Neo900 v2 Prototype

Jörg Reisenweber[*], Werner Almesberger[†]

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The Neo900 v2 prototype is the forthcoming first major implementation of large portions of the Neo900 design. The prototype is intended to:

- confirm mechanical compatibility with the N900 design,
- validate design and implementation of the various circuits and connectors, mainly on LOWER, and
- test software compatibility with the Neo900 architecture.

In v2, we reduce the complexity of UPPER by deferring integration of the OMAP (the principal CPU or SoC) and related components to a later prototype, and use a BeagleBoard-xM ("BB-xM" [1]) as "brain" for v2. This complexity reduction serves the following purposes:

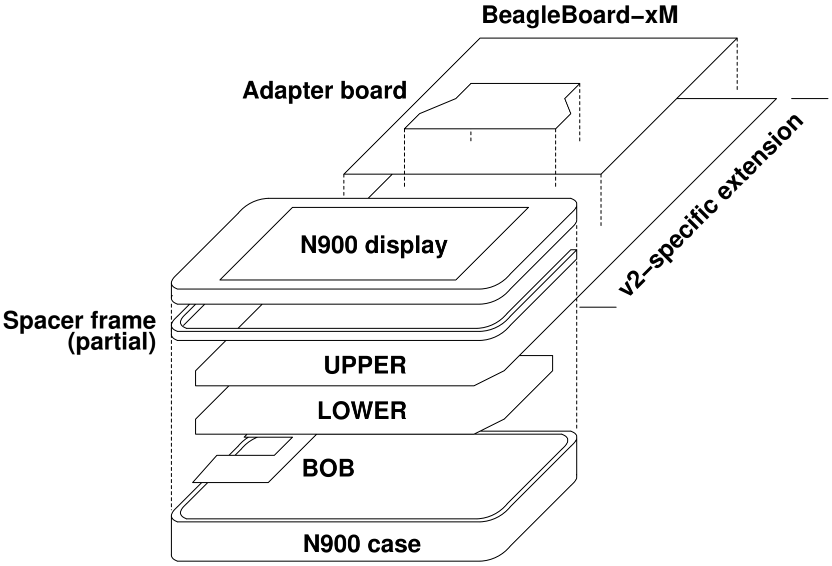
- limit the risk of design flaws in UPPER that may prevent the prototype from operating and would delay testing of LOWER,
- reduce the layout effort for v2, and
- lower the cost of producing v2.

[*] Design requirements.

[†] Specification details and illustrations.

1 Overall system structure

The following drawing illustrates the structure of the various parts of the Neo900 v2 prototype. Note that this is greatly simplified and abstracted, and a number of items (e.g., camera, battery) are not shown.



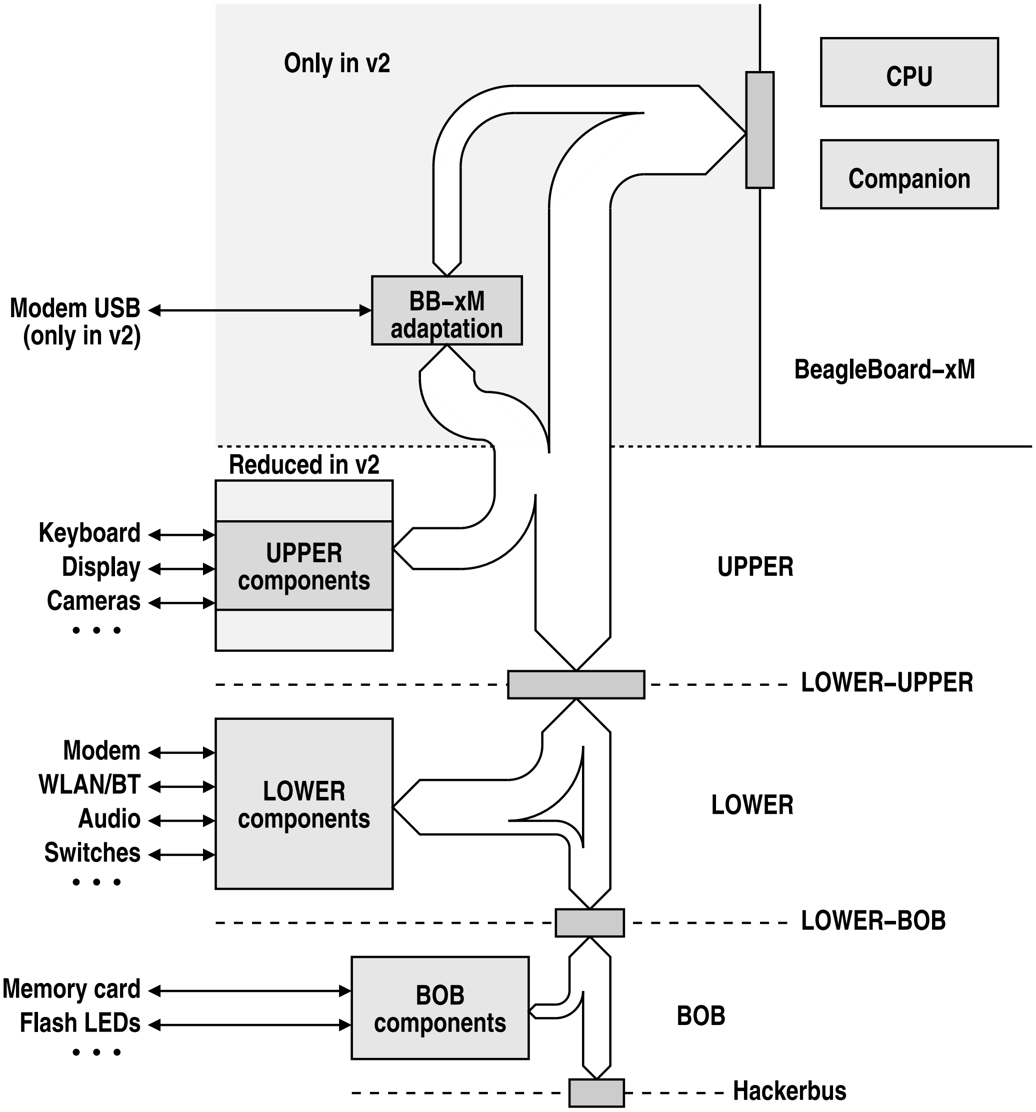
There are three principal boards of v2 proper: the LOWER board contains most of the peripherals, including modem, WLAN/BT, and audio. LOWER interfaces mechanically with the N900 case. The UPPER board has the keyboard, the display connector, the camera interfaces, and some sensors. Memory card, the flash LEDs, and a few sensors are on BOB (the Break-Out Board). BOB also features the Hackerbus interface [2] that connects to user-provided external circuits.

