NOVEMBER 2024

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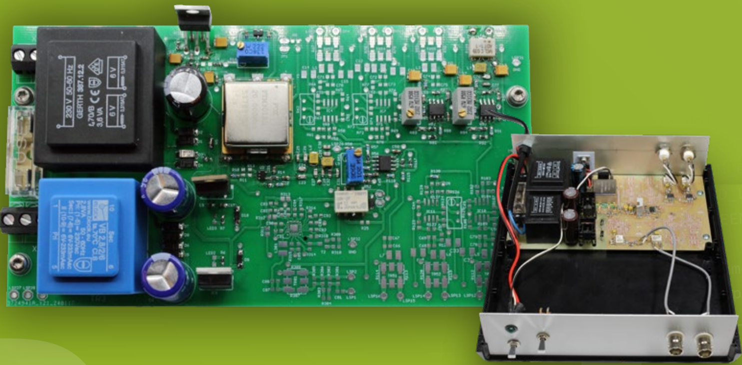
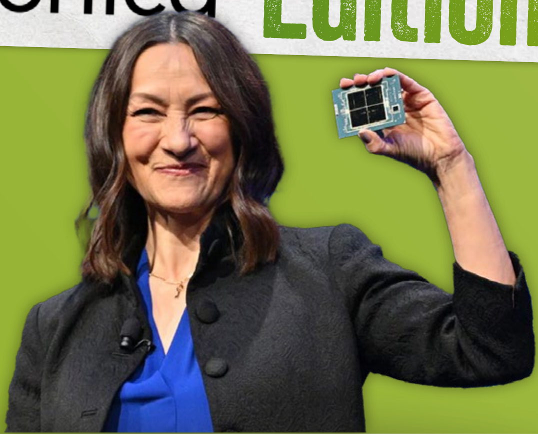
# Digital electronica Edition

## 10 MHz Reference Generator

Highly Accurate, With Distributor and Galvanic Isolation

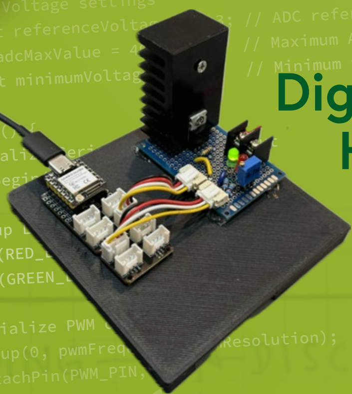




## CEO Interview

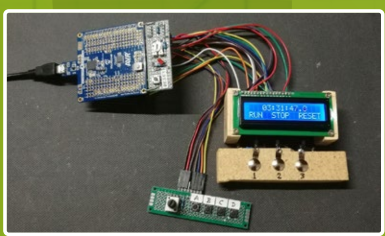
Sandra Rivera of Altera on the move to Intel 18A

## Trust in Rust



## Digital Load for High-Current Testing

From Necessity to Innovation



## Touch Sensing Made Simple

A DIY Guide for Any Microcontroller

## Vaire Co-Founders

Discuss Adiabatic Reversible Computing

## Elektor @ electronica 2024

**Live Elektor Lab Talk Shows**

***Influencer Forums***

*Experts on Stage*

electronica Fast Forward 2024

and More!

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Nick Flaherty
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*Editor-in-Chief, Elektor*

# Empowering Innovation at electronica 2024

Elektor × eeNews EUROPE

As the world's leading electronics innovators gather for electronica 2024 in Munich, Elektor and eeNews Europe are proud to present this special digital edition — a collaborative showcase of the strengths of both publications. Tailored specifically for this event, our digital magazine combines Elektor's hands-on project expertise with eeNews Europe's deep-dive industry insights, capturing many of the articles that appear in our print edition, which will be distributed at the event.

In this digital issue, engineers, makers, and industry professionals will discover practical electronics projects that push the boundaries of innovation from Elektor, alongside eeNews Europe's interviews, key industry trend reports, and expert analysis on the future of electronics. Dive in!

If you're attending electronica 2024, come meet us at booth B4.440! Our teams will be there to discuss the latest technology, share insights into the electronics industry, and host live interviews with influential voices. Business leaders can also learn how Elektor and eeNews Europe can help achieve marketing and innovation goals.

We hope you enjoy this digital edition and look forward to connecting with you at electronica 2024! Can't make it? Catch our live streams and event coverage at *youtube.com/@ElektorTV*.

## The Elektor Team

**Editor-in-Chief:** Jens Nickel | **Editorial Staff:** Asma Adhimi, Roberto Armani, Eric Bogers, Jan Buiting, Stuart Cording, Rolf Gerstendorf (RG), Ton Giesberts, Saad Imtiaz, Alina Neacsu, Dr. Thomas Scherer, Jean-Francois Simon, Clemens Valens, Brian Tristam Williams

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# THIS EDITION

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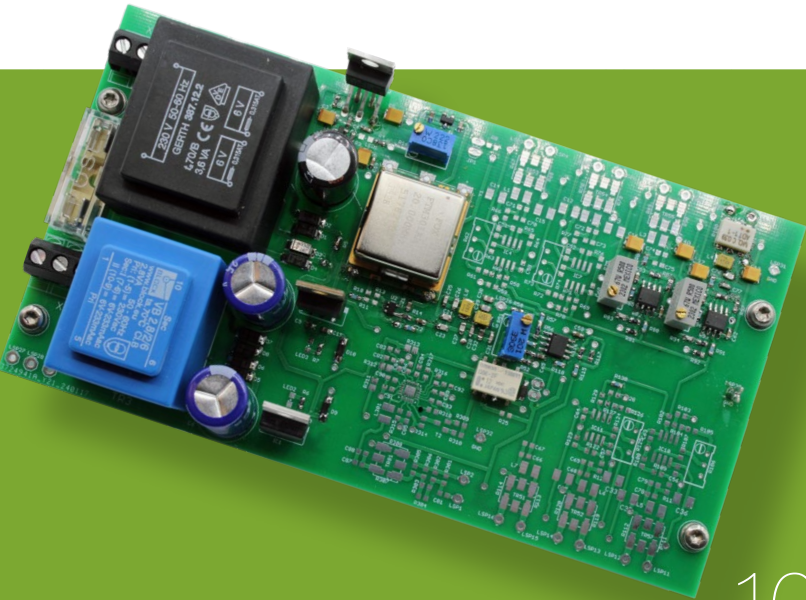


## 10 MHz Reference Generator

Highly Accurate,
With Distributor and
Galvanic Isolation

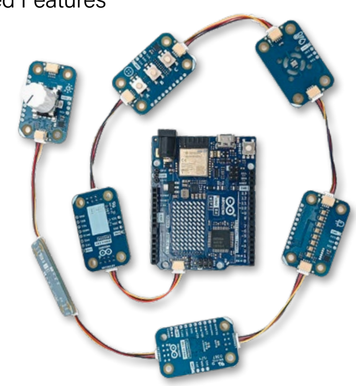
10

## Elektor and eeNews



## Features



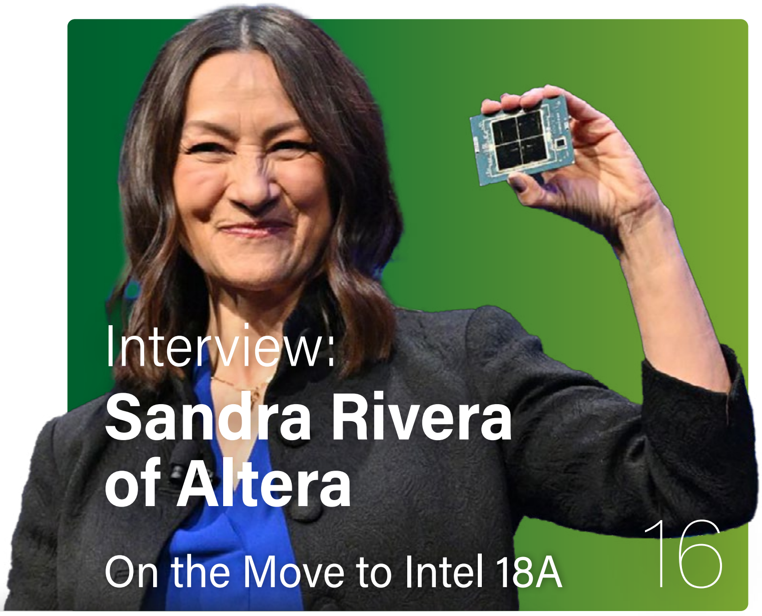


## Projects



## News







# Interviews



# Industry



FOCUS ON elektor MAG & eeNews EUROPE

# Elektor @ electronica 2024

## electronica Fast Forward 2024, Experts on Stage, Influencer Forums, Live Elektor Lab Talk Shows, and More

**By the Elektor Team**

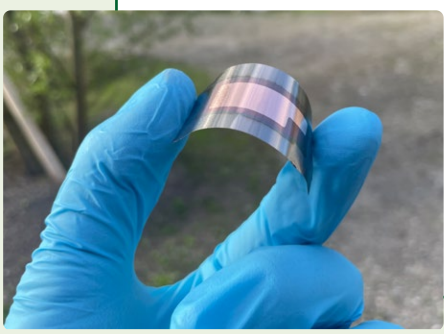
electronica 2024 (November 12–15) in Munich is on track to be bigger than ever before. Around 2,800 exhibitors from 50 countries will showcase their latest products and developments in 18 halls. It goes without saying that Elektor also has its own booth. This year we are cooperating with Messe Munich again for the electronica Fast Forward Award. Additionally, well-known electronics content creators, such as GreatScott!, will be presenting their latest projects, we will be interviewing experts, and we will have a daily live Lab Talk video show. See you in Munich!

Every two years, Munich becomes a mecca for electronics professionals and enthusiasts. At electronica 2024 (November 12-15, Messe Munich) you can expect to see the latest developments in AI, IoT, smart energy, GaN and SiC semiconductors, and much, much more. If you're attending, we invite you to visit Elektor at booth B4.440, where our teams will be available to discuss the latest technology, offer insights into the electronics industry, and host live interviews with key influencers and experts. If you're a business leader, we also offer the opportunity to explore how Elektor and eeNews Europe can support your marketing and innovation goals. Whether you're an industry professional or a tech enthusiast, be sure to visit **Booth B4.440** to meet the innovative startups, influencers and experts up-close. This is your opportunity to see cutting-edge technology firsthand and engage with the people behind it. Come join us!


### electronica Fast Forward 2024

At electronica Fast Forward 2024, startups will take center stage to showcase the future of electronics. In this sixth edition of our startup event, which is organized by electronica and Elektor, the startups will cover groundbreaking innovations in IoT, robotics, battery development, and more. The five selected startups at electronica Fast Forward are tackling some of the most critical challenges in the electronics sector.

As always, electronica Fast Forward isn't just a showcase — it's a competition. The startups will pitch their technologies to industry leaders and decision-makers, competing for a total media budget prize of €85,000. The first-place winner will also secure a fully paid booth at electronica 2026. On Friday, there will be the ceremony showing the three Award winners (see **Timetable**).

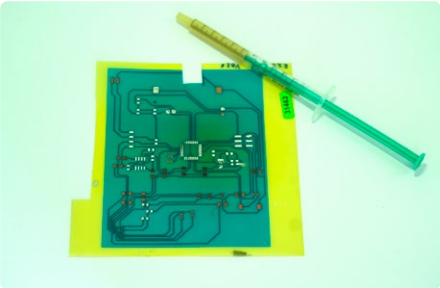


**BTRY AG (Switzerland)**
BTRY is an ETH spinoff developing the industry's first energy-dense solid-state battery made with advanced semiconductor manufacturing methods. The product is an advanced lithium-ion battery that can be charged within one minute. It operates at very high and low temperatures, and can sustain several thousand charge-discharge cycles.
*www.btry.ch*

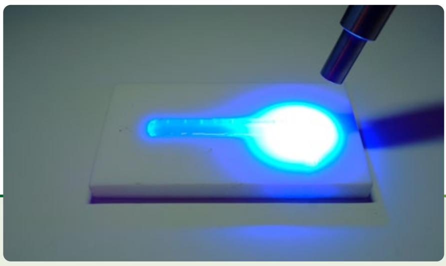
**Nightjar Technologies (India)**
Nightjar Technologies is a spinoff of RESOLVE, a Washington DC-based environmental NGO. Their flagship product, Trail-Guard AI, is an AI-enabled camera system designed to combat poaching and mitigate human-wildlife conflict in developing countries.
*www.nightjar.in*

**ICECAP Systems (Malta)**
The goal of ICECAP Systems is to develop a compact cooling system for widespread application within various products. Using multistage thermoelectric modules (TEMs), novel assembly techniques and innovative optimization algorithms, lower temperatures can be achieved in smaller packages, allowing for easy integration within portable devices. Applications include high-speed cameras, radio receivers, telescopes, medical transporters, benchtop lab equipment and high-performance processors amongst others.
*www.icecapsystems.com*

**Banyan.eco (France)**
Banyan.eco aims to help the world of electronics achieve net-zero, meaning that the total amount of greenhouse gases produced is balanced by the amount removed from the atmosphere. The multi-layer electronics supply chain and industrial process is one of the most complex among industrial sectors, making it extremely hard to be able to measure emissions across a product lifecycle, from cradle to grave. Banyan.eco uses AI and digital Eco-twins to order to estimate product and company carbon footprints in electronics in minutes.
*www.banyan.eco*



**SpeedPox (Austria)**
SpeedPox offers innovative and ultra-fast curing epoxy resins, conductive adhesives and inks. Their epoxies are one-component systems with practically unlimited pot life at room temperature. Upon heat or UV stimulus, a patented self-propagating mechanism is triggered, which saves 99% of time and energy. Instead of several hours in an industrial furnace, SpeedPox enables curing within seconds.
*www.speedpox.com*



**electronica Fast Forward 2024 Sponsors**
Key industry sponsors, including **NXP**, **MikroE**, **Mouser**, and **PCBWay**, are supporting the event to foster growth and collaboration across the electronics community.

## Elektor @ electronica: Timetable

**Tuesday, November 12**

09:00 **Startup pitch: Banyan.eco** (B4.440)
10:00 **Startup pitch: BTRY AG** (B4.440)
10:30 **Krüger Consulting GmbH** (B4.440)
11:00 **Startup pitch: ICECAP Systems** (B4.440)
12:00 **Startup pitch: Nightjar Technologies** (B4.440)
13:00 **Startup pitch: SpeedPox** (B4.440)
14:00 **Interview: GreatScott!, LiPo Kit** (B4.440)
15:00 **Interview: Jean-Pierre Joosting, eeNews Europe** (B4.440)
17:00 **Elektor Lab Talk live** (B4.440)

**Wednesday, November 13**

09:00 **Startup pitch: SpeedPox** (B4.440)
10:00 **Startup pitch: Banyan.eco** (B4.440)
10:30 **NXP** (B4.440)
11:00 **Startup pitch: BTRY AG** (B4.440)
12:00 **Startup pitch: ICECAP Systems** (B4.440)
13:00 **Startup pitch: Nightjar Technologies** (B4.440)
14:00 **Interview: Max Imagination** (B4.440)
15:00 **Interview: Hungarian Consulate** (B4.440)
17:00 **Elektor Lab Talk live** (B4.440)

**Thursday, November 14**

09:00 **Startup pitch: Nightjar Technologies** (B4.440)
10:00 **Startup pitch: SpeedPox** (B4.440)
11:00 **Startup pitch: Banyan.eco** (B4.440)
12:00 **Startup pitch: BTRY AG** (B4.440)
13:00 **Startup pitch: ICECAP Systems** (B4.440)
13:30 **Lavorro Inc.** (B4.440)
14:00 **Interview: Jorge Costa Dantas Faria, European Innovation Council EISMEA** (B4.440)
15:00 **Interview: Peter Dalmaris, KiCad 8** (B4.440)
16:00 **B2B & Influencer Marketing** (B4.131, Visionary Stage)
17:00 **Elektor Lab Talk live** (B4.440)

**Friday, November 15**

10:00 **Interview: Nick Flaherty, eeNews Europe** (B4.440)
11:00 **Influencer Marketing for Students** (B4.131, Visionary Stage)
12:00 **electronica Fast Forward 2024 Prize Ceremony** (B4.131, Visionary Stage)
13:00 **Soldering competition with DIY GUY Chris** (B4.440)

**A plan of B4 hall can be found at**
*https://exhibitors.electronica.de/ausstellerportal/2024/hallenplaene/hallenplan/?lid=b4*

*This schedule is subject to change.*

## Meet the Influencers:
### Driving Engagement and Innovation

Influencers play a pivotal role in bridging the gap between innovative tech and mainstream adoption. At the Elektor booth, three notable electronics industry influencers are presenting their latest projects: GreatScott!, Max Imagination, and DIY GUY Chris. Together, these creative innovators represent more than 2 million followers.

**GreatScott!** is a standout renowned for his in-depth electronics tutorials that empower enthusiasts and professionals alike. His popular DIY projects, such as his custom power bank tutorial, have inspired countless viewers to engage with electronics.
*www.youtube.com/@greatscottlab*

**Max Imagination** brings a creative, artistic approach to his projects, blending engineering with innovation. His channel features unique builds such as custom robots and 3D-printed gadgets, making complex ideas accessible.
*www.youtube.com/@MaxImagination*

**DIY GUY Chris** simplifies advanced electronics through step-by-step guides on topics like LED displays and CNC machines, encouraging beginners to take on new challenges. He will also hold a soldering competition on our electronica Fast Forward Streaming Stage. Don't miss out.
*www.instagram.com/diyguychris*

Attendees can meet the influencers at the Elektor booth, where they will offer live demos, lead Q&A sessions, and more. Their presence adds a dynamic layer to the event, amplifying the reach and impact of the innovations on display.

## Experts Talk Live / Elektor Lab Talk

Each afternoon (Tuesday to Thursday) at the Elektor booth, Elektor editor Brian Tristam Williams and his colleagues will interview a range of experts, such as Peter Dalmaris, who will talk about the latest version KiCad, the popular open-source ECAD software solution. If you cannot attend electronica in person, you can watch our interviews and Lab Talk shows at *https://www.youtube.com/@ElektorTV*. See the **Timetable** above for details.

Katja Stolle

Exhibition Director, electronica

Caroline Pannier

Deputy Exhibition Director, electronica

# electronica: 60 Years and Still Growing!

## Shaping the Future of Electronics Through Decades of Innovation

electronica has been a driving force in the electronics industry for six decades. Event leaders share the story of its rise to prominence and give a glimpse into the future of electronics that will be on display at the 2024 edition. This year, the show is celebrating its 60th anniversary and will be bigger than ever before. For the first time, all 18 halls of the Munich fair will be utilized. In this short interview, Katja Stolle (Exhibition Director electronica) and Caroline Pannier (Deputy Exhibition Director electronica) are talking about 60 years of electronica and beyond.

**Elektor: What was electronica's mission when it first launched 60 years ago? Has the essential mission changed since then?**

**Katja Stolle:** While electronica's core mission — to showcase innovations and promote industry collaboration — has remained the same over the past 60 years, its focus has broadened significantly. In 1964, the event started as the first trade fair in Germany devoted exclusively to electronic components, while it already had an international focus. Over the following years, electronica grew steadily and quickly became the most important meeting place for the international electronics industry. Today, we provide a platform to showcase the complete spectrum of technologies, products and solutions from the entire electronics industry, to connect people from all over the world and to highlight the latest trends, thus driving innovation and growth in the industry.

**Elektor: Numerous technological milestones were first presented at electronica. Which innovations have had the most lasting impact on both the industry and the world at large?**

**Caroline Pannier:** Over the past decades, electronica has been the stage for a number of technological milestones. These include, for example, the introduction of microprocessors in the 1970s, the development of mobile communications in the 1980s and 1990s, and the rapid advances in digitalization in the 2000s with the spread of the wireless internet. These innovations have had lasting and transformative impacts on the world, from making electronics smaller, faster, and more efficient, to enabling whole new industries such as IoT, autonomous vehicles, and smart cities. These breakthroughs continue to shape the future of technology in virtually every sector.

**Elektor: As we look forward to the next few years of technological advancement, which emerging technologies do you anticipate will dominate future editions of electronica?**

**Katja Stolle:** In the years to come, electronica will continue to serve as a global stage for the latest innovations that are driving the electronics industry forward. These include several technologies that are likely to continue to play a dominant role in future editions of electronica, such as artificial intelligence and machine learning, or sustainable electronics with a broad focus on energy efficiency, recyclability and waste reduction.

**Elektor: This year, in celebration of its anniversary, the trade show will spotlight the theme of an all-electric society. Tell us more about the decision to focus on this topic and what attendees can expect to see at the event from November 12–15, 2024.**

**Caroline Pannier:** The All Electric Society (AES) describes a vision of the future in which all energy needs are met by CO2-neutral electricity. It is a concept that aims to combat climate change while securing energy supplies. We have chosen it as the motto for this year's electronica in close collaboration with the industry. The AES and sustainability will be recurring themes throughout the exhibition and supporting program. In addition to showcasing sustainable technologies at the booths, there will be various presentations, and a number of special events dedicated to this topic. For example, a day-long program of lectures and panel discussions by the green leaders network, or an individual tour supported by the German Electro and Digital Industry Association (ZVEI), where visitors can experience the contribution of selected exhibitors to the AES live at their booths.


### Two Live Influencer Forums

At electronica 2024 in hall B4.131, Elektor will be moderating two informative forums: a discussion about smart influencer marketing (Thursday, November 14) and a discussion for students about the process of becoming electronics influencers (Friday, November 15). The first forum, "The Future is Now: How to Incorporate Smart Influencer Marketing for Your Company," will feature a discussion with influencers whose combined reach exceeds 2 million followers, focusing on the power of influencer marketing in the electronics industry. The second forum, "The Future is Now: How to Become an Influencer in Electronics," will be aimed at students and young engineers, offering them insights into building a career as an influencer in the field of electronics. Both events will feature a professionally moderated panel discussion.

240566-01

# 10 MHz Reference Generator

## Highly Accurate, With Distributor and Galvanic Isolation

**By Alfred Rosenkränzer (Germany)**

In complex measurement setups where frequencies and times must be accurately recorded and precisely correlated, the measuring devices should operate in near synchronization. They are synchronized using a highly accurate reference frequency. This article explains the construction of such a reference generator.

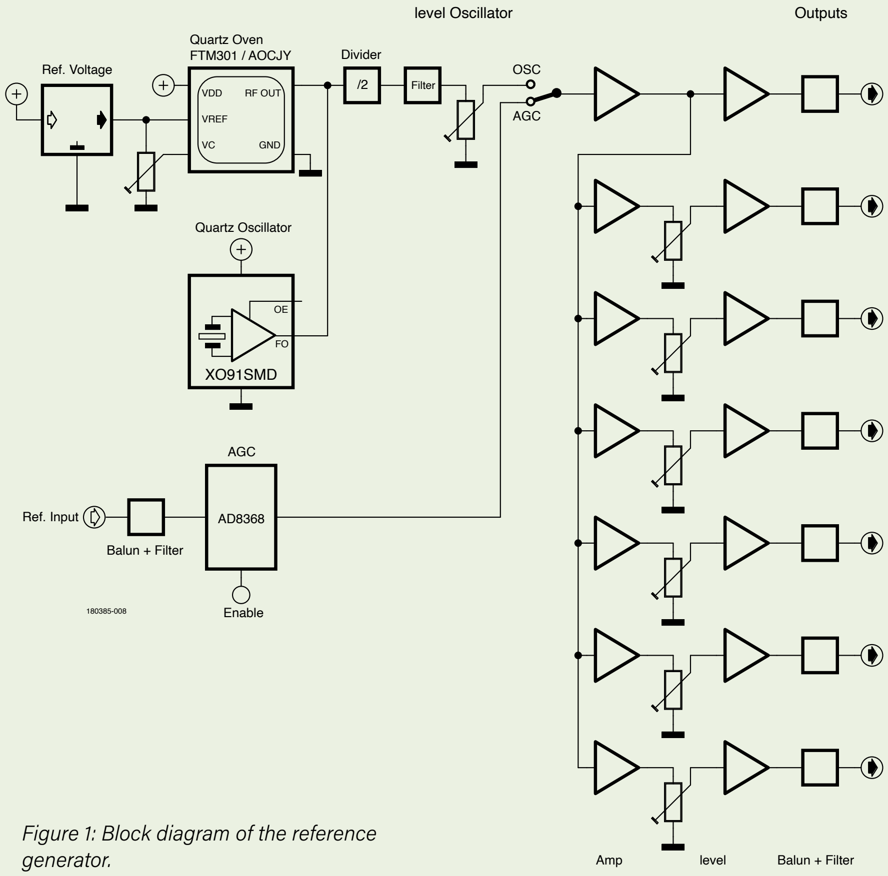



*Figure 1: Block diagram of the reference generator.*

If there are no conflicting reasons, the device with the most accurate time base is declared the master in such measurement setups and its output signal serves as a reference for the other devices. The signal distribution can be implemented in the form of a "daisy chain," for example, in which each device passes the reference frequency at its input through to its output, creating a serial chain. The alternative is a star connection using a distribution amplifier, so that several reference signals are available in parallel. A frequency of 10 MHz has been established as standard reference.

### Ground Issues

A frequently encountered problem in such measurement setups are ground loops, which can severely interfere with sensitive measurements. Background: The grounds of the input and output sockets are connected to the protective earth (PE) of the mains socket, the plug connectors of the data interfaces (GPIB, USB) and the grounds of the sockets of the reference signals. Magnetic interference fields can couple into the resulting ground loops or equalizing currents can flow; the useful signals are thus impaired by unwanted interference signals.

For reference signals, ground loops can be prevented by galvanic isolation using HF transformers. Such transformers are available in small housings with BNC connectors, for example from Mini-Circuits. For a daisy chain arrangement, they must be inserted between each pair of devices. When using a distributor, such a transformer is inserted between the distributor and each reference input of a measuring device. Distributors with integrated RF output transformers for simplified, ground-free connection of measuring devices do not seem to be available on the market at present. This shortcoming inspired me to develop a reference generator that is not only equipped with a high-precision, heated oscillator, but also offers several ungrounded outputs.

### Basic Circuit

A block diagram of the generator circuit is shown in **Figure 1**. The generation of the 20 MHz base clock can be seen at the top left, with a simple quartz oscillator or a more complex, calibratable oven-controlled crystal oscillator (OCXO). After halving to 10 MHz and filtering, the reference frequency is ready for buffering and distribution (right-hand side).

## Component List

**Resistors**
SMD 0603, unless otherwise specified
R1, R3, R9, R53, R309, R314, R315 = 10k
R2, R310 = 4k7
R4 = 820 Ω
R5 = 0 Ω, SMD 2012 *
R6, R7 = 1k2
R8, R14, R52, R64, R75, R86, R97, R108, R123 = 390 Ω
R10, R17 = 100 Ω
R11, R18, R54, R57, R58, R61, R63, R66, R69, R72, R74, R77, R80, R83, R85, R88, R91, R94, R96, R99, R102, R105, R107, R110, R115, R118, R121, R124, R126, R129, R130 = 50 Ω
R13, R67, R68, R78, R79, R89, R90, R100, R101, R111, R112, R113, R114, R119, R120, R307, R308, R318 = 0 Ω *
R15 = 130 Ω
R16 = 2k5, multi-turn trim pot, vertical, RM 1/10"
R25 = 1k
R50 = 120 Ω
R51 = 200 Ω, multi-turn trim pot, vertical, RM 1/10"
R55, R56, R60, R65, R71, R76, R82, R87, R93, R98, R104, R109, R116, R117, R122, R127 = 470 Ω
R59, R70, R81, R92, R103, R128 = 330 Ω
R62, R73, R84, R95, R106, R125 = 500 Ω, multi-turn trim pot, vertical, RM 1/10"
R301, R306 = 150 Ω
R302, R305 = see text
R303, R304 = 75 Ω
R311...R313 = 10 Ω, SMD 2012
R316 = 68 Ω
R317 = 180 Ω

**Capacitors**
SMD 0603, unless otherwise specified
C1 = 4,700 µ / 16 V, electrolytic, RM 5 mm, ø 13 mm *
C2, C4, C8...C11, C19...C22, C34, C35, C51...C54, C56...C65, C82, C83 = 100n
C3, C5, C12...C18, C33, C36...C40 = 22µ / 20V, SMD SMCB
C6, C7 = 2,200 µ / 16 V, electrolytic, RM 5 mm, ø 13 mm
C23, C32 = 33p
C24 = 120p
C25, C90 = 5p6
C26 = 10p
C27 = 150p
C28, C31 = 100p
C29 = 12p
C30 = 39p
C66, C68, C70, C72, C74, C76, C78, C87 = 47p
C67, C69, C71, C73, C75, C77, C79, C88 = 3p3
C81, C89, C94 = 10n
C84...C86, C91..C93 = 1n

**Inductors**
All SMD 1210
L1...L7, L301 = 4µ7
L8 = 1µ8
L9 = 1µ5

**Semiconductors**
D1...D4 = SK56, Schottky, 60 V / 5 A, DO214AA *
D5...D8 = SK56, Schottky, 60 V / 5 A, DO214AA
D9, D10 = SK540, Schottky, 40 V / 5 A, DO214AC
D31 = 1N4148, SOD-123
LED1...LED3 = LED, SMD 0805
T1...T2 = 2N3904, SOT23-BEC
IC1 = 7805
IC2 = 7905
IC3 = LT1963AET-3.3 *
IC4...IC11 = MAX4392ESA, SOIC8
IC6 = MCP1525TT, SOT-23-3 *
U1 = AD8368ACPZ-WP, LFCSP-24 *
U2 = SN74LVC1G80DBVR, SOT-23-5 *
Y1 = AOCJY-20.000MHZ-F, SMD *
XO1 = XO91, 20 MHz, SMD *

**Miscellaneous**
X1 = 2-pin screw terminal, RM 5 mm
X5 = 3-pin screw terminal, RM 5 mm
JP1, JP2 = 2-pin header
Tr1 = transformer 2× 6 V, 2 x 300 mA, RM 20 mm, PCB mounting *
Tr3 = transformer 2× 6 V, 2 x 233 mA, RM 27.5 mm, PCB mounting
Tr51...TR81 = ADT1-1, RF transformer, SMD *
F1 = fuse 250 mA, 20× 5 mm
Fuse holder for F1, PCB mounting
K1 = relay FTR-B4S, SMD

* See text

Alternatively, the circuit can also be used simply as a distribution amplifier. If you have a high-quality external reference frequency available, you can feed it into the reference input at the bottom left. After amplitude stabilization by a special RF amplifier (AGC), this signal is fed to the distribution amplifier bank on the right as a reference.

## Circuit

As you can see in the circuit in **Figure 2**, the digital and analog parts are supplied separately. The clock generation is supplied by the 3.3 V power supply around Tr1 and IC3. The heating of an optional OCXO is also fed from this branch. Its configuration ensures that an accurate and low-drift reference frequency is obtained.

The analog amplifiers are supplied symmetrically with ±5 V from Tr3 and the two classic voltage regulators IC1 and IC2. To ensure clean voltages, a large number of small decoupling electrolytic capacitors, each with 22 µF and 100 nF multilayer capacitors, are distributed across the circuit. The level stabilization of an external reference signal via AGC takes place via the +5 V branch, with small RC filters (R311/C85 and R312/C84) included. Two LEDs on the circuit board indicate that the system is ready for operation. An additional LED can be mounted on the front panel. When all output stages are fitted, a current of around 180 mA flows in the ±5 V branch.

