Gnublin 2 Linux Board

A build-it-yourself alternative to the Raspberry Pi

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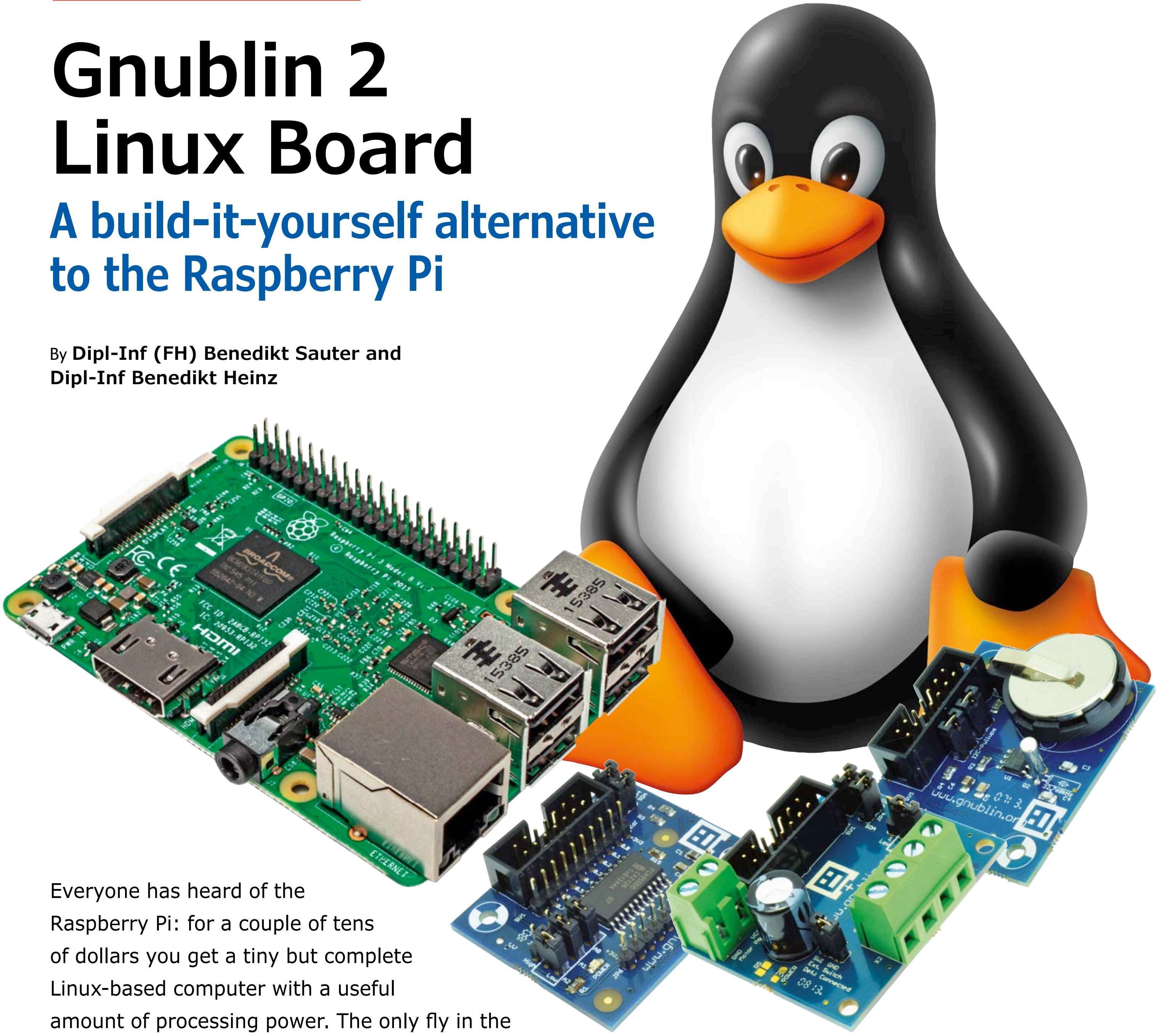

Everyone has heard of the Raspberry Pi: for a couple of tens of dollars you get a tiny but complete Linux-based computer with a useful amount of processing power. The only fly in the ointment is that although it represents very good value, the hardware design is not completely open. The authors therefore decided to design their own single-board computer using a modern ARM Cortex-A5 CPU. Although our Linux board is not able to compete fully with the Raspberry Pi on price, it's completely open software and hardware can be modified to your heart's desire and customized for your educational, development or industrial application.

