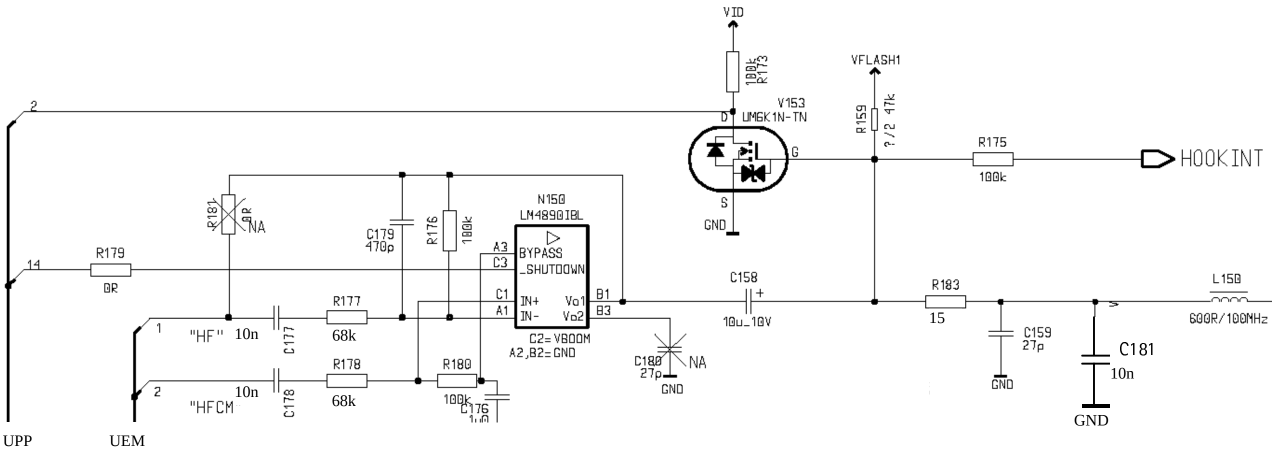

Figure 16. External Earpiece Interface

Table 14: UEM HF output specifications

Parameter	Test condition	Min	Typ	Max	Unit
Output voltage swing single ended mode	with 60 dB signal to total distortion ratio	1.0			V_{PP}
Output voltage swing fully differential mode	with 60 dB signal to total distortion ratio	2.0			V_{PP}
Output resistance (0 Hz to 4 kHz)	PDM Data with 50 % pulse ratio in the DAC input			1	Ohm
Parasitic load resistance	HF to HFCM (with external audio circuitry)			10	nF
Load resistance	HF to HFCM or VSA (with headset)	30		45	Ohm

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Table 14: UEM HF output specifications

Parameter	Test condition	Min	Typ	Max	Unit
Offset voltage		-50		50	mV
Common voltage level for HF output (HF and HFCM)	VCM_{HF}	0.75	0.8	0.85	V
Pull down resistor value in HF output	R_{PD}	3	10	25	kOhm
Pull down swhich resistance in HFCM output	R_{SW}			400	Ohm

HEADINT and **HOOKINT** are 'interrupts input' in UEM.

Headint is used to identify the type of accessory that is connected to the system connector. The interrupt is generated by pulldown resistors in the respective accessories.

Hookint is used for detecting the hook swhich of the headset.

HF is the audio output through which audio can be routed to either Headset-earpiece or Carkit earpiece. HF is wired as single ended output, which in reality performs the audio-amplification.

MIC2P, **MIC2N**, **MIC3P** and **MIC3N** are all inputs to the microphone amplifier in the UEM. In short form the main difference for the listed inputs are:

MIC2P, MIC2N: Rated to audio signals up to 2 Vpp (with gain 0 dB). Used for Headset and Carkit microphone.

MIC3P, MIC3N: Rated to audio signals up to 2 Vpp (with gain 0 dB). Used for FM Radio

Both types of inputs can be wired and used to either fully differential or singled-ended operation, however the fully differential configuration is chosen for the DCT3 interface.

External Audio Connector

The accessibility to the external audio interface is reached by the system connector.

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The configuration for the bottom connector is shown in the following figure.

