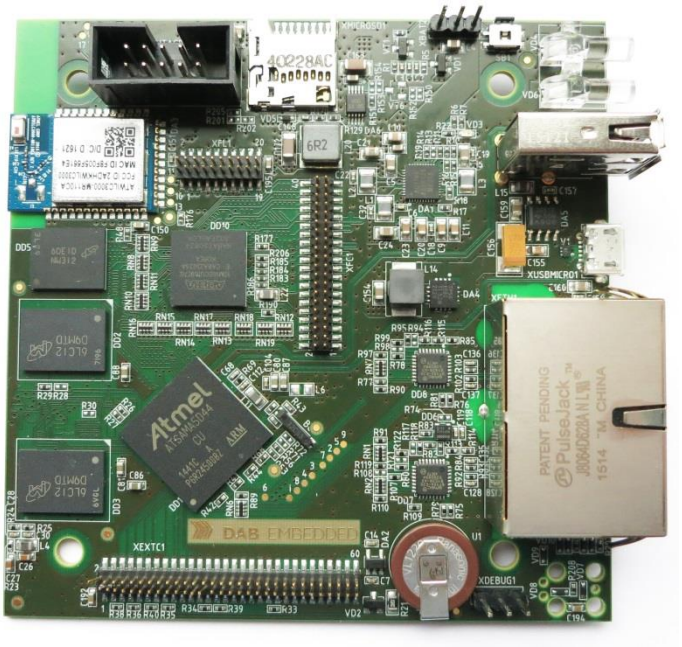
DAB-EMBEDDED



IoT Solution: Smart Router

powered by OpenWRT (Linux-based)

DAB-EMBEDDED

Web: http://www.dab-embedded.com
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Aartselaar, Belgium

1. Overview

Highlights

- **Dual LAN**
- **WiFi IEEE® 802.11 b/g/n, BLE 4.0**
- **USB Host, Device**
- **FPGA Altera MAX10**
- **Ultra low power consumption**

Overview

DAB-OWRT-SAM5D4 Smart Router was designed by DAB-Embedded BVBA for collecting and processing data from different wired and wireless interfaces. This router has ability to interconnect a lot of general and specific wireless interfaces like WiFi, ZigBee, Z-Wave and more, with wired interfaces like Ethernet, USB, CAN 2.0A/B, RS232, KNX and more. All data from such interfaces can be processed or stored in microSD card or in NAND Flash.

Heart of the DAB-OWRT-SAM5D4 Smart Router is Atmel SAMA5D44 processor with 600MHz ARM Cortex-A5 core (with Floating-Point Unit and NEON instruction set support). Well known processor gives an unlimited opportunity to customize free OpenWRT Linux firmware for achieving any client request.

Key features

- CPU: Atmel SAMA5D44 (ARM Cortex-A5, 600MHz, FPU, NEON)
- FPGA: Altera MAX 10 FPGA with integrated ADC
- Memory: Up to 512MB DDR2, Up to 2GB NAND Flash
- External storage: MicroSD card slot
- 2x 100Mbit/s LAN ports
- USB 2.0 HS Host
- USB 2.0 HS Device
- WiFi IEEE® 802.11 b/g/n (Wi-Fi Direct, station mode and Soft-AP support)
- Bluetooth low energy 4.0
- Power supply: (External +5V AC/DC power supply, External Li+ battery)
- Expansion connector for:
    - Wired interfaces: RS232, CAN 2.0 A/B, KNX, RS-485/422 and more
    - Wireless: ZigBee, Z-Wave, KNX RF, LoRa, LTE, and more

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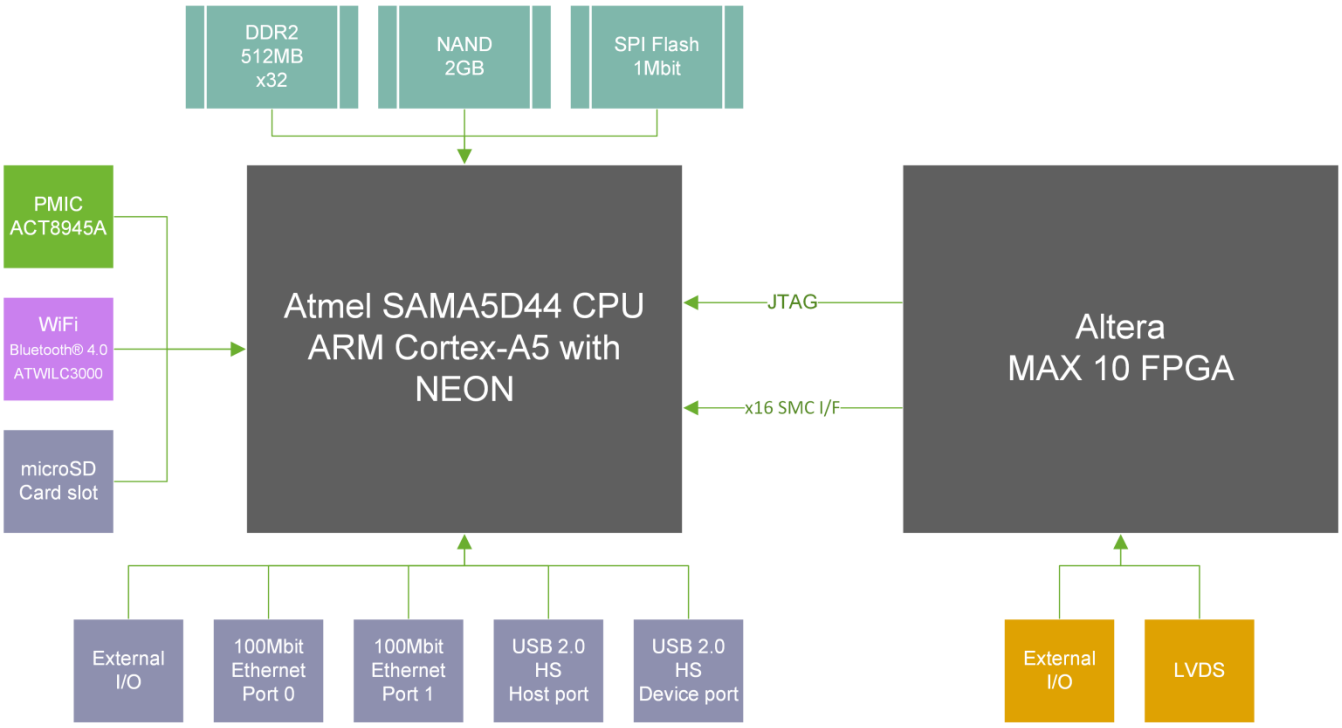
2. Block diagram