As the '2' in 'Gnublin 2' hints, the design has some history behind it. Its predecessor, the Gnublin 1, formed the basis for the Elektor Linux board and an embedded Linux course in Elektor [1]. A number of further articles followed, and a wide range of hardware is still available for purchase from the Elektor Store [2]. Our company 'embedded projects GmbH' also has its own web pages covering the design [3].
Five years have passed since that original design: practically an eternity in microelectronics terms. During that period we have seen not only the appearance of the Raspberry Pi and all its successors, but also an ever-increasing range of other new and improved Linux boards addressing a similar target market. So the question arises: does it make sense to produce an updated version of the Gnublin board? If the answer is going to be 'yes', then we will need to create

something more than a 'me-too' design. Now, the Gnublin 1 continues to be a popular board, and we feel that this can be put down to the following features where other designs fall short:

- Gnublin 1 is a completely open design. The circuit diagram, board layout and software are all made available;
- the components used are available for purchase in small quantities, and the printed circuit board, which has 'only' six layers, can also be made reasonably economically in small quantities;
- in contrast to most modern Linux boards which aim to offer as much computing power as possible, the Gnublin 1 has an exceptionally low power consumption. Many embedded systems applications have no need for flashy 3D graphics: for long-term operation low energy use is a more desirable feature.

And so we started to look to see if there was an ARM SoC (system-on-chip) available on the market that might form a suitable basis for version 2 of the Gnublin board. Our two main criteria were low power consumption and top-notch Linux support.

SoC choice

As low power consumption was important to us, our eyes were naturally drawn to single-core SoCs based around ARM Cortex-A5 and Cortex-A7 cores. We finally plumped for the Atmel ATSAMA5D41 [4], which uses a Cortex-A5 core. As far as Linux support is concerned, we had already had plenty of experience, as well as plenty of frustration, with the Gnublin 1 and other designs. The LPC3131 used in the Gnublin 1 was a particular culprit: the most recent version of the Linux kernel that can be used with this SoC is 2.6.33, which is more than six years old! Although the LPC3131 is still listed as 'active' and 'in production', it has not been supported in the Linux kernel for some time.

The situation is rather different with Atmel. Almost all Atmel SoCs, even those that are several years old, are still supported today. Special 'patches' from the manufacturer are not required, as the official Linux kernel provides built-in support for the devices. Also, Atmel provides extensive documentation without the bother of an NDA (non-disclosure agreement), and the company cooperates closely with the Linux community during development. Consequently the kernel development team maintains the code for these ICs when the kernel is modified. This forms a sound basis for long-term support for the SoC in up-to-date versions of the kernel.

Using the ATSAMA5D41 also opens up other possibilities lacking on other Linux boards. For example, the device has two serial ports available: one for the Linux console and one for application-specific use. Also, the Gnublin 2 can be connected directly to a PC using its high-speed USB device port, something that is not possible on a Raspberry Pi, for example. A common requirement in embedded systems is a real-time clock that can maintain the correct time even when power is lost, and the Gnublin 2 includes the option of adding a back-up battery for this purpose. And it is possible to connect a resistive touchscreen directly to the device, without the need for an external power supply.

All these advantages added up to enough reason to go ahead with a Gnublin version 2 based on this device. Like its predecessor, Gnublin 2 is designed as a basis for your own designs and products: even test reports from the EMC laboratory will be included along with the usual documentation.