### Oscillators

A high-precision, heated quartz generator of type FTM301 from FOX or, for example, type OH300-50503CF-020.0M [1] from

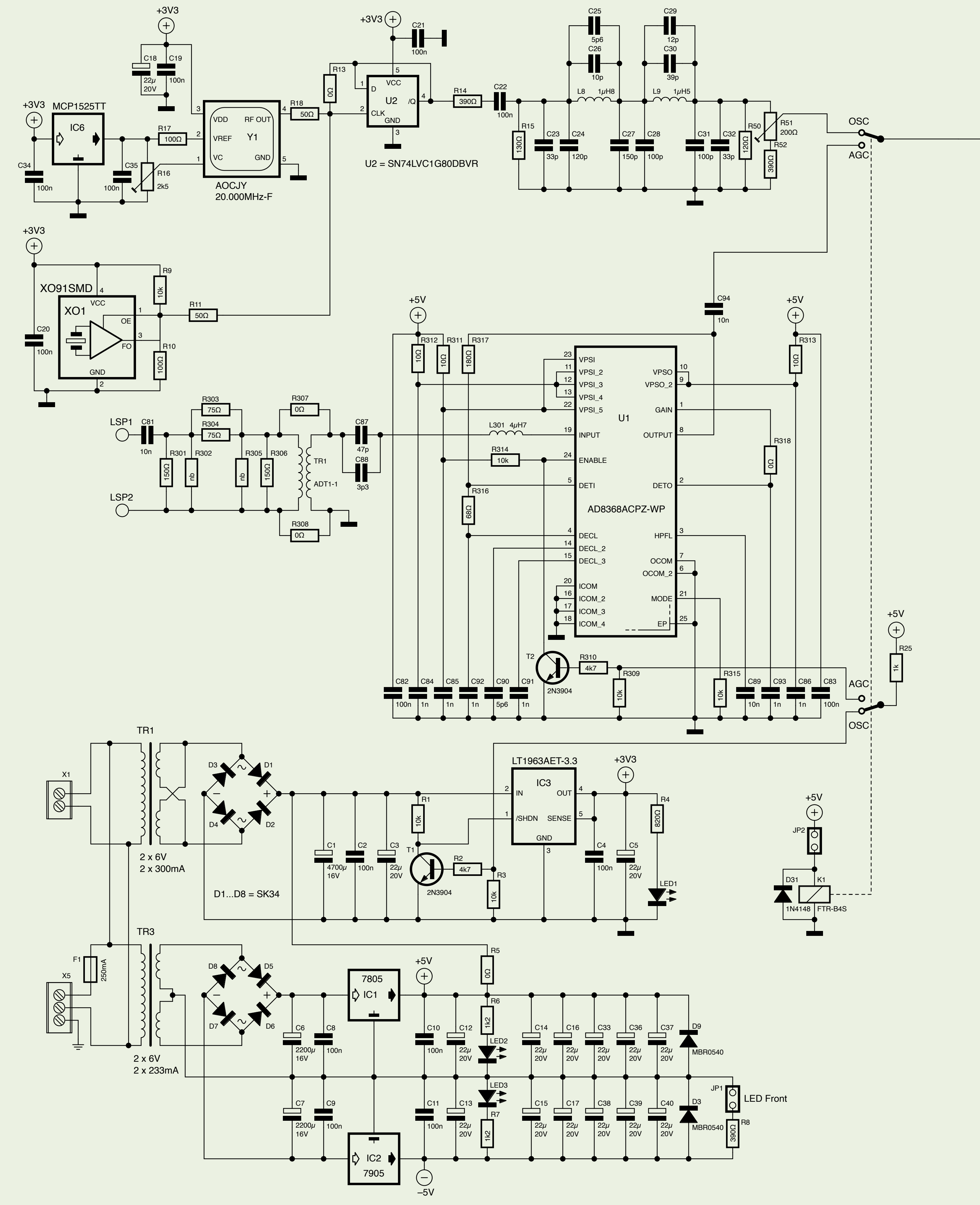
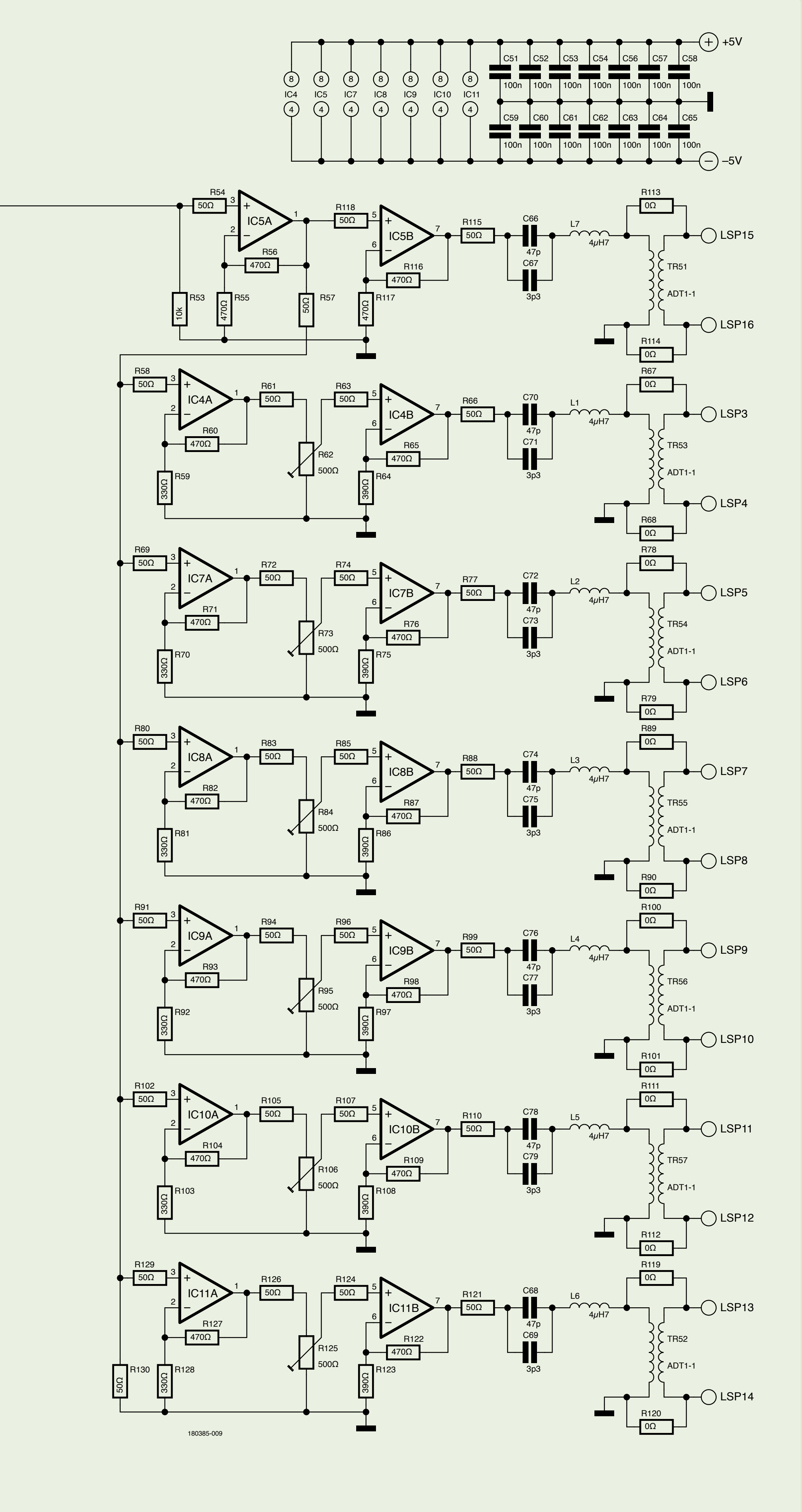



*Figure 2: The detailed circuit of the reference generator is somewhat more extensive, but the seven output amplifiers are constructed in the same way.*




Connor-Winfield (Y1 in Figure 2) is used as the oscillator. For lower quality requirements, a simple 20 MHz quartz oscillator (XO1 in Figure 2, [2]) is also sufficient. Of course, only one of the two alternatives has to be fitted. If Y1 is fitted, the circuit will draw up to 800 mA from the 3.3 V branch for a few seconds after switching on during heating. The current is then reduced to approx. 350 mA.

The frequency of Y1 can be influenced to a small extent via input VC (pin 1) with a control voltage of 0…2.5 V generated by IC6 and adjustable with R16. If XO1 is fitted instead of Y1, IC6 and the trimming potentiometer R16 can be omitted. Some oscillators contain their own reference voltage, which can be tapped at pin 2. In this case, IC6 can be omitted and R17 can be fitted instead. For oscillators without their own reference voltage, IC6 must be fitted and R17 can be omitted. The reference frequency can be calibrated with R16, which of course requires a suitable and, above all, highly precise external reference frequency.

If absolute accuracy is not very important, the simple and inexpensive XO1 crystal oscillator in an XO91 housing will also do. Once again: Only one oscillator is to be fitted — either Y1 or XO1. Due to the lower current consumption, no extra transformer TR1 is required for XO1 and the rectifier from D1...D4 is also omitted. Instead, R5 is fitted to derive the required 3.3 V from the 5.5 V branch. R11 is fitted when XO1 is used and R18 when Y1 is used.

In order to achieve an optimum duty cycle of 50% of the 10 MHz signal, the 20 MHz of the primary clock generator is divided by a D flip-flop. An alternative is to fit 10 MHz generators, which means that U2 is omitted and its input is connected to the output pin by fitting R13. The 10 MHz signal is then freed from harmonics by a passive fifth-order Cauer low-pass filter around L8 and L9, turning the rectangular signal into a sine wave. The cut-off frequency of the filter is 11 MHz, its ripple is only 0.1 dB, and the input and output impedance is 100 Ω. The voltage divider R14/R15 reduces the input signal, and C22 removes the DC voltage components (= half the operating voltage).

R50, R51, and R52 terminate the output of the filter. The amplitude can be adjusted with trim

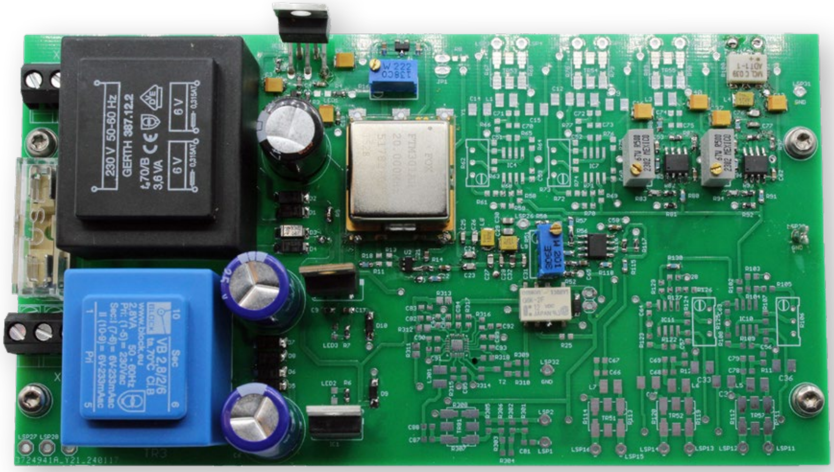


Figure 3: The partially assembled circuit board of the prototype.

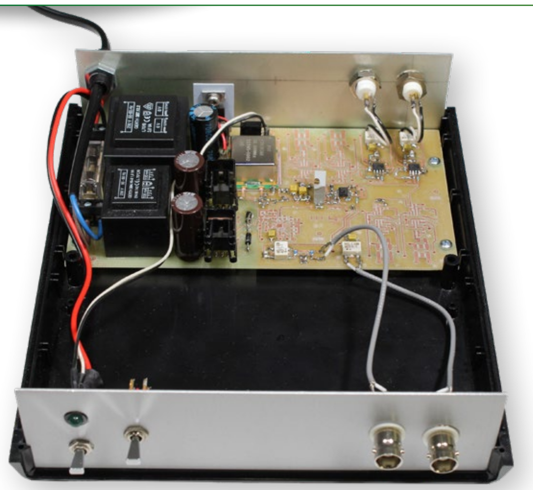


Figure 4: A partially assembled circuit board installed in a Teko housing.

pot R51 and adapted to the input level range of the AGC. The relay K1 and a switch on the front panel can be used to select between the signal from the internal generator and the reference input.

**Distribution Amplifier**

IC5A amplifies the signal by a factor of 2 and distributes it to six of the seven output stages via a line terminated with 50 Ω (R130) to avoid reflections on the PCB traces and to achieve as equal a level as possible at all inputs of the seven output stages. The 50 Ω resistor of these stages is used to decouple the input capacitance of the op-amps installed there. Six of these stages are fitted with two video op-amps each. The amplitudes of these six channels can be individually adjusted with their 500 Ω trimpots.

The second op-amp of IC5 drives a serial bandpass filter consisting of the two parallel-connected capacitors C66 and C67 plus the coil L7 and finally the HF transformer Tr51 of type ADT1-1 [3] via a 50 Ω resistor. This output stage has no trimmer potentiometer and its output voltage is therefore not adjustable.

Generally speaking, if you don't need galvanic isolation, you can leave out the HF transformers Tr51 to Tr57 and fit two 0-Ω resistors instead. In my prototype, I used MAX4392ESA [4] op-amps in a SOIC8 package. However, you can also use other video amplifiers that are suitable for a power supply of ±5 V. With galvanic isolation and a metal front/rear panel, it is obviously necessary to ensure that the BNC sockets are insulated!

**Reference Input and AGC**

An AGC IC of type AD8368 [5] from Analog Devices (U1) is used for this subcircuit. The wiring in Figure 2 corresponds to the recommendation in the data sheet. In order not to overdrive the input, an attenuator of 6 dB is connected before the HF input transformer Tr81. If galvanic isolation is not required, the transformer can also be omitted here and replaced by the two resistors R307 and R308. Level stabilization via AGC works with input signals between 70 and 2,000 $mV_{SS}$ at 50 Ω. Lower input levels will reduce the output level — higher input levels will increase it.

## Power Supply

After switching on the circuit with a cold OCXO, significantly more current flows than later in the tempered state. For this reason, a relatively powerful transformer with Schottky diodes and a large filter capacitor is provided. The stabilized 3.3 V is generated by the LT1963AET-3.3 low-drop regulator (Analog Devices). The regulator must be cooled. For this purpose, it can be screwed onto the rear wall of an aluminum housing with insulation. Its output voltage can be switched off via the shutdown input if you want to use the external reference frequency and operate the circuit as a distribution amplifier only. This measure prevents interference between the internal generator signal and the external reference signal. Relay K1 is controlled by a switch on the front panel, which is connected to JP2. A changeover contact of the relay selects the input signal for the distribution amplifier. The other contact controls the SHDN input of IC3 via T1 and the ENBL input of the AGC via T2.

One more note on the design: Good thermal insulation of the OCXO will reduce its power consumption. It has reached its maximum accuracy after 30 minutes at the latest.

## Fitting Options

As has already become clear, the circuit board provides for several fitting options. The optional components are marked with an asterisk in the parts list. For the sake of clarity, the fitting options are specified here once again:

**OCXO or Simple Quartz Generator**

For the OCXO Y1, Tr1, the diodes D1…D4, and C1 must be fitted. R5 is omitted. For XO1, Tr1, D1…D4 and C1 are omitted. R5 is fitted instead.

**Oscillator with 20 or 10 MHz**

For 20 MHz oscillators, the divider U2 must be fitted. R13 is omitted. For 10 MHz oscillators, U2 is omitted. R13 must be fitted.

**Reference Voltage of the OCXO**

If the OCXO has an internal reference voltage source, IC6 is not required and R17 must be fitted. Without an internal reference voltage source, IC6 is required. R17 should not be fitted in this case.

**Internal or External Frequency Generation, or Both**

It is possible to equip only the internal oscillators or only the input for an external reference with AGC, or both parts. When using an internal generator, the AGC is switched off. When using the external input with AGC, the 3.3 V power supply and thus the oscillators and the divider are switched off.

### Galvanic Isolation

If galvanic isolation is not required, the RF transformers can be omitted. In this case, the two 0 Ω resistors per transformer must be fitted to bridge them. In this case, the correct polarity must be observed when connecting the BNC sockets.

### R302 and R305

These resistors are used to achieve an exact resistance value by connecting them in parallel with R301 and R306. The specified values of R301 and R306 are accurate enough for the attenuation of 6 dB envisaged here. R302 and R305 can therefore be omitted.

## Construction

**Figure 3** shows the partially assembled board, the layout files of which can be downloaded free of charge in Eagle format from the Elektor website [6]. **Figure 4** shows a board installed in a plastic case with metal front and back panels. As already mentioned, the BNC sockets should be installed with galvanic isolation. The reference generator described in this article is versatile, very accurate, and avoids ground loops in complex test setups. By the way, some empty boards are still available from the author.

*Translated by Jörg Starkmuth* — 180385-01

*Editor's note: This article first appeared in Elektor May/June 2024.*

### Questions or Comments?

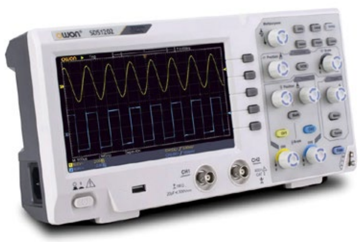
Do you have questions or comments about this article? Email the author at alfred_rosenkraenzer@gmx.de, or contact Elektor at editor@elektor.com.

### About the Author

Alfred Rosenkränzer worked for many years as a development engineer, initially in the field of professional television technology. Since the late 1990s, he has been developing digital high-speed and analog circuits for IC testers. Audio is his private hobbyhorse.

### Related Products

- **JOY-iT JDS6600 Signal Generator & Frequency Counter**
  www.elektor.com/18714
- **OWON SDS1202 2-Channel Oscilloscope (200 MHz)**
  www.elektor.com/20251

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[3] HF Transformer datasheet [minicircuits.com]: https://tinyurl.com/4fzxkfky
[4] MAX4392 datasheet: https://analog.com/en/products/max4392.html
[5] AD8368 datasheet: https://analog.com/en/products/ad8368.html
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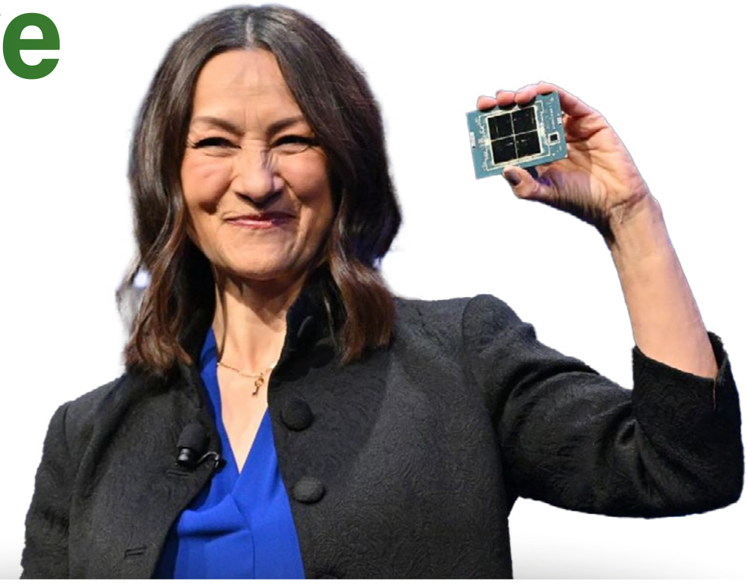
# CEO Interview: Sandra Rivera of Altera on the move to Intel 18A



Sandra Rivera, Altera CEO (Source: eeNews Europe)

**By Nick Flaherty (eeNews Europe)**

The spinning out of Altera from Intel is opening up key decisions for process technology over the next few years. Sandra Rivera, CEO of the Programmable Solutions Group (PSG), talks about the plans going forward.

"Everything is requiring more and more compute," Sandra Rivera at Altera tells *eeNews Europe*. "The defence sector and aerospace are growing in the US, Europe and India, we see growth in automotive, smarter vehicles, autonomous driving, robotics, industrial, manufacturing, wireless from 5G Advanced and 6G, and AI, AI, AI. Every application and market segment will have some AI. AI will add $3bn by 2028 for FPAGs on a $10bn market."

This is driving demand for higher performance and higher density with lower power consumption, which is leading to the next-generation process technologies. As an Intel company [1], Altera is naturally in line for the 18A process to be offered by Intel Foundry Services. This could also ensure that FPGAs are produced in the US to minimise supply chain issues that hit the company hard during the pandemic [2],[3].

"Our next-generation products will be on a new process node, and we are looking at all the process technologies and the next one that looks really appealing is 18A," she said.

"One of the things we value about the relationship with Intel is tapping into the technology which will be over time remain the majority owner."

Agilex 5 is based on the 7nm Intel 7 process, but Altera has traditionally developed its Cyclone and other FPGAs on TSMC process technology. "TSMC will be a critical partner for years to come with the 2040 commitments," she said.

"We get to make the best process node decision for our customers and we are happy to be on Intel for many products but TSMC will continue to be a great partner. Having run the datacentre and AI business with the Xeon I've seen all the products being introduced with Intel 3. The next generation will be 18A in 2025 so the FPGAs will not be the first. That means the IP will be quite robust by the time we need to make a decision later this year."

The innovations in backside power for 18A in reducing power consumption and improving density are important in the decision [4].

"Sith backside power you get real performance per watt in our fabric which we have today but if you think about what you get with process on your side it's quite attractive," she said.

The company is seeing the FPGA market pick up later this year, largely as a result of the drive for AI but also for automotive.

"Our market for FPGAs is really great, the end user demand is strong but the challenge is there was so much inventory building during the pandemic and the anxiety for customers and that is through H1."

"In automotive we are recommitting to this part of the portfolio with Agilex 3 with power and cost constrained devices, and we will refresh the Max and Cyclone lines [5]."

A key move was to make the Quartus design tools free to users.

"The way to unlock the innovation is ease of use so a lot will be software, it's the software, stupid," she said. "So much of what we are showing in not just the Agilex 5 and Agilex 7 but reference designs and boards with software that is built on Quartus Prime Pro. The time to value can be accelerated if you use a reference design or system on module and that's what we invest in with our channel."

The company will develop AI models but is not aiming to be a supplier.

"We will go as far as we need to go to show the art of the possible, demonstrating how you would implement a robotics application, a broadcast application, but only to show all the pieces are there. That's why you have to invest in the channel as you have to package this up. We go as far as the frameworks," she said.

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**Editor's Note**
*eeNews Europe* first published this article on April 19, 2024. Visit *www.eenewseurope.com* for more news and interviews.

*Altera is naturally in line for the 18A process to be offered by Intel Foundry Services. This could also ensure that FPGAs are produced in the US to minimise supply chain issues that hit the company hard during the pandemic.*

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# Digital Load for High-Current Testing

## From Necessity to Innovation

By Saad Imtiaz (Elektor)

Ever found yourself in the middle of a project only to realize you don't have the right equipment? That's exactly where I was — needing to push my AmpVolt Power Meter to its limits but lacking a DC load beyond 2 A. But what do you do when you're short on time and resources? You innovate! With this MOSFET-based setup, I can reach about 8 A and beyond.

In every engineering workspace, the importance of testing equipment cannot be overstated. It's often the difference between "good enough" and perfection. High-quality testing gear ensures that the designed hardware is living up to its expectations and performing under various conditions, meeting the high standards expected in modern electronics. But if one doesn't have the test equipment at hand, and time is short, or they simply want to test it without any delays, then one might have to create their own solution. This is the exact situation I had to face when I needed to test the limits of the AmpVolt Power Meter [1], and I didn't have a load capable of reaching beyond 2 A. This limitation led me to develop a small but effective solution that can be used when a proper DC load isn't available.

Whenever we mention the term "load" in electronics, a resistive load is often the first thought. However, the concept of a digital load introduces significant advancements over traditional resistive options, particularly beneficial in contemporary testing environments. Digital loads leverage power semiconductors such as MOSFETs, IGBTs, and BJTs, etc. to dynamically adjust to varying electrical conditions, facilitating the precise simulation of electrical behaviors without the need for manual adjustments. This ability streamlines testing processes and enhances accuracy. Additionally, digital loads can integrate measurement and data logging capabilities, coupled with efficient thermal management and built-in safety features.

### The Circuit

The schematic diagram is shown in **Figure 1**. The choice of the IRF3205 MOSFET [2] was deliberate. With a 55-V threshold and a 110-A current

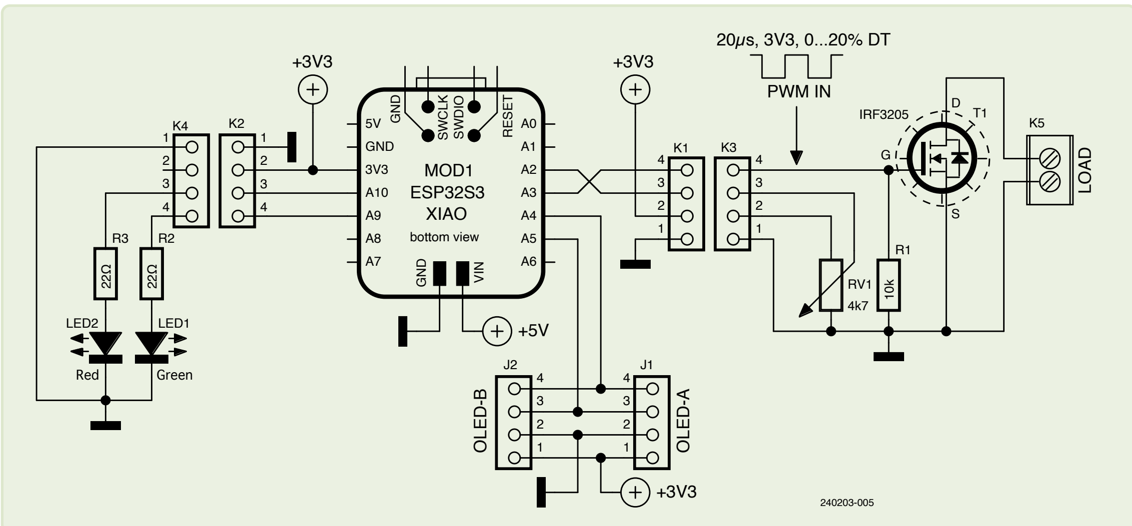


*Figure 1: Schematic diagram of the project.*

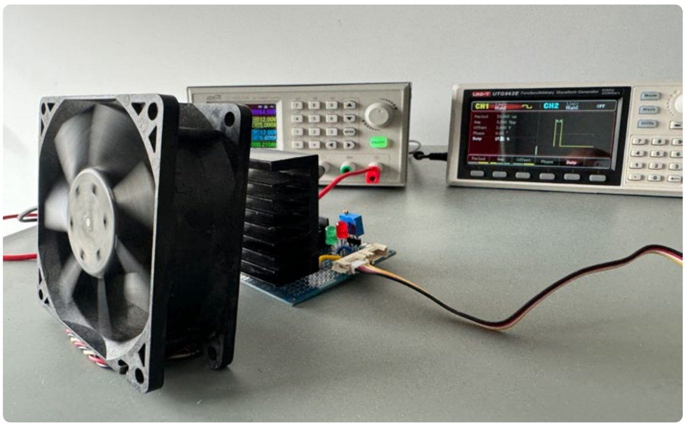

*Figure 2: Test setup, with using a function generator to control the circuit via PWM.*

rating, it's able to handle tough tests without hesitation. With a heat sink, it can consistently dissipate heat, despite the stringent demands of continuous power dissipation.

Central to the design is the small XIAO ESP32S3 [3] microcontroller breakout board from Seeed. To simplify prototyping, I used a very compact extension board for this XIAO module. (Meanwhile, we developed our own Elektor XIAO extension board, see [4].) At such an extension board, the GPIOs at the pin headers of the XIAO board are wired to Grove connectors, which always feature a pin for GND, a pin for 3.3 V, and two input/output/bus pins. You can see these connectors in the circuit diagram as K2, K1, J1 and J2, the latter two one are dedicated for I2C.

K2/K4 connect with each other to control LED1 and LED2, which are used to indicate the operational status and provide visual feedback for the load condition. K1/K3 are utilized with a PWM output pin switching the MOSFET, and an analog input pin sensing the potentiometer value. With that potentiometer it is possible to let the firmware adjust the PWM duty cycle, delivering granular modulation of the load.

R1 is a pull-down resistor between the gate and source of the MOSFET, ensuring the gate is properly discharged when the PWM signal is off, preventing unintended switching.

The schematic for the digital load includes options for future enhancements, such as an OLED display and a current sensor. However, to maintain simplicity in the initial design, a potentiometer is utilized for straightforward manual control of the load settings. This approach allows for basic operation while keeping the door open for more complex functionality to be integrated later.

## Test Setup

I made a test with the right part of the circuit, inserting a PWM signal coming from a wave generator at pin 4 of K3. A digital power supply was hooked up with the K5 connector, with the source of the T1 connected to the negative terminal and the drain of T1 connected to the positive terminal of the power source . After that PWM wave was applied to the gate with a period of 20 µs with 3.3 Vpp amplitude and 3% to 50% duty cycle, and I measured the current going through the MOSFET with the digital power supply and a multimeter.

On about 21.3% duty cycle, the electronic load was close to 4.9 A, as seen in **Figure 2**. Further increasing the duty cycle can increase the current flow, but this also leads to high case temperature, reaching 70°C, without any active cooling, so it's recommended that we use a bigger a heat sink with active cooling. Using two or more MOSFETs in parallel can also to increase the current limit and reduce high temperatures.

## Software

The firmware was built on Arduino IDE, designed to control a PWM signal using an ESP32, with a potentiometer to adjust the duty cycle and LEDs to indicate the system's state (**Listing 1**). It begins with defining the necessary pins for the potentiometer, PWM output, and LEDs, as well as setting PWM parameters, including a 50 kHz frequency, 8-bit resolution, and a maximum PWM value of 255. In the setup function, the Serial interface is initialized for debugging, and the LED pins are configured as outputs. The PWM is set up on the specified pin with the defined frequency and resolution. Initially, the code reads the potentiometer's position and checks if it exceeds the minimum voltage threshold. If so, the red LED lights up, and the system waits for the user to adjust the potentiometer to its minimum value.

In the main loop, the code continuously reads the potentiometer value, converts it to a voltage, and maps this voltage to a PWM duty cycle ranging from 0 to 50% of the maximum PWM value. This duty cycle is then written to the PWM pin. The green LED is turned on to indicate normal operation. Additionally, the code prints debug information, including the duty cycle percentage and potentiometer voltage, to the Serial Monitor. In **Figure 3** you can see the project in action, adjusting the load based on the potentiometer setting.