In the final version of Neo900, UPPER will also contain the CPU, the companion chip that provides voltage regulators and various other peripheral functions, and the memories. In v2, all this resides on a BeagleBoard-xM that attaches to UPPER.

In v2, UPPER extends far beyond the rear of the N900 case, where it connects to the bottom side of BB-xM. An additional adapter board (see section 3.2) makes a connection between UPPER and the camera connector on the top side of BB-xM.

A more detailed top view can be found in section 3. The vertical stacking is explained in section 3.3.

This drawing shows the flow of electrical signals between the boards:



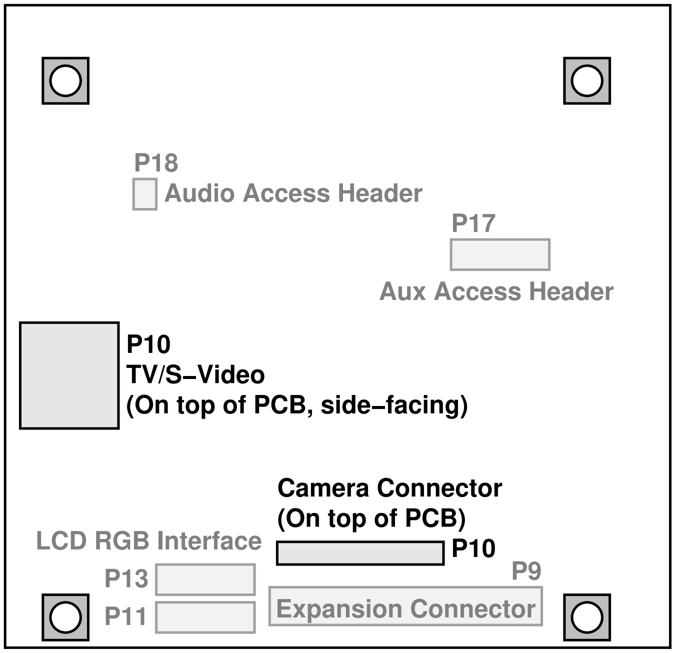
Since BB-xM does not provide all the functionality we need, UPPER of v2 also contains circuits for adapting and extending what BB-xM provides. These adaptations are discussed in more detail in section 4.

2 BB-xM connections

The v2 prototype of Neo900 connects to BB-xM through various 2.54 mm and 1.27 mm headers. Most of these headers are located at the bottom of BB-xM.

2.1 Connector locations

The following illustration shows where on BB-xM the connectors we use are located, when looking at the board from the top:



Except for the S-Video connector P4 and the camera connector P10, all are on the bottom of BB-xM. P4 is a side-facing mini-DIN connector from which we can feed the analog TV output signal to Neo900 v2.

The exact placement of the headers can be found in section 5, the numbers of pins and pitch (between rows and columns) are as follows:

Reference	Pins	Pitch	Name
P9	28	2.54 mm	Expansion Connector
P10	34	1.27 mm	Camera Connector
P17	20	1.27 mm	Aux Access Header
P18	4	1.27 mm	Audio Access Header
P11, P13	20	1.27 mm	LCD RGB Interface