- ✓ External I/O (SAMA5D44):
  - / LCD (24-bit)
  - / UART/USART
  - / SPI
  - / I2C
  - / ADC/Analog touch
  - / SSP/Audio
  - / ISI/Camera
  - / Timers/PWM
  - / USB Host
- ✓ External I/O (FPGA MAX10):
  - / LVDS I/O (diff pair)
  - / FPGA I/O
  - / ADC inputs
- ✓ External Li+ battery (+3.7V) support
- ✓ External +5V DC power supply
- ✓ Board dimensions: 90x90 mm

- ✓ Software:
  - / Yocto Linux Embedded
  - / Windows Embedded Compact
  - / Baremetal application support
  - / FPGA firmware

3. Connectors

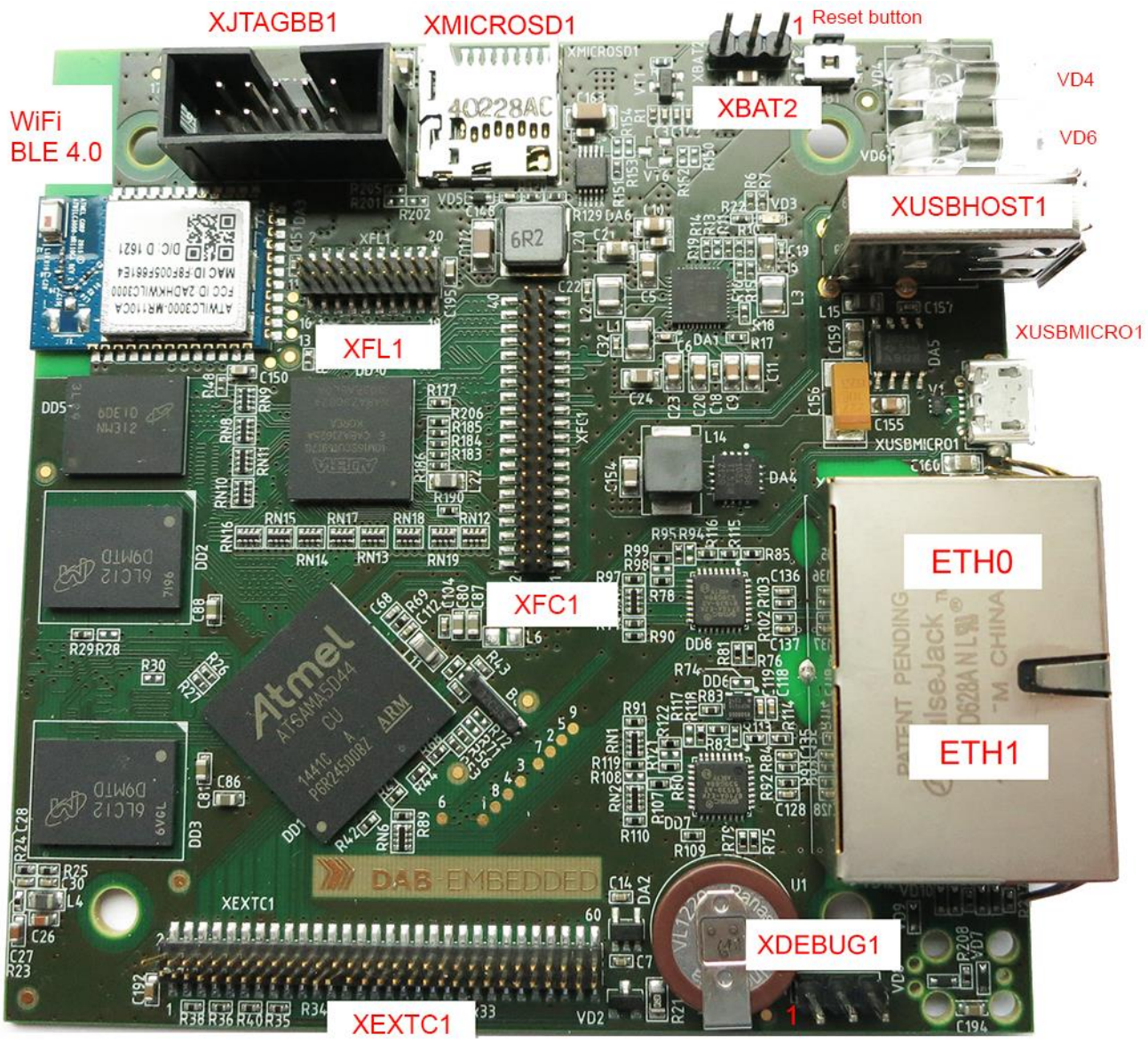


Figure 1: Top view

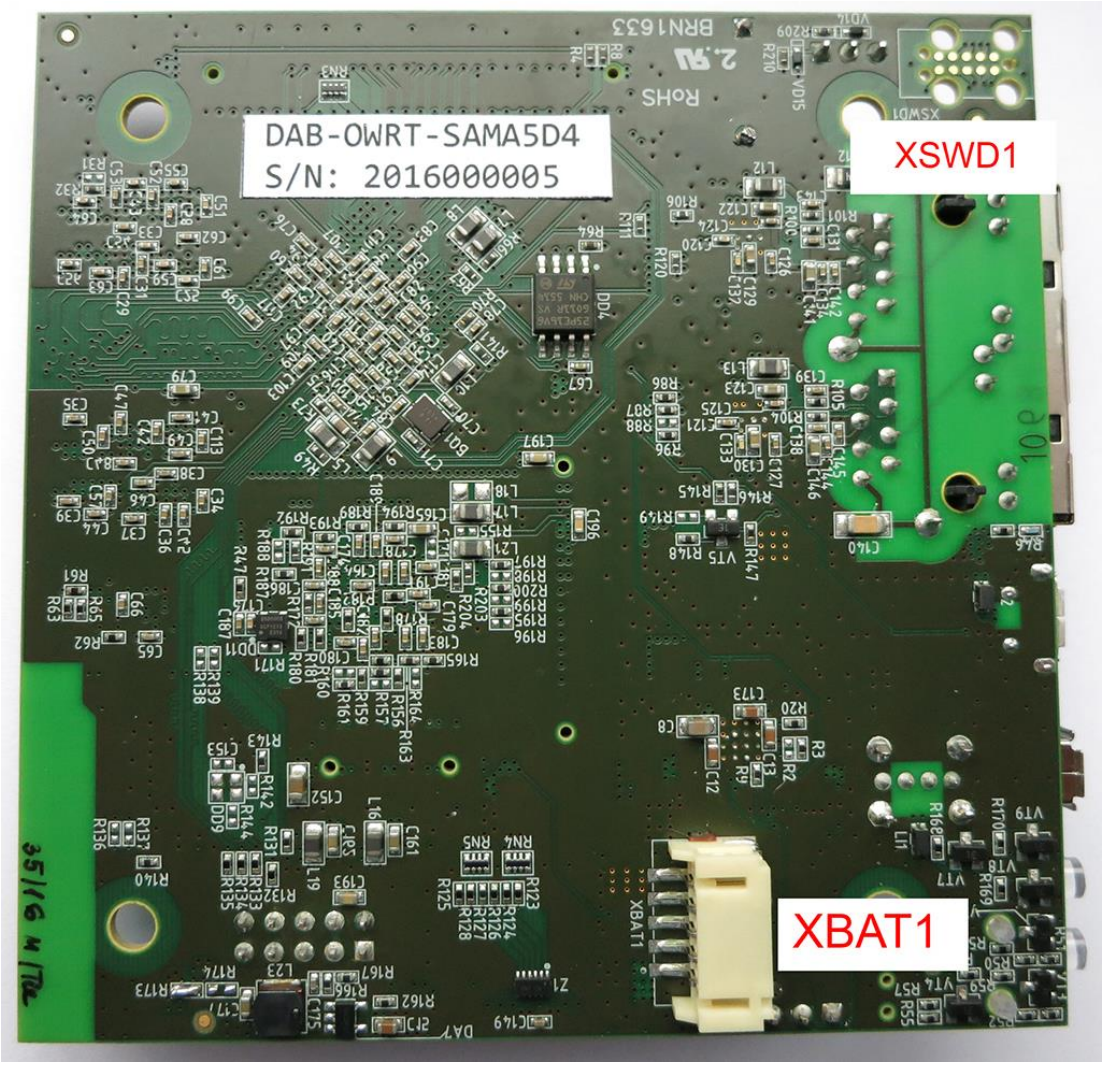


Figure 2: Bottom view

Table 1: XBAT1 connector

Pin No	Name	Function
1	EXT_BAT_VCC	Li-Ion/Pol+ positive input (3.3V…4.3V)
2	EXT_BAT_TC	Li-Ion/Pol temperature sensor input
3	GND	Ground

Table 2: XBAT2 connector

Pin No	Name	Function
1	EXT_BAT_VCC	Li-Ion/Pol+ positive input (3.3V…4.3V)
2	EXT_BAT_VCC	Li-Ion/Pol+ positive input (3.3V…4.3V)
3	EXT_BAT_TC	Li-Ion/Pol temperature sensor input
4	GND	Ground
5	GND	Ground

Table 3: XDEBUG1 connector

*COM settings (default): 115200, 8 data bits, 1 stop bit, no parity

Pin No	Name	Function
1	CPU_DEBUG_RX	SAMA5D4 Debug UART RX (3.3V-level)
2	CPU_DEBUG_TX	SAMA5D4 Debug UART TX (3.3V-level)
3	GND	Ground

Table 4: XEXTC1 connector

PA – port A shared with Ethernet PHY1. For using Port A as LCD display output – need to remove RN1, RN2 and RN3 resistor arrays.

Port A (PA[x]) pins are 3.3V tolerant.