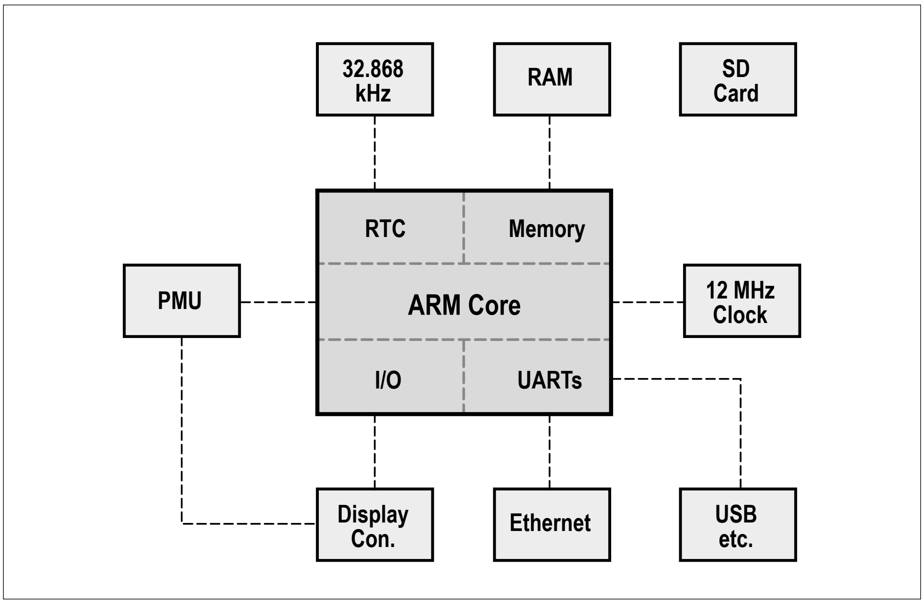

Figure 1. The block diagram of the Gnublin 2 shows the SoC and its submodules outlined in bold, along with the hardware connected to it.

Potential applications

Gnublin 2 is at home in any application involving measurement and control, or indeed in any application or product where it is desired to replace an old-school microcontroller with a more powerful CPU capable of running Linux. The cost of the basic components, including the processor, memory and power supply, comes to only about 15 to 20 dollars, depending on quantity. Gnublin 2 is thus also suitable for short-run production.

The freely-available parts list, circuit diagram and printed circuit board layouts, as well as EMC test results and calculation tools remove a lot of the difficulties usually associated with short-run manufacture of products based on modified versions of 'ready-made' boards such as the Raspberry Pi and its variants.

The documentation also makes connecting up additional hardware a piece of cake. In the usual prototype development process using hand-assembled samples, the first trip to the EMC lab is generally only made when mass production is about to start. Having the results of EMC testing already available saves valuable time at this point. And even for one-off applications there is comfort in knowing where one stands regarding RF characteristics.

Organization and components

Happily, with the Linux system in its

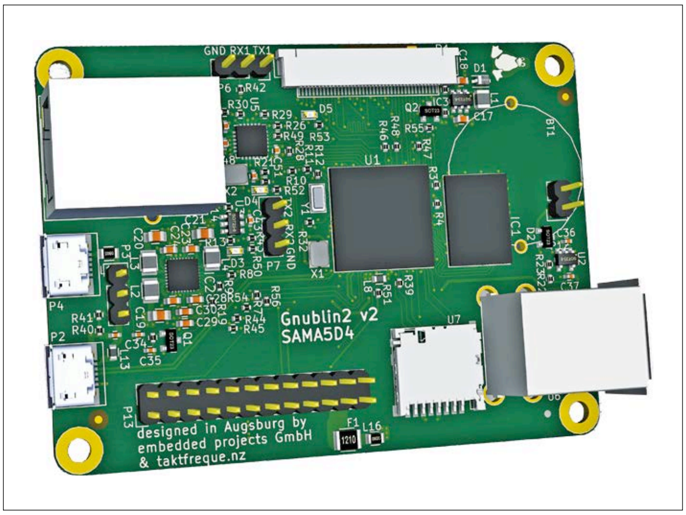

Figure 2. 3D rendering of the Gnublin 2 printed circuit board.