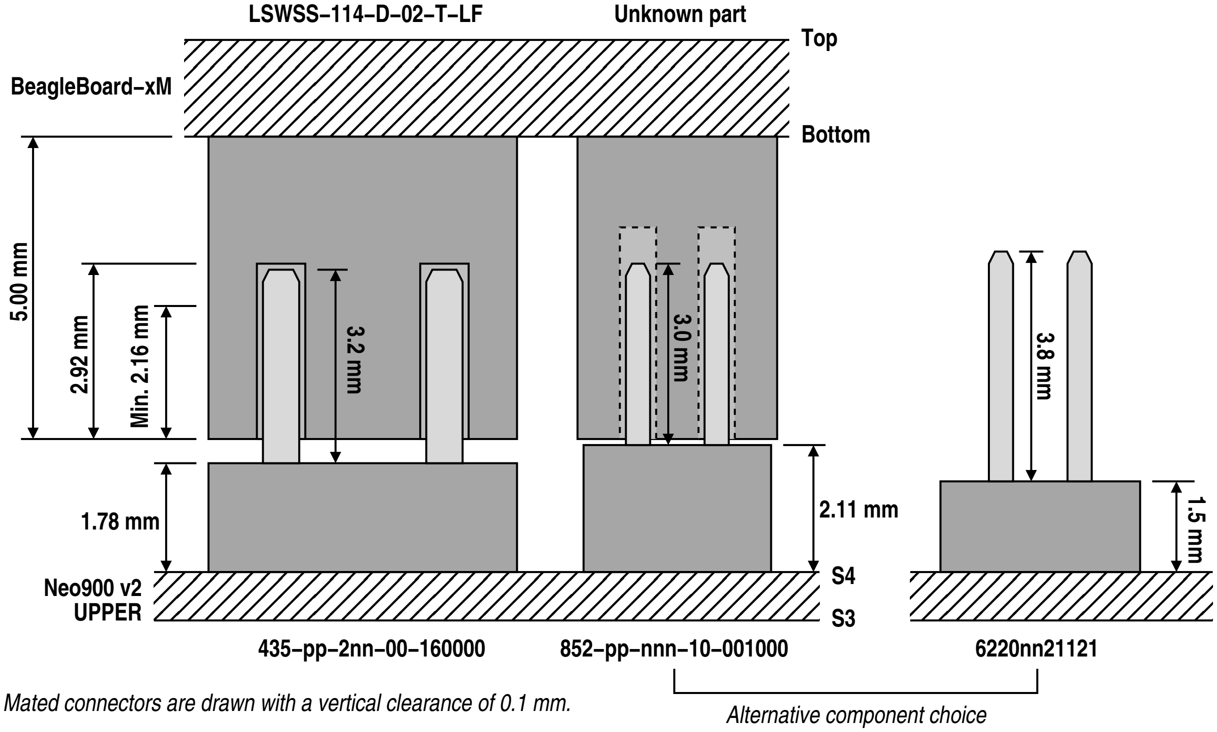
2.2 Component selection

The BB-xM documentation provides part numbers only for the following two connectors:

Reference[1]	Part number
P9	LSWSS-114-D-02-T-LF[2]
P10	F618-MG -D051-XX-CF358[3]

The Aux Access Header, the two LCD headers, and the Audio Access Header are just specified as "HDR *n*X2_1.27mm". All these connectors are female, and we assume that they have an insertion depth of at least 3 mm, like to similar parts we examined for [2].

Since all the connectors on the bottom side of BB-xM connect to UPPER, their mated height has to match. The following illustration shows the Expansion Connector and the 1.27 mm connectors:



We select the following parts to mate with the BB-xM connectors:

[1] In the BB-xM revision C schematics from `http://beagleboard.org/static/BB-xM_REV_C-2011-05-23.zip`

[2] Data sheet: `https://s3.amazonaws.com/mle-assets/parts/LSWSS-1/LSWSS-1-D+REV+D.pdf`

[3] The original data sheet does not seem to be available from the manufacturer, but this copy can still be found: `http://markmail.org/download.xqy?id=l7gxdc4kfmshw7dy&number=1`
A similar (without positioning posts) and still active part from the same manufacturer is specified here: `http://php2.twinner.com.tw/files/cherngweei/P605-SGN-030_023-XX.pdf`

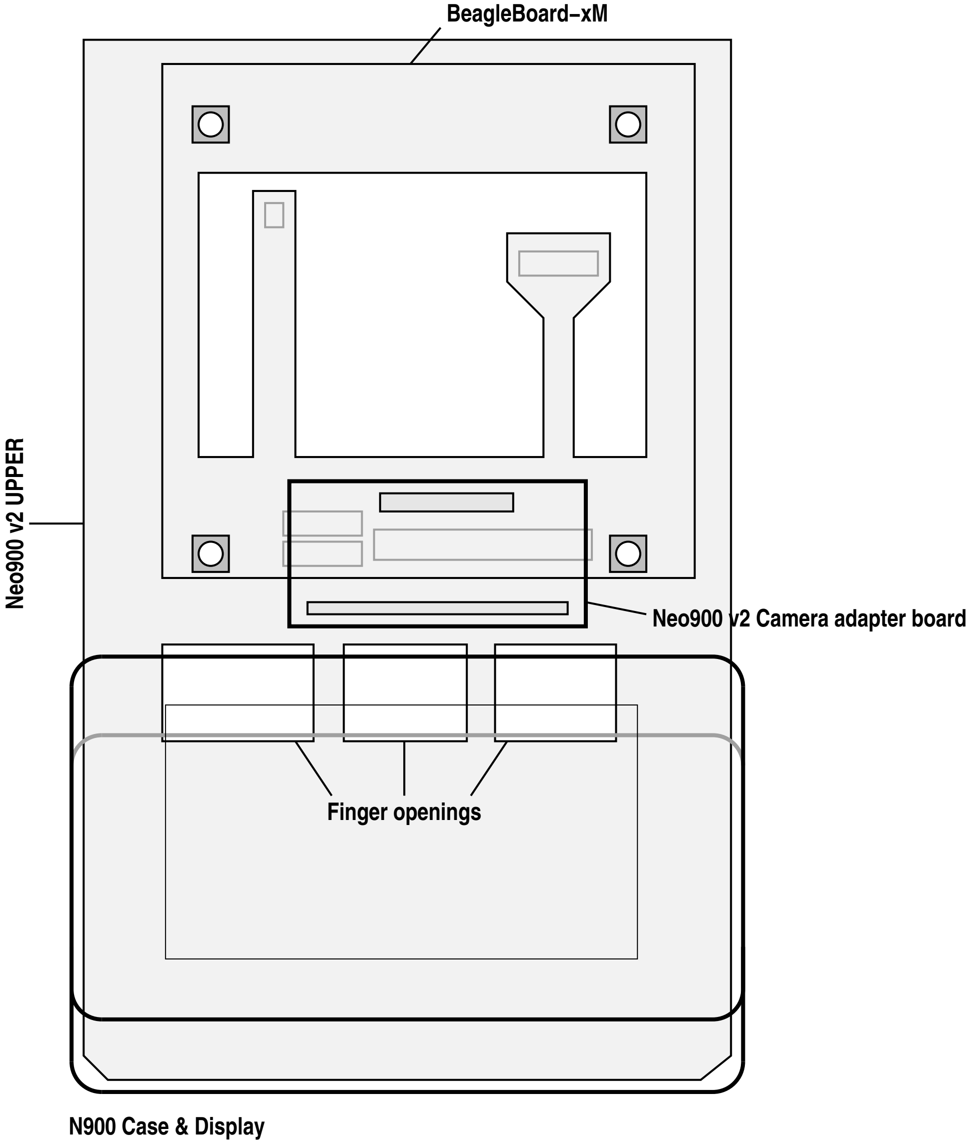
Reference	Manufacturer	Part number	Positions
P9	Mill-Max	435-40-228-00-160000	28
		435-40-272-00-160000	72
P10	Preci-Dip	852-80-034-10-001101	34
	Mill-Max	852-10-100-10-001000	100
P11, P13, P17	Mill-Max	852-10-020-10-001000	20
		852-10-100-10-001000	100
P18	Würth	62200421121	4
	Mill-Max	852-10-100-10-001000	100

All these connectors are “breakaway” headers, and in some cases only strips with a large number of contacts (e.g., 100) are manufactured and are then cut (be it by the manufacturer, the distributor, the board assembler, etc.) to the number of pins the respective application needs. The above table shows both the customized part and – in case the customized part should turn out to be difficult to source and we need to take care of customization ourselves – the larger off-the-shelf header.