Pin No	Name	SAMA5D4 pin	Function
1	VCC_IOP	-	+3.3V power line
2	VCC_IOP	-	+3.3V power line
3	PA[0]	A7	LCD interface - LCDDAT0
4	CPU_TOUCH_AD2	R13	Analog signal for touch screen (input Y+)
5	PA[5]	B6	LCD interface – LCDDAT5
6	CPU_TOUCH_AD4	T13	Analog in 4
7	PA[6]	A6	LCD interface – LCDDAT6
8	CPU_TOUCH_AD3	T12	Analog signal for touch screen (input Y-)
9	PA[3]	C6	LCD interface – LCDDAT3
10	CPU_TOUCH_AD1	T11	Analog signal for touch screen (input X-)
11	PA[8]	A5	LCD interface – LCDDAT8
12	CPU_TOUCH_AD0	U12	Analog signal for touch screen (input X+)
13	PA[1]	F6	LCD interface – LCDDAT1
14	GND	-	Ground
15	PA[7]	E5	LCD interface – LCDDAT7
16	PA[15]	B5	LCD interface – LCDDAT15
17	PA[21]	B4	LCD interface – LCDDAT21
18	PA[23]	A4	LCD interface – LCDDAT23
19	PA[20]	A3	LCD interface – LCDDAT20
20	PA[4]	D6	LCD interface – LCDDAT4
21	PA[19]	C4	LCD interface – LCDDAT19
22	PA[14]	E4	LCD interface – LCDDAT14
23	PA[17]	D4	LCD interface – LCDDAT17
24	PA[22]	B3	LCD interface – LCDDAT22
25	PA[30]	D3	I2C0 SDA
26	PA[2]	E6	LCD interface – LCDDAT2
27	PA[16]	H6	LCD interface – LCDDAT16
28	PA[11]	D5	LCD interface – LCDDAT11
29	PA[24]	H5	LCD interface – LCDPWM (backlight PWM)
30	PA[13]	C5	LCD interface – LCDDAT13
31	PA[26]	E3	LCD interface – LCDVSYNC (LCD V Sync)
32	PA[10]	F5	LCD interface – LCDDAT10
33	PA[9]	F4	LCD interface – LCDDAT9
34	PA[12]	G5	LCD interface – LCDDAT12
35	PA[25]	F3	LCD interface – LCDDISP (display on/off)

36	PA[28]	G3	LCD interface – LCDPCK (LCD Pixel clock)
37	PA[18]	G4	LCD interface – LCDDAT18
38	PA[29]	J5	LCD interface – LCDDEN (LCD DE)
39	PA[27]	H4	LCD interface – LCDHSYNC (LCD H Sync)
40	GND	-	Ground
41	PA[31]	J4	I2C0 SCL
42	CPU_SSC_TD0	K1	Digital audio interface I2S - Transmitter Data
43	GND	-	Ground
44	CPU_SSC_TK0	L2	Digital audio interface I2S - Transmitter Clock
45	CPU_PD15_RTS1	N4	USART1 - RTS
46	CPU_SSC_TF0	L1	Digital audio interface I2S - Transmitter Frame Synchro
47	CPU_PD14_CTS1	P2	USART1 - CTS
48	CPU_SSC_RK0	M5	Digital audio interface I2S - Receiver Clock
49	CPU_PD16_RXD1	R2	USART1 - RX
50	CPU_SSC_RD0	M3	Digital audio interface I2S - Receiver Data
51	CPU_PD17_TXD1	R3	USART1 - TX
52	CPU_SSC_RF0	M4	Digital audio interface I2S - Receiver Frame Synchro
53	GND	-	Ground
54	GND	-	Ground
55	PMIC_TWCK	U2	I2C1 SCL - With 22 Ohm bypass resistor
56	USBH_E_DP	W15	USB Host +
57	PMIC_TWD	V1	I2C1 SDA - With 22 Ohm bypass resistor
58	USBH_E_DM	V15	USB Host -
59	VCC_VSYS	-	Battery power supply
60	VCC_VSYS	-	Battery power supply

Table 5: XJTAGBB1 connector (Altera USB Blaster JTAG connector)

Pin No	Name	Function
1	BBJ_TCK	
2	GND	Ground
3	BBJ_TDO	
4	VCC_MAX10_3V3	+3.3V power line
5	BBJ_TMS	
8	BBJ_JTAGEN	
9	BBJ_TDI	
10	GND	Ground

Table 6: XFL1 connector (LVDS)

XFL1 – LVDS ports or general FPGA I/O.

All pins has same voltage as bank 2 and 3 power lines.

Pin No	Name	MAX10_pin	Function
1	VCC_MAX10_BANK2_3	-	FPGA Bank 2&3 power line
2	GND	-	Ground
3	MAX10_LVDS2_SP	L11	
4	MAX10_LVDS1_SP	M12	
5	MAX10_LVDS2_SN	M11	

6	MAX10_LVDS1_SN	M13	
7	GND	-	Ground
8	GND	-	Ground
9	MAX10_LVDS0_CK_INN	H5	
10	MAX10_LVDS3_SN	J8	
11	MAX10_LVDS0_CK_INP	H4	
12	MAX10_LVDS3_SP	K8	
13	GND	-	Ground
14	GND	-	Ground
15	MAX10_LVDS0_CK_OUTP	L4	
16	MAX10_LVDS0_SP	M7	
17	MAX10_LVDS0_CK_OUTN	L5	
18	MAX10_LVDS0_SN	N6	
19	VCC_MAX10_BANK2_3	-	FPGA Bank 2&3 power line
20	VCC_MAX10_BANK2_3	-	FPGA Bank 2&3 power line

Table 7: XFC1 connector

Pin No	Name	MAX10 pin	Function
1	GND	-	Ground
2	VCC_MAX10_3V3	-	+3.3V power line
3	MAX10_AIN1	D1	FPGA L1P or AIN2 (only for FPGA with ADC)
4	MAX10_AIN2	C2	FPGA L1N or AIN1 (only for FPGA with ADC)
5	MAX10_AIN3	E3	FPGA L1N or AIN3 (only for FPGA with ADC)
6	MAX10_AIN4	E4	FPGA L1N or AIN4 (only for FPGA with ADC)
7	MAX10_ADC_VREF	-	TBD
8	GND_ADC_MAX10	-	Analog ground (only for FPGA with ADC)
9	MAX10_ANAIN1	D2	Ground or ANAIN1 (only for FPGA with ADC)
10	GND	-	Ground
11	VCC_MAX10_BANK2_3	-	FPGA Bank 2&3 power line
12	MAX10_L5P	B1	
13	MAX10_L5N	C1	
14	MAX10_B7N	J6	
15	MAX10_L14N	F4	
16	MAX10_B9N	J7	
17	MAX10_L14P	G4	
18	MAX10_B7P	K6	
19	MAX10_L16N	H2	
20	MAX10_B9P	K7	
21	MAX10_B19N	J1	
22	MAX10_B3P	J5	
23	MAX10_B19P	J2	
24	MAX10_L16P	H3	
25	MAX10_B21P	M2	
26	MAX10_B28P	K2	
27	MAX10_B21N	M1	
28	MAX10_B28N	K1	
29	MAX10_B27N	M3	
30	MAX10_B3N	K5	
31	MAX10_B4N	N4	
32	MAX10_B27P	L3	
33	MAX10_B4P	N5	
34	MAX10_B6N	N7	