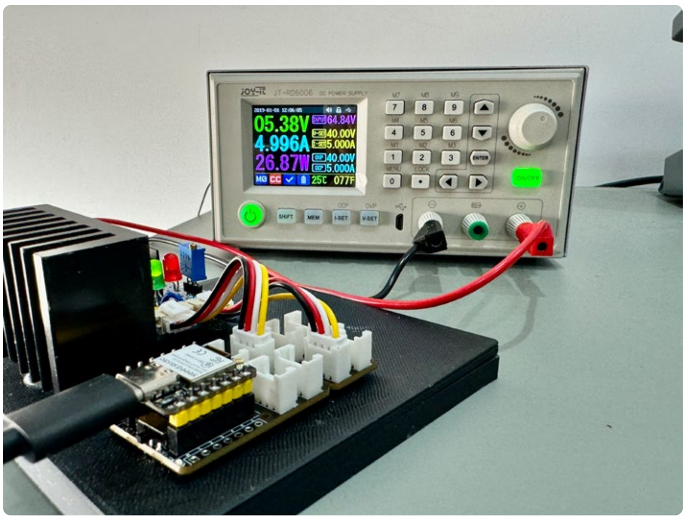

*Figure 3: The ESP32 digital load is hooked up to a power supply, measuring and controlling the current.*

For those interested in replicating or customizing this project, all the code and schematics are shared on GitHub [5]. This provides you with all the necessary resources to get started and adapt the electronic load to your specific requirements. As we are using a ESP32, it unlocks the ability to control the digital load wirelessly, by running a web server on the ESP32 to control the digital load via web interface over Wi-Fi, or even through the internet remotely. Possibilities are endless!

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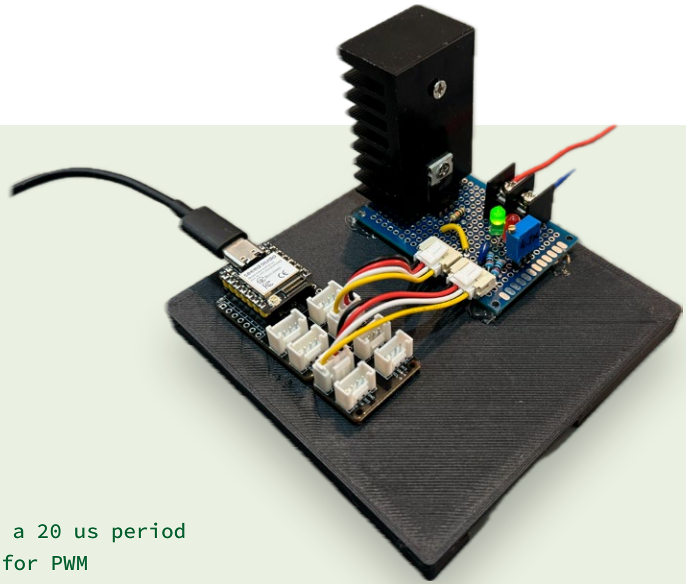
*Editor's note: This article first appeared in Elektor Circuit Special 2024.*



## Listing 1: Basic firmware.

```
#include <Arduino.h>

// Pin definitions
#define POT_PIN 3
#define PWM_PIN 2
#define RED_LED_PIN 9
#define GREEN_LED_PIN 8

// PWM parameters
const long pwmFrequency = 50000; // 50 kHz to achieve a 20 us period
const uint8_t pwmResolution = 8; // 8-bit resolution for PWM
const uint8_t maxPwmValue = 255; // Maximum value for 8-bit resolution PWM

// ADC and Voltage settings
const float referenceVoltage = 3.3; // ADC reference voltage in volts
const int adcMaxValue = 4095;       // Maximum ADC value for 12-bit resolution
const float minimumVoltage = 0.1;   // Minimum voltage threshold to start PWM

void setup() {
  // Initialize Serial for debug output
  Serial.begin(9600);

  // Set up LED pins
  pinMode(RED_LED_PIN, OUTPUT);
  pinMode(GREEN_LED_PIN, OUTPUT);

  // Initialize PWM on pin
  ledcSetup(0, pwmFrequency, pwmResolution);
  ledcAttachPin(PWM_PIN, 0);

  // Check initial position of the potentiometer
  float initialVoltage = (analogRead(POT_PIN) * referenceVoltage) / adcMaxValue;
  if (initialVoltage > minimumVoltage) {
    digitalWrite(RED_LED_PIN, HIGH); // Turn on red LED
    digitalWrite(GREEN_LED_PIN, LOW); // Make sure green LED is off
    while ((analogRead(POT_PIN) * referenceVoltage / adcMaxValue) > minimumVoltage) {
      // Wait for the user to adjust the potentiometer to minimum
      delay(100); // Delay to avoid excessive reading
      Serial.println("Adjust potentiometer to minimum to start.");
      Serial.println((analogRead(POT_PIN) * referenceVoltage / adcMaxValue));

    }
  }
```

```
    // Potentiometer is at minimum value, proceed with normal operation
    digitalWrite(RED_LED_PIN, LOW);
    digitalWrite(GREEN_LED_PIN, HIGH);
  }

  void loop() {
    // Read the potentiometer value and convert to voltage
    float potVoltage = (analogRead(POT_PIN) * referenceVoltage) / adcMaxValue;

    // Calculate the PWM duty cycle (0 - 50% of maximum PWM value)
    int pwmDutyCycle = map(potVoltage * 1000, 0, referenceVoltage * 1000, 0, 128);

    // Set the PWM duty cycle
    ledcWrite(0, pwmDutyCycle);
    digitalWrite(GREEN_LED_PIN, HIGH);
    // Debug output to Serial Monitor
    Serial.print("Duty Cycle: ");
    Serial.print((float)pwmDutyCycle / maxPwmValue * 100);
    Serial.println("%");
    Serial.print("Potentiometer Voltage: ");
    Serial.print(potVoltage);
    Serial.println(" V");
  }
```


## About the Author

Saad Imtiaz (Senior Engineer, Elektor) is a mechatronics engineer with experience in embedded systems, mechatronic systems, and product development. He has collaborated with numerous companies, ranging from startups to enterprises globally, on prototyping and development. Saad has also spent time in the aviation industry and has led a technology startup company. At Elektor, he drives project development in both software and hardware.


## Questions or Comments?

If you have questions about this article, feel free to email the author at saad.imtiaz@elektor.com or the Elektor editorial team at editor@elektor.com.

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eeNews EUROPE

# Trust in Rust

*Fabrice Derepas, Cofounder & Chief Evangelist of TrustInSoft (Source: eeNews Europe)*

**By Nick Flaherty (eeNews Europe)**

Static analysis tools will be help the development of embedded systems using the Rust language, says Fabrice Derepas, Cofounder and Chief Evangelist of TrustInSoft in Paris, France.

C and C++ continue to dominate the embedded-systems landscape. But developers are equally aware of the way in which the use of these languages can lead to problems during development. Their treatment of pointers and similar objects can lead to serious memory-safety issues.

Rust offers a similar syntax but shows great promise as a language that provides much of the flexibility of these older languages but with much stronger guarantees of safe operation. Rust uses elements pioneered in functional languages and other advanced concepts that are now taught to young software developers at college.

But an important factor behind the growth in Rust support is that it overcomes many of the memory-related problems encountered by C and C++ programmers, and the users of their code. These features are helping Rust become a strategic choice for the development of new software modules in high-criticality systems, such as those found in the automotive, industrial, and other sectors.

Rust is gaining broad support, with several of the largest software companies in the world already major users of Rust, thanks to its emphasis on reliability and memory safety.

At the end of 2022, Rust became the first language to be supported by the Linux community, alongside C, for the development of kernel modules. Rust gained further momentum earlier this year with the publication of a report by the US White House Office of the National Cyber Director that called for the use of memory-safe language, such as Rust, to guard against cyber-attacks.

US research agency DARPA has even started an ambitious programme to automate the translation of legacy C code to the inherently safer Rust programming language using large language models (LLMs) and generative AI.

The Translating All C to Rust (TRACTOR) programme at DARPA aims to identify tools that can create the same quality and style that a skilled Rust developer would produce, thereby eliminating the entire class of memory safety security vulnerabilities in C programs.

## Memory Issues

A significant difference between C/C++ and Rust lies in the treatment of pointers. The pointer provides a low-overhead way to manipulate data in memory. But the ease with which pointers can be created and modified by a C or C++ program makes them risky to use.

For example, a function in a program may define a pointer access memory in a temporary buffer allocated by the operating system. Attempts to use that pointer if another part of the code has already deallocated the memory will probably result in data corruption. The failure of the program may well follow in short order. Similarly, a null pointer that has been defined but not initialised correctly should generate a memory-access fault when used. This will often also lead to a program failure.

Programs can also fail to deallocate memory when it is no longer needed. In a long-running program, such memory leaks will lead to system instability when the operating system cannot find any free memory to allocate to additional objects.

There are other risks. If the address a pointer contains strays further than the bounds of the memory allocated to data structure or buffer the result is often dangerous data corruption. Hackers exploit this property with buffer-overflow attacks. Illegal writes made through buffer overflows remained the most common vulnerability in the 2022 edition of Mitre's Common Weakness Enumeration (CWE).

## A Safer Choice

Rust users can avoid many of these and other memory-safety issues by taking advantage of its strict rules and built-in support for memory allocation. Compile-time checks help guarantee the correct behaviour of references. Rust has datatypes that provide pointer-like features, but which are supported by compile-time checks. These checks help prevent the issues encountered with C-like pointers.

The memory model supported by Rust also ensures that temporary memory structures will be safely deleted once they are no longer required by the program. Importantly for real-time systems, there is no need to run a garbage-collection process in the background. By providing memory-safe structures and manipulation techniques, Rust can speed up the development and testing of software. And it leverages the skills that college-educated developers now learn. These two factors are important in sectors such as automotive, where the software content of vehicles is growing rapidly.

> *Rust uses elements pioneered in functional languages and other advanced concepts that are now taught to young software developers at college.*

## The Need for Legacy

However, reuse of existing code modules is equally important to organisations developing high-criticality systems. Safety-critical development needs to be conservative. Changes should be made to existing systems only where necessary. It is impractical and even undesirable to rewrite modules in a new language, even if its protection mechanisms offer significant advantages over legacy C or C++. These existing modules will need to be verified once integrated into a target that includes large portions written in Rust or a similarly memory-safe language.

There are also situations where, even if a language does offer strong behaviour guarantees, engineers need to perform additional checks to ensure safety. This is particularly true of embedded control. Many low-level interactions, such as accesses to memory-mapped hardware registers or data buffers, cannot easily be performed using Rust's references and similar memory-safe elements. Programmers can manage these interactions in Rust by using raw pointers. These pointers behave similarly to those provided by C and C++. But without Rust's safeguards they need additional checks.

## Advanced Static Analysis

The static analysis performed by the Rust compiler is conservative and inevitably so because of limits on the depth of analysis it can perform. Code that dereferences a raw pointer in Rust will trigger a compile error unless developers encapsulate that code within `unsafe{}` blocks. This marking tells the compiler to not perform its usual safety checks when compiling this code. As a result, it provides no guarantees of memory safety.

There are other situations where developers need to use `unsafe{}` blocks. Without them, the compiler will disallow any calls to unsafe functions or methods, as well as code that attempts to access the fields of unions. Though unions are not a core Rust feature, support for unions can be important to provide compatibility with C and C++. The compiler cannot guarantee the safety of operations on any of the fields because it cannot determine whether writes to one field will or will not corrupt the other fields that share the same memory structure.

There are many situations where unsafe markings are required in native Rust code. Within the general-purpose library that Rust uses, roughly 30% of the packages within the collection at *crates.io* use the `unsafe{}` construct. A compiler cannot check the safety of operations within these packages.

However, formal verification and mathematical-reasoning techniques exist that make it possible to analyse code before execution. They can determine whether code will suffer from memory-safety issues such as buffer overflows, null-pointer accesses and other problems. Static-analysis techniques are exhaustive in a way, providing guarantees that even extensive dynamic testing cannot.

*By providing memory-safe structures and manipulation techniques, Rust can speed up the development and testing of software.*

Developers are working on tools for Rust-based that can highlight detected problems, indicating where programmers need to insert additional safeguards such as checks on the address range of a pointer reference. As Rust will often need to coexist with C and C++ modules from earlier development, tools like TrustInSoft Analyzer will be used to ensure the combined codebase is free of memory issues.

Even in modules that rely fully on the memory-safety features of Rust and which do not include code inside `unsafe{}` blocks, it will be important to test program behaviour exhaustively before deployment. Errors that are caught by Rust at runtime will often terminate the program completely, which is not acceptable in high-criticality systems. Static tools can examine the likelihood of these situations occurring and warn the development team so that any problems are fixed before product release.

There are also some behaviours which are defined but not desired. For instance, a division by zero or some errors can trigger a "panic" state, which could lead the system to crash. Detecting all of these unwanted behaviours is also key in using an advanced static analyser.

Verification of correct behaviour can be further augmented by automatically generating assertions to test whether code written in any language can handle unexpected or out-of-range inputs safely. This kind of testing emulates the "fuzzing" that is often used by hackers to identify vulnerabilities.

Such tools will provide formal, verifiable proof of the absence of memory safety vulnerabilities that could cause safety-critical vehicles to behave unpredictably and dangerously. To prevent developers being overwhelmed with potential errors, there are tools that have been designed to limit the number of false positives to ensure they only point to code that is likely to suffer from memory-safety issues.

As Rust continues to make further inroads into high-criticality systems development, there will always be a need to verify that external code modules and low-level functions do not have latent issues that will disrupt operations in the field. Using additional static testing and verification ensures that developers will catch and fix undefined behaviours early in the integration cycle, and long before deployment.

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### Editor's Note

eeNews Europe first published this article on August 16, 2024. Visit *www.eenewseurope.com* for more news and interviews.

### WEB LINKS

[1] TrustInSoft: https://trust-in-soft.com

# Plug and Make Kit

## A New Way of Doing Arduino

By Clemens Valens (Elektor)

The Arduino Plug and Make Kit introduces daisy-chaining extension modules on an I²C bus as a new way for rapid prototyping with Arduino. Targeted at beginners and makers alike, the new concept lets the user quickly create smart cloud-based connected IoT applications.

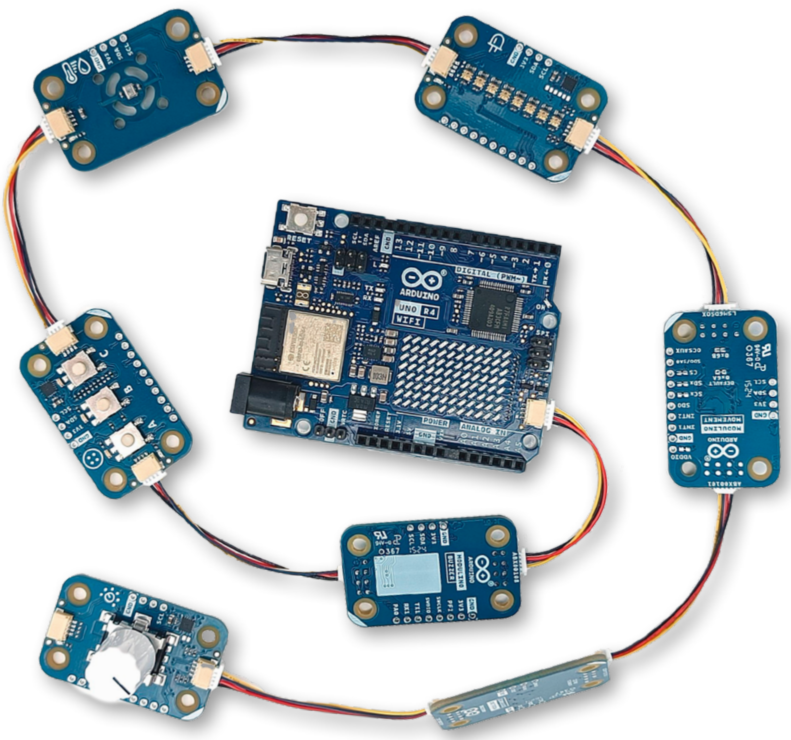

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*Figure 1: Modulino are daisy-chained and communicate over I²C.*

The original Arduino concept emerged about fifteen years ago. It was based on a microcontroller board with extension boards ("Shields") that plugged in on top of the main board. A shield adds functionality in the shape of a sensor, a motor driver, a relay, or something else entirely, such as a display. Shields can be stacked on top of each other to create a compact, stacked microcontroller system. This made and still makes Arduino practical for rapidly prototyping applications. Over the years, hundreds — if not thousands — of shields have been created by Arduino users.

### The Rise of I²C

However, technology continues to evolve, and the I²C bus, a somewhat dusty and forgotten communication bus when Arduino was born, has since become a de facto standard for connecting all sorts of components to microcontrollers. Today, a plethora of I²C-based extension modules is available, allowing you to build applications quickly by connecting them to the microcontroller's I²C port.

### Only Fools Never Change Their Minds

The Arduino UNO has always had an I²C port. Initially, it was a bit like a peripheral that happened to be available before getting its own pins on the extension header. In the latest iteration, the UNO R4 WiFi, the I²C port also got its own connector (compatible with SparkFun's Qwiic specification). Now, with their new Plug and Make Kit, Arduino has fully embraced the I²C method of rapid prototyping. Stacking shields is, of course, still possible as well.

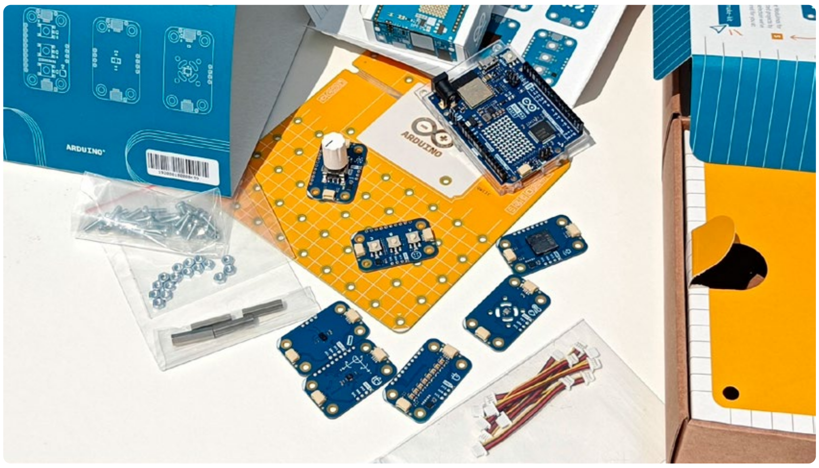
### Plug and Make Kit

The Plug and Make Kit is based on the Arduino UNO R4 WiFi and a family of extension modules called Modulino (note that plural doesn't take an "s"). A Modulino provides a function such as a sensor, a button, one or more LEDs, etc. At the time of writing, there are seven of them: Buttons, Buzzer, Distance, Knob, Movement, Pixels, and Thermo. Modulino do not plug into the shield extension connectors, but instead connect to the UNO R4 WiFi's Qwiic I²C port. Modulino can be daisy-chained to create more complex applications (**Figure 1**).

### Cloud Support and IoT

While similar systems have been around for several years, Arduino's Plug and Make Kit takes the concept a bit further. Firstly, given Arduino's educational origins, the Plug and Make Kit is supported by a cloud-based teaching environment. Not only is this intended to help the user get started quickly, but it's also the base camp for the user's IoT applications. Clearly, a lot of effort has gone into making the cloud as easy to use as possible.

Figure 2: Modulino can be stacked too.



## Modulino Features

The second difference from other I²C-based prototyping systems is that Modulino nodes can also be used with other Arduino boards and third-party systems, since the tiny Qwiic connector can be bypassed, thanks to a footprint for a four-way 0.1" pitch connector. Therefore, if needed, you can simply connect a Modulino to another system by soldering wires (keeping in mind that Modulino require 3.3 V).

## Wait a Minute, There Is Another MCU...

A third interesting difference is that Modulino featuring a device that does not have an I²C port, such as a pushbutton or a buzzer, are equipped with an STM32C011F4 Arm Cortex-M0 microcontroller to provide the I²C port. Some of this MCU's pins are accessible through a row of contacts on the side of the Modulino. Therefore, these Modulino can be used independently and even as the main controller in a Modulino chain.

## Stack Anyway

Finally, Arduino did not drop the stacking concept altogether, because Modulino can be stacked too. This is possible as they all have the same footprint (or form factor, if you prefer) with the aforementioned solderable I²C port in the same position. This way, you can create a small, stacked device comprising, for example, Buttons, Buzzer, Movement, and Thermo Modulino (**Figure 2**). The application program can execute on the MCU of either Buttons or Buzzer (or on both).

## Get Started

To get started with this new concept, Arduino put together a kit combining an Arduino UNO R4 WiFi, the seven Modulino mentioned above, and a Modulino Base. The base is a square 14 cm by 14 cm board on which you mount the UNO R4 WiFi and the Modulino needed for your application. Bolts, nuts, and four spacers are included. The kit also contains Qwiic interconnection cables and a USB-C cable (with a USB-C-to-A adapter, not shown in **Figure 3**).

▲

Figure 3: The Plug and Make Kit unpacked. The USB-C cable is not visible.

## Quality Shows in Details

Arduino tends to spend a lot of time and effort on design quality, looks, and details, and the Plug and Make Kit is no exception. You'll notice it as soon as you open the box. Everything looks great, fits perfectly, and nothing seems cheaply made. For example, the knob on the Knob Modulino is well-designed. The print on the boards is clean and readable. All the boards have orientation marks (a white corner). The cardboard support for the Modulino Base has holes and cutting marks, allowing you to use it for storing your assembled project inside the box it came in (**Figure 4**).

Figure 4: The kit's packaging allows the assembled system to be stored.

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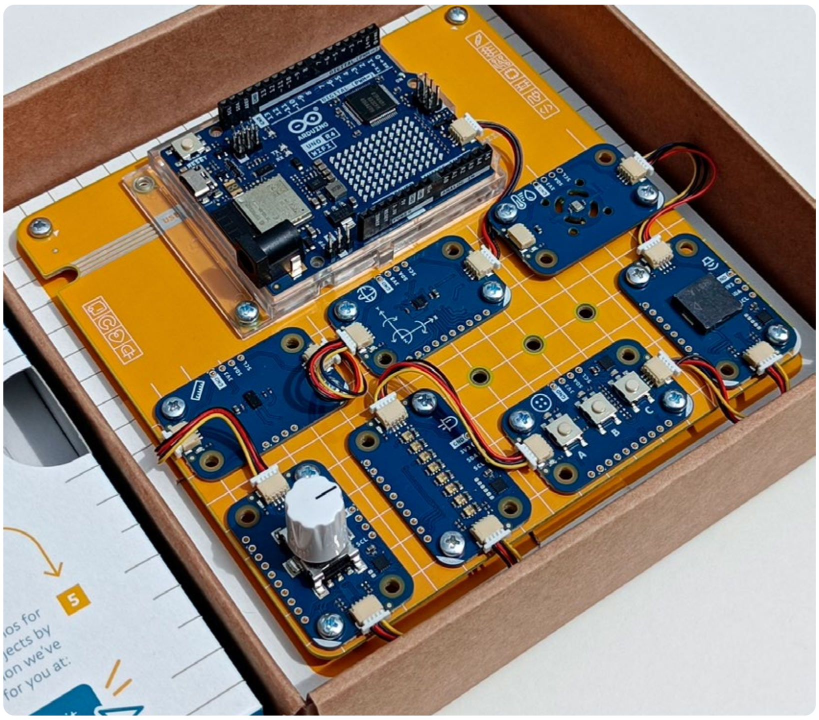


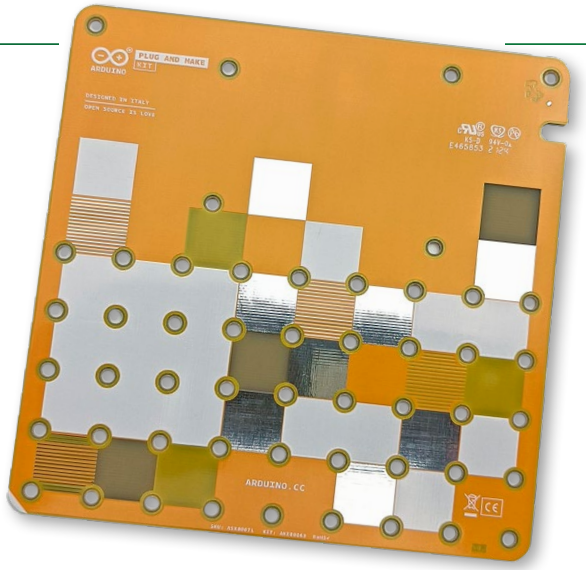


*Figure 5: The backside of the Modulino Base is a true work of art.*

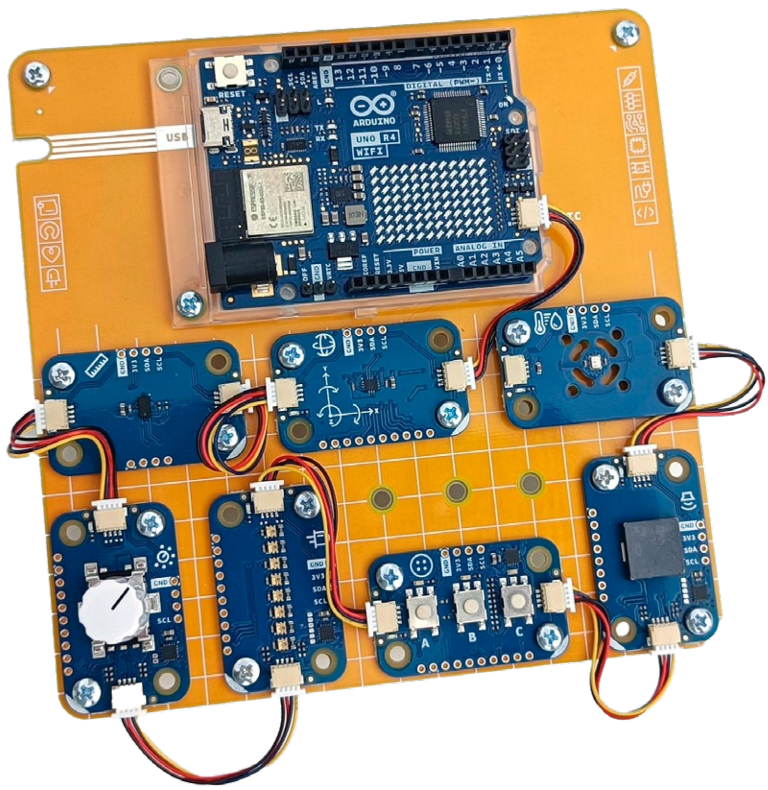
## Kudos for PCB Artwork

Being an engineer with a strong interest in PCB design, I couldn't help but notice the artwork on the backside of the Modulino Base (**Figure 5**). It features a colorful geometric pattern built from squares. The color of a square is determined by the PCB (plated) copper layer, the solder mask, and two silkscreen layers instead of applying full-color silkscreen (which some pooling services have started to propose). Some colors are obtained by "mixing" layers. I like it a lot.

## Modulino Base Space Is a Bit Tight

All Modulino nodes can be connected together, but none of the initial projects suggested requires using all of them at once. That's why the baseboard might seem a bit tight, if trying to mount all seven Modulino and connect them simultaneously (**Figure 6**). For the same reason, there aren't enough bolts (24) and nuts (20) to secure all 36 mounting holes (counting the four standoffs). This is not a problem, however, as two bolts per Modulino and UNO R4 WiFi are enough. Keep in mind that if you develop your own idea including all seven Modulino, you have to fix two of them to standoffs in a corner. Once you have bolted them to the base, connecting them together will become a bit of a challenge as space is tight. As mentioned before, it can be done, but you can also re-bolt only the Modulino you need when you change configuration.

*Figure 6: Mounting all seven Modulino on the base is a tight fit.*



## Into the Cloud

I connected my all-singing, all-dancing Plug and Make Kit to my computer and then pointed my browser to the Arduino Plug and Make content platform. To access it requires logging in to your Arduino Cloud account. If you don't have one, you can create an account for free.

In the cloud, I simply clicked *Welcome* (**Figure 7**). This guided me through the process of setting up my kit, or, to be more precise, the UNO R4 WiFi board. I did not encounter any difficulties worth mentioning and went on to importing my first template. This too went smoothly, and I found myself with a Pixels Modulino showing a colorful rainbow. Turning the knob moved the rainbow up and down and also moved the striped pattern shown on the UNO R4 WiFi's LED matrix to the left or right. The only thing I had to type to get this far was the credentials for my Wi-Fi network.

Incidentally, it is interesting to note that I ended up with this demo, and not another, as there are six to choose from (**Figure 8**). You choose a demo by connecting two Modulino from a list of possible combinations. As I had all seven connected, I had selected every possible combination. The demo I got is (coincidentally?) the last one in the list.

## Trying Out a Project

Now it was time to try out a demo project. There are seven of them, and I opted for Sonic Synth. For each demo, an estimate is given of the time it will take to complete a project. Sonic Synth takes about 35 minutes.

Sonic Synth uses only four Modulino (Buttons, Buzzer, Knob, and Pixels) but I tried with all seven strung together. To load the demo, you must import the corresponding template, detach from the current project, and associate the UNO R4 WiFi to the new template. This means re-entering your network credentials. After going through all the steps, nothing happened. No sound. After removing the superfluous Modulino and rebooting the kit, there was still no sound.

## Fixed It

Trying to reload the template again was not possible as I had reached my free cloud plan limits. Deleting the first demo template solved this problem. A beginner user would not face the same issue, as they would not have used up their free Arduino Cloud allowance, like I had from tinkering with other projects. After going through the project steps once more, I finally got sound when pressing the pushbuttons. The tone's frequency and duration are controlled by sliders in the cloud dashboard. Even though listed at the start of the project, Knob and Pixels come into play only in the second step of the project.

## User Experience

Fiddling around with this demo showed me two things:

1. With Plug and Make Kit, the objective is to build a clever connected gadget in a few minutes without having previous knowledge about IoT and programming. As much as Arduino has simplified the experience, if something goes wrong you still need to be comfortable diving into the cloud environment to find clues and ways to fix the problem.