Further information about connector characteristics can be found in [3].

3 Board placements

The UPPER board of the v2 prototype of Neo900 extends beyond the N900 case and overlaps with the bottom side of BB-xM. The following drawing (top view) shows the approximate placement of BB-xM, N900 and display, the extended UPPER board, and the adapter board for the camera connector:



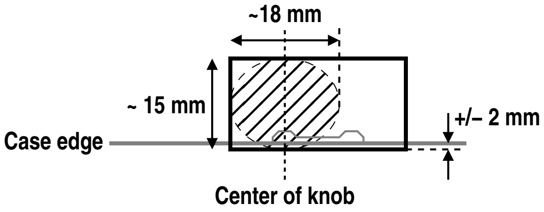
The parts of UPPER that reach remote connectors are deliberately made of narrow PCB strips. These strips allow the PCB to flex a little and thus adapt to mechanical tolerances.

In the above drawing, the dimensions and the shape of UPPER are only indicative, and the board outline chosen by layout may differ.

3.1 Finger openings

UPPER has openings at the rear end of the N900 case that allow the operator to access the buttons located there. The openings should allow for the insertion of fingers of at least 15×18 mm, with the fingers placed on the center of the button or, in the case of the volume button, on the two small protruding knobs.

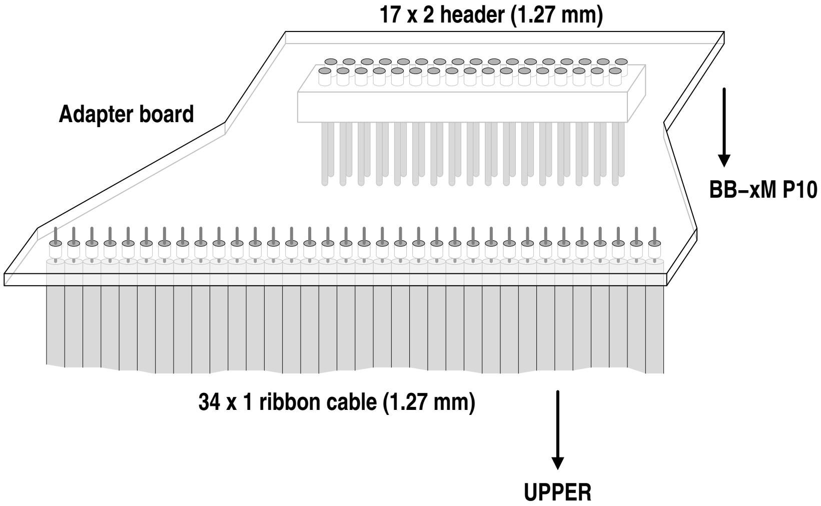
The drawing below illustrates the general idea:



The exact location and width of the finger holes should be determined from the placement of the respective switches on the PCB, which is outside the scope of this document.

3.2 Camera adapter board

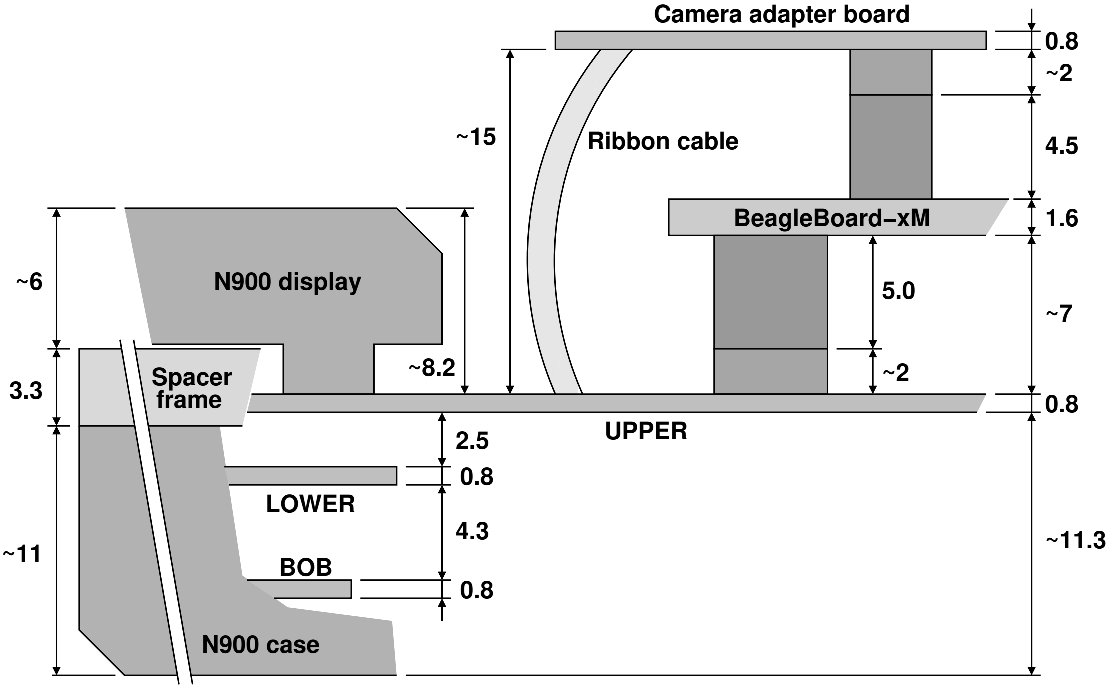
Since the camera connector (P10) is placed on top of BB-xM, we cannot plug into it directly from UPPER. Instead, we use a small adapter board that is attached to UPPER with a 50 mil (1.27 mm) ribbon cable.