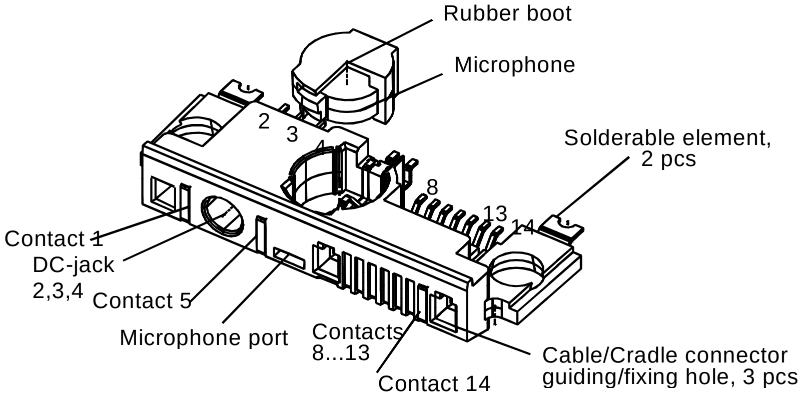

Figure 17. System connector – mechanical outline

External Audio Signal Electrical Specification

Table 15: System connector pin assignment

Pin	Name	Min	Typ	Max	Unit	Notes
1	VIN	0 0		8.5 850	V mA	Unloaded Fast Charger Supply current
		0		16.9 1.0	Vpeak Apeak	Unloaded Standard Charger Supply current
2	L-GND	0	0	0	V	Supply ground DC Jack
3	VIN	0 0		8.5 850	V mA	Unloaded Fast Charger DC Jack Supply current
4	CHRG_ CTRL	0 1.7		0.8 2.9	V	Charger control (PWM) *dig. Low* DC Jack Charger control (PWM) *dig. High*
		1	32	37	Hz	PWM frequency for a fast charger
		1		99	%	PWM duty cycle
5	CHRG_ CTRL	0 1.7		0.8 2.9	V	Charger control (PWM) *dig. Low* Bottom charger contacts Charger control (PWM) *dig. High*
		1	32	37	Hz	PWM frequency for a fast charger
		1		99	%	PWM duty cycle
6	MICP	0	2	100	mV	Connected to UEM MIC1P input. (re. SGND)
7	MICN	0	2	100	mV	Connected to UEM MIC1N input. (re. SGND)

Table 15: **System connector pin assignment**

Pin	Name	Min	Typ	Max	Unit	Notes
8	XMIC	2.0		2.2	kΩ	Input AC impedance
				1	Vpp	Maximum signal level
		0		1.55	V	Mute (output DC level)
		2.5		2.9	V	Unmute (output DC level)
		100		600	μA	Bias current from UEM
				2	Vpp	Microphone signal (Gain 0 dB) Connected to UEM MIC3P + MIC2P input
9	SGND		330		Ω	Resistance to phone ground, return path for XMIC. When the DLR-3 datacable is connected, SGND swhiches to be a supply line for the cable (2.8V)
10	XEAR		47		Ω	Output AC impedance (ref. LGND)
			10		μF	Series output capacitance
		16		300	Ω	Load AC impedance to GND (Headset) pin #14
		4.7	10		kΩ	Load AC impedance to GND (Accessory) pin #14
			1.0		Vpp	Maximum output level (no load)
			6.8		kΩ	Load DC resistance to GND (Accessory) pin #14
		16		1500	Ω	Load DC resistance to GND (Headset) pin #14
		2.78	2.8	2.86	V	DC voltage (47k pull-up to Vflash1)
	HEAR	0	14	220	mV	Earphone signal Connected to UEM HF output
11	MBUS	0 2.0		0.8 2.8	V	Serial bi-directional control bus. Baud rate 9600 Bit/s Phone has 4.7kΩ pull up resistor in UEM
12	FBUS_RX	0 2.0		0.8 2.8	V	Fbus receive. Serial Data Baud rate 9.6k-230.4kBit/s Phone has 220kΩ pull down resistor
13	FBUS_TX	0.1 1.7		0.8 2.8	V	Fbus transmit. Serial Data Baud rate 9.6k-230.4kBit/s Phone has 47kΩ pull up resistor in UEM
14	L-GND	0		0	V	Supply ground

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Accessory Detection, Identification and Control

Accessory Detection

Accessories are detected when the XMIC signal is loaded with either DLR3, Loopset or Headset. The interrupt is generated by pulldown resistors in the respective accessories.

Carkit 91 is detected via communication on the MBUS line.

BT accessories are connected after BT connectivity is chosen in UI. Communication with UEM is done over the CBUS lines.

Accessory Identification

The voltage on the XMICP is used to identify which type of accessories that are connected to the system connector. See Table 16: HEADINT Voltage Value Table used for Accessory Identification. The HEADINT interrupt is detected in the UEM and this voltage level is used to determine the type of accessory.

A voltage is measured on the HeadInt input on the UEM. This signal is multiplexed to an A/D converter in the UEM. From this level an Accessory server recognises the type of accessory and chooses the relevant audio accessory tuning if applicable. If the detection voltage window is as described in Table 16: HEADINT Voltage Value Table used for Accessory Identification for headset and loopset the microphone bias is enabled.

If DLR3 is used the detection voltages are as in Table 16: HEADINT Voltage Value Table used for Accessory Identification, no bias for the microphone is enabled and 2.8 V DC for DLR3 is supplied.

Table 16: HEADINT Voltage Value Table used for Accessory Identification

ACCESSORY CONNECTED	HEADINT VOLTAGE LEVEL		NOTES
	MIN	MAX	
Headset HDC-9P and Loopset LPS-1	19 mV	300 mV	Without MBias Varying with microphone FET working line.
Carkit CARK-91			Detected and acknowledged by the phone on MBUS
DLR3	300 mV	800 mV	

Accessory Control

Headset and Loopset

In the HDC-9P the headset-button is electrically connected across the XEAR and L-GND lines. When the Headset button is activated, XEARP is short-circuited to L-GND and a HOOKINT interrupt is detected in the UEM. This is used to lift the receiver, to put it down or initiate voice call.