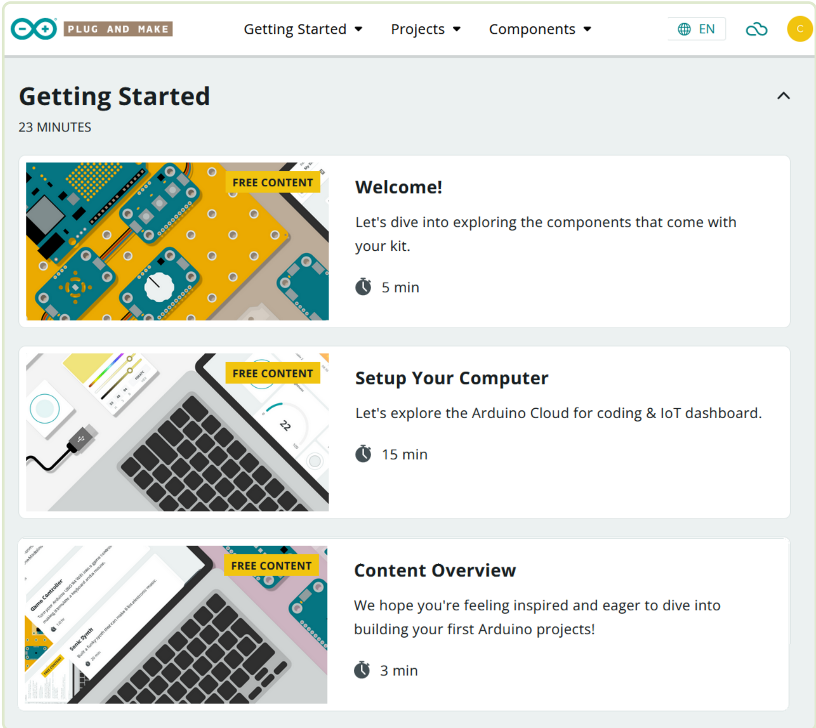



*Figure 7: The Plug and Make Kit start page in Arduino Cloud.*

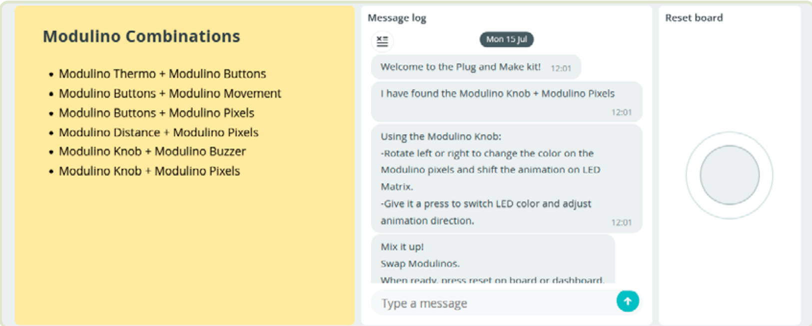


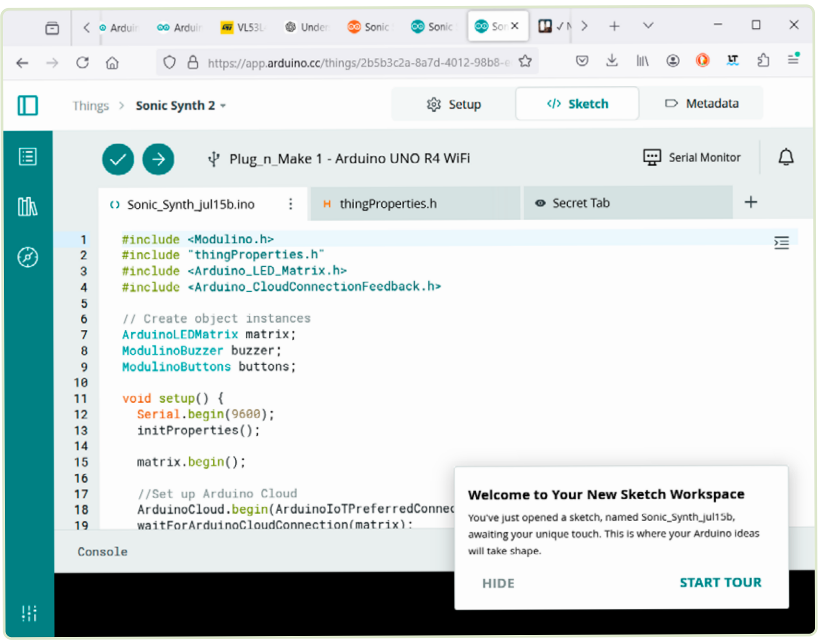

Figure 8: The Getting Started demo depends on which Modulino combination you chose.

2. Personally, I feel the Modulino Base is more in the way than it is helpful, when experimenting and playing around. In a classroom, it may help to protect the hardware, but reconfiguring the system is a bit tedious. Shorter bolts would help, but ideal would be some sort of clipping system. Also, the UNO R4 WiFi is positioned too far to the right for the short Qwiic cables. Therefore, I preferred working without the baseplate.

## Classic Arduino

The Arduino Plug and Make Kit is targeted at cloud-connected IoT applications. Behind Arduino Cloud shines the Arduino programming environment. You can inspect and modify the source code of your applications by opening the *Sketch* tab. Doing this for the Sonic Synth project reveals a rather simple Arduino sketch that imports a Modulino library (**Figure 9**). This library is also available in the library manager of the classic offline Arduino IDE. Therefore, nothing obliges you to develop cloud-based IoT applications with the Plug and Make Kit. You are free to do with it whatever you want.

Figure 9: A Modulino library is included at the beginning of the Sonic Synth sketch.




## Competition

As said at the beginning of this article, the concept of Arduino's Plug and Make Kit is not new, but it adds a few interesting things. Probably the first I²C-based prototyping system is Grove from Seeed Studio (it is a bit more, actually). The main problem of the Grove system is the proprietary connector it uses with a 2 mm pitch. Grove has been copied by other manufacturers, who all replaced the Grove connector with their own non-standard or difficult-to-solder/cable/find connector. Examples are Adafruit's Stemma and Sparkfun's Qwiic, but there are more. Arduino has done the community a favor by equipping the Modulino nodes also with a normal (read: maker accessible) I²C connector besides a Qwiic connector.

## BBC micro:bit?

While playing around with the Plug and Make Kit, I couldn't help but think of the BBC micro:bit. This is a small microcontroller board designed to introduce children to programming and electronics. It targets an even younger audience (10+) than the Plug and Make Kit (14+). Both boards/systems have similar features: an Arm Cortex-M4 microcontroller, wireless capabilities, an LED matrix, several sensors connected to an I²C bus, a buzzer, pushbuttons, and cloud-based programming and IoT applications. The main difference is that the BBC micro:bit integrates all this onto a single board, whereas the Plug and Make Kit consists of eight boards (the baseplate does not count as it has no electrical functionality, and only serves as a structure to organize projects). So, if you want something smaller, take a look at BBC micro:bit.

## New Way of Using Arduino

The Arduino Plug and Make Kit introduces a new way of using Arduino. Instead of stacking shields on a baseboard, the extension modules (Modulino) are daisy-chained on an I²C bus. This bus is provided by the kit's Arduino UNO R4 WiFi. A Modulino Base is included for securing the various Modulino and the UNO R4 WiFi, creating a transportable system.

The Plug and Make Kit embodies everything we have come to expect from Arduino: aesthetics and high-quality hardware and software (even though it wasn't yet 100% up to speed at the time of writing because I'd received an advanced sample of the product before launch). Targeted at electronics newbies, hobbyists, and makers, the kit is supported by a good amount of online documentation, example projects, and tools in Arduino Cloud.

The new Modulino product line may have some potential, I believe, especially if support for the STM32 microcontroller used on some of them is provided (schematics, libraries, and bootloader). Arduino is planning to release more Modulino nodes in the future, but cannot confirm any further details at the moment. Competition is fierce in the I²C arena.

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*Editor's note: This article first appeared in Elektor Circuit Special Bonus 2024.*

### Questions or Comments?

Do you have technical questions or comments about his article? Email the author at clemens.valens@elektor.com or contact Elektor at editor@elektor.com.

### Related Products

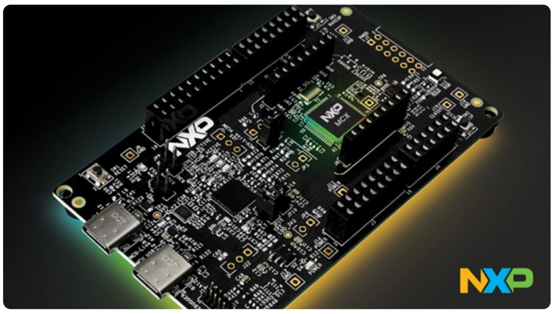
- **Arduino Plug and Make Kit**
  www.elektor.com/20920
- **Clemens Valens, *Mastering Microcontrollers Helped by Arduino* (Elektor)**
  www.elektor.com/17967

### WEB LINKS

[1] Arduino Plug and Make Kit: https://store.arduino.cc/products/plug-and-make-kit
[2] Arduino Plug and Make in the cloud (requires login to Arduino service): https://courses.arduino.cc/plugandmake

# Innovating with NXP

## The Evolution of the FRDM Platform



Questions by the Elektor Content Team

In this exclusive interview, NXP's Justin Mortimer, Senior Director Marketing, BL Secure Connected Edge, shares how their FRDM development platform has evolved and highlights the key innovations in their MCX portfolio. Discover what's next as they prepare for electronica 2024.

**Elektor: Let's start with some history. NXP's FRDM boards aren't new to the market, but they've evolved significantly over time. Could you walk us through the key milestones in the development of the FRDM ecosystem? How have changes in technology and market demands shaped the evolution of these boards?**

**Justin Mortimer:** It all started over 10 years ago when we first introduced the FRDM board. When it was launched, it was very well received and complemented the Tower System we had at Freescale at the time. The goal was to adopt a modular approach to the market, and that strategy has stayed consistent throughout the platform's evolution. However, we've made some significant advancements since then.

One of the major improvements has been in software and development tools. We've put a lot of effort into providing excellent tools, especially with the introduction of MCUXpresso. We've also expanded to support IDE options like VS Code, and we've developed a richer ecosystem of application examples through our application code hub. In terms of hardware, we've upgraded the development boards, adding features like extra expansion headers and an enhanced debug circuit, making it easier for our customers to use.

**Elektor: How many FRDM boards are currently in the ecosystem? Can you share a few examples?**

**Mortimer:** If we focus on the newest boards, we started with two in January, and now we're approaching 10 in the market. Since January, we've introduced nine FRDM boards, with many more in the pipeline. But, when we talk about the FRDM boards, we also have to consider all the expansion boards.

By expansion boards, I mean that we're not just thinking about the microcontroller on the base development platform, but all the combinations of expansion boards we offer. These expansion boards enable users to plug and play, facilitating rapid prototyping of their applications. When you combine all these options, we're approaching hundreds of possibilities — definitely in the dozens already. As a company, we're working hard to continue expanding the options, both for the FRDM development board itself and for the expansion boards.

**Elektor: Can you explain the power-saving features of FRDM boards, such as low-power modes or dynamic voltage scaling? Are these suitable for battery-operated applications?**

**Mortimer:** Some of the technologies we've introduced are capabilities within the silicon, while others are features on the board itself. Our goal has been to optimize both. For instance, with the first FRDM boards we introduced — like the FRDM boards for MCX A, MCX N, MCX C, and MCX W — we specifically designed them for various types of applications.

The MCX A, MCX W and MCX C boards, in particular, are great for battery-operated applications. We've seen many people build battery-powered projects using them — even, to some degree, MCX N, but definitely more so on the lower-end and lower-power options. Our focus has been on making power optimization easier for developers. The boards themselves include features like power measurement capabilities through MCU-Link. The debug circuit can measure and monitor power consumption, helping developers save energy and analyze power usage in their systems.

Additionally, we've provided plenty of training materials and content on our website to help developers fully utilize the FRDM platform. This includes guidance on entering low-power modes and maximizing power savings by transitioning between power states efficiently.

**Elektor: FRDM boards seamlessly integrate with MCUXpresso tools. How does this integration specifically benefit developers in terms of expediting the development process and enhancing code portability across different NXP MCUs?**

**Mortimer:** That's a great question. When it comes to developing an application, a big part of an engineer's time is focused on software. The FRDM development platform is just one piece of the puzzle — it's a hardware development platform, but a large portion of application development relies on software. We've spent a lot of time ensuring that the FRDM ecosystem integrates seamlessly with all the software and tools we offer.


The board natively works with our MCUXpresso IDE and our MCUXpresso Software Development Kit, which provides a strong collection of peripheral drivers and middleware for the target silicon on the board. We've also introduced extensions for VS Code, and for those working with real-time operating systems, we've enabled Zephyr for our microcontrollers. Additionally, we offer a wide range of application examples through our application code hub. This helps customers get started more quickly, allowing them to focus on innovation within their product design rather than having to start from scratch.

We've really concentrated on integrating hardware and software while providing comprehensive application examples, which simplifies the development process for our customers.

**Elektor: Are there wireless connectivity options natively built in FRDM boards? Or are external shields or modules required?**

**Mortimer:** We aim to offer both options. First, we've added multiple expansion headers on the boards, allowing developers to purchase expansion boards or shields from partners and plug them in. These expansion boards, whether for mikroBUS or Arduino headers, add different connectivity technologies to the FRDM development boards.

More recently, we've introduced two new FRDM boards. One is the MCX W, which is our first wireless MCX-based MCU that supports Matter. It includes an 802.15.4 radio for BLE, Zigbee, Thread, and more. The other board has our first Wi-Fi 6 Tri-Radio on board. In these cases, a shield isn't required because the board itself provides the wireless connectivity.

For example, the FRDM-RW612, in addition to the expansion headers on the top, has pins on the bottom. This allows it to function as either a standalone development board or an expansion board for another system. It's all about modularity and giving developers options. For anyone getting started with wireless connectivity, we recommend the MCX W or RW612 FRDM boards, which provide built-in wireless functionality.

**Elektor: The NXP MCX A series MCUs leverage the FRDM development platform. Can you elaborate on the key innovations in the MCX A series compared to previous NXP MCU offerings, and how the FRDM platform has evolved to support these advancements?**

**Mortimer:** The MCX A series is all about simplicity and scalability. What we aim to do with the MCX A is make development easier for customers, especially when they are interfacing with sensors or controlling motors. We've created a variety of application examples that allow developers to connect the MCX A's capabilities to different use cases seamlessly. For instance, we provide examples that demonstrate how to connect various sensors and leverage the low-power modes available in MCX A. This includes using autonomous peripherals to save power and transition between power modes.

One example is waking up from a low-power mode with a sensor, utilizing the rich set of examples we offer. We also provide motor control examples that show how to use MCX A's PWM, timers, and motor control subsystems. Our focus has been on the areas where customers are most likely to use MCX A, such as sensor interfacing and motor control, to make their development process smoother and more efficient.

## About Justin Mortimer

Justin Mortimer has extensive experience in the semiconductor industry, with a specialty in embedded processing for the industrial multi-market. With an expansive network of industry relationships, including global distribution channels and key partners, Justin has a passion for engaging with embedded developers around the world, excels at distilling complex topics and translating ideas into action. Known for a results-driven approach and strong leadership, Justin has successfully led teams as we introduce to market numerous new products and development platforms, and works hard to bring value to engineers around the world.

**Elektor: In which industries and applications have you seen the FRDM development boards have a notable impact? Can you a give us a success story where rapid prototyping with FRDM boards made a significant difference?**

**Mortimer:** One area I'm particularly excited about is time-series analysis. In the microcontroller space, there's been a lot of talk about edge AI, which is a big trend. But what's really exciting is how microcontrollers can take sensor data and bring a higher level of intelligence into systems. By gathering and analyzing sensor data over time, we can more autonomously control systems, like those in industrial settings.

We introduced a time-series-based edge AI application that collects sensor data from across NXP products and feeds it into a microcontroller. This allows for anomaly detection in motors or industrial systems, enabling remote monitoring and control. We've had great reception from customers, where they've been able to apply this kind of anomaly detection and time-series analysis in their own products. One notable example is with the MCX N, where customers have utilized the FRDM board and the integrated eIQ(R) Neutron Neural Processing Unit IP to streamline their development and improve system monitoring.

**Elektor: What does NXP have planned for electronica 2024 in Munich, Germany (November 12–15)? Will you have any special demos on display for attendees?**

**Mortimer:** What's been really exciting about the FRDM platform is the widespread reception it's received across the industry. No matter where I go — events, sessions around the world — the FRDM platform is well-received. At electronica, you'll see the FRDM platform showcased not only by NXP but also by our distribution and ecosystem partners. It's become the heart of many innovative products, applications, and demonstrations.

I'm excited to see how the FRDM platform will be featured across the show and how it's driving innovation in so many development efforts. It's great to witness how the platform continues to inspire new ideas and solutions across the industry.

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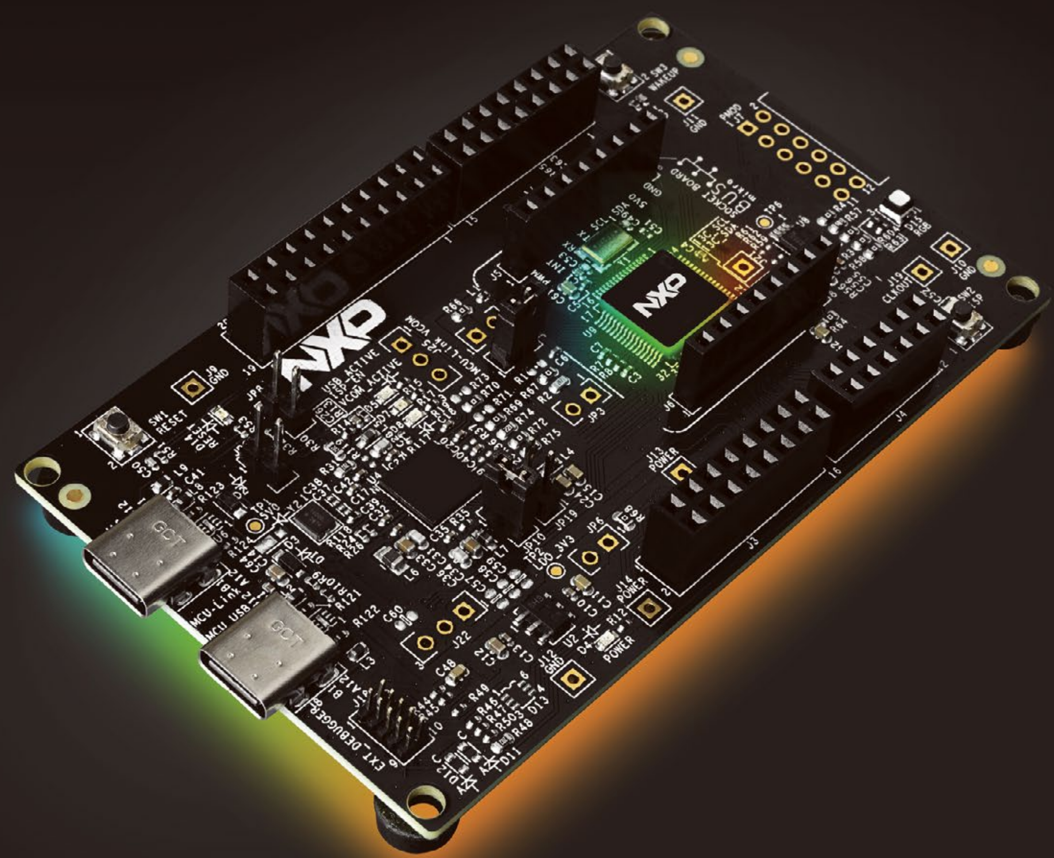

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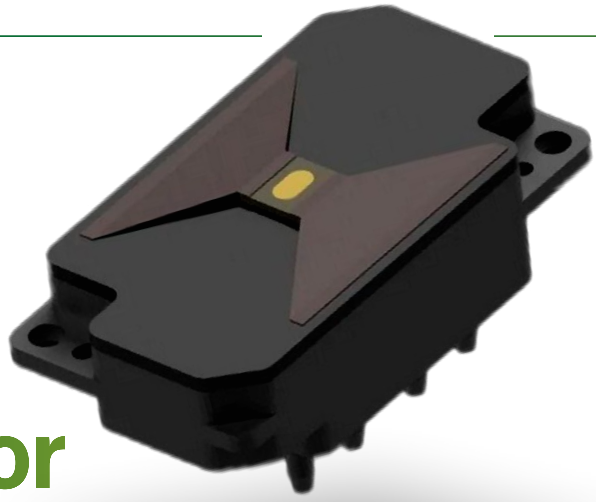

# CEO Interview: Inkjet Printing for Semiconductor Equipment

**By Nick Flaherty (eeNews Europe)**

Nick Flaherty talks to Patrick Heisler and Patrick Galliker at Scrona as it raises €4m for its third-generation inkjet print heads for semiconductor equipment.

Swiss startup Scrona has raised €4m as it launches its third generation inkjet print head to scale up semiconductor manufacturing equipment.

Patrick Heisler joined as CEO in June 2024 having worked on packaging technology at TUM Munich and UC Berkeley and joining from FrontierLight Technologies and Suss MikroOptics. Former CEO Patrick Galliker takes on the CTO role.

"I am very happy about that development to focus on the technology," Galliker tells *eeNews Europe*.

The company has also raised €4m in a bridge round to scale up its third generation MEMS-based technology for semiconductor equipment for microLED displays and chiplet substrates. "We are aiming to replace 22 steps in semiconductor manufacturing and packaging with two steps," said Heisler.

The Gen 3 print head currently has 8 nozzles available that can scale up to 256 in a similar form factor.

"It's a real product and we are shipping it out to customers right now. All the inlets and outlets are made for commercial use. Gen 1 and 2 were R&D tools, they required a lot of manual work. Gen3 with 8 nozzles will be on the open market by the end of Q3 in a 7 x 7 mm print head and this is not fully optimized," said Heisler. "It's the electrical contacts that use the most space and we have a robotic system that will be used for the contacts so the precision will increase to reduce the pitch with a 1 µm resolution."

The company is aiming for a version with 128 nozzles in Q1 2025. "We have not decided on the configuration of the 128 design because it could be a matrix," said Heisler.

The Gen 3 is a scalable platform with the same injection moulded packaging and the same electronics for the MEMS inkjet printhead die. The driver that is giving the 128 signals is sitting in the print head and use the same electronics to feed an 8 or a 128 so its possible to start with an 8 nozzle version and move to 128 or even a 256 nozzles in the same package, says Galliker.

"We are not trying to dictate anything in the process," he said. The nozzle count can be scaled but there is a limitation on the channel count and the drivers. We have techniques to scale the nozzles without scaling the connections. We want to keep Gen 3 attractive [in cost] but it is not limited in the nozzle count," he added. "If we see requirements for more nozzles, or higher throughputs and voltages we will move to Gen 4."

This would see up to 1000 nozzles in a print head. "We are not going to push Gen4 just to have it out there. We want to drive Gen 3 as far as possible," said Heisler.

"The main application are displays and advanced packaging in Taiwan, Korea, the US and Europe," said Galliker. "We are seeing the advanced backend applications that are employing front end solutions that are too costly or too wasteful for redistribution layers (RDLs) or 3D interconnects."

"We are moving away from the capex model with full utilisation to an opex driven model that can be lower volumes and more custom with CoWoS," he says.

"As things develop we see Gen 3 as the main platform. Inkjet is very good at scaling. You need a printhead with many nozzles and many nozzles working together. We have been talking with one of the big semiconductor equipment makers, they are looking at the multiple print heads, an our main objective is to have many nozzles on the print head."

> *The Gen 3 print head currently has 8 nozzles available that can scale up to 256 in a similar form factor.*

"We can scale up Gen3-8 to 48 nozzles in the same MEMS die in three staggered lines of 16, with the same design, manufacturing, to the wafer, to the packaging and testing. With 8 channels as you might not need access to every nozzles, so we might scale to thousands of nozzles," he said.

The MEMS chip is built on an in house 2in wafer where the company can design, manufacture and test a new print head chip in a week.

The company is also working on a print engine that can be completely controlled by any equipment, not just initial partner Notion.

"This is not a plug and play replacement and if it requires an adapter but we are happy to do that or a custom form factor we can do that," said Heisler. "This is the economies of scale of semiconductor manufacturing with the mix and match on a wafer. We have easily the capacity for 100,000 print heads per year out of the fab for the big versions we have and it's a scalable process, for the 3-8 the capacity is probably a million units," he said.

Scrona's proprietary technology is based on the electrostatic ejection principle which provides very fine, submicron-scale printing and jetting, while allowing the adoption of various ink materials—such as metals, dielectrics, organic, and biomaterials. The MEMS printheads allow for high nozzle density and customisation to accommodate application requirements across many industry verticals.

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**Editor's Note**
*eeNews Europe* first published this article on July 9, 2024. Visit *www.eenewseurope.com* for more news and interviews.

**WEB LINK**

[1] Scrona AG: https://www.scrona.com

eeNews EUROPE

CEO Interview:
# MIPS' Sameer Wasson on a RISC-V Reboot

*Sameer Wasson, MIPS CEO (Source: eeNews Europe)*

**By Peter Clarke (eeNews Europe)**

MIPS Inc. is emerging as a significant RISC-V processor core licensor under its recently appointed CEO Sameer Wasson. eeNews Europe interviewed Wasson to find out how he expects to navigate the choppy waters of a processor market in flux.

MIPS [1] was founded in 1984 and was one of the pioneers of the first RISC revolution in processor architecture. This carried the company through to the 1990s, where it found itself opposite a UK startup called Arm. Arm's focus on power efficiency enabled it to capture the smartphone market and large swathes of the general embedded markets. MIPS was more performance-oriented. It started out providing workstation processors and performed well in networking and communications. But eventually, it went through a series of corporate acquisitions and sales before ending up being majority-owned by Tallwood Ventures with a remit to continue its processor core licensing business based on the RISC-V open-source architecture.

Wasson joined the company in September 2023 from Texas Instruments (see [2]). There he was responsible for high-performance microcontrollers and processors. "I could see RISC-V has a lot of potential and that it provides an opportunity to give control back to engineers. I think of MIPS as 40 year-old startup, or a restartup. In fact, the company was already heading in the RISC-V direction since 2018-2019."

## Starting Over

As a "restartup" MIPS has the advantage of a royalty stream from existing licensees of its historical MIPS instruction set architecture (ISA) processor cores. It also gives a base of customer relations to stand on. As a private company, MIPS does not have to reveal revenue details on a quarterly basis but Wasson said the company is at about a 50:50 split between MIPS ISA royalties and upfront licensing fees for MIPS upcoming high-performance RISC-V core, the P8700. Most RISC-V processor core providers are private companies, making sales estimates difficult but Wasson reckons that MIPS is already one of the top two or three RISC-V licensors out there.

Wasson said the philosophy for MIPS is to take the things that the original MIPS ISA does well and recast them using the RISC-V base ISA and extensibility under RISC-V. This provides an upgrade path for existing MIPS licensees as well as a way in to certain applications for new customers.

"We don't want to try and 'boil the ocean' and take on Arm. MIPS does some things well so we focus on those," said Wasson. He gives the example of efficient data movement under the MIPS ISA which translated into successful licensing into networking and modems and into some automotive applications.

“This capability we are translating into datacentre networking, traffic management, DPU applications,” Wasson said.

In the automotive case, MIPS has been part of Mobileye’s offering over many generations of ADAS processor. “We have Mobileye as a RISC-V customer and also a couple of hyperscalers, which we can’t name,” said Wasson. He added that the passage of time has made MIPS networking capability relevant to more applications.

## P8700

“Our RISC-V processor is a MIPS-like processor, multi-threaded, that supports hardware virtualization and cache coherency,” said Wasson. He asserts that such high-performance and security support is finding its place in such areas as ADAS and intra-vehicle networking, the combination of ADAS and infotainment; hence the Mobileye engagement.

> *As an open-source architecture, RISC-V is available for use royalty-free and comes with support for instruction set extension and design implementation by all-comers.*

In addition, Wasson reckons the increasing use of electronics in vehicles — whether electric or internal combustion engine — will give rise to an increasing need for over-the-air upgrades. “ECUs will need to be real-time capable and able to handle multiple environments,” he said.

The P8700, a 64-bit, super-scalar out-of-order operation RISC-V processor, was released at the end of 1Q24, Wasson said. “It is available as a scalable multicore cache coherent network-on-chip (NoC). It is also available in multiple clusters. It boots Linux and will come with documentation for inclusion in an SoC and will be safety-certified as well,” he added.

The design targets TSMC’s 7 nm manufacturing process initially although MIPS engineers are working to go beyond that, Wasson said. “We may also have a 16 nm optimization as well.” Wasson said that at launch the P8700 will be one of the highest performing RISC-V processor cores available.

## Pro and Con?

As an open-source architecture, RISC-V is available for use royalty-free and comes with support for instruction set extension and design implementation by all-comers. However, those implementors can still license out their specific implementations and charge for engineering support. This marks a major distinction from the Arm architecture which is proprietary, and rigorously controlled by the UK company.

But could openness create both a benefit and a hindrance to users of RISC-V? The customization enabled by RISC-V allows for easier optimization for performance, energy-efficiency and other parameters, but that in turn could produce a market fragmentation that inhibits ecosystem support, or makes support more expensive?

Wasson sees it differently. “RISC-V allows you to take the best of both cases. You have basic compliance of debug, trace and standards out of the box. There is a standard that provides interoperability. But you can then tune cores — just as you do elsewhere — for performance or power or data movement.”

## The AI Elephant

The elephant inside the R&D lab of just about every technology company in 2024 is artificial intelligence. Is AI processing or acceleration part of the MIPS roadmap?

“We will address AI by making sure we have the best data-movement processor,” said Wasson, indicating that he sees a major market in supporting GPUs and AI accelerators in servers for the datacentre. “MIPS may offer inference in time but there is an ecosystem requirement (that needs to settle) and I will wait on that,” he added.

“The software perspective comes first, but addressing things in the ISA is always going to be superior. And engineers don’t want to deal with multiple ISAs,” said Wasson. One of the issues is that AI is still relatively immature in terms of development and has a power consumption problem, Wasson explained.

AI hardware has so far been optimized for generality and for performance, he asserts. “We need to do more processing without blowing up the power consumption. AI has not yet been designed with power budget as a first constraint,” said Wasson. When it is designed like that, Wasson indicates that RISC-V is a compelling choice.

## Competitive Landscape

Another aspect of the open-source nature of RISC-V is it is much more competitive than a proprietary ISA ecosystem. There are already many companies offering processor cores and supporting fabless chip companies with implementations. In contrast, Arm is, in most aspects, a monopoly supplier around its own ISA.

As part of that competition, MIPS is recruiting and senior executives Drew Barbier and Brad Burgess have joined the MIPS leadership team. Both were previously with RISC-V pioneer SiFive. Barbier joins MIPS as vice president of products and Burgess as chief architect (see [3]).

“RISC-V is a very active space. And I expect more competitors to show up,” said Wasson. “I don’t see that as negative. You need competition to bring out the best in engineering. But if we have the right fundamentals it comes down to our ability to execute,” Wasson concluded.

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### Editor’s Note

*eeNews Europe* first published this article on January 5, 2024. Visit *www.eenewseurope.com* for more news and interviews.

### WEB LINKS

[1] MIPS website: https://www.mips.com
[2] W. Hettinga, “MIPS to Drive RISC-V Market Penetration and Innovation,” eeNews, 2023: https://www.eenewseurope.com/en/mips-to-drive-risc-v-market-penetration-and-innovation/
[3] P. Clarke, “MIPS recruits former senior SiFive execs to boost RISC-V play,” eeNews, 2024: https://www.eenewseurope.com/en/mips-recruits-former-senior-sifive-execs-to-boost-risc-v-play/

# Elektor Webinars: Technical Insights for Electronics Innovators

By The Elektor Content Team

Elektor webinars enable electronics engineers, students, and makers to learn about next-generation technologies, products, and essential engineering techniques. By partnering with us, companies get to engage new customers with their products and solutions. Check out some of the most popular webinars from the past several months.

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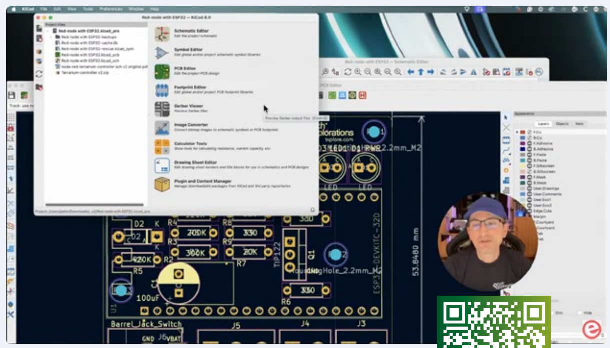

youtube.com/live/DzeHxLZ0d8A

## KiCad 8 Essentials (Editorial Webinar)

*September 12, 2024*

Whether you're a weekend maker or a professional engineer, KiCad can streamline your design process. Peter Dalmaris, prolific author and KiCad expert who is behind the *KiCad Like a Pro* book series, was our guest for this webinar, where we dug into the latest developments in KiCad 8. Geared toward both seasoned PCB designers and newcomers eager to learn more about the capabilities of this powerful open-source tool, the webinar covered the following topics: the transition from KiCad 7 to KiCad 8, key improvements in the user interface, cross-platform compatibility, and new features that enhance workflow efficiency.