The exact size and shape of the board is to be determined by layout. Note that some signals on the P10 are not used by v2 or are redundant, so the ribbon cable could have less than 34 conductors.

3.3 Vertical stacking

The following drawing shows the vertical stacking of the v2 system, including the Neo900 boards, N900 parts, and BeagleBoard-xM:



Dimensions are in mm. The drawing is only approximate and some artistic liberties have been taken especially in the horizontal direction. Further details on the stacking of items in Neo900 can be found in [4].

4 Differences to Neo900

Some signals of the OMAP processor and the companion chip are not available on any connector of BB-xM or are used in different ways than in Neo900. We therefore have to replace or modify some functions, assign them to different pins, or just omit them. The following sections detail the principal differences.

GPIO assignments are normally not specified in this document. They can be found in the schematics[4] and in our BB-xM pin assignment table:
`https://neo900.org/git/misc/tree/pinmux/bb-xm.assign`

4.1 Functions performed by BB-xM

BB-xM provides the CPU (OMAP), its companion chips, and the system memories required for the system to run. All these chips are tightly interconnected (with over 100 signals) and "outsourcing" them to BB-xM greatly reduces the complexity of the UPPER board of the Neo900 v2 prototype.

By using the same CPU as in Neo900 and disturbing N900 compatibility of the Neo900 design as little as possible, v2 can still be able to run certain non-open code written for N900, should the need for doing so arise.

The key functions provided by BB-xM are:

- Running the Linux environment, test code, and selected other code,
- some voltage regulators (see section 4.3), provided by the companion chip,
- various digital protocols (UART, I^{2}C, I^{2}S, SPI, ...), implemented by function blocks in the CPU,
- an ADC input, and
- last but not least, GPIOs.

The other peripherals on BB-xM are only used for access and operation of BB-xM itself.

4.2 Memories

The v2 prototype relies on BB-xM to provide most of the memories. The following table compares the memories available in N900, BB-xM (Neo900 v2), and the Neo900 design beyond v2:

Memory	N900	BB-xM / Neo900 v2	Neo900 > v2
RAM	256 MB	512 MB	1 GB
NAND	256 MB	—	512 MB
eMMC	32 GB	—	To be defined
Memory card	MMC#1	I^{2}C	MMC#1

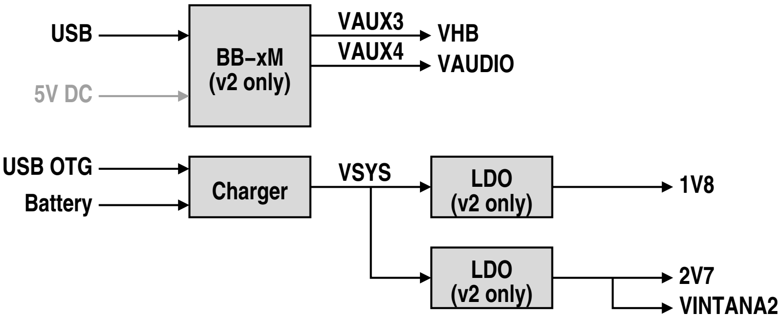
[4] `https://neo900.org/stuff/werner/tmp/ee/pdf/neo900.pdf`

BB-xM has a memory card interface that is occupied by a card containing the boot and system files. The memory card connector of Neo900 is also accessible in the v2 prototype, but only through an I^2C-attached IO expander.

4.3 Power supplies

In v2, we use a mixed supply architecture where part of the system is supplied from BB-xM (i.e., USB) and the rest from the charger circuit of Neo900 (i.e., USB or battery). Furthermore, v2 has regulators for power rails that will be supplied by the companion chip in later versions, but where the corresponding rail is not suitable (or unavailable) on BB-xM.

Power rails that are implemented differently in v2 and the post-v2 design are shown in the drawing below:



A 5 V DC adapter (regulated) can be used instead of USB to provide BB-xM with power. While we do not expect to need this, we show it as a possible choice.

The remaining rails (VBUS, BATT, VBAT_RAW, VBUS_OTG, VMODEMx, VGNSS, VBAT_SWITCHED, and VSIM_x) are the same as in the post-v2 design. Their structure is shown in the power tree [5].

4.4 IO expander

The number of GPIOs available on the BB-xM connectors is slightly too low for Neo900 v2. We therefore add an IO expander to provide additional GPIOs. The role of IO expanders in Neo900 is discussed in detail in [6].

Note that the IO expander (XRA1201P) enables pull-ups on all GPIOs on reset, which may differ from reset behaviour of the corresponding pin on OMAP.

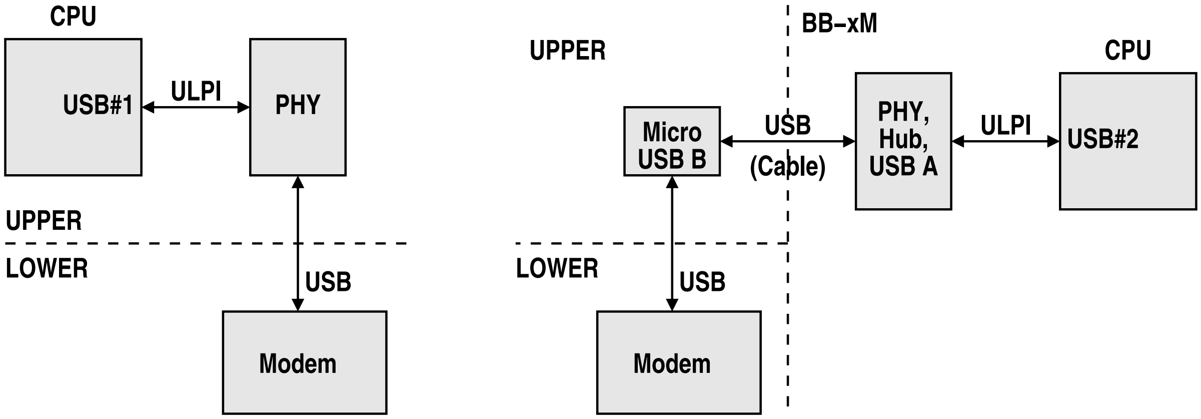
4.5 Keyboard controller

The companion chip contains a 8 × 8 keyboard matrix controller, which we plan to use in Neo900. Since access to the companion chip (in BB-xM) is very limited in the v2 prototype, the prototype uses a dedicated I^2C-attached controller chip (TCA8418[5]) instead.