35	MAX10_B8N	M8
36	MAX10_B8P	M9
37	MAX10_B11P	N9
38	MAX10_B16N	M10
39	MAX10_B16P	L10
40	MAX10_B11N	N10

XSWD1 – JTAG connector for SAMA5D4. Needle adapter required:
https://www.segger.com/jlink-needle-adapter.html

XJTAGBB1 – JTAG connector for Intel MAX10 FPGA. JTAG adapter required:
http://www.terasic.com.tw/cgi-bin/page/archive.pl?No=46

4. Power supply

DAB-OWRT-SAM5D4 Smart Router has 2 power sources:

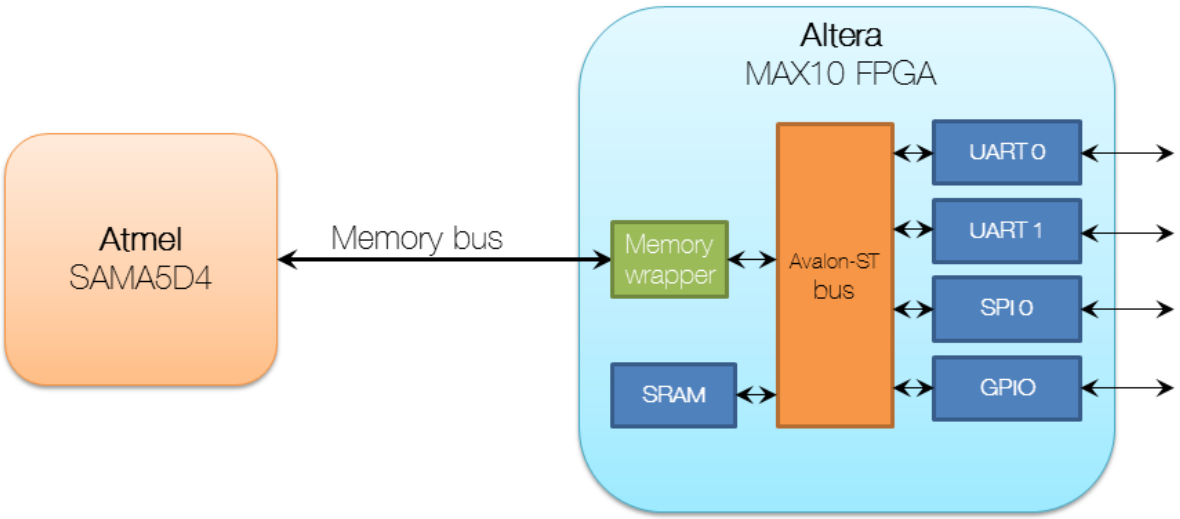
- From microUSB (XUSBMICRO1) connector (+5V @ 2A);
- From Li-ion/Pol 3.7V battery, connected to XBAT1 or XBAT2 connector.

Also smart router able to charge Li-ion/Pol battery by using microUSB power source.

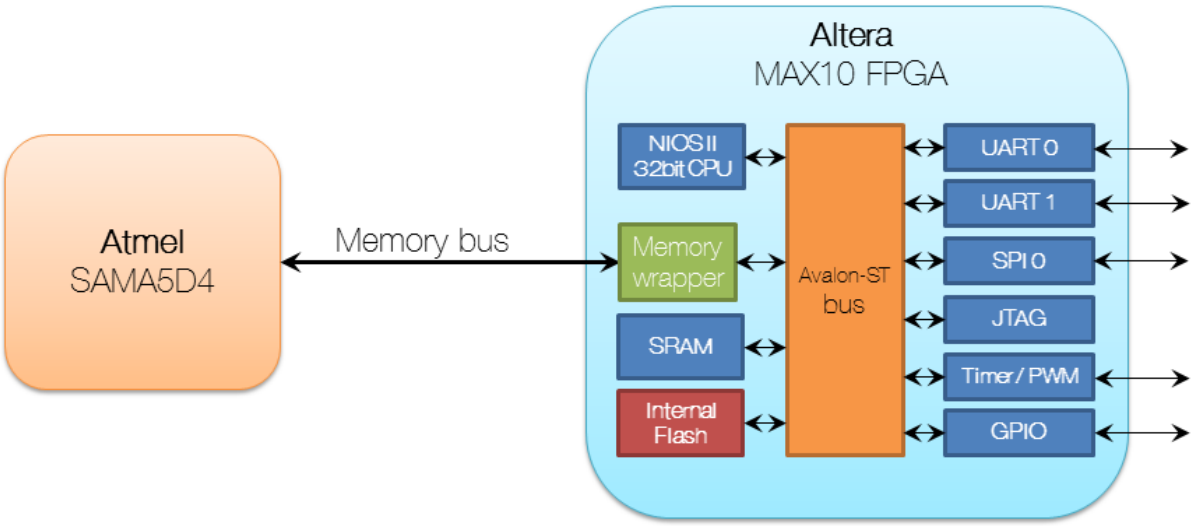
5. FPGA

Altera MAX10 FPGA connected to Atmel SAMA5D4 CPU with EBIU 16bit SRAM-like bus. Developer can create IP core to handle requests from CPU to FPGA.