### Getting Started With the Arduino Opta PLC Family (Client Webinar)

*May 2, 2024*

In the webinar, "Get to Know Arduino PLC," we offered an in-depth exploration of how Arduino technology intersects with the precision of Programmable Logic Controllers (PLCs). The session featured Francesca Gentile from Arduino, who provided valuable insights into Arduino's capabilities, enriching the content with her expertise. Participants learned both the fundamentals of PLCs and advanced Arduino integration techniques. The webinar included an interactive Q&A session with Francesca, allowing for engaging discussion and direct learning. It was an excellent opportunity for hobbyists, professionals, and enthusiasts to enhance their skills and stay current in the fields of electronics and automation.

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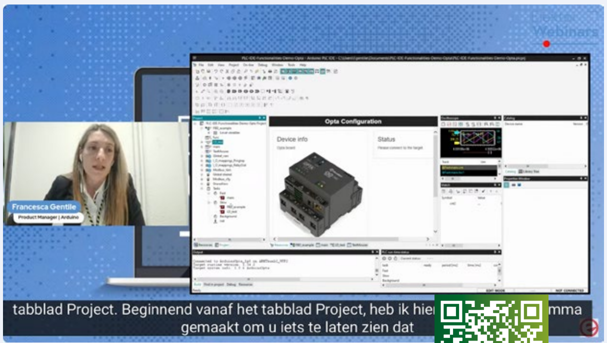


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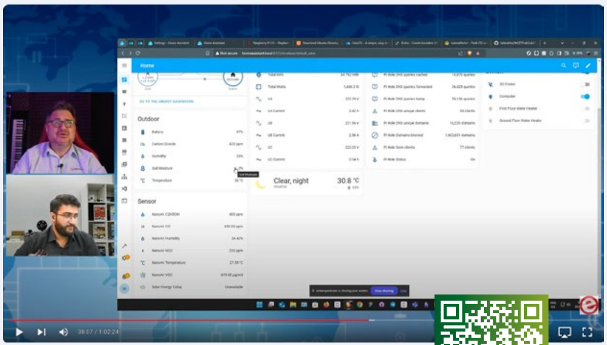

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## Use Home Assistant to Unlock the Power of the Smart Home (Editorial Webinar)

*August 22, 2024*

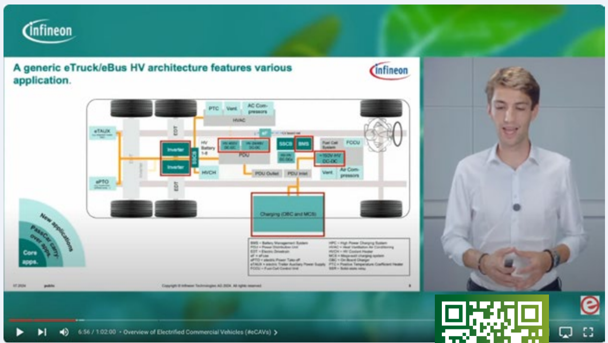
Many electronics community members are eager to elevate their smart home and home automation skills. In this free editorial webinar, Elektor engineers explored Home Assistant, the ultimate platform for home automation. Intended for both newbies and seasoned pros, Saad Imtiaz and Brian Tristam Williams presented the essentials and beyond, from understanding Home Assistant's core features to setting it up step-by-step on various platforms, including the official Home Assistant Green hardware. Attendees learned how to integrate their devices, create powerful automations, and implement advanced features like voice assistant integration and security best practices.

*youtube.com/live/HZVu4aD1iE0*

## Electronics Workbench - Tips and Tricks (Editorial Webinar)

*July 11, 2024*

In this Elektor webinar, experts shared practical tips and tricks for electronics workbenches, focusing on helpful test and measurement techniques. The session covered a range of topics, including electromagnetic compliance, analog signal generation, and the use of vintage measurement devices. Special guests including Sebastian from Baltic Lab, Thomas Scherer, Alfred Rosenkränzer, and Saad Imtiaz shared insights about using oscilloscopes, handling radiated emissions, and optimizing audio measurements. The webinar, sponsored by Siglent, provided valuable guidance for both beginners and seasoned engineers on enhancing their electronics workbench skills.




*youtu.be/xRpwZhQ3-no*

## Infineon's Inverters, BMS, and Power Conversion for Commercial Vehicles (Client Webinar)

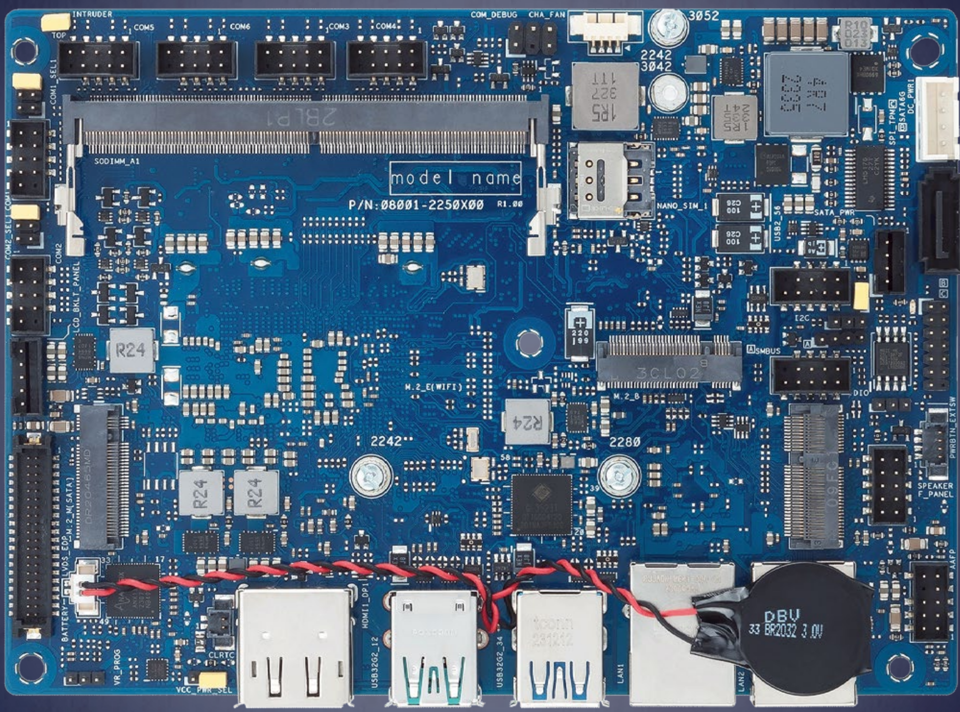
*June 24, 2024*

In this engaging webinar, attendees explored the latest advancements in electrified commercial vehicles with experts from Infineon. The session covered essential topics such as traction inverters, battery management systems, and power conversion solutions designed specifically for e-trucks and e-buses. Infineon engineers provided insights into the newest trends and technologies shaping the future of commercial vehicles, including high load capacity traction inverters, advanced battery management systems with cutting-edge sensing and protection features, and innovative power conversion technologies like silicon carbide and gallium nitride. It was a valuable opportunity for attendees to deepen their understanding of electrified vehicle technology and its applications.

# ASUS IoT Amston Lake SBC

With **Intel® Deep Learning Boost**, the SBC enables up to **6x faster AI processing**, ideal for complex tasks such as advanced machine learning and image processing.

The Asus IoT Amston Lake SBC is based on the **Intel® Atom™ x7000RE series** and doubles the number of cores without increasing power requirements.



The SBC offers up to **16 GB DDR5 RAM** with **in-band ECC**, which thus ensures maximum performance and also **minimum susceptibility to errors** in edge computing applications.

Designed for temperatures from **-20°C to +70°C** and with a very wide input voltage range of **9-36V**, the board is ideal for harsh industrial conditions.

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# KiCad 8

## Top New and Updated Features

By Peter Dalmaris (Australia)

KiCad, the open-source electronics CAD software, gets more and more popular, also among professional developers. And the software gets constantly improved. This year, version 8 was released. KiCad 8 features several improvements over KiCad 7, particularly in the PCB editor and the built-in simulator. Let's explore some of these updates and enhancements!

The KiCad team introduced KiCad 8 in early 2024, almost exactly one year after KiCad 7. After the project reached a refreshing level of maturity with versions 5 and 6, new major releases of KiCad are almost always shipped with new features and improvements, designed to enhance productivity and close the gap with its commercial competitors.

KiCad 8 is no exception. The new version [1] represents the next step in KiCad's evolution, with several improvements and additions over KiCad 7. As with KiCad 7, KiCad 8 will not break your older projects. There are no new and radically different features, as was the new file format introduced in KiCad 5. The features introduced in KiCad 8 will not require you to spend hours or days learning them. You can ignore this article (though you shouldn't!), download KiCad 8, and start using it. Your KiCad 7 workflow will work just fine.

Instead, in KiCad 8, we find many relatively small improvements. Most of these improvements are in the two main KiCad apps, the schematic and PCB editors, to enhance their individual capabilities and integration. In this article, I'll highlight some of KiCad 8's most important improvements, starting with the PCB editor.

### Multiple Footprint Drag

In KiCad 7, users could only drag one footprint at a time. Having to drag one footprint at a time after completing the wiring to fix an issue or improve a board was a big time-waster, and I always dreaded having to do that. KiCad 8 enhances this by allowing multiple footprints to be selected and moved together without breaking any attached tracks. This streamlines the design process, particularly for complex boards with numerous components.

I'll use an ESP32 board as an example to demonstrate this feature. Suppose you want to move the position of footprints D1 to D4 (**Figure 1**). The process is intuitive. Start by selecting the footprints you want to drag. You can do that by clicking on the footprints while holding down the *Command* or *Control* key or using mouse drag, having checked the *Footprints* checkbox only in the selection filter. Then, press the *D* key to initiate the drag operation. As you move the mouse, the attached footprints will move.

As you drag the selected footprints, the interactive router will provide feedback when any rule violation occurs. If moving the footprints causes a short, the router highlights the issue in bright green. For instance, if D6 causes a short by crossing a wire, the router immediately indicates this, allowing quick adjustments. I dragged the footprints to the left in **Figure 2**, causing a short. The interactive router highlights this violation by highlighting the affected segment with green.

Once satisfied with the new positions of the components, simply click to drop them into place. This feature makes arranging components on the PCB more intuitive and less time-consuming. KiCad 8's ability to drag multiple footprints simultaneously is a productivity multiplier, making small (or larger) adjustments painless.

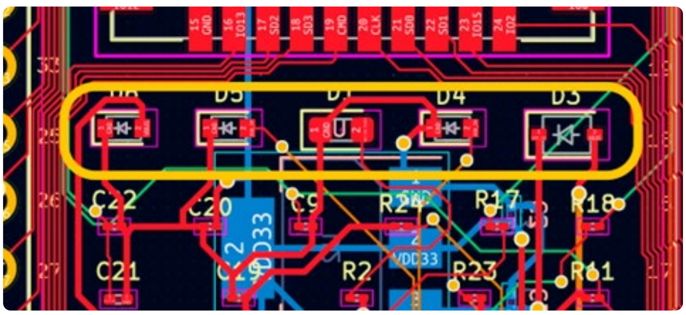



*Figure 1: I will drag these footprints simultaneously.*

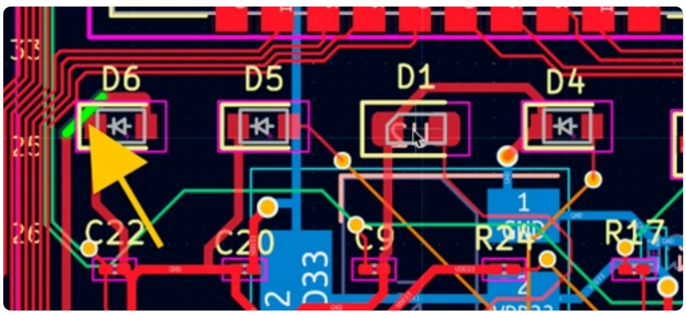



*Figure 2: When you drag multiple footprints, tracks are redrawn, and the interactive router highlights violations in real time.*

## Teardrop Properties

Teardrops are not new, but in KiCad 8 you have more options when adding them. Teardrops reinforce the pad's connection to tracks, reducing the risk of track lifting and breakage due to mechanical stress or repeated thermal cycling. The new feature of KiCad 8 adds a tapered or teardrop-shaped extension at the junction of pads, vias, and tracks, improving the PCB's durability and reliability, while also making your PCB look more professional! Let's explore the key benefits of incorporating teardrops into your PCB designs as well as the procedure to add them using KiCad 8.

One of the primary advantages of teardrops is improved durability and reliability. They help manage thermal stress by providing more surface area for the copper layer to bond to the PCB substrate, making it less likely that the pads will delaminate from the board during soldering. This can be helpful, as copper and epoxy expand and contract at varying rates when exposed to heat. Teardrops also contribute to better manufacturability. The broader and more robust connections they create reduce the likelihood of defects like open circuits caused by tiny imperfections during the etching process, particularly for very fine tracks and pads.

Likewise, they also increase the repairability of your PCBs. As they add more copper at the connection points, they can make it easier to solder to a pad or via. Finally, signal integrity is another area where teardrops shine, especially in high-frequency designs. Sharp corners in PCB tracks can cause signal reflections, but teardrops provide smoother transitions that help maintain cleaner signal transmission. On the other hand, these high-frequency designs often rely on tracks of carefully controlled impedance, and introducing teardrops might inadvertently affect it or create unwanted effects. Therefore, they can require careful consideration in some designs.

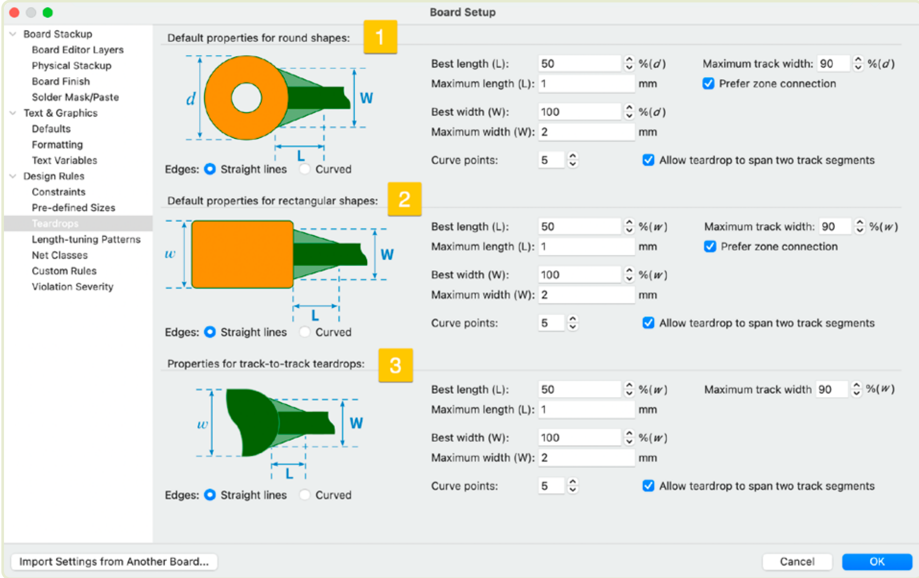


Figure 3: The Teardrops setup options in Board Setup.

In KiCad, you can set up the properties for teardrops in the *Teardrops* tab of the *Design Rules* list of the *Board Setup*. The properties are shown in **Figure 3**. You can set up the intended default settings for teardrops attached to circular and rectangular pads and the connection between tracks. It is possible to add teardrops to new and existing designs. Let's set teardrops for one of the projects (the MCU Datalogger) featured in the second volume of *KiCad Like a Pro* (4$^{th}$ Edition): Projects and Recipes" [2]. Currently, this project has plain pad-to-track connections. I will work with the circular pad teardrop properties from Figure 3. In **Figure 4**, you can see the original pads on the left. After applying the teardrops on these pads, the result is on the right.

While teardrops offer several benefits in PCB design, there are situations where they might not be the best choice. In space-constrained designs, particularly high-density PCBs, every millimeter counts. The additional space taken up by teardrops can limit your ability to place components or route tracks efficiently, making them impractical in some cases.

## Grid Size Overrides

This feature is new to KiCad in version 8. With Grid Overrides, KiCad automatically switches to a specific grid size when performing operations such as moving or placing objects in the schematic editor. The *Grid Overrides* button in the left toolbar allows you to enable or disable this feature.

One of the great things about this feature is that KiCad can switch between different grids for operations like placing text, while keeping symbols and wires on a 50 mil grid

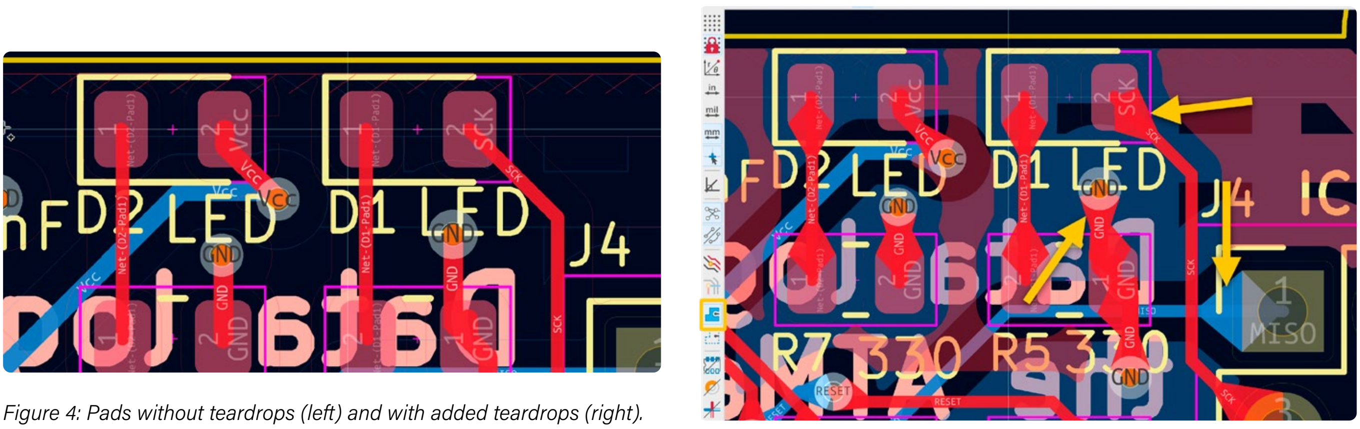


Figure 4: Pads without teardrops (left) and with added teardrops (right).

to match the symbol library pin spacing. This level of flexibility in grid handling is a game changer for ensuring precision and consistency in my schematic designs. It means you can set the grid sizes you want for connected items, wires, text, and graphics (**Figure 5**) and have KiCad automatically switch to the appropriate grid when one of those items is selected (so you don't have to do this manually).

I can't stress enough how much of a time-saver this feature is. It allows me to seamlessly switch between grids based on the specific needs of my design without having to adjust the grid settings manually each time. Once you set your preferred overrides in the *Preferences*, you can simply go on with your work and only rarely have to think about the grid size you are using. The automation allows the grid to adjust to the tool you are using, be it wiring, drawing, or writing text, and select the appropriate grid size.

## Net Class Assignment Integration

In KiCad 8, the integration between the schematic and PCB layout has been improved with the automatic reflection of net class assignments. Any net class assignments in the schematic are now seamlessly integrated into the PCB layout, visible in the PCB editor environment. The PCB editor will automatically reflect those changes when you create or modify net classes in the schematic. For example, if you have defined a net class for high-speed signals in the schematic, those signals will be grouped together, and the appropriate design rules will be applied to them in the PCB layout.

This new feature streamlines the design process and ensures that net classes are consistent between the schematic and layout, reducing the potential for errors and mismatches. It also saves time by manually eliminating the need to replicate net class assignments in the schematic and layout.

To illustrate this, let's consider a practical example, again from the book *Kicad Like A Pro* (4th Edition). In one of the projects the net classes are set, in the schematic editor, as per **Figure 6**. As I continued the work in the PCB editor, I decided to add a new

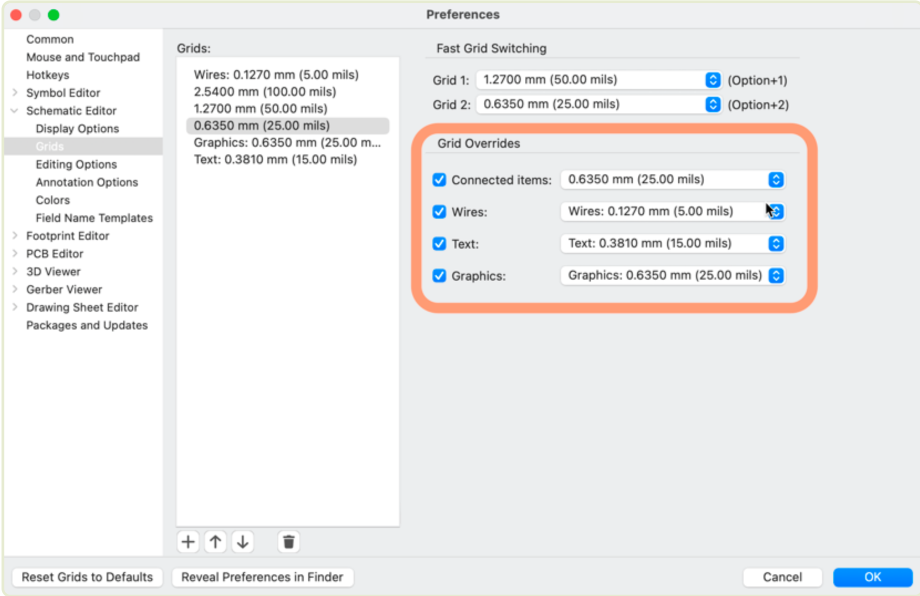


Figure 5: The Grid Overrides setup pane in the Schematic Editor preferences.

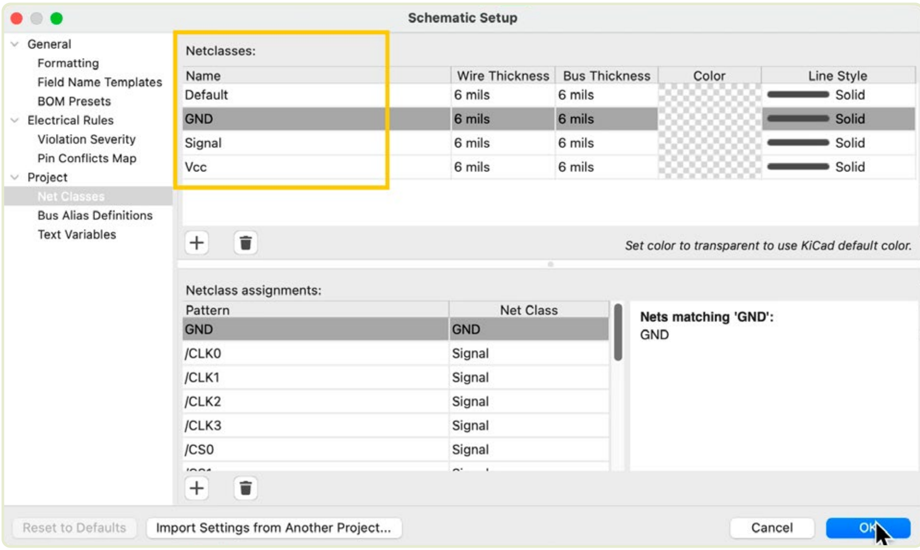


Figure 6: Net classes and their net assignments are now integrated across the schematic and PCB editors. Here, you can see the existing netclasses in the schematic editor.

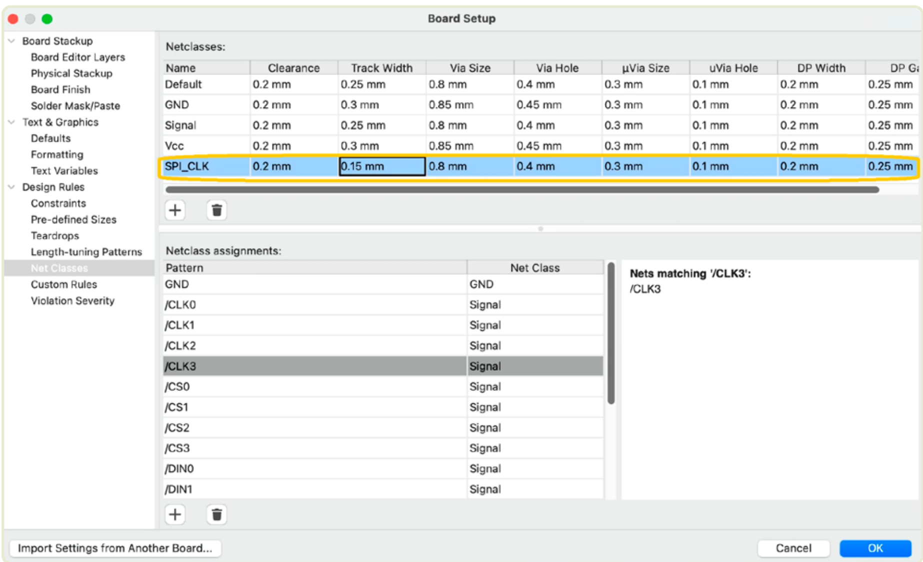


Figure 7: Created a new net class in the PCB editor.

netclass for the SPI clock. Still, in the PCB editor, I created this netclass in the *Board Setup Net Classes* tab like in **Figure 7**.

In previous versions of KiCad, the new *SPI_CLK* netclass would not be available in the schematic editor, so the schematic and PCB would be out of sync. However, in KiCad 8, the improved integration syncs netclasses automatically. To check this, I can see that the new netclass exists in the schematic editor (**Figure 8**).

The automatic net class assignment integration in KiCad 8 greatly enhances the design process. This new feature reduces the manual workload and potential for oversight, just as you saw with the grid size override feature. We can now focus more on optimizing their designs than managing administrative tasks.

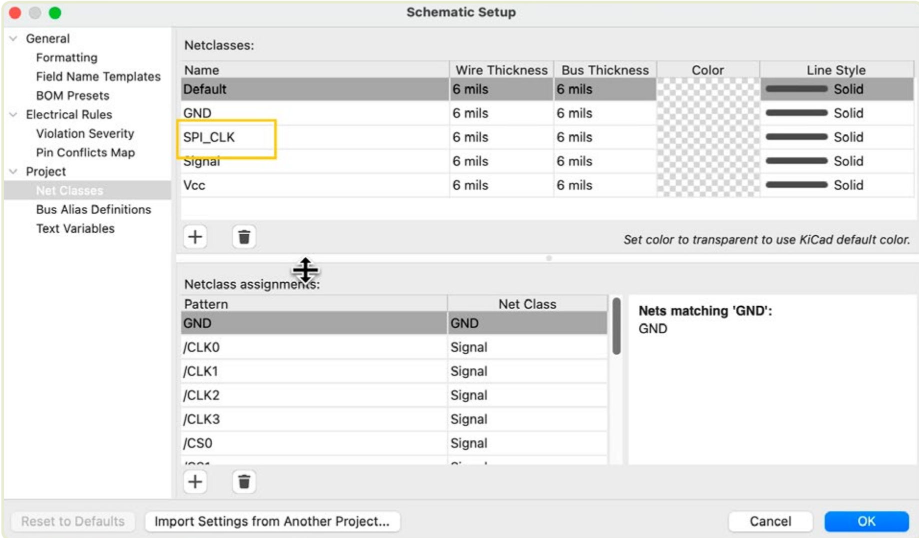


*Figure 8: The new net class has been synced in the schematic editor.*

## Simulator

One of the standout updates in KiCad 8 is enhancing the embedded SPICE simulation tools powered by ngspice [4]. The collaboration between KiCad and ngspice developers has led to several new features and bug fixes, making circuit simulation more powerful and practical for users.

Ngspice, a mixed-level/mixed-signal electronic circuit simulator, is widely used to simulate analog and digital circuits. It provides detailed analyses of circuit performance, which is crucial for design verification and optimization. Integrating ngspice within KiCad allows users to annotate schematics with SPICE directives, simulate circuits, and analyze results without leaving the KiCad environment. This seamless integration streamlines the design process and improves efficiency.

KiCad 8 introduces an overhauled simulator user interface. One of the most interesting new features is the ability to manage plots of multiple signals at the same time. Additionally, the simulator now supports plotting power signals alongside voltage and current, providing a complete picture of the circuit's power usage. These updates make the simulator an even more powerful circuit design and analysis tool and greatly enhance the user experience. **Figure 9** shows the result of a transient

(TRAN) simulation. The plot shows multiple values, including voltage, current, and power over time.

KiCad 8 adds four new simulation types: pole-zero, noise, S-parameter, and FFT. This expansion allows for a more comprehensive and accurate analysis of electronic circuits. Users can define custom signals and add plots for expressions such as `V(/in)` and `V(/out)`, visualizing a broader range of simulation outputs directly within KiCad.

Moreover, operating point (OP) simulation results can be visualized directly on the schematic canvas. This feature allows users to gain deeper insights into the behavior and performance of their circuits, making it easier to optimize and refine designs. **Figure 10** shows the operating point simulation results displayed directly in the schematic editor within red labels. I found these improved simulation features and their integration between the simulator and the editor very useful. They reflect KiCad's commitment to continuously improving and advancing its capabilities to meet the evolving needs of its users.

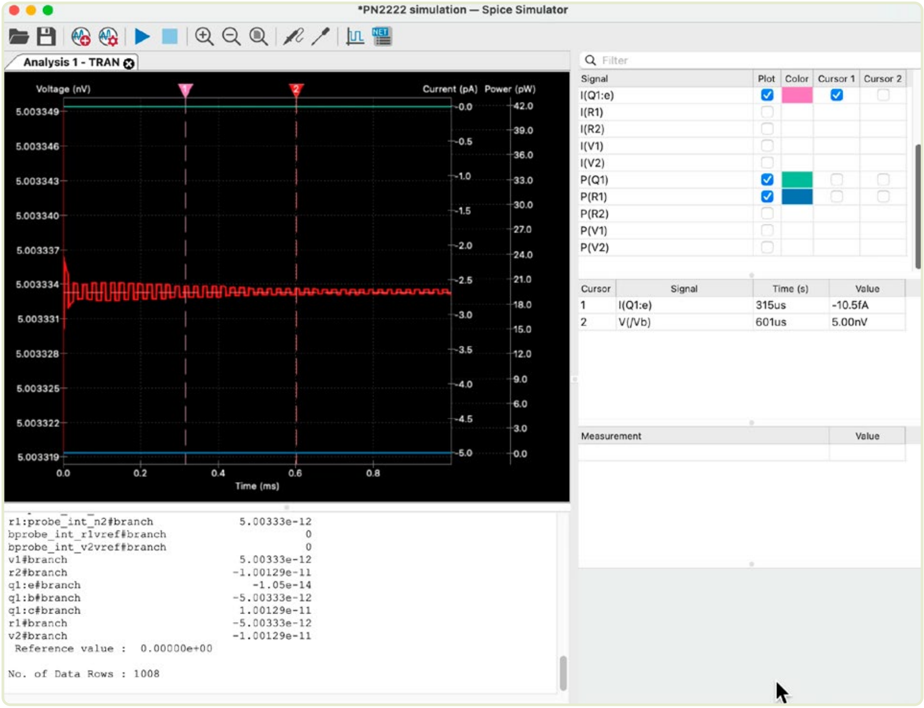



Figure 9: A transient simulation plot in the updated KiCad circuit simulator.