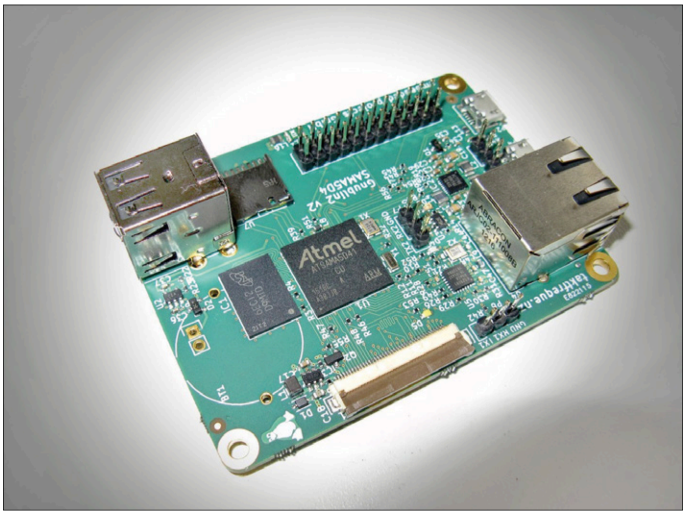

Figure 3. The assembled Gnublin 2 prototype.

idle state, the Gnublin 2 (including its 256 MB of RAM) dissipates less than 0.3 W at a clock rate of 600 MHz. In the block diagram shown in **Figure 1** the SoC is outlined in bold. As you can see, besides the processor core itself, the SoC includes a number of important modules such as the RTC (real-time clock) and interfaces to external memory hardware. A detailed circuit diagram can be downloaded at [6]: it is too large to include here.

The 256 MB memory device IC1 is connected to the ATSAMA5D41 SoC (U1) over a 16-bit bus. Compared to other boards, which use a bus 32 bits wide, this results in a simpler and cheaper printed circuit board and in lower power consumption. Even so, with a RAM clock of 300 MHz the DDR2 interface achieves a total data rate of over 1 Gbit/s.

The SoC needs various supply voltages for its I/O pins and for the processor core. These voltages are generated by IC2, an ACT8865 PMU (power management unit) [5]. The PMU includes several switching and linear regulators and can be configured from the SoC over its I²C bus.

The supply for the real-time clock integrated into the SoC comes from a type TPS78001 low-dropout and ultra-low-power linear regulator (U2), which in turn can be supplied from a button cell or externally over a connector. The real-time clock of course uses a standard 32.768 kHz watch crystal (Y1). The main system clock

Surfing the Internet with a display and a browser

There is a wide variety of Linux distributions that can be used with our Cortex-A5 board. Our personal preference for development purposes is Debian Jessie [1], but Yocto and Ubuntu are also both possible. The base installation of Debian is considerably more lightweight than Ubuntu, but nevertheless offers a huge choice of software packages that can easily be downloaded over the network and then installed using the 'apt' tool. Installed packages can also be updated automatically over the network, which is very useful and desirable, especially in the case of security-related updates. Even the GNU C compiler can be installed using 'apt'.

Software can be compiled directly on the board itself, as long as the code is not too complex. A graphical user interface is available in the form of LXDE [2]: this is very lightweight and can be installed using the command 'apt-get install lxde'. The available 256 MB of RAM may not be sufficient these days to display the most resource-intensive web pages; the Midori browser [3] is a lightweight option that can handle web sites that use HTML5, CSS and Javascript. The command 'apt-get install midori' can be used to install this browser.

The illustration shows that Gnublin 2 has no problems loading and displaying normal web pages.

[1] Debian Jessie: https://www.debian.org/releases/jessie/
[2] LXDE: https://wiki.lxde.org/en/Debian
[3] Midori: http://midori-browser.org/

is derived from 12 MHz crystal X1.