[5] http://www.ti.com/lit/ds/symlink/tca8418.pdf

4.6 Modem USB

The modem module communicates with the CPU through the USB#1 host interface and UART#1. The USB#1 setup in Neo900 is shown on the left-hand side of the following drawing:



Since there is no CPU and therefore no ULPI bus on v2, we instead add a Micro USB B connector that can be connected to any regular USB port – e.g., one of the USB ports of BB-xM, as shown on the right-hand side of the above drawing.

4.7 Hackerbus USB

Neo900 provides a dedicated USB host interface on the Hackerbus. This interface consists of a PHY connected to the USB#2 ULPI bus of the CPU, similar to modem USB.

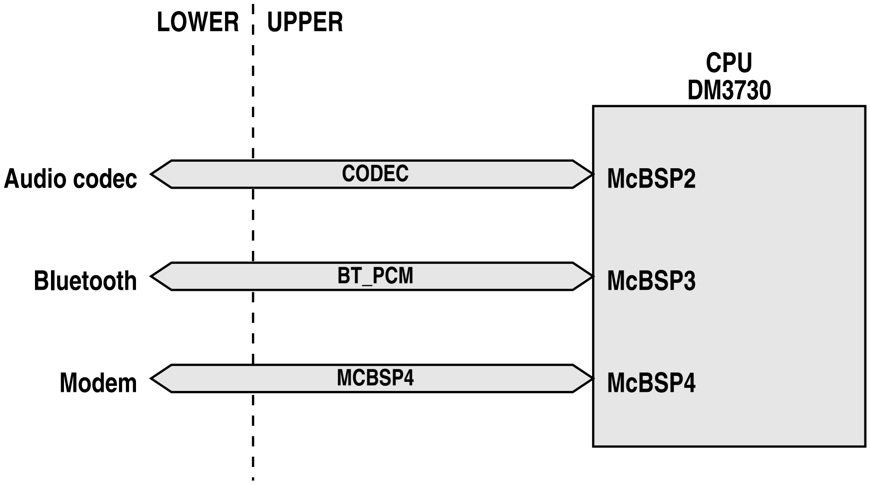
Since we have no ULPI on v2, and the Hackerbus USB interface has no other function in Neo900 than being available on Hackerbus, we omit this functionality in v2.

4.7.1 PCM routing

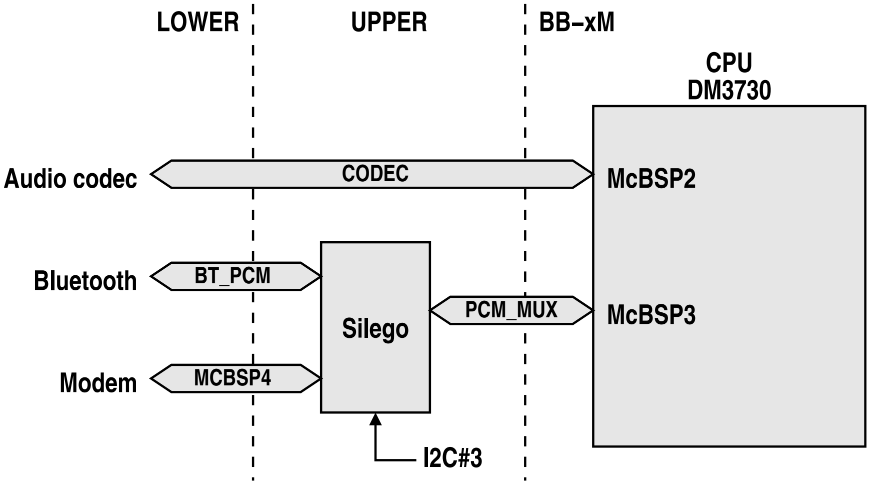
Neo900 has the following bidirectional digital audio busses:

Bus	Type	Port
Audio codec	I^2S	McBSP2
Bluetooth	PCM	McBSP3
Modem	PCM	McBSP4

Each audio bus is served by a serial port ("Multichannel Buffered Serial Port", McBSP) in the CPU:



BB-xM only gives access to two of these ports. We therefore share McBSP3 between Bluetooth and modem, and insert a Silego mixed-signal matrix to act as programmable multiplexer:



The Silego chip is configured through I^{2}C.

4.8 Audio master clock

N900 uses the HFCLKOUT output (19.2 MHz) of the companion chip as master clock for the audio codec (CODEC_MCLK). BB-xM uses a 26 MHz crystal instead of 19.2 MHz, and HFCLKOUT is not available on any connector.

While the very flexible PLL in the audio codec should make it possible to produce a suitable clock also from a different source, we add a dedicated crystal oscillator for maximum compatibility.

The oscillator is controlled with an enable signal (HFCLK_EN) from the v2 IO expander. This signal also drives a LED, and can thus be used to test basic operation of the I^{2}C #3 bus.

4.9 32.768 Hz clock

The 32.768 kHz clock generated by the companion chip is not available on any connector of the BB-xM. We use a dedicated crystal oscillator for it in v2.

4.10 Camera strobe

The camera strobe signal (cam_strobe, ball D25, controlled by the Camera Image Signal Processor function block in the CPU) is used in Neo900 to trigger the camera flash. BB-xM does not make this signal available on any connector.

In order to be able to test the flash function, even if without proper synchronization with camera capture, we use a GPIO instead.

4.11 TV output

The analog TV output signal (cvideo1_out, ball Y28, connected to the DAC of the Display Subsystem in the CPU) is only available on the S-Video connector (P4) of BB-xM.