HDW-1 is a Bluetooth Headset. The BT headset is recognised by the phone after a BT search for any BT component in the vicinity has been performed and a connection is set up via the BT module in both phone and accessory.

In case of BT audio the BT accessory and the phone is connected by both an ACL and SCO air link. ACL is used for connection commands and SCO for the actual audio transmission. In both cases the BT module (in accessory and phone) receives the audio signal. In the phone this signal is routed from BT module over LPRF to DSP where it follows the regular audio path through out the rest of the system. The BT module and MCU is connected by the CBUS for exchanging low level information.

Carkit

CARK-91

The carkit communicates with the phone through the system connector via the MBUS lines. No interrupts are detected on the HeadInt or HookInt. Headint is disabled so a voltage on the XMIC line is not able to initiate the interrupt. All communication is controlled in the HFU-2 unit. Voice dialling is only possible in CARK-91 via phone "name" softkey.

The HFU-2 sends an MBUS registration messages to the phone when the HFU-2 is powered up. This message includes an identification number for the HFU-2 box. The phone will send an acknowledge message and communication are set-up.

The HFU-2 box includes power amplifier for Earpiece (nom. gain 26 dB) and preamplifier for Microphone (nom. gain 30 dB).

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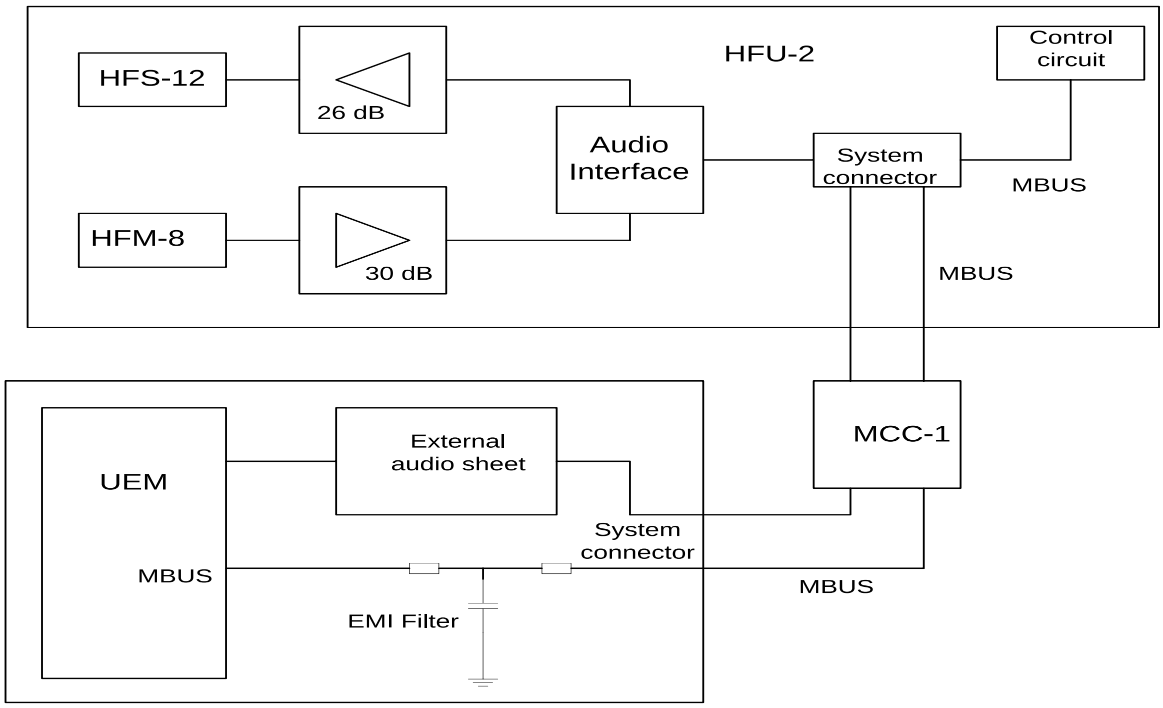

Figure 18. Carkit audio interface. Block diagram.

CARK-64

This carkit is a passive kit and is just a holder for the phone. No detection is done anywhere.

CARK-112

This is a Bluetooth carkit. The BT Carkit is recognised by the phone after a BT search for any BT component in the vicinity has been performed and a connection is set up via the BT module in both phone and accessory.

In case of BT audio the BT accessory and the phone is connected by both an ACL and SCO air link. ACL is used for connection commands and SCO for the actual audio transmission. In both cases the BT module (in accessory and phone) receives the audio signal. In the phone this signal is routed from BT module over LPRF to DSP where it follows the regular audio path through out the rest of the system. The BT module and MCU is connected by the CBUS for exchanging low level information.

Voice dialling is only possible in CARK-112 via phone "name" softkey.

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