Example 1 – Additional UARTs and SPIs



Example 2 – Additional UARTs and SPIs + NIOS II CPU



6. Quick start

DAB-OWRT-SAM5D4 requires power source from Li-Ion/Pol battery or from microUSB. Board can use only microUSB for powering system.

1. Connect UART TTL-USB converter to XDEBUG1 pin header. Please use only 3.3V-level UART converter.
2. Open console with UART TTL-USB serial port.
3. Connect cable from your HostPC to microUSB connector.
4. If NAND has bootloader, it SAMA5D4 automatically start it.

Note: microSD card pins are multiplexed with NAND Flash pins. So is not possible to use microSD and NAND Flash in same time.

6.1. Using wireless blocks on board

6.1.1. Bluetooth

Script for Enabling Bluetooth:

```
echo BT_POWER_UP > /dev/at_pwr_dev
echo BT_DOWNLOAD_FW > /dev/at_pwr_dev
echo BT_FW_CHIP_WAKEUP > /dev/at_pwr_dev
sleep 1
hciattach ttyS3 any 115200 noflow
hciconfig hci0 up
```

Detect nearby Bluetooth devices

To scan nearby Bluetooth devices, issue the following command. It will search for Bluetooth devices and display their addresses and user-friendly names.

```
# hcitool scan
# hcitool lescan
```

6.1.2. WiFi

Script for Enabling WiFi:

```
# ifconfig wlan0 up
```

Detect nearby WiFi AP

```
# iw wlan0 scan
```

6.2. Using ADC on board

6.2.1. How to read ADC values in Linux for SAMA5D4

All values

```
# cat /sys/bus/iio/devices/iio\:device0/in_voltage[0-4]_raw
```

How to read separate ADC channel

```
# cat /sys/bus/iio/devices/iio\:device0/in_voltage0_raw
```

ADC mapping

SAMA5D4 ADC	IIO device	IIO channel	XEXTC1 pin	Linux sys class
ADC1_IN0	iio:device0	in_voltage0_raw	6	/sys/bus/iio/devices/iio\:device0/in_voltage0_raw
ADC1_IN1	iio:device1	in_voltage1_raw	5	/sys/bus/iio/devices/iio\:device0/in_voltage1_raw
ADC1_IN2	iio:device2	in_voltage2_raw	10	/sys/bus/iio/devices/iio\:device0/in_voltage2_raw
ADC1_IN3	iio:device3	in_voltage3_raw	7	/sys/bus/iio/devices/iio\:device0/in_voltage3_raw
ADC1_IN4	iio:device4	in_voltage4_raw	8	/sys/bus/iio/devices/iio\:device0/in_voltage4_raw

6.3. Using FPGA

FPGA mapping:

```
SYSID      - 0x10000000..0x10000007
GPIO       - 0x10000010..0x1000001F
GPIO MX    - 0x10000020..0x1000002F
SRAM       - 0x10000040..0x1000007F
UART       - 0x10000080..0x1000009F
```

List of GPIOs in system

```
# cat /sys/kernel/debug/gpio
```

FPGA RGB LEDs control

```
# echo 464 > /sys/class/gpio/export
# echo out > /sys/class/gpio/gpio464/direction
# echo 1 > /sys/class/gpio/gpio464/value
```

7. Software

- ✓ Linux Kernel 4.1 and BSP
- ✓ OpenWRT firmware
- ✓ NIOS II example (MAX 10)
- ✓ Windows Embedded Compact 7

7.1. Software update

Extract DAB-OWRT-SAMA5D4_SW_1_0.zip in your machine.

Under Windows environment:
1. Install Atmel SAM-BA 2.x from Atmel website
2. Erase NAND Flash on device:
    2.1. Connect USB-UART cable to XDEBUG1 connector and open COM-port you're your favorite terminal program. Please use next COM-settings: 115200bps, 8bit, 1stop bit, no parity.
    2.2. Press "Reset" button on device
    2.3. Stop Uboot by pressing "Space"
    2.4. Run next command:
    nand erase.chip

2.5. Press “Reset” button on device again
2.6. In COM-console “BootROM” should appear
2.7. Connect microUSB cable between XMICROUSB1 connector on board and your Windows Host machine and install drivers (drivers located in SAM-BA folder)
2.8. Open device manager and check port number of AT91 COM-port
2.9. Open “demo_linux_nandflash.bat” file with your favorite text editor and find string “\USBserial\COMxx”.
2.10. Replace “xx” to AT91 COM number and save the file
2.11. Run this bat-file and wait until Log file appears, then close it.
2.12 Board is ready. Press “Reset” button.