In order to test the signal routing in v2, we connect TVOUT_U to a footprint for a 100 mil 2-pin through-hole header on UPPER. An adapter cable can then connect this to the analog video output of BB-xM.

4.12 Vibration motor

The outputs of the vibration motor driver in the companion chip (VIBRAP F16 and VIBRAM G15) are not available on any connector of BB-xM. We therefore do not support use of the vibration motor in v2.

4.13 UART flow control signals

Neo900 uses the following UARTs, each consisting of the data lines TX and RX, and the flow control lines CTS and RTS:

Destination	Name prefix	Port
Modem	UART1	UART#1
Bluetooth	BT_UART	UART#2
IR, Hackerbus	UART3	UART#3

The data lines of all three UARTs are available on BB-xM connectors. However, CTS and RTS are only available for UART#2. We therefore provide the missing CTS and RTS signals on GPIOs in v2.

4.14 MMC/SD interface

The memory card of Neo900 is connected to the MMC#1 bus. BB-xM connects this bus to the "uSD connector" (a card holder) on BB-xM and does not make it available on any other connector. This interface is typically occupied for operation of the BB-xM.

In order to be able to test connectivity, the signals of the Neo900 memory card holder are connected in v2 to an IO expander.

4.15 Hackerbus GPIOs

Since the number of signals available on the BB-xM connectors is limited, the CPU-side signals (HB_A to HB_D) of the four Hackerbus GPIOs are connected to the v2 IO expander. While this limits the use of these GPIOs, it still allows testing of overall connectivity.

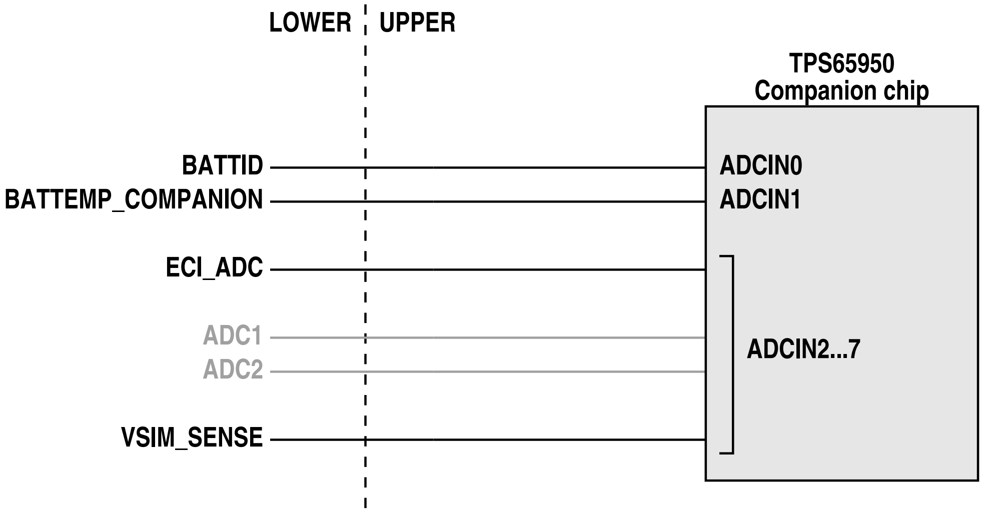
4.16 ADC multiplexing

The following signals pass from LOWER to the ADC in the companion chip:

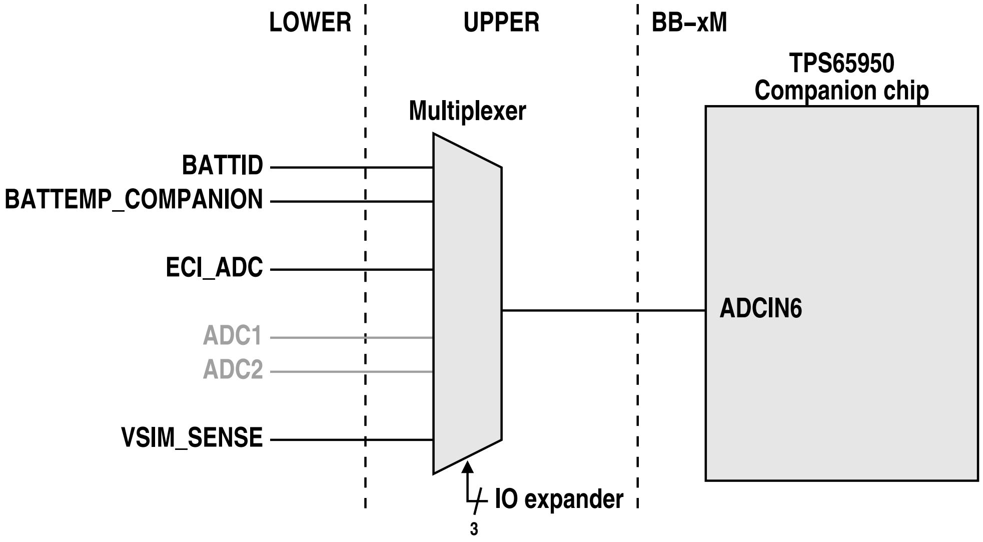
Signal	Origin
ADC_1	Inbound cellular antenna power detector
ADC_2	Outbound cellular antenna power detector
BATTID	Battery multipurpose contact
BATTEMP_COMPANION	Battery temperature sensor
ECI_ADC	ECI signal
VSIM_SENSE	SIM current sensor

ADC_1 and ADC_2 are "nice to have" but can be omitted if the number of contacts on the LOWER-UPPER connection should turn out to be insufficient.

BATTID should connect to ADCIN0, BATTEMP_COMPANION to ADCIN1, which are both designed for the respective function. ECI_ADC should follow the N900 design and connect to ADCIN2 (ball G3). The other signals connect to any of the general-purpose inputs ADCIN2 to ADCIN7.