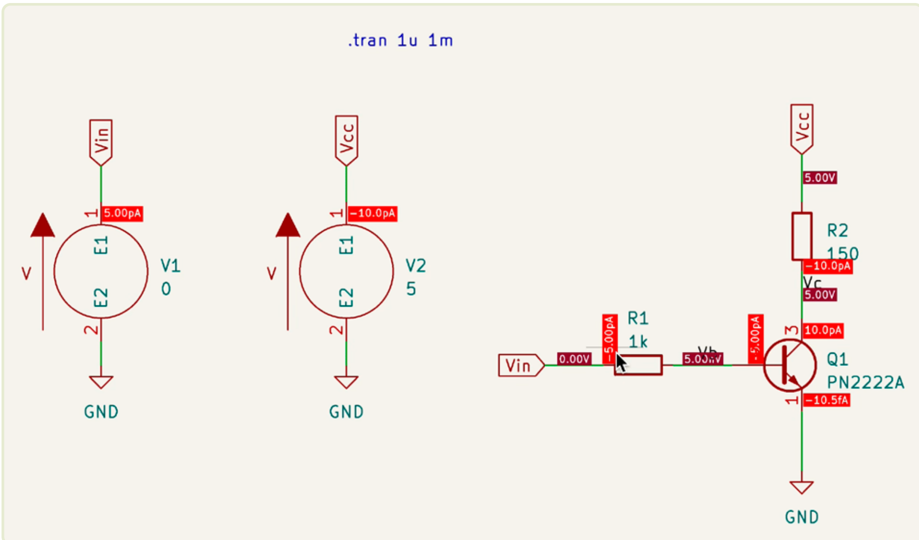



Figure 10: A new feature in KiCad 8 is the simulator labels in the schematic editor.

## Other Improvements

There are many other small yet important improvements in KiCad 8, and before finishing this article, I'd like to mention these:

- **Enhanced import and export capabilities:** KiCad 8 introduces improved data import and export tools. Users can now import projects from various tools, including Solidworks and LTSpice, and export in formats like IPC-2581 and STEP with copper shapes, for better collaboration with other tools.
- **Updated schematic and symbol editor:** The schematic editor now features new UI panels for properties, search, and net navigation, improving navigation and editing efficiency. The latest BOM exporter allows in-app customization, while editable power symbols and pin helpers streamline design processes.
- **3D viewer enhancements:** The 3D viewer now has an updated user interface with an appearance panel, visibility

## WEB LINKS

[1] KiCad 8 download page: https://kicad.org/download
[2] Peter Dalmaris, KiCad Like A Pro - 4th edition - Volume 1 (Elektor, 2024): www.elektor.com/20928
[3] Peter Dalmaris, KiCad Like A Pro - 4th edition - Volume 2 (Elektor, 2024): www.elektor.com/20930
[4] ngspice: https://ngspice.sourceforge.io

presets, and viewports, making it easier to inspect and manipulate 3D models.

- **Command line interface (CLI) enhancements:** The expanded CLI in KiCad 8 supports new functions like DRC/ERC reports in JSON, BOM generation, and exporting glTF/VRML models, offering more control and flexibility for advanced users.
- **Interactive length-tuning and custom-shape pads:** The interactive length tuning tools now support modifiable patterns, and users can define custom thermal spoke templates for pads, which can come in handy for specific uses cases.

While KiCad 7 is already an excellent tool, these enhancements make KiCad 8 an even more robust and efficient electronic design tool for novice and advanced users!

240278-01

*Editor's note: This article first appeared in Elektor November/December 2024.*

## Questions or Comments?

Do you have technical questions or comments about this article? If so, please contact the Elektor editorial staff at editor@elektor.com.

## About the Author

Dr. Peter Dalmaris is an educator, electrical engineer, electronics hobbyist, and Maker. Creator of online video courses on DIY electronics and author of several technical books including the series *KiCad Like a Pro*, *KiCad 6 Fundamentals and Projects* and their updated versions. His company, Tech Explorations, offers a variety of educational courses and bootcamps for electronics hobbyists, STEM students, and STEM teachers.

## Related Products

- Peter Dalmaris, *KiCad Like A Pro - 4th edition - Volume 1* (Elektor, 2024)
  www.elektor.com/20928
- Peter Dalmaris, *KiCad Like A Pro - 4th edition - Volume 2* (Elektor, 2024)
  www.elektor.com/20930

# SMT Inductors

## Coils and Ferrites — Selection Made Easy

By Dr. Heinz Zenkner (Würth Elektronik eiSos)

How do you choose the right inductor for your application? This article compares the differences between three inductive SMT components: ceramic inductors, SMT ferrites, and wire-wound ferrite inductors. Their electrical properties make them suitable for different applications, and their physical parasitic properties can be used to your advantage in circuit design.

Inductive components are available in numerous forms. SMT versions are very popular, as they are easy to mount on circuit boards. However, not all inductors are the same, as this article demonstrates using three representatives of SMT inductors: ceramic inductance, SMT ferrite, and wire-wound ferrite inductance.

**Figure 1** shows the impedance curves of the three inductor types in comparison:

- SMT ferrite: WE-CBF [1]
- SMT inductor with ceramic core ("air coil"): WE-KI [2]
- Wire windings on ferrite core ("wire-wound ferrite"): WE-RFI [3]

The components were selected so that they have a similar impedance curve in the range below their impedance peaks. The differences in the impedances can be seen in the area of the peaks, the SMT ferrite has its maximum at the lowest frequency, while the wire-wound ferrite at the highest. The ceramic inductor has the steepest rise and fall in the area of the impedance maximum, and therefore the highest quality factor Q.

### Electrical Parameters in Comparison

**Figure 2** compares the electrical parameters of the inductors. For inductors without a ferrite core (WE-KI), the inductance is given as a value in the data sheets, in this case 560 nH. Although the inductance value is specified at a particular measuring frequency, the value below the resonant frequency is almost constant (see data sheet).

On closer inspection, the reactance of the inductance does not increase linearly with frequency. Two effects increase the impedance of the air-core coil: the increase in reactance due to Lenz's law and the increase in resistance due to the skin effect.

In the purely inductive circuit, the coil is connected directly to the AC supply voltage. As the voltage rises and falls with frequency, the self-induced counter-electromagnetic force (EMF) in the coil also rises and falls as a function of this change. This self-induced back EMF is directly proportional to the rate of change of the current

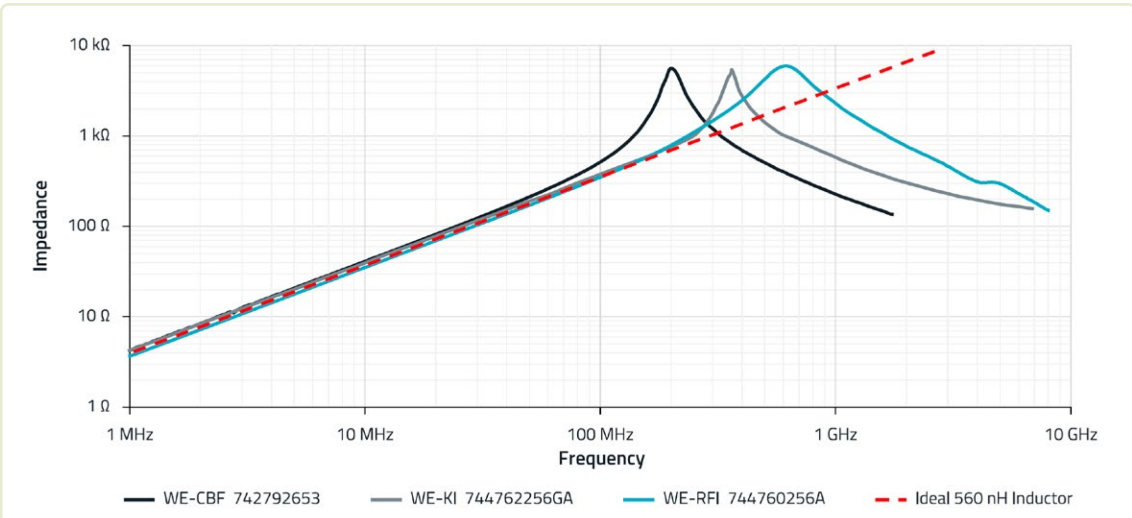
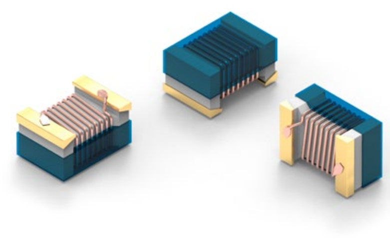
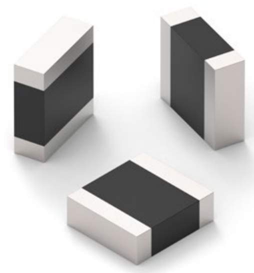


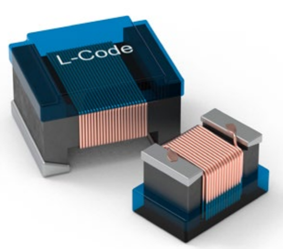

*Figure 1: Comparison of the impedances of SMT ferrite, ceramic/air inductance and wire-wound ferrite.*



| Properties | | Test conditions | Value | Unit | Tol. |
|---|---|---|---|---|---|
| Inductance | L | 25 MHz | 560 | nH | ±2% |
| Q-Factor | Q | 100 MHz | 45 | | min. |
| DC Resistance | $R_{DC}$ | @ 20 °C | 1.5 | Ω | max. |
| Rated Current | $I_R$ | ΔT = 15 K | 310 | mA | max. |
| Self Resonant Frequency | $f_{res}$ | | 430 | MHz | min. |



| Properties | | Test conditions | Value | Unit | Tol. |
|---|---|---|---|---|---|
| Impedance @ 100 MHz | Z | 100 MHz | 600 | Ω | ±25% |
| Maximum Impedance | $Z_{max}$ | 200 MHz | 4500 | Ω | typ. |
| Rated Current 1 | $I_{R\,1}$ | ΔT = 20 K | 300 | mA | max. |
| Rated Current 2 | $I_{R\,2}$ | ΔT = 40 K | 500 | mA | max. |
| DC Resistance | $R_{DC}$ | @ 20 °C | 0.65 | Ω | max. |
| Type | High Speed | | | | |




| Properties | | Test conditions | Value | Unit | Tol. |
|---|---|---|---|---|---|
| Inductance | L | 25.2 MHz | 0.56 | µH | ±5% |
| Q-Factor | Q | 100 MHz | 45 | | min. |
| Impedance @ 100 MHz | Z | 100 MHz | 350 | Ω | ±25% |
| Maximum Impedance | $Z_{max}$ | 600 MHz | 5570 | Ω | typ. |
| Rated Current 1 | $I_{R\,1}$ | ΔT = 15 K | 450 | mA | max. |
| Rated Current 2 | $I_{R\,2}$ | ΔT = 40 K | 620 | mA | max. |
| DC Resistance | $R_{DC}$ | @ 20 °C | 0.55 | Ω | max. |
| Self Resonant Frequency | $f_{res}$ | | 340 | MHz | min. |

*Figure 2: Comparison of the parameters of SMT ferrite, ceramic/air inductance and wire-wound ferrite.*

through the coil (Lenz's law) and therefore increases with frequency. Consequently, the reactance of the inductance also increases with frequency; this relationship is proportional.

A further increase in impedance is caused by the skin effect. At low frequencies, a conductor uses its entire cross-sectional area as a transport medium for charge carriers. If the frequency increases, an increased magnetic field in the direction of the center of the conductor represents an impedance for the charge carriers, causing the current density in the center of the conductor to decrease and the current density at the edge of the conductor to increase. This increased current density near the edge of the conductor is known as the skin effect. The effect increases with frequency and also occurs with all other inductors (with a ferrite core).

The resonant frequency of the inductance without a ferrite core is primarily caused by the parasitic capacitance between the individual windings. Whenever two conductors are arranged in close proximity but separated by a dielectric and there is a voltage difference between them, a capacitor is formed.

The chain of these winding capacitances is connected in parallel to the winding inductance and thus forms a parallel resonant circuit. In addition, there is a parasitic capacitance between the connections (solder pads), which is parallel to the winding capacitance. This results in a parasitic total capacitance in parallel with the winding as an equivalent circuit. The equivalent circuit is shown in **Figure 3** on the left.

For inductors with a ferrite core (WE-RFI) and SMT ferrites (WE-CBF), the data sheet does not specify an inductance value, but rather an impedance at a measuring frequency. It can also be seen that the SMT ferrite has the highest tolerance, whereas the inductance without ferrite has the lowest tolerance.

Since the WE-KI inductor does not have a ferrite core, it requires more turns of wire for the same impedance as the components with ferrite, which explains why the WE-KI also has the highest wire resistance $R_{DC}$. A Q factor, i.e. a quality factor, is specified for both the WE-KI and the WE-RFI, but not for the WE-CBF.

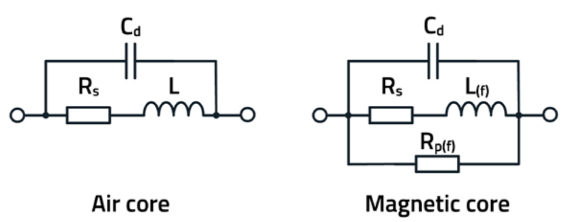



*Figure 3: Equivalent circuit of an inductor without magnetic core (left) and with magnetic core (right).*

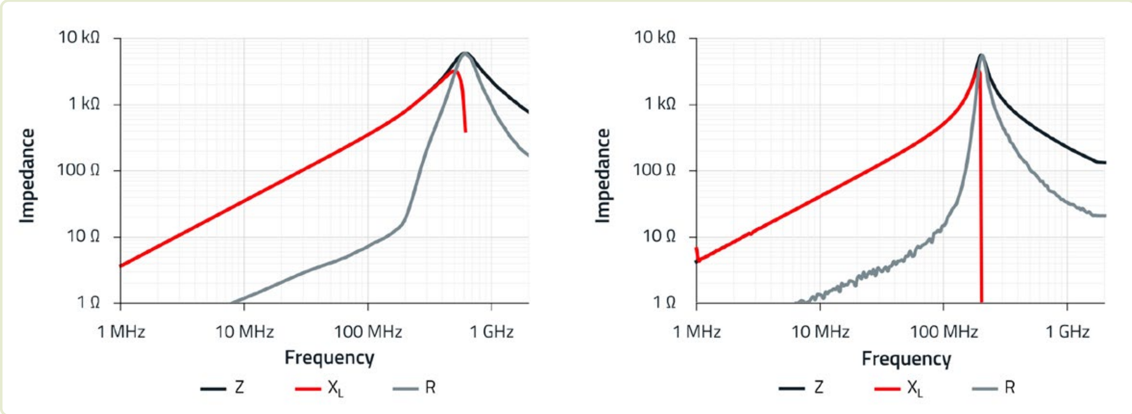



*Figure 4: Typical impedance curves of the WE-RFI 744760256A inductor (top) and the WE-CBF 742792653 SMT ferrite (bottom).*

The Q factor is a measure of the dissipative property of an inductor. Inductors with a high Q factor have low losses and a narrower impedance curve. Inductors with a low Q factor, on the other hand, have higher losses and a broader impedance curve. The magnitude of the maximum impedance of the inductor is related to the quality factor Q. Low-loss inductors with a high Q factor have a very high maximum impedance, while an inductor with high losses has a lower maximum impedance. By changing the way an inductor is wound or the core materials used, the impedance maximum and the frequency range of the impedance maximum can be adjusted. But what is the maximum impedance all about?

## Magnetic Core Materials

**Figure 4** shows the impedance curves as a function of the frequency of the WE-RFI inductor and the WE-CBF SMT ferrite. Both components use ferrite materials as the core material. The diagrams each show three different curves, R — as resistive (ohmic) resistance, $X_L$ — as reactance (inductive) and Z — as the value of the component's impedance. It is important to understand these diagrams in order to successfully use inductors with ferrite material in circuits.

In many radio frequency applications where large inductance values are required in a small space, inductors with an "air core" cannot be used due to their size. The design of the inductor can be smaller if the air core is replaced by a core material with a higher magnetic permeability ($\mu_r > 1$).

If the size remains the same, the inductance value is maintained despite the reduced number of windings.

This allows several advantages to be achieved:

- Smaller size — due to the smaller number of turns required for a given inductance.
- Increased Q — fewer turns mean less wire resistance.
- Adjusting the impedance of the inductance over frequency — through targeted selection/mixing of the core material.

However, the use of magnetic cores presents some major problems and care must be taken to ensure that the core material chosen is the right one for the job; some of these problems are:

- Every core material is highly lossy above a specific frequency range. For example, adding a magnetic core to an air core coil can reduce the quality of the inductance depending on the material used and the operating frequency.
- The permeability of all magnetic cores changes with frequency and generally falls to a very small value at the upper end of their operating range. Eventually, it approaches the permeability of air ($\mu_r = 1$) and becomes "invisible" to the circuit.
- The higher the permeability of the core, the more sensitive it is to temperature fluctuations. The inductance of the coil can therefore fluctuate considerably over wide temperature ranges.
- The permeability of the magnetic core changes with the applied signal level. If the current through the inductance is too high and the magnetic flux density through the core becomes too high, the core will saturate.

These problems can be overcome if care is taken during the development stage to ensure that the inductors are selected correctly for their intended use. For this purpose, the impedance diagrams with the three different impedance curves R, $X_L$ and Z are required. The behavior of the curves as a function of the frequency depends strongly on the magnetic properties of the core material.

The equivalent circuit of an inductor without a magnetic core is shown in **Figure 3** above.

The quality factor of an inductor with an "air core" is given by **equation 1**:

$$Q = \frac{X_L}{R_S}$$

where (**equation 2**) applies to $X_L$:

$$X_L = \omega \cdot L$$

where $R_S$ is the resistance of the windings.

If a magnetic core is added to the inductance, the equivalent circuit resembles **Figure 3** (right). The resistance $R_p(f)$ has been added to represent the losses that occur in the core itself. These frequency-dependent losses occur in the form of magnetic hysteresis. Hysteresis is the power loss in the core that occurs due to eddy currents and the realignment of the magnetic particles in the material when the magnetization changes. Eddy currents flow in the core due to the currents induced in it. In addition, the inductance L is also given a frequency dependence L(f), since, as already mentioned earlier, the magnetic permeability of the material varies non-linear with frequency f. The quality of an inductor with a ferrite core is therefore a variable parameter that depends on the current flowing through the inductor, and must therefore be determined on a case-by-case basis.

Ferrite is a material that mainly contains iron. It is made from a mixture of iron oxide and other micro metals. Since the material has a low electrical conductivity, it reduces eddy currents and therefore eddy current losses remain low. A special property of these materials is their strong dependence on frequency, magnetic flux density, and temperature.

## Complex Permeability

The magnetic properties of materials can be described by the "magnetic permeability" μ. μ describes a property that quantifies the magnetic response of the flux density B when the material is exposed to a magnetic field strength H. It is proportional to the magnetic field strength and to the ratio of the changes in B and H (**equation 3**):

$$\mu = \frac{\Delta B}{\Delta H}$$

The value of the absolute permeability μ expresses the direct ratio of B (T) to H (A/m), with the resulting SI unit is (H/m). The relative permeability is unitless, it refers to the permeability of vacuum ($\mu_0$) and is usually specified in data sheets of inductors. The relative values provide an easily comprehensible indicator of the extent to which the material in question concentrates the magnetic field "better" than the vacuum.

This results in the relationship given in **equation 4**:

$$\mu = \mu_r \cdot \mu_0$$

with $\mu_0$: Magnetic permeability of the vacuum: $1.26 \times 10^{-6}$ (H/m).

Most of the ferrite materials used are iron powder mixtures with manganese-zinc (MnZn) and nickel-zinc (NiZn) additions; $\mu_r$ is typically in the range of 600 to 15,000 for MnZn and 10 to 1,500 for NiZn. It is important to note that the relative permeability strongly depends on the frequency of the magnetic field. Moreover, the curves in Figure 4 already indicate that the relative magnetic permeability has two components, a real component $\mu_r'$ and an imaginary component $\mu_r''$. This complex permeability becomes relevant with high-frequency magnetic field effects, in which a phase shift between H and B occurs. This relationship results in **equation 5**:

$$\mu = \frac{B_0 \cdot e^{j(\omega t - \delta)}}{H_0 \cdot e^{j\omega t}} = \frac{B_0}{H_0} \cdot e^{-\delta} = \frac{B_0}{H_0} \cdot \cos(\delta) = -j \cdot \frac{B_0}{H_0} \cdot \sin(\delta)$$

applied to the inductor with ferrite core results in **equations 6 and 7**:

$$L_S = \mu' \cdot L_0 \qquad \text{and} \qquad R_S = \omega \cdot L_0 \cdot \mu''$$

where $L_0$ is the inductance of the wire winding without ferrite.

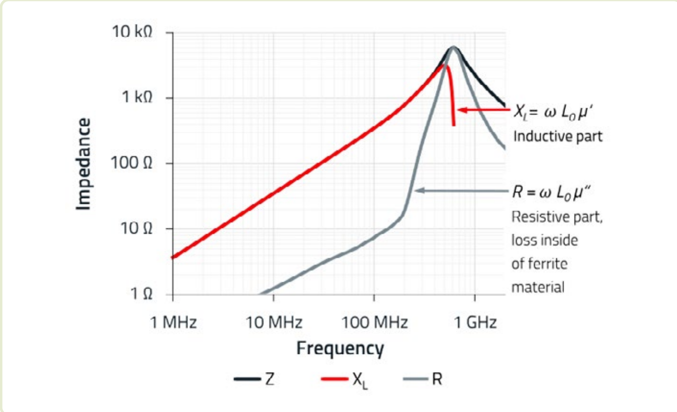


*Figure 5: Impedance curves of the WE-RFI 744760256A inductor.*

The relationship in **equation 8** therefore applies:

$$\underline{Z} = j \cdot \omega \cdot L_0 \cdot (\mu' - j \cdot \mu'') = R + j \cdot X$$

with $L_0$: Inductance without ferrite.

It is easy to see from the formulas that a high permeability leads to a high inductance, but it is also typically associated with higher core losses.

The individual components of the impedance, i.e. Z(f), $X_L$(f) and R(f), are shown in the ferrite inductor data sheets. **Figure 5** shows the impedance curves of the WE-RFI 744760256A inductor once again.

This also makes it clear why the impedance curves are of great importance for a functioning circuit when using inductors with a ferrite core. The impedance (Z) is a vector combination of resistance and phase. The ohmic resistance R has a dissipative property; energy is converted and not recovered. The reactance $X_L$ is the part of the impedance that is generated by the inductance. The phase is the delay between a voltage applied to the component and the current flowing through the component. Both the ohmic resistance and the reactance vary with the frequency, and therefore so does the phase.

But that's not all. Magnetic materials exhibit saturation effects that, above certain frequencies, depend primarily on the magnetic flux density, i.e. the current flowing through the ferrite inductor. This is referred to as core saturation, an effect that "air inductance" does not experience. **Figure 6** shows the impedance of the two inductors WE-RFI 744760256A and WE-CBF 742792653 with different DC bias over the frequency. The difference is clearly visible.

Wire-wound inductors are less sensitive to DC bias than SMT ferrites for the same rated current.

The influence of bias magnetizations of different strengths on the impedance curves can be simulated for all part numbers using the online simulation platform from Würth Elektronik REDEXPERT [4].

## Preferred Fields of Application for Inductors

**Table 1** provides an overview of the most important parameters of the three inductor types and their preferred fields of application. The aspects of measuring impedance behavior and detailed tips on using the right inductor in various applications are beyond the scope of this article.

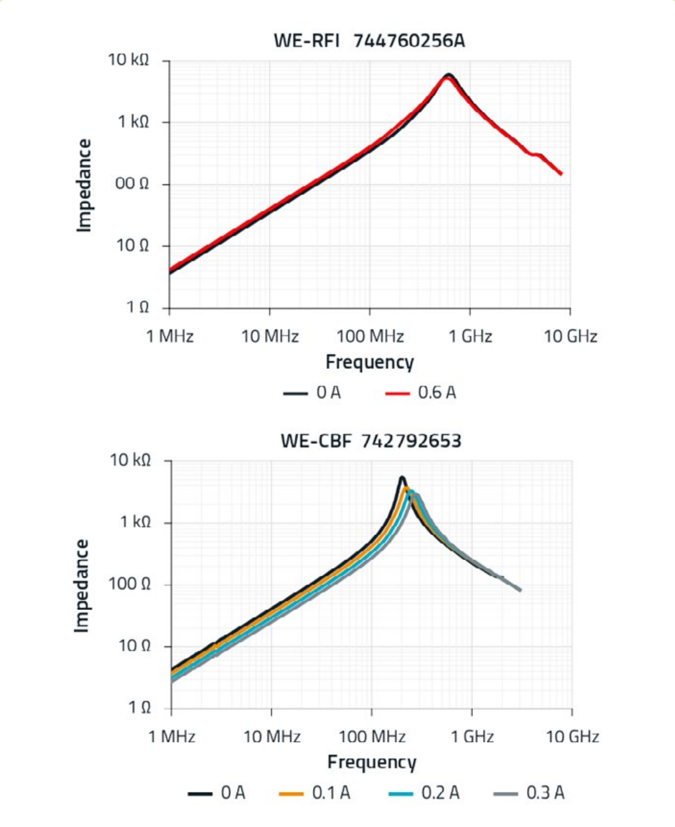



*Figure 6: Impedance of the two inductors WE-RFI 744760256A and WE-CBF 742792653 with different DC bias current over the frequency.*


## About the Author

Dr.-Ing. Heinz Zenkner studied electrical engineering with a focus on communications and radio frequency technology and holds a doctorate. He has been a publicly appointed and sworn expert for EMC for many years. In addition to numerous scientific publications, he is a frequent author of many works on EMC. Heinz has also worked as a lecturer at various universities, at the Chamber of Industry and Commerce and at numerous seminars. He has been involved in industrial electronics for many years, from the initial idea of a product through to series production. He is particularly interested in wireless energy transmission, for which he has developed his own theoretical and practical concepts.


The AppNote ANP129 from Würth Elektronik [5], on which this article is based, suggests a more detailed setup for measuring impedance behavior and presents a simple method for measuring impedance.

In addition, the various fields of application of the different inductor types are illustrated using the example of a 20-MHz signal generator.

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**Table 1: Overview and comparison of the most important parameters of SMT ferrite, ceramic inductance and wire-wound ferrite inductance.**

| Parameter | SMT ferrite | Ceramic inductor | Wire-wound ferrite inductor |
|---|---|---|---|
| Inductance range | --- | low | high |
| Impedance range | high | low | high |
| Tolerance of the inductor | high | very low | low |
| Rated current range | high | very high | low |
| Loss resistance RDC | low | very low | medium/high |
| Self-resonance frequency | high | very high | low/medium |
| Shape of the resonant frequency (bandwidth) | wide | narrow | narrow, multiple |
| Quality Q in the range below the resonant frequency | low | very high | medium |
| Preferred application | Attenuation/reduction of HF currents | HF filters and resonant circuits | High-frequency decoupling, steep filters, attenuation/reduction of HF currents |

## WEB LINKS


[1] SMT ferrite WE-CBF from Würth Elektronik: https://www.we-online.com/en/components/products/WE-CBF

[2] SMT inductor with ceramic core from Würth Elektronik: https://www.we-online.com/en/components/products/WE-KI

[3] Wire-wound SMT bead ferrite from Würth Elektronik: https://www.we-online.com/en/components/products/WE-RFI_FERRITE_BEAD

[4] Example simulation in RedExpert: https://we-online.com/re/5oGcZLA5

[5] Zenkner, H., "Inductors, SMT ferrites and wire-wound SMT ferrites - The wire makes the difference," AppNote ANP129 from Würth Elektronik: https://www.we-online.com/ANP129

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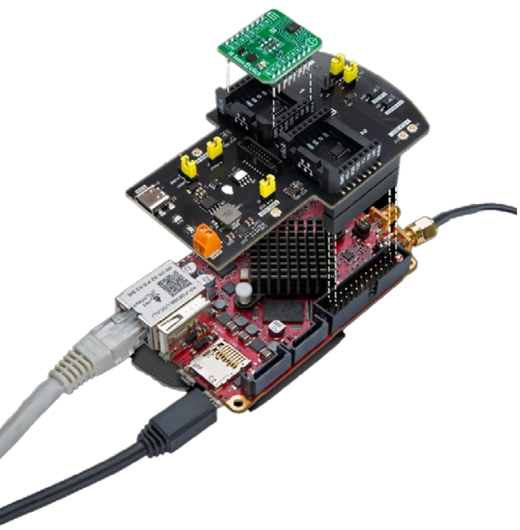

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# Siglent Presents Its New **Vector Network Analyzer Platform SNA6000A**

**Contributed by Siglent**

Siglent has introduced the new SNA6000A Vector Network Analyzer series, designed to meet the rigorous demands of modern RF designs with outstanding specifications and a wide range of powerful features. The series includes eight models, offering bandwidths of 13.5 GHz and 26.5 GHz. Each bandwidth is available in both 2-port and 4-port configurations. Additionally, all models come in a standard version, or an extended version (SNA61xxA) equipped with Direct Receiver Access (DRA), which enhance the flexibility and performance of the instrument, especially in advanced applications.

*Figure 1: The SNA6024A Vector Network Analyzer.*

A high dynamic range enables more precise and reliable measurements, critical in research, development, and production. The SNA6000A stands out with a dynamic range exceeding 135 dB, making it ideal for detailed analysis of weak signals, even in the presence of stronger ones (**Figure 1**). This makes the analyzer a perfect solution for tasks like measuring filters with low insertion loss and high stopband attenuation. Additionally, the high dynamic range helps reduce signal distortion, enhancing signal integrity and improving calibration accuracy, especially in scenarios where external factors like cables or adapters need to be minimized.

In practice, calibration alone cannot always fully eliminate all external influences. Therefore, it is essential to have the right tools to mitigate interference from cables or test sockets. The SNA6000A series provides features such as an adjustable reference plane, adapter removal, and embedding/de-embedding to address these issues effectively.

The Time Domain Reflectometry (TDR) functions enhance the VNA with the capability to thoroughly diagnose and characterize signal paths, lines, and cables. These functions can be added to the SNA6000A with the SNA6000-TDA and SNA6000-TDR options. The TDR option also enables the creation of eye diagrams, which are critical for assessing signal integrity in high-speed digital communications (**Figure 2**). Combining TDR with the VNA allows for jitter analysis, essential for examining the temporal stability of signals — both key features in high-speed digital development.

Additionally, the analyzer can be upgraded to perform pulsed measurements, which is particularly beneficial when characterizing high-frequency components in real-world operating conditions, such as radar and communication systems. This method allows for detailed analysis of components with short pulses, precise evaluation of fast switching operations, and optimization of performance in time-sensitive applications.