8. Build software from sources

a. How to build at91-bootstrap bootloader

TBD

b. How to build Uboot bootloader

TBD

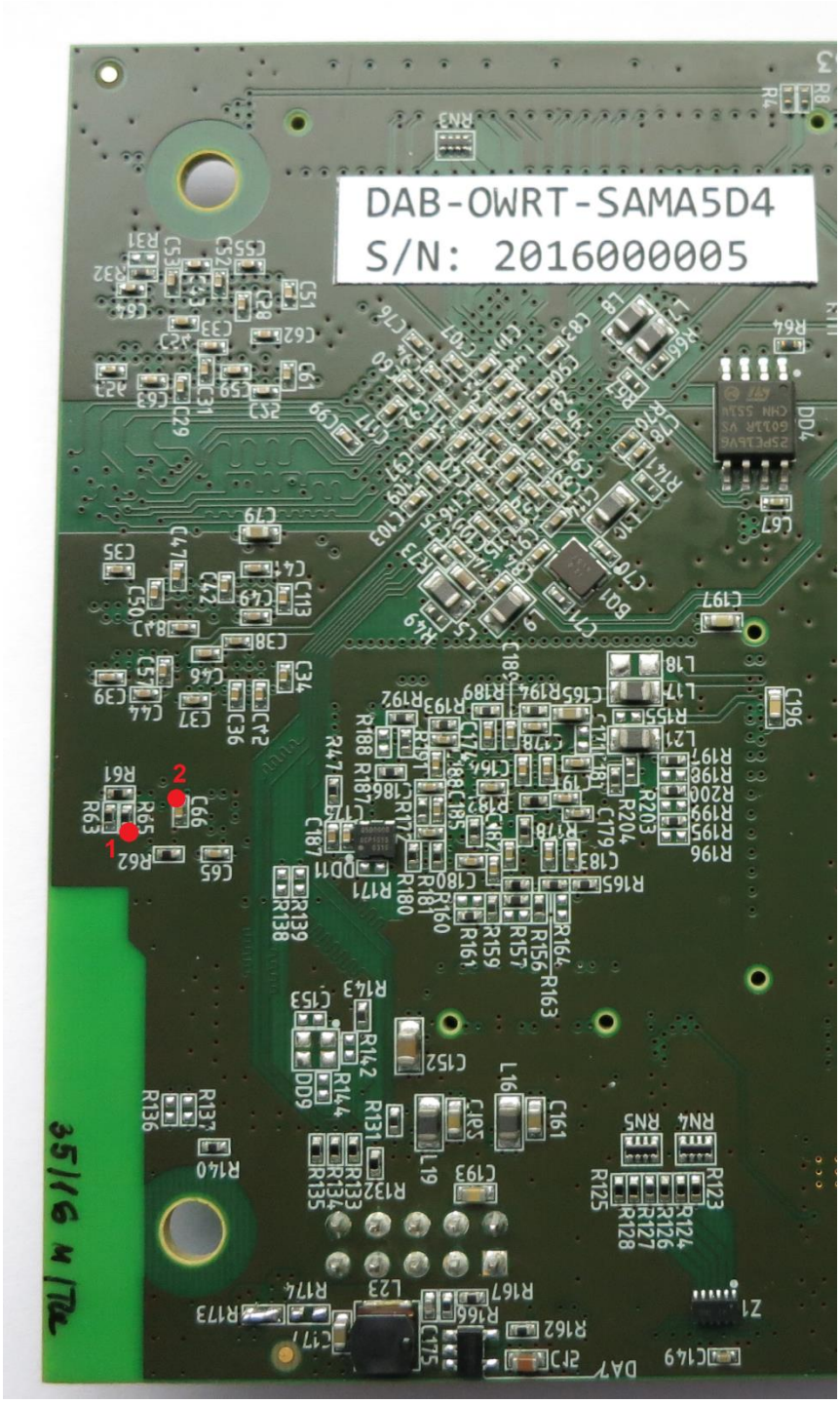
c. How to build Linux kernel

TBD

d. How to build Yocto rootfs for DAB-OWRT-SAM5D4

TBD

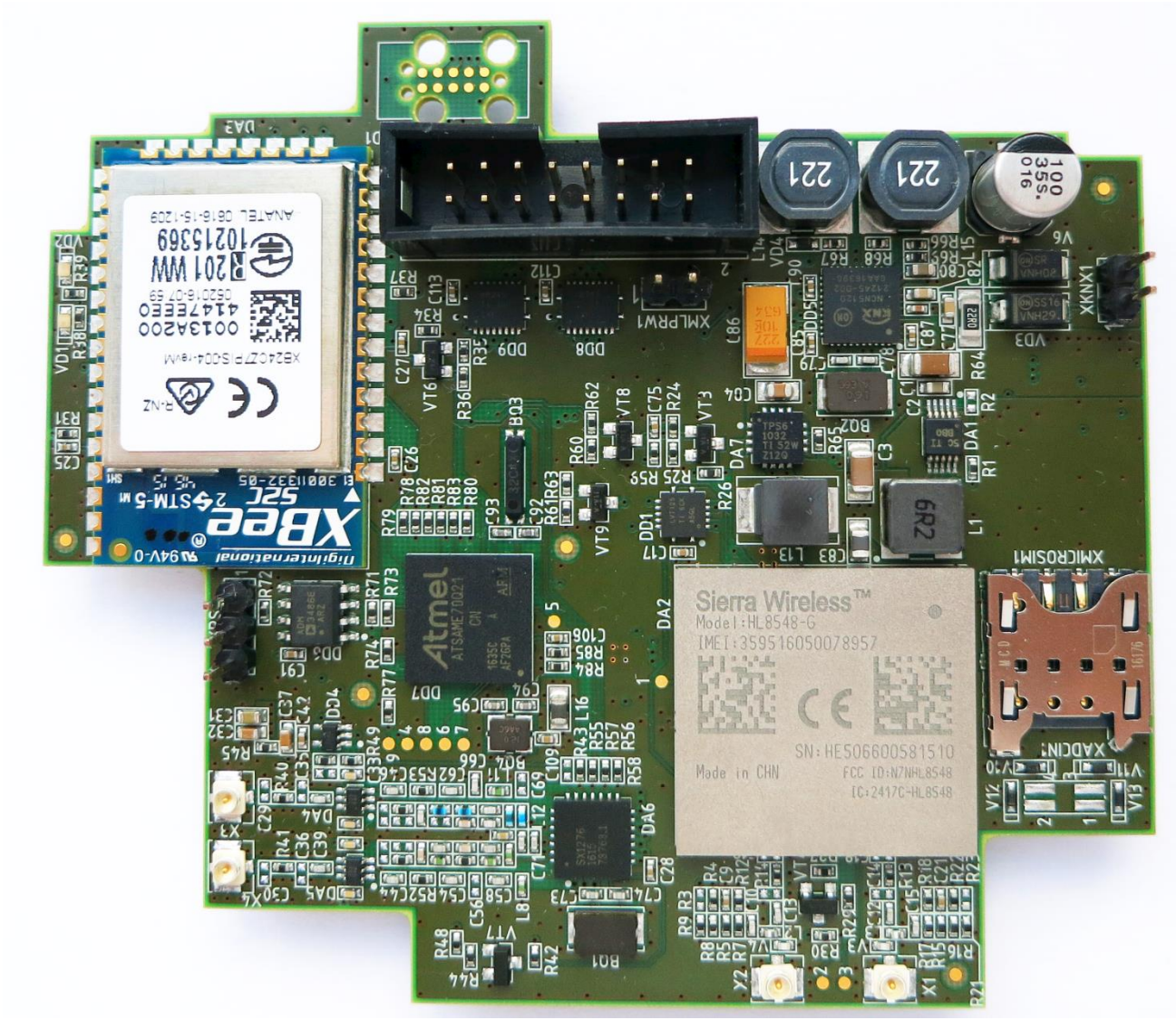
9. Recovery firmware in NAND Flash



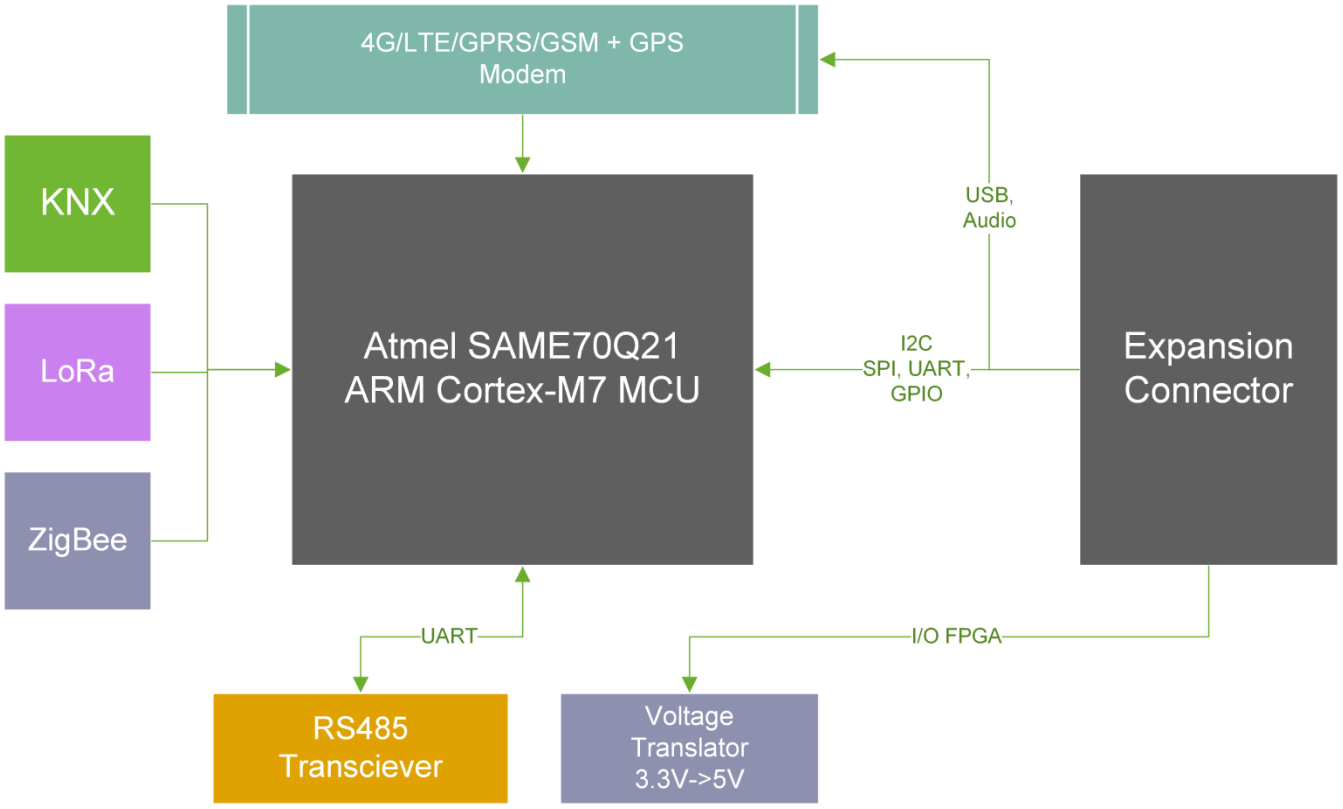
For emergency recovery firmware in NAND Flash need to short points 1 and 2.

10. Expansion boards

10.1. Wireless board



LoRa™ ZigBee® 3.5G KNX



- ✓ Software:
  - / Yocto Linux Embedded
  - / Windows Embedded Compact
  - / Baremetal application support
  - / FPGA firmware

Key features

- MCU: Atmel SAME70Q21 (ARM Cortex-M7)
- 3G/2G/GSM modem with GPS (Sierra Wireless HL8548-G)
- Dual band LoRa modem: 433MHz and 915MHz (Semtech SX1276)
- ZigBee based on 2.4GHz XBee module (Digi XB24CZ7PIS-004)
- KNX Transceiver with DC/DCs (ON Semiconductor NCN5120)
- RS485 Transceiver (Modbus RTU support)
- FPGA I/O lines with voltage translation possibility (3.3V to 5V)
- 4x ADC lines (12-bit ADC channel)

Software

- LoRa stack
- KNX stack (can choose stack supplier)
- ModBus RTU stack (over RS485 bus)
- FreeRTOS-based software