BB-xM only provides a single ADC input, ADCIN6 on the Auxiliary Expansion Header. While this limits the use of at least some of the signals, we can still monitor them for correct levels. To that end, v2 uses an analog multiplexer to select which of the available analog signals gets sent to the BB-xM:



The analog multiplexer is configured through three control signals from the v2-specific IO expander (see section 4.4).

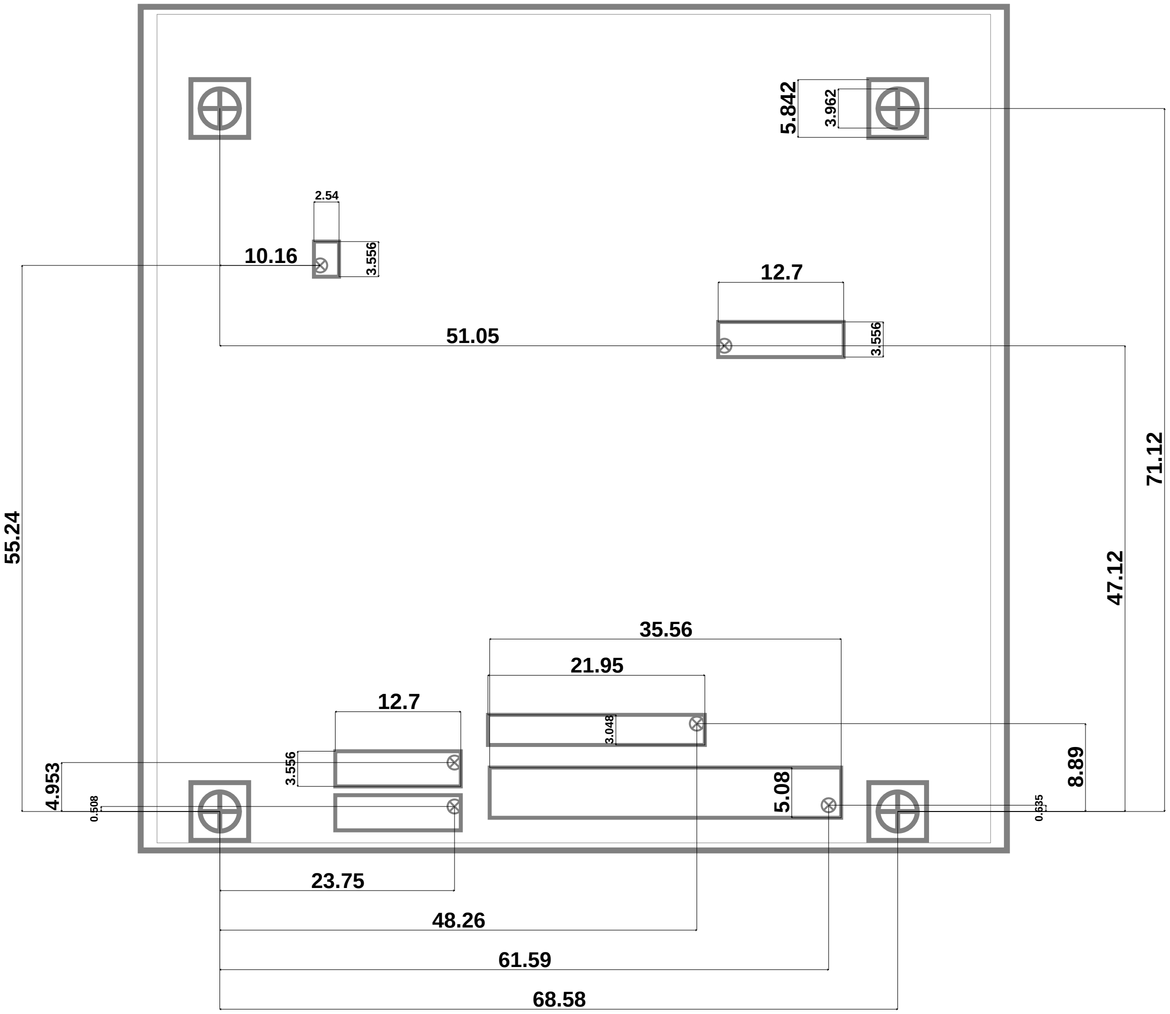
4.17 Speaker amplifier enable

Neo900 uses signal SPEAKER_EN to enable the speaker amplifier. This corresponds to IHF_EN in N900. IHF_EN is connected to GPIO7 (ball N14) of the companion chip.

BB-xM does not connect ball N14. We therefore connect SPEAKER_EN in v2 to the v2-specific IO expander (see section 4.4).

5 BB-xM geometry

The following diagram shows the location of pin 1 of each connector on BB-xM, relative to the center of the lower left mounting hole. Furthermore, the size of the connector outlines (on silk screen) is shown. Distances are in mm.[6]



The board is shown from above. The position of the board edges relative to the mounting holes is only an approximation.

[6] To show sizes in mil, like in the original BB-xM design, load `https://neo900.org/git/misc/tree/v2/bbxm.fpd` with fped and change the unit by clicking on the box in the lower right corner.

6 References

[1] beagleboard.org *BeagleBoard-xM Rev C System Reference Manual*, Revision 1.0, April 2010. `http://beagleboard.org/static/BBxMSRM_latest.pdf`

[2] Reisenweber, Jörg; Almesberger, Werner. *Neo900 Hackerbus*, November 2016. `http://neo900.org/stuff/papers/hb.pdf`

[3] Almesberger, Werner. *Header Part Selection Overview*, December 2016. `http://neo900.org/stuff/papers/hdr.pdf`

[4] Neo900 project. *Neo900 Stacking and Measurements*, Work in progress 2016-10-26. `https://neo900.org/stuff/werner/stacking/`

[5] Neo900 project. *Neo900 Power Tree*, Work in progress 2016-10-27. `https://neo900.org/stuff/werner/power-tree/`

[6] Reisenweber, Jörg; Almesberger, Werner. *Neo900 IO Expanders*, June 2016. `http://neo900.org/stuff/papers/iox.pdf`