In contrast to the Gnublin 1 the updated version can drive a TFT display module directly, which opens the door to many new applications. So that the whole system, including the display, can be powered from a single 5 V supply, we have included an extra step-up regulator based on an AP5724 (IC3). This can supply the display's LED backlight with a constant current of 40 mA at around 24 V. The ADC built into the SoC also allows the direct connection of a resistive touch panel.

Ethernet PHY KSZ8081RNA/D (U5) allows the board to be connected directly to a network at 10 Mbit/s or 100 Mbit/s. The necessary magnetics are integrated into RJ45 connector U4, and U3, a type 24AA025E48 I^2C EEPROM, is used to provide a valid MAC address.

As is the case for practically every other Linux board, the Gnublin 2 has built-in mass storage: at system start-up the boot loader and the Linux system are loaded from microSD card U7.

The SoC includes a total of three high-speed USB ports. Of these, two are made available as host ports on dual connector U6, while the third port is brought out to micro USB socket P2 as a device port. This allows the board to act as almost any type of USB device when connected to a host computer, and for example it is possible to set up a network connection over USB between the host and the Gnublin 2. It is possible to power the board directly over socket P2, and a second micro USB socket (P4) is also provided as an alternative dedicated connection for a higher-current supply such as a smartphone charger. The latter is handy when several USB devices are to be connected to the Gnublin 2. Jumper P3 selects whether the board is powered over P2 or P4.

The SoC's I/O pins operate at 3.3 V logic levels, and many of the pins are brought out on header P13. As on the Gnublin 1, this connection includes an SPI bus with a number of individual chip select outputs. An I^2C bus is also available on P13, along with connections for the SoC's second UART. This serial interface is also accessible on P7: it is not used as a console by the Linux system and so can be freely employed for whatever application-specific purposes you might have. Finally, P6 provides access to the first UART, which is used by the Linux system as a console. Kernel messages are output on this port at start-up, and it is also possible to use it to control the boot loader.

Figure 2 shows a 3D rendering of the printed circuit board, designed using KiCAD. The layout files as well as the circuit diagram, software, documentation and other information are available for free download at [6]. **Figure 3** shows the assembled board. The **Text Box** contains some basic information on how to put together the software required for a complete Linux computer based on a Gnublin 2 board and a display.

Outlook

This article has given just a brief overview of the Gnublin 2 system. With the help of the resources at [6] you will find it easy to start building your own projects. During the course of development of the Gnublin 2 several interesting topics arose that are worthy of articles in their own right. For example, we are planning a detailed description of how we went about laying out the printed circuit board using KiCAD: we hope that using the Gnublin 2 board as a case study will be considerably more realistic than the artificially simplified circuits normally used in tutorials. Also, we plan an article on RF interference and EMC testing based on our experience from this design. And, last but not least, we are planning an article that describes step by step how you can go about making your own variant of our Linux board. ⏮

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Crowdfunding!

Elektor and embedded projects GmbH have launched a crowdfunding campaign for this project. If you would like to take part or order a Gnublin 2 board, you can find more information at **www.gnublin.org**

About the authors

Benedikt Sauter studied Computer Science; after his studies he worked on a range of microcontroller projects and began to work independently. Shortly afterwards the company embedded products GmbH was founded. He has had a passion for software and hardware from a young age, and has had several open-source projects published in Elektor.

Benedikt Heinz has been developing software and digital electronics for microcontrollers and CPUs for over 15 years. A long-time desktop Linux user, he has a strong preference for open-source software, and contributes to open-source projects. He is currently working on software to simplify the layout of complex boards (using PCIe, DDR DRAM and so on) using KiCAD.

Web Links

[1] Embedded Linux made easy: www.elektormagazine.com/120026

[2] Gnublin products: www.elektor.com/development/gnublin/

[3] Gnublin website: http://gnublin.embedded-projects.net/

[4] ATSAMA5D41: www.atmel.com/devices/ATSAMA5D41.aspx

[5] ACT8865: www.active-semi.com/products/power-management-units/act88xx

[6] Gnublin 2 resources: www.gnublin.org/index2.html