The integration of a spectrum analysis function into a vector network analyzer (VNA) opens up expanded possibilities, especially in the development and testing of high-frequency amplifiers, oscillators and communication systems. This extension is also available as an option, namely SNA6000-SA. It allows precise analysis of harmonics, intermodulation products and other nonlinear effects, while simultaneously optimizing signal quality and bandwidth utilization in communication applications. The combination of VNA and spectrum analysis in one device not only offers space and cost-saving advantages, but also enables deeper and more comprehensive signal characterization. This expanded measurement functionality leads to more efficient diagnostics and improved insight into the behaviour of high-frequency components and systems.

In addition to the functions and extensions described, currently two further options are available. Firstly, the SNA6000-SMM scalar mixer analysis, i.e. measurement on frequency-converting components. Secondly, the material analysis option. This enables the VNA to determine important parameters for electronic applications, especially the permittivity and permeability of materials. An integrated formula editor and mask test support developers in analyzing the test object and speed up the evaluation. The large 12-inch touchscreen can be flexibly configured and enables a clear display of several windows with different measurements.

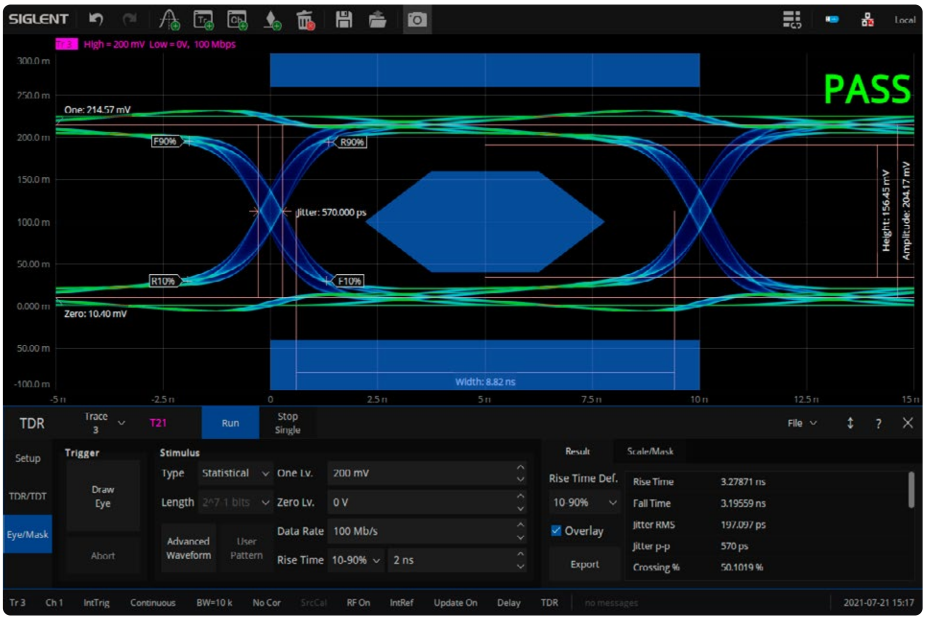


*Figure 2: The Time Domain Reflectometry (TDR) functions enhance the Vector Network Analyzer with the capability to thoroughly diagnose and characterize signal paths, lines, and cables.*

**SNA6000A Vector Network Analyzer**

- Frequency Range: 100 kHz to 13.5 GHz and 100 kHz to 26.5 GHz
- Range of IFBW: 1 Hz to 10 MHz
- Dynamic Range: 135 dB
- Setting Range of Output Level: -55 dBm to +10 dBm
- Standard Bias-Tee connection and pulse hardware
- 4-port models include standard second source
- Jumpers / DRA (Source, Ref and Meas) standard on SNA61xxA models

For characterizing large RF networks within a complete multiport test system, the SNA6000A can be paired with the Siglent SSM5000A Switch Matrix Series. Available with two or four input ports to match the VNA, the system sequentially captures S-parameters across up to 24 output ports. With numerous switch configurations available, you can quickly design a custom test system tailored to your devices, offering exceptional value compared to competing packaged solutions. The SSM5000A series connects to the analyzer via USB or LAN, with automatic matrix detection and port allocation. Users can easily operate it as a complete multiport vector network, with the software already integrated into the VNA firmware.

In summary, the SNA6000A series from Siglent offers a powerful solution for the increasingly demanding challenges in the field of high-frequency technology. The series impresses with its excellent basic specifications and flexibility in use and useful expansion options. Overall, the SNA6000A series represents a versatile, powerful and user-friendly solution for the measurement and analysis needs in modern electronics. More information can be found here [1].

240588-01

## WEB LINK

[1] SNA6000A Vector Network Analyzer: https://www.siglenteu.com/vector-network-analyzer/sna6000a-vector-network-analyzer

# Challenges of DFM Analysis for Flex and Rigid-Flex Design

**Contributed by DownStream Technologies**

Flex and rigid-flex PCB construction is not a new concept. It has become commonplace as engineers look for alternative circuit packaging for ever shrinking electronic products. A flat one-sheet schematic for a straight ribbon cable is analogous to its physical flat substrate. A flat multi-sheet schematic that details circuitry for a rigid-flex design bears little visual resemblance to its three-dimensional, variable material rigid-flex assembly. However, in both schematic examples, schematic-based analysis tools are applied equally. This same truth also applies to common FR4-based two-layer or multilayer PCBs. Today's PCB analysis tools are applicable across all combinations of rigid PCBs, regardless of layer count or size. However, due to unique properties of flexible substrates and combined flexible and rigid substrates, flexible designs require a specific collection of analysis — both functional and manufacture-oriented. Integrity analysis such as impedance, coupling, crosstalk and noise is complicated by variable stackups across flexible designs. A single transmission line can be stripline in a rigid-flex area and microstrip in a flex area. Material types and dielectric constants above or below a trace as it traverses a design also vary. While the challenges for signal integrity analysis for flexible designs are worthy of conversation, this article will focus on the current challenges to *Design for Manufacture* analysis of flex and rigid-flex designs.

## Contrast Rigid PCBs With Flex and Rigid-Flex

Some designers design flexible PCBs as simple bendable circuit boards, but there are vast differences between rigid and flexible. Both technologies produce an electrical interconnect function, but are manufactured using different types of materials and processes. They also have varying applications. No need to design a rigid-flexible PCB for the motherboard of a desktop PC, but rigid-flex is required for most medically implanted devices.

A typical rigid PCB is composed of electro-deposited copper-clad fiberglass substrates bonded together. While there are variances in materials used to bond substrates, it is commonly sheets of cloth pre-impregnated with uncured epoxy. This bonding material composition is not engineered to be flexible. The copper is chemically etched to create a circuit pattern. The hardness of the bonded substrates requires mechanical routing to trim the raw PCBs. All layers of the PCB are commonly identical in size and shape unless cavities, embedded components, or other such exotic construction are present. The rigid PCB layer stackup is identical across the entire PCB area. Soldermask and silkscreen are almost always applied.

Flexible PCBs are comprised of rolled annealed copper over flexible polyimide substrates. Flexible layers or cores are produced with or without adhesives. Adhesiveless flex is prevalent in applications requiring higher performance, while those with adhesives are often found in low-layer-count applications. The most common usage is copper foil laminated to a substrate with epoxy or acrylic adhesive. Both substrate material and adhesive are engineered for bending to minimize trace fracture. Like rigid PCBs, a chemical etching process is used to create a circuit pattern. The flexible nature of the materials requires die cutting or "blanking," rather than mechanical routing. Each layer of

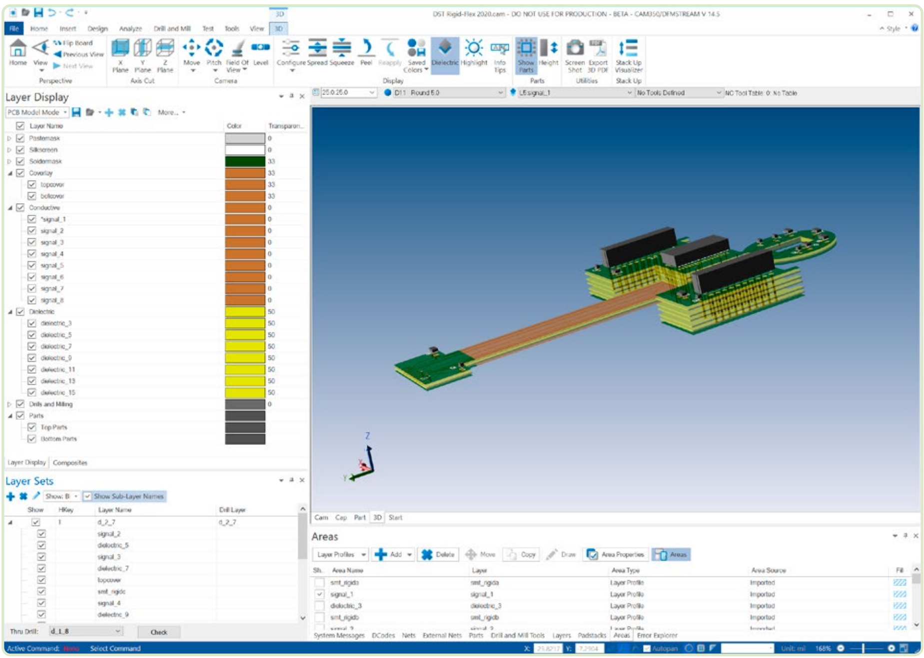

*Figure 1: A rigid-flex design in 3D with layers separated for improved visualization.*

a flexible double-sided core has an identical shape. However, multiple-layer flex is likely to have variances in shape for each layer or core. Flexible PCBs require a thin film insulator over the conductors, known as a coverlay. Unlike rigid PCB soldermasks, coverlays are die cut, much like the flexible layers they insulate. The stackup of a multi-layer flexible PCB can vary across the PCB area. This is especially true with multi-layer flex, where layer shape varies among the collection of layers or cores. A flexible ground or power plane area is typically crosshatched, versus solid for rigid PCBs. The crosshatch reduces potential for conductors to fracture. Alternatively, flexible layers can be shielded with a layer of copper or silver foil. Masking and screening over flexible layers is not rare, but uncommon.

Rigid-flexible PCBs are obviously a combination of rigid and flexible materials. Rigid-flex is in essence a hybrid PCB combination of materials and processes from both rigid and flexible PCBs. The two material types are generally processed separately and bonded together later in the fabrication process. The layer stackup commonly varies greatly across the entire PCB (**Figure 1**). There may be areas of rigid-flex, flex only, various combinations of rigid and flex layer count and so on.

There is also rigidized flex, where blank FR4 or other rigid materials are selectively bonded to flexible substrates to provide stiffness. The rigid stiffener material rarely has conductors present.

## Application of Rigid vs Flex and Rigid-Flex

Rigid PCBs are a foundational technology in today's electronic products. Rigid PCBs offer mechanical integrity and electrical conductivity and reliability, but are limited by their two-dimensional profile. Their flatness limits designers to two dimensions, which severely limits design flexibility, especially as electronic devices decrease in size. Flexible PCBs are bent to take advantage of a three-dimensional space, while also accommodating components. Flexible PCBs enable maximal utilization of space to package electronics, but at a premium cost compared to conventional PCBs.

Rigid and flexible PCBs are present in many electronic products. However, some applications benefit more from one type of circuit board. Rigid PCBs make sense for products such as televisions, desktop PCs, Blu-ray players and other larger electronic products. Flexible PCBs are present in smartphones, smartwatches, tablets, cameras, printers and laptops. They are a fundamental requirement for implanted miniature medical devices such as pacemakers, cochlear implants, and implanted defibrillators. Complex multi-PCB assemblies interconnected with wires or cabling are often redesigned with rigid-flex PCBs to improve reliability and reduce weight and space. This is the catalyst for many military and aerospace products being designed with rigid-flex. One example is a single use smart bullet that can change its trajectory if its intended target moves.

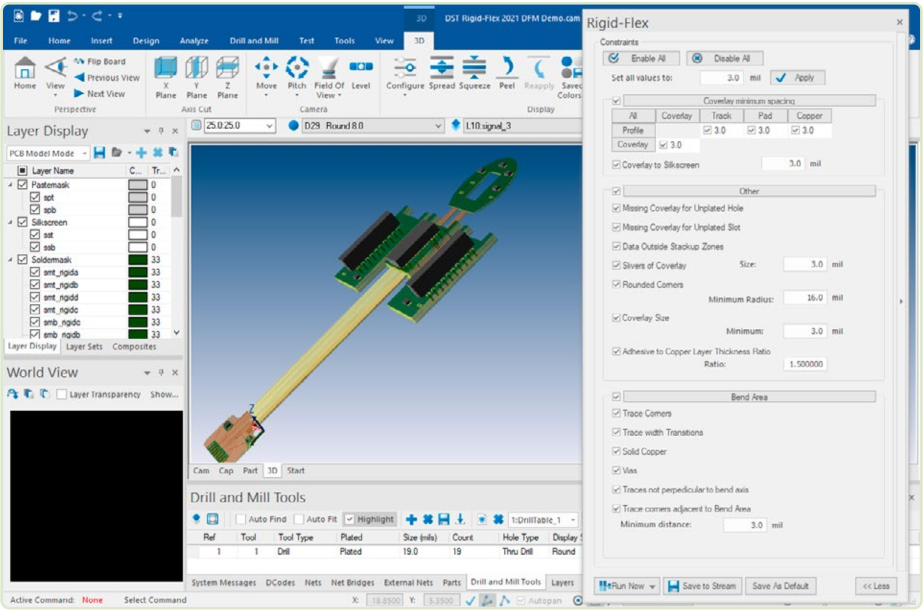


*Figure 2: Rigid-Flex DFM analysis currently available in DownStream's DFMStream product.*

The introduction of small outline, or all surface-mounted semiconductors ushered in a revolution of miniature re-packaging. Think Sony Walkman versus a typical boom box. For years, flexible PCBs were relegated exclusively to replacement of multi-wire cables. Who would not recall the presence of a flexible, flat cable connected to the head of a dot matrix or impact printer. The head would bob back and forth across the paper while the cable dynamically flexed and provided a more reliable interconnect between the printer head and motherboard. The introduction of rigid-flex is not the same game changer as surface mounted packages because of its somewhat limited application and cost differential. We shouldn't expect a new collection of desktop PCs to be designed with rigid-flex motherboards as a means to reduce costs. However, miniaturized and reliable technology such as pill cameras, foldable cell phones or implanted medicals devices would not be without rigid-flex technology.

## Conclusion

Designers and fabricators alike have managed fairly well to date with limited access to flex-specific DFM analysis tools. Today, Flex and rigid-flex have become more main stream and the underlying technology is continuously evolving. As is common with all newer technologies, PCB design and analysis tools are playing catch-up. PCB CAD tools have now been updated to support design for flex and rigid-flex, but many still lack the support needed for intelligent data relaying to fabricators. Likewise, most DFM tools to date have been inadequate for properly analyzing flex and rigid-flex designs for manufacturing problems. At DownStream, we are fortunate to have a long list of users fully enmeshed in flex designs who partnered with us to develop a flex-specific DFM solution, and we continue to work with these customers to enhance our capabilities for flex DFM analysis. In addition to the DFM analysis support described in this document, our plans include the ability to analyze additional trace fracture potential, such as I-beaming, as well as improved 3D visualization and DFM for flex and rigid-flex in their bent state (**Figure 2**). These are just a few examples. Like the underlying technology, the PCB design and analysis tools must also continuously evolve to ensure customer success, and this is a cornerstone of Downstream's commitment to our industry.

**www.downstreamtech.com**

240570-01

# Using EMI Shielding to Achieve Electromagnetic Compatibility Compliance

By Mark Patrick (Mouser Electronics)

In this article, we discuss the importance of electromagnetic interference (EMI) shielding in achieving electromagnetic compatibility (EMC) compliance, particularly in the context of modern technologies like 5G and the Internet of Things (IoT). The article also explores various EMI shielding techniques, materials, and strategies that engineers can use throughout the design process to prevent interference and ensure product reliability.

Technological advances, including the expanding rollout of 5G and the increasing reach of the Internet of Things (IoT), are leading to a greater need for electromagnetic interference (EMI) shielding. Achieving electromagnetic compatibility (EMC) compliance and reducing sources of EMI early in the design process are crucial to eliminating inefficiency, avoiding costly redesign, and preventing delays in product launch. Each design part or sub-system — from the enclosure to the module to the printed circuit board (PCB) — may incorporate EMI shielding.

A wide range of shielding options are available to engineers for every stage of the design process in almost every application, from commercial to energy infrastructure, defence to automotive. This article aims to give engineers some insight into what technological advances challenge current approaches to EMI shielding and to provide an overview of the materials on the market.

## Electromagnetic Interference Is Everywhere

Electromagnetic fields are a feature of virtually every circuit. Oscillatory electric fields and magnetic flux lines (**Figure 1**) occur around the conducting path when an alternating current flows along a wire or through a PCB track. These become unwanted noise or interference when these fields become induced or transferred to another circuit or wire. This unwanted noise, generally referred to as EMI, can interfere with or disrupt the other circuit's operation.

An electrostatic discharge (ESD) is another form of EMI. ESD tends to be of varying frequency, whereas EMI typically occurs constantly. Any high-voltage, short-duration (high dV/dt) transients can cause erratic operation or permanent damage to sensitive electronic systems. Most electronic systems generate EMI unintentionally, including clocks, high-speed digital switching, DC/DC converters, and wireless interfaces.

EMI emissions find their way into other circuits through either conduction or radiation. For example, small signal clocks

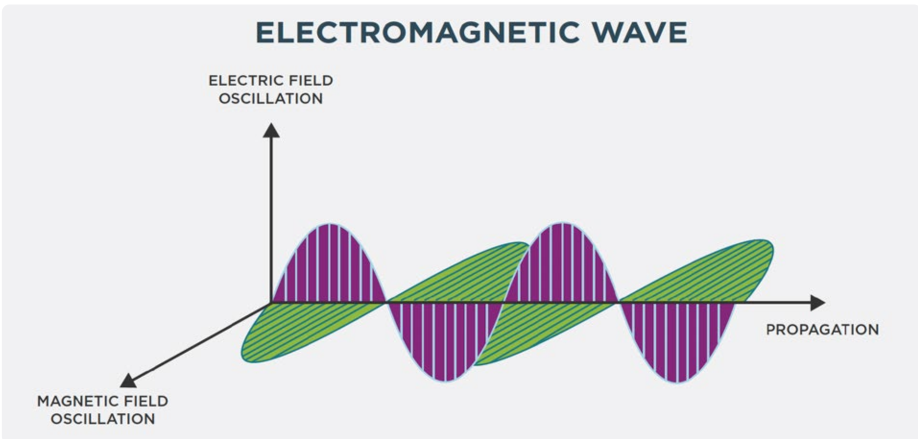


*Figure 1: The magnetic and electric fields of an electromagnetic wave. (Source of all images: Kemtron Ltd, now part of TE Connectivity)*

passing along a PCB trace may radiate, typically above 10 MHz, since the tracks become effective antennas. The guiding principle behind EMC is that a circuit or system is immune to EMI (**Figure 2**).

## Market Dynamics and Trends

Always-on connectivity has become ubiquitous. Whether at home, on the move, work, or in our car, our society never had so many benefits of reliable and resilient communications infrastructure. The rise of the IoT and its counterpart the Industrial Internet of Things (IIoT) and the growth of cellular communications have driven our need and dependence on wireless communications, which, unfortunately, is an essential enabler and a potential EMI source. The deployment of 5G wireless infrastructures, using previously unused, ultra-high frequency wireless spectrum, further expands the possibility of EMI. Consequently, ensuring products have EMI immunity has never been more critical.

## Electromagnetic Compatibility Standards

National and regional EMC standards, which typically align with internationally recognised EMC standards (**Figure 3**), provide manufacturers with specifications products must meet before sales occur. The standards stipulate the maximum emissions permitted from a product development and its immunity or susceptibility to radiated or conducted emissions. When embarking on a new design, it is recommended that design engineers consider the possibility of EMI and incorporate EMC countermeasures during the prototyping process rather than as an afterthought. An understanding of the EMI and EMC standards that apply, the likely sources of emissions, and circuit functions that may be more susceptible to EMI noise are paramount (see **Table 1**).

## Achieving EMC Certification

Although an accredited EMC test facility can only perform EMC certification, there is a lot the engineering team can investigate before handing over the product to the test lab. Basic radiated and conducted emission measurements using a spectrum analyser or an EMI receiver equipped with

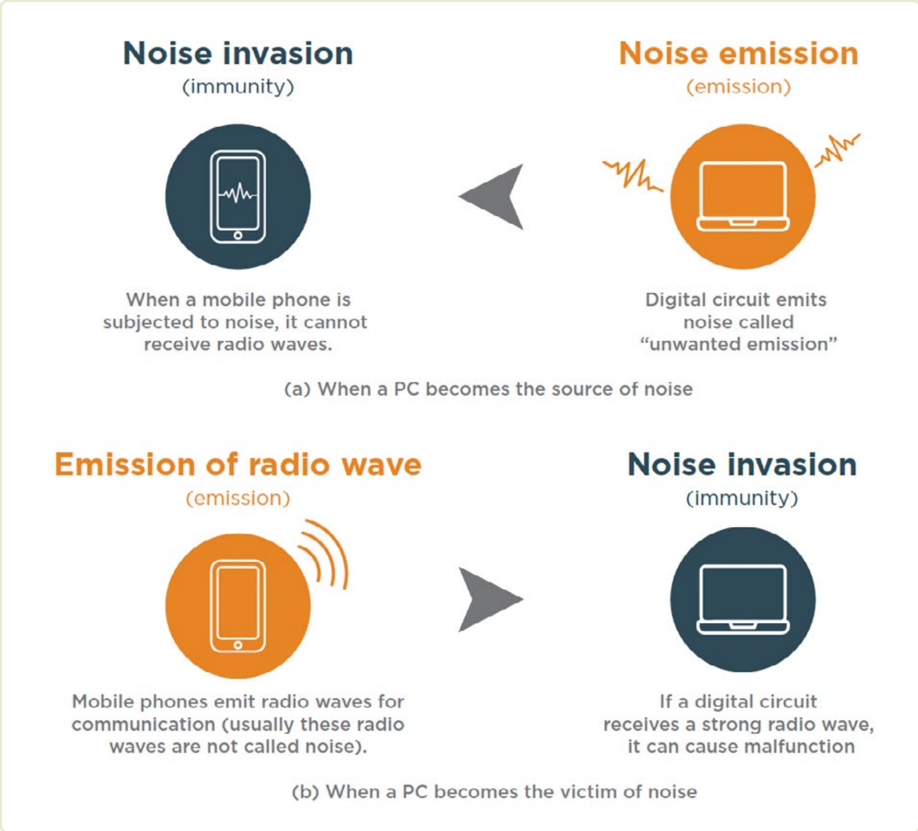


*Figure 2: Immunity to EMI emissions is key to achieving EMC compliance.*

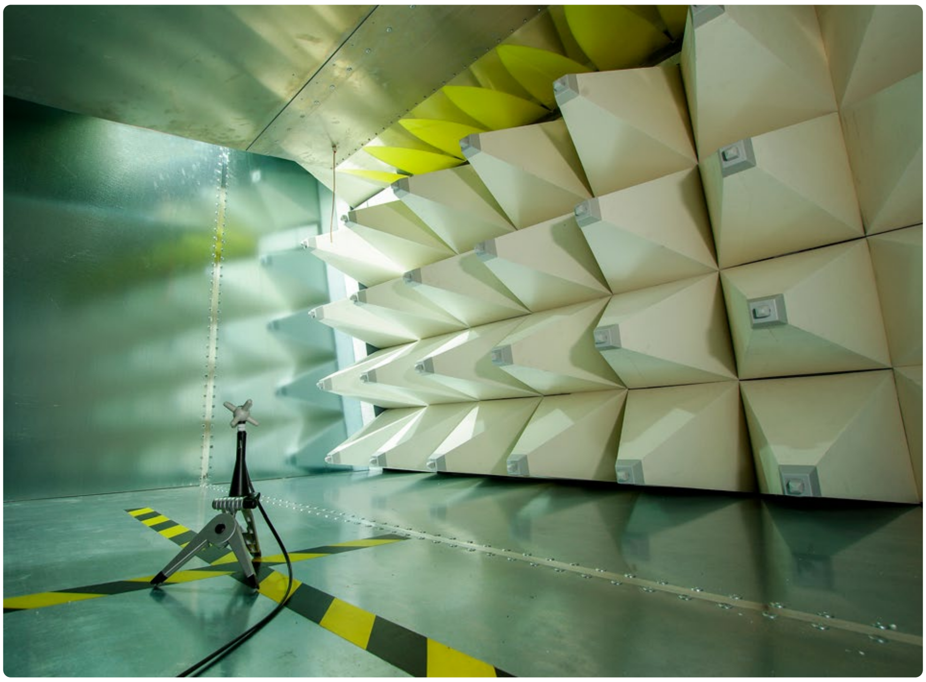

*Figure 3: Pre-compliance testing of a device under test to EMI emissions.*

**Table 1: Popular EMI and EMC standards detailed by industry and application.**

| Application / Industry | EMC Standard |
|---|---|
| Aerospace, Defense and Marine equipment | DEF STAN 59-411<br>MIL-STD-461<br>MIL-STD-704<br>MIL-STD-1275<br>MIL-STD-1399 |
| Automotive components | IEC CISPR 25<br>ISO 11451<br>ISO 11452<br>ISO 7637<br>SAE (multiple numbers) |
| Commercial equipment | FCC Part 15 class B<br>IEC 61000-6-1 (generic)<br>IEC 61000-6-3 (generic) |
| Industrial devices | FCC Part 15 class A<br>IEC 61000-6-2 (generic)<br>IEC 61000-6-4 (generic) |
| Medical devices | IEC 60601-1-2 |
| Power station and substitution equipment | IEC 60000-6-5 |
| Power station and measurement equipment (<1000 V AC, 1500 V DC) | IEC 61326-1 |
| Switch gears and control gears (1000 V AC, 1500 V DC) | IEC 60947-1 |

**IEC: International Electrotechnical Commission**
**ISO: International Organization for Standards**
**SAE: Society of Automotive Engineers**
**FCC: Federal Communications Commission**

*(Source: Kemtron Ltd, now part of TE Connectivity)*

suitable H and E field probes will indicate whether further testing or EMI countermeasures are required. These are expensive items of test equipment for a small product design team to acquire, but specialist EMI test and measurement rental companies offer a cost-effective alternative. Undertaking pre-compliance testing is highly recommended since it allows the design team to locate potential noise sources and implement EMI reduction methods such as shielding, ground planes, and decoupling. Exposing a product to EMI emissions is also important.

## Levels of EMI Shielding

Reducing EMI and making circuit functions immune to EMI require a systematic approach through the product design process. This includes aspects of the PCB design, incorporating ground planes and separating EMI noisy devices from sensitive analogue signal chains. Shielding components, functional parts, and modules offer a practical approach for many applications based on a three-level method, focused on enclosure, module, and PCB (**Figure 4**).

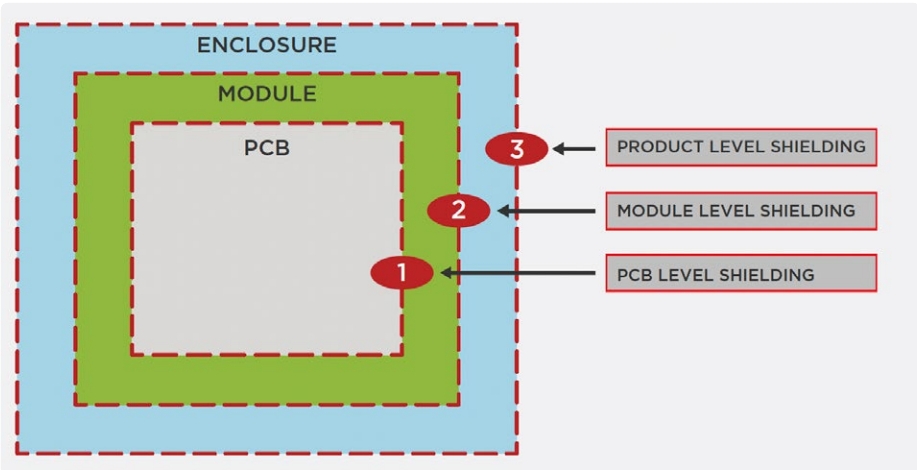


*Figure 4: The three-level approach to implementing EMI shielding.*

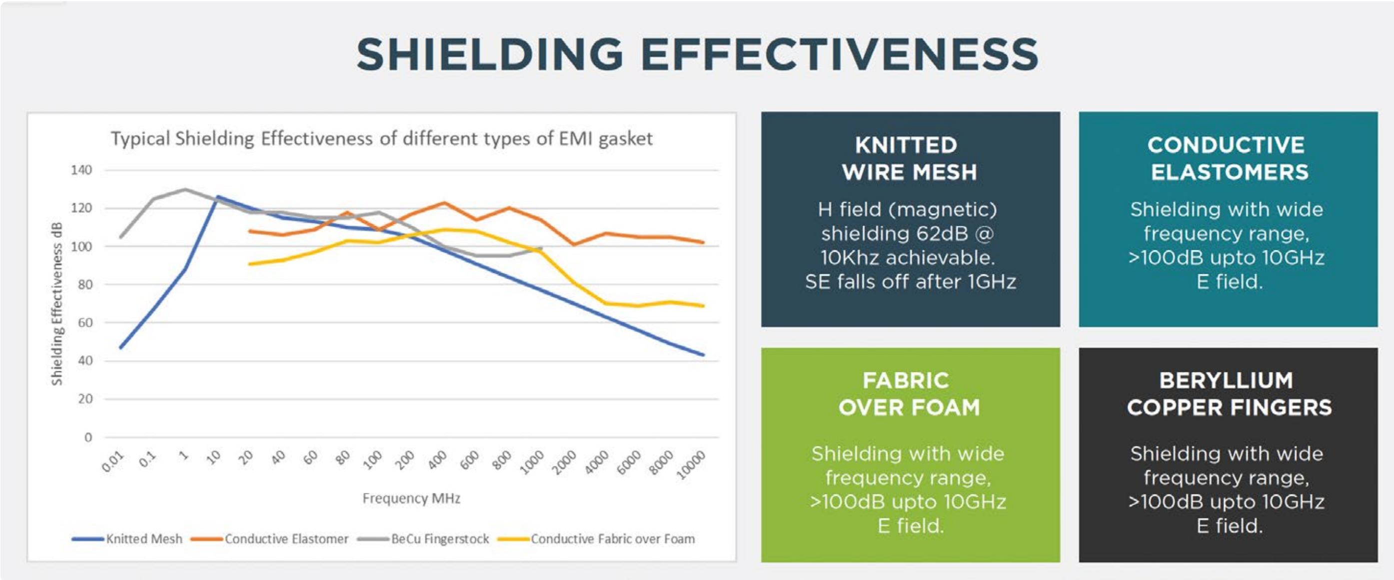


*Figure 5: The EMI attenuation characteristics of four popular EMI shielding methods plotted against frequency.*

Shielding radiated emissions works by creating a Faraday cage around the EMI source. Implementing shielding at an enclosure level reduces any potential noise source leaving or entering. However, some circuit functions may require extra levels of protection to prevent internal EMI from impacting other circuit functions. Shielding at a modular level greatly assists and is regularly used around wireless modules, DC/DC switching converters, and LCD panels. It may be necessary to provide shielding at the board level for sensitive components, such as an analogue-to-digital converter IC. Shielding also applies to any form of interconnect, so preventing radiated emissions from escaping through cable glands, plugs, and sockets should not be overlooked.

*Figure 6: TE Connectivity's Kemtron knitted wire mesh gaskets are available in continuous lengths and shaped into specific sizes.*

## EMI Shielding Materials

Examples of EMI shielding components include knitted wire mesh gaskets, electrically conductive elastomers, conductive fabrics, and metal fingers. Each type exhibits slightly different EMI attenuation characteristics and suits specific use cases. **Figure 5** illustrates the attenuation performance of these four shielding types against frequency.

**Knitted wire mesh:** Using multiple layers of wire knitted over a sponge or tube core using different mesh materials offers an effective EMI solution and galvanic compatibility. The knitted approach permits fabrication to suit complex shapes and bonding to carrier materials to create ingress protection. Mesh shielding suits various use cases, including cabinet doors, lids, and removable cover plates. Shield performance tends to reduce beyond 1 GHz unless additional layers are incorporated. Examples include TE Connectivity's Kemtron range of knitted wire mesh gaskets (**Figure 6**), available in cut lengths or fabricated into finished gasket shapes [1].

**Electrically conductive elastomers:** Available in various materials and shapes, Kemtron Ltd (now part of TE Connectivity) range (**Figure 7**) offer better than 100 dB

*Figure 7: Electrically conductor elastomers from Kemtron/TE Connectivity offer up to 100 dB of attenuation at 10 GHz.*

attenuation up to 10 GHz [2]. Filler Materials include silver-plated aluminium and nickel-plated graphite, binder options include silicone or fluorosilicone. Popular shapes include sheets, flat gaskets and O-rings. "Jam nut" O-ring seals are designed explicitly for RF EMI shielding and are available for the most popular connector formats [3].

**Honeycomb air vents:** For applications where forced air cooling uses a fan, the fan aperture offers a direct path for noise to exit an otherwise EMI-sealed enclosure. To prevent this, using a honeycomb air vent, such as the Kemtron/TE Connectivity line-up, offers enhanced EMI performance while permitting adequate airflow through its laminated, single-layer aluminium foil honeycomb cell construction. The vents are available in all popular fan sizes, from 40 mm to 120 mm [4].

## Improve EMI Immunity

EMI from unwanted noise emissions from equipment disrupts reliable system operation. Achieving EMC is a regulatory requirement and a necessity to avoid erratic system behaviour. This short article highlighted some shielding methods engineers could implement to improve EMI immunity.

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### About the Author

As Mouser Electronics' Director of Technical Content for EMEA, Mark Patrick is responsible for creating and circulating technical content within the region — content that is key to Mouser's strategy to support, inform, and inspire its engineering audience. Before leading Technical Content, Mark was part of Mouser's EMEA Supplier Marketing team and played a vital role in establishing and developing relationships with key manufacturing partners. Mark's previous experience encompasses hands-on engineering roles, technical support, semiconductor technical sales, and various marketing positions. A "hands-on" engineer at heart, Mark holds a first-class Honors Degree in Electronics Engineering from Coventry University. He is passionate about vintage synthesizers and British motorcycles, and thinks nothing of servicing or repairing either.


## WEB LINKS


[1] Knitted Wire Mesh Gaskets: https://www.mouser.de/new/te-connectivity/te-kemtron-knitted-wire-mesh-gaskets/
[2] EMI Connector Gaskets: https://www.mouser.de/new/te-connectivity/te-kemtron-emi-connector-gaskets/
[3] Jam Nut Seals: https://www.mouser.de/new/te-connectivity/te-kemtron-jam-nut-seals/
[4] Aluminum Honeycomb Air Vents: https://www.mouser.de/new/te-connectivity/te-kemtron-honeycomb-air-vents/

ynvisible

# Applications of Ynvisible's E-paper Displays

## Transform Businesses and Shape the Future


**Contributed by Ynvisible**

Ynvisible develops and commercializes the most sustainable, energy-efficient, cost-effective, and customizable e-paper displays in the market. Ynvisible's displays have the potential to transform industries, from logistics to retail to medical diagnostics, enabling greater efficiency, connectivity, and sustainability.

Industry leaders around the world choose Ynvisible's eco-friendly, thin and flexible, innovative, printed e-paper displays for the indisputable benefits they provide. There are three main product platforms Ynvisible provides to the market:

### Visual Indicators

Visual indicators use Ynvisible's thin, flexible, ultra-low power e-paper displays to communicate the status of a product or provide important notifications, in a clear and efficient way.

Customers in the medical, hygiene, supply chain, and industrial sectors have implemented these indicators into their products to replace analog, traditional, or LED indicators with a more sustainable, functional, and user-friendly solution.

This year, Ynvisible announced its collaboration with an industrial leader that was looking for an improved way of tracking maintenance activities for its industrial equipment. Ynvisible developed a maintenance timer based on its e-paper displays that offers improved functionality and user-friendliness when compared with traditional analog time monitoring stickers. Ynvisible's e-paper displays are resistant to conditions such as humidity, dust, and vibrations, ensuring long-term durability and reliability, as well as applicability to a wide range of industries and applications.

### Smart Labels

Ynvisible's e-paper-based smart labels leverage e-paper display technology to provide critical, dynamic, real-time information about a product or process. Smart labels can be integrated with sensors, power sources and other electronic components, making them ideal for applications such as cold supply chain monitoring or smart expiration date labels.

Ynvisible has partnered with Swiss company Hive-Zox for a new, compact, smart label, designed for pharmaceutical and healthcare shipment monitoring. Hive-Zox was on the lookout for an ultra-thin, highly flexible, low-power display to be integrated into their tracking labels for temperature-sensitive products. Ynvisible's solution perfectly met the customer's requirements, offering slim, ultra-low power, reflective displays that serve as dynamic interfaces, providing real-time feedback without driving up costs.

### Digital Signage

Digital signage can come in many formats, from small price electronic shelf labels to large retail or public information signs. Digital signs are critical to customers who need to display information about their products or services, especially in environments with changing visibility conditions (e.g., outdoors).

Ynvisible's work in digital signage stands out in its latest partnership with Fortech S.r.l., Italy's leading provider of bespoke solutions for the fuel retail sector. For their daily average fuel price signs, Fortech sought an innovative, battery-operated, lightweight and durable display solution. Ynvisible's printed e-paper displays met these market needs with ultra-low power consumption, for extended battery life, and a slim, portable design.

### Conclusion

These examples demonstrate how Ynvisible's e-paper solutions are solving real-world challenges across multiple industries, offering a path to a more sustainable, tech-forward world, merging profitability with positive change. Ynvisible is not just commercializing displays; Ynvisible is shaping the future of digital communication.

Learn more at *ynvisible.com*.

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▲
*Figure 1: The SPECTRAN® V6 PLUS XPR 250XB-WR12 offers 10 dB NF at 77 GHz. This makes it the perfect choice for radar measurements in the automotive sector (76 GHz to 81 GHz).*

# Real-Time Spectrum Analyzer with Waveguide Technology and Multi-Interface PCs

## Aaronia Establishes New Product Segment and Presents First Prototypes at Electronica in Munich

**Contributed by Aaronia AG**

It's that time again, the world of electronics meets at electronica in Munich. From November 12-15, over 2,500 exhibitors will make the world's leading trade fair the most important source of inspiration for the international electronics industry. This year, Aaronia AG from Strickscheid will not only be showcasing the latest developments in its SPECTRAN® series of real-time spectrum analyzers and the Aartos drone detection system. In fact, the world market leader from Germany will surprise visitors with its entry into the PC business and present prototypes of future Aaronia PC boards.

Real-time spectrum analyzers (RTSA) are indispensable tools in modern radio technology. The ever-increasing complexity of RF signals, driven by technological advances such as 5G, IoT and satellite communications, requires precise and efficient measurement methods. 5G, Wi-Fi 6 and ultra-wideband (UWB) communication systems use complex modulation techniques and high bandwidths.

### Equipped for IEEE 802.11ax

Real-time spectrum analyzers offer decisive advantages here, as they can record and analyze RF signals simultaneously. Aaronia's SPECTRAN® V6 series real-time spectrum analyzers in particular enable continuous and therefore seamless data acquisition without losing information about short or intermittent signals. This enables the detection, characterization and, if necessary, decoding of sporadic or transient events, which play an essential role in modern communication technology. Once recorded, the data is fully available to the user on the PC used, for example to optimize channel assignment, localize individual devices or determine repeater locations.

*The number of available USB interfaces was one of the reasons for our entry into the development of PC boards. This is where all conventional devices quickly reach their limits.*

## Measurements in the EHF Band

5G uses a wide range of frequency bands that have a much higher frequency than previous mobile radio standards, such as the extremely high frequency (EHF) band from 30 GHz to 300 GHz. The analysis of such high-frequency signals requires spectrum analyzers that offer high frequency resolution and sufficient bandwidth to represent the complex structure of the signals. In addition, 5G systems use beamforming techniques and massive MIMO (multiple input multiple output), which further complicates the analysis. Aaronia supplies the SPECTRAN® V6 5G for this purpose and for measurements in the mobile radio environment. The device also supports the WiGig 45 GHz (802.11aj) and 60 GHz (802.11ad/aj/ay) profiles, which are now included in the latest version of the RTSA Suite PRO for signal recording and data analysis.

## Affordable Solution for Automotive Applications

With a real-time bandwidth of up to 490 MHz and a sweep speed of 3 THz/s, the SPECTRAN® V6 Xplorer is the new reference in terms of speed. Equipped with waveguide connections, the analyzer allows measurements in the millimeter wave range that are not possible with conventional cables. Waveguides transmit the signal without distortion or loss. They are less susceptible to external disturbances such as electromagnetic interference, which is important in an environment with many electrical devices and radio signals. As a result, the signal remains clean and the measurements of the spectrum analyzer are not distorted.

The new SPECTRAN® V6 Xplorer is an efficient and, above all, affordable solution for maintaining and checking modern safety sensors that determine the distance between vehicles, blind spot assistants and, in some cases, for adjusting parking aids. Such sensors determine the distance to objects by emitting electromagnetic waves and measuring the time it takes for the reflections to return. These waves travel very quickly, almost at the speed of light. Garages are generally overburdened with the maintenance of such sensors. They can hardly be expected to purchase equipment worth several hundred thousand euros. However, technical inspection associations, for example, could purchase a SPECTRAN® V6-based system and check these sensors during vehicle inspections.

With the SPECTRAN® V6 real-time spectrum analyzers with waveguide technology, these high-frequency and rapidly changing signals can be reliably analyzed and evaluated. Thanks to the waveguide connection, the real-time spectrum analyzers from Aaronia AG can be connected to their own amplifier and splitter systems according to the respective requirements with the waveguides that will be available in the future. Aaronia thus provides affordable solutions for such applications.

## Entering the PC Market

Data analysis is one aspect, the available computing power is the other. Although very efficient processing of even IQ data is already possible with standard computers using the Aaronia real-time spectrum analyzer in conjunction with the RTSA-Suite PRO, the requirements for bandwidth and processing speed are increasing in many cases. "We are constantly on the lookout for

*Figure 2: Thorsten Chmielus, CEO of Aaronia AG*

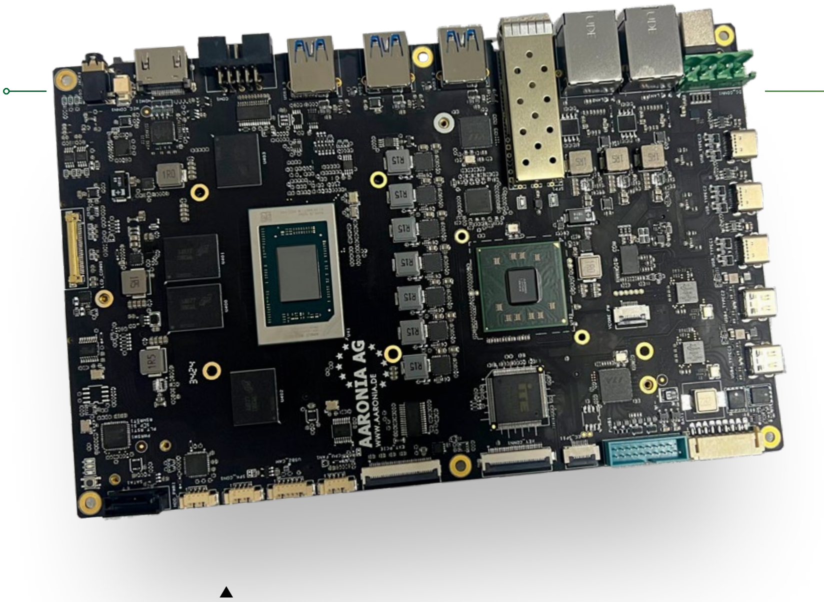


*Figure 3: The PC boards based on the latest Intel® or AMD® processors are true I/O all-rounders and allow, for example, the simultaneous use of 4 SPECTRAN® V6 ECO analyzers (4× USB PD).*

computer systems that meet our requirements in terms of speed, storage capacity and interfaces," explains Thorsten Chmielus, CEO of Aaronia AG. "Accordingly, we have decided to develop the necessary hardware ourselves and are pleased to be able to present the first results for the first time now." The PC boards based on the latest Intel® or AMD® processors are true I/O all-rounders and allow, for example, the simultaneous use of 4 SPECTRAN® V6 ECO analyzers (4× USB PD).

With the SPECTRAN® V6 MOBILE, Aaronia presents the world's first portable real-time spectrum analyzer with an RTBW of 490 MHz. This means that even the 320 MHz wide channels of the new IEEE 802.11ax standard can be fully recorded. With a frequency range from 9 kHz to 140 GHz and a sweep speed of 3 THz/s, the Aaronia spectrum analyzers used are equipped for all tasks. The tablet is powered by the latest generation of processors. There is a choice of a variant based on the Intel Ultra 985H or AMD® Ryzon 7949 HF. The integrated 16-bit single-chip sampling analog-to-digital converter (ADC) has a conversion rate of up to 2 gigasamples per second (GSPS).

One unusual feature is the 8 USB ports, four of which are PD-capable. USB Power Delivery (USB PD) is a USB extension standard that enables up to 100 W to be received via a USB-C cable. As a rule, PC-based systems have a maximum of two USB PD ports. Chmielus comments: "Increasing the number of available USB interfaces was one of the reasons why we started developing PC boards. In measurement technology, more and more peripheral devices have to be connected to the real-time spectrum analyzers via USB. Conventional devices quickly reach their limits and the use of USB extensions is out of the question due to runtime delays, among other things. In addition, USB devices are increasingly being supplied with power via the USB port, which makes it necessary to have a larger number of USB PD interfaces."

A robust aluminum housing for outdoor use protects the electronics and display. With the new SPECTRAN® V6 tablets, Aaronia remains true to its philosophy of offering the right solution for every application. Customers can either purchase a pre-configured version or customize the device according to their requirements.

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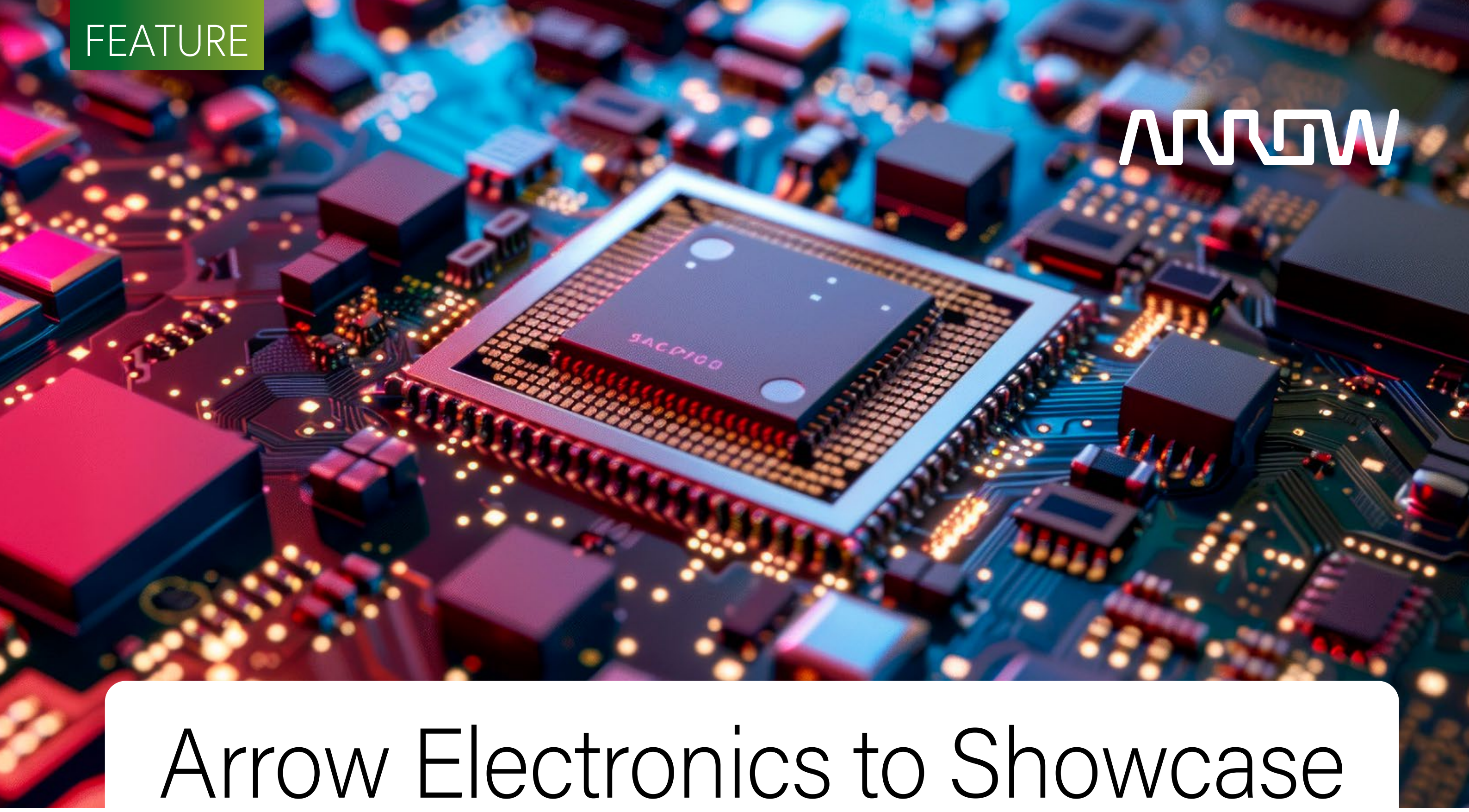
## About Aaronia AG

Aaronia AG is a technology company based in Strickscheid in the Eifel region of Germany. Founded in 2003 by Thorsten Chmielus, the company mainly produces spectrum analyzers based on patented spectrum analysis processes. From conception and design to final assembly and software development, everything takes place in Germany. High-tech made in Germany.

The first spectrum analyzer was produced and delivered in 2004. In 2008, the next generation of Spectrum Analyzers was presented with the V4 series, which set a world record in handheld sensitivity of DANL -170 dBm (Hz). The 6th generation of SPECTRAN real-time analyzers has been on the market since 2020.

With the new generation of spectrum analyzers, AARONIA is raising the bar in terms of speed. By cascading several SPECTRAN devices, real-time bandwidths in the GHz range can be realized. The SPECTRAN® V6 series thus sets new benchmarks in the USB compact class. The system is used worldwide in numerous individual installations and complex systems.

Aaronia AG develops, distributes and trades in measuring devices, technologies and rights in the field of low- and high-frequency measurement technology, robotics, and the shielding of low- and high-frequency fields of all kinds. In addition, the company conducts basic research in the field of communications and measurement technology and designs its own circuit and measurement methods, particularly for the development of extremely sensitive and precise high-frequency measurement technology.



# Arrow Electronics to Showcase **Innovative Technologies** at electronica 2024

**Contributed by Arrow Electronics**

Arrow Electronics will be exhibiting at electronica, presenting its latest innovations and cutting-edge technologies under the banner of "Guiding Innovation Forward."

Arrow's 875 m² booth will display a mixture of demos and exhibits explaining how Arrow is actively contributing toward today's megatrends for a better future tomorrow. Visitors can immerse themselves in the Technology & Solution Zone, in which a variety of technology solutions will be presented that are inspired by trends such as electrification of everything, autonomous machines, smart everything, and energy management. Cutting-edge innovations at Arrow's booth include an air taxi demo, automotive digital rear-view technology as well as healthcare, e-mobility, and energy storage solutions.

Arrow's booth will feature the SAM Car (Semi-Autonomous Car), a McLaren 720S Spyder equipped with a groundbreaking AI-enhanced steering system. The SAM Car also features AI-based leading-edge facial recognition and advanced throttle and brake controls. The technologies combine to allow for head control at racetrack speeds.

Throughout the show, a large area of Arrow's booth will be available for networking and talks from experts. Specialists representing the breadth of Arrow's product and solution portfolio will be available for discussion to explain how Arrow is collaborating with suppliers to enhance the future of technology. Visitors will be able to discuss ideas to bring their products and solutions to market quickly and efficiently, covering topics such as design engineering and supply chain management.

For more information about Arrow Electronics at electronica, please visit the event page: *www.arrow.com/electronica*

240596-01

**Arrow Electronics @ electronica:**
**Munich, 12-15 November 2024, Hall C4, Booth 420**

RFbeam Microwave

# V-LD1 Distance Radar Module

Contributed by RFbeam Microwave GmbH

The V-LD1 FMCW radar sensor simplifies distance measurement without the need for specialized signal processing expertise, making it ideal for industrial applications. To enable fast development, RFbeam provides the V-LD1 evaluation kit, a powerful tool to evaluate the use of the V-LD1 for your applications.

The V-LD1 is an easy-to-use 61 GHz FMCW distance radar sensor with integrated signal processing (**Figure 1**). No special knowledge in analogue or digital signal processing is needed to adapt the module to different applications, resulting in a fast time to market. Transmit frequency and sweep bandwidth are controlled internally, and a selection of settings is available to adapt to application requirements.

The beam width of the module itself is 170 × 60 degrees. However, RFbeam [1] also offers a plastic lens that narrows the beam to 8 × 8 degrees (as shown in Figure 1), which is perfect for contactless tank level gauging applications. For applications requiring other beams, RFbeam offers the development of custom lens designs. Additionally, RFbeam provides full integrations of the lens into custom housings, ensuring optimal performance for specific needs. The use of a dielectric lens allows to radiate into a tank either through plastic walls, optical windows or using a watertight flange/lens assembly.

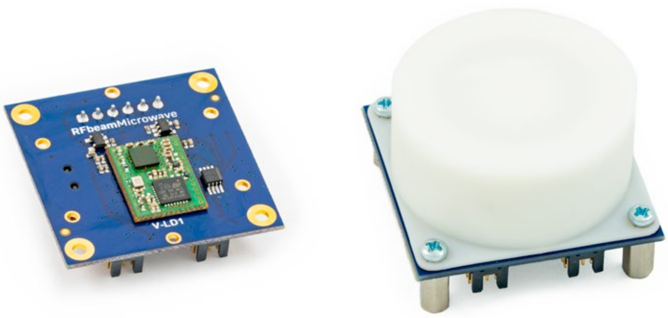



*Figure 1: V-LD1 module mounted on evaluation PCB and the view of evaluation kit with mounted plastic lens.*

The V-LD1 module with dimensions of 12 mm × 16 mm can be integrated onto any OEM PCB using a standard SMT reflow process. Operating on a single 1.8 V power supply, it ensures low-power consumption, making it ideal for battery-operated systems. Once powered, the sensor defaults to a *SLEEP* mode to conserve energy. It remains in this low-power state until the host system, such as a microcontroller unit (MCU), sends a command to start a measurement. This command wakes the sensor momentarily to perform a measurement before it returns to *SLEEP* mode, making it ideal for battery-operated devices.

The V-LD1 needs only a connection to a power supply and a serial interface of a host (for example MCU or PC) to read out the distance measurement data and configure the sensor if needed. Further it is also possible to read out advanced processing data like the ADC or FFT values or to start a firmware update over the integrated bootloader.

## Theory of Operation

The V-LD1 is a digital FMCW distance measurement sensor and consists of an analogue RF frontend and a powerful signal processor with a fully digital serial interface. The RF frontend features a PLL controlled transmitter with a FMCW modulation mode and one receiver. The signal processing unit controls the FMCW modulation and samples the ADC values for further processing.

A range FFT is then calculated to measure the distance to all targets inside of the antenna beam. The sensor can separate targets based on the distance resolution of the used distance setting. Further the signal processing is capable to compute a high accuracy distance of one target if this option is enabled. The user has full access to analog sampled signals and FFT raw data.

## Distance Range

The sensor allows setting the maximum unambiguous distance measurement range, with options of 20 m or 50 m. The resolution depends on whether high-precision mode is enabled. In low-precision mode, the resolution is 3.934 cm at 20 m and 9.943 cm at 50 m.

## Precision

By default, the sensor operates in high-precision mode. For single targets the accuracy is typically 1 mm with an accuracy of ±5 mm for both range settings and over specified temperature range. The high accuracy mode can be turned off to reduce computation time and power consumption, which can be advantageous for less demanding applications.

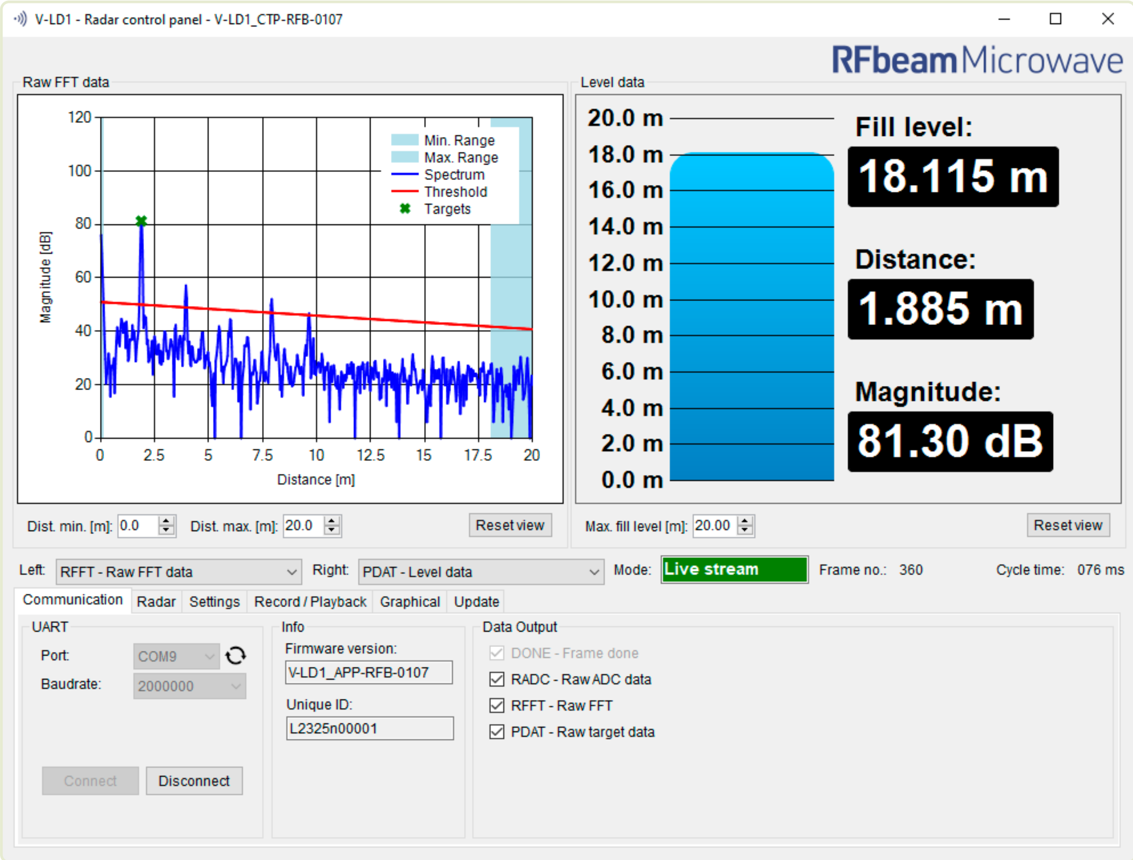



*Figure 2: Screenshot of the control panel software.*

## Distance Filter

To filter out unwanted targets, a minimum and maximum distance range can be configured. This filter adjusts the search area in the FFT spectrum, enabling to focus on specific distance ranges of interest or exclude objects at the bottom of the tank or near the top.

## Target Filter

The target filter parameter allows choosing which target to measure. Options include measuring the distance to the strongest target above the threshold, the nearest target, or the farthest target.

## Threshold Offset

This parameter sets the distance in dB between the raw FFT data floor and the threshold line. Lowering the offset increases sensitivity, making the sensor more responsive to weaker signals, while raising the offset reduces sensitivity, helping to filter out less significant measurements. The threshold offset is displayed as a red line in the control panel view of the FFT signal.

## Chirp Integration Count

This feature controls the number of FMCW sweeps integrated per measurement, which can lower the noise floor. This is useful for measuring low-reflective materials like oil, grain or animal feed. Increasing the chirp integration count reduces the FFT noise floor and improves the signal-to-noise ratio, though it also extends measurement time and increases power consumption.

## V-LD1 Evaluation Kit with Control Panel Software

To enable a fast development, RFbeam provides the V-LD1 evaluation kit, a powerful tool to evaluate the use of the V-LD1 for your application idea. The kit consists of a PCB with a mounted V-LD1 sensor in the centre together with the focusing lens. Further, it features an easy connection to a PC over a simple USB connection without the need of an external power supply. With the supplied powerful *Control Panel* software (**Figure 2**), the development time is reduced drastically. All the sensor parameters can be modified using the *Control Panel*. The influence of changed parameters can be directly checked in the real-time views of the software. The *Control Panel* features a lot of different views to analyse the measured data in detail. A special view of a tank level display is also provided. It is possible to record all measured data and replay it directly in the software to analyse different application scenarios offline without the sensor. To realize the own application ideas, a Python script is available from RFbeam to read out the distance information and to set the parameters of the V-LD1 module. The datasheets of the V-LD1 module and V-LD1 evaluation kit can be downloaded from [1].

RFbeam microwave is a leading manufacturer of 24 GHz and 60 GHz radar modules. Production takes place at certified partners in Switzerland and other countries. The products are exported worldwide. Key markets are traffic sensors, security and movement detection and industrial sensing.

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## WEB LINK

[1] RFbeam Microwave GmbH: https://rfbeam.ch/

# HDI in the Middle

## A New Cost-Effective PCB Pooling Service for Tiny BGAs

**Contributed by Eurocircuits**

Sometimes there's a part that we really want to use, but it's only available in a fine-pitch BGA package — using it will tip our design over the 'standard PCB technology' line into HDI territory. HDI technically means *high-density interconnect*, and practically means that we're able to design with smaller clearances and thinner tracks. And, we're able to use 'microvias': vias with smaller pads and smaller hole diameters than what is normally possible with mechanical drilling.

HDI enables miniaturization, which is great, but it may be annoying if it is 'forced' on us from a single tiny component onto the entire board, which then becomes prohibitively expensive. At Eurocircuits, we have the solution 'in the middle' that can help our customers deal with both the annoyance and the cost. Our HDI pool (**Figure 1**), an 8-layer buildup, keeps the 'standard technology' pattern classifications as they are, and adds microvias between layers 1–2 and 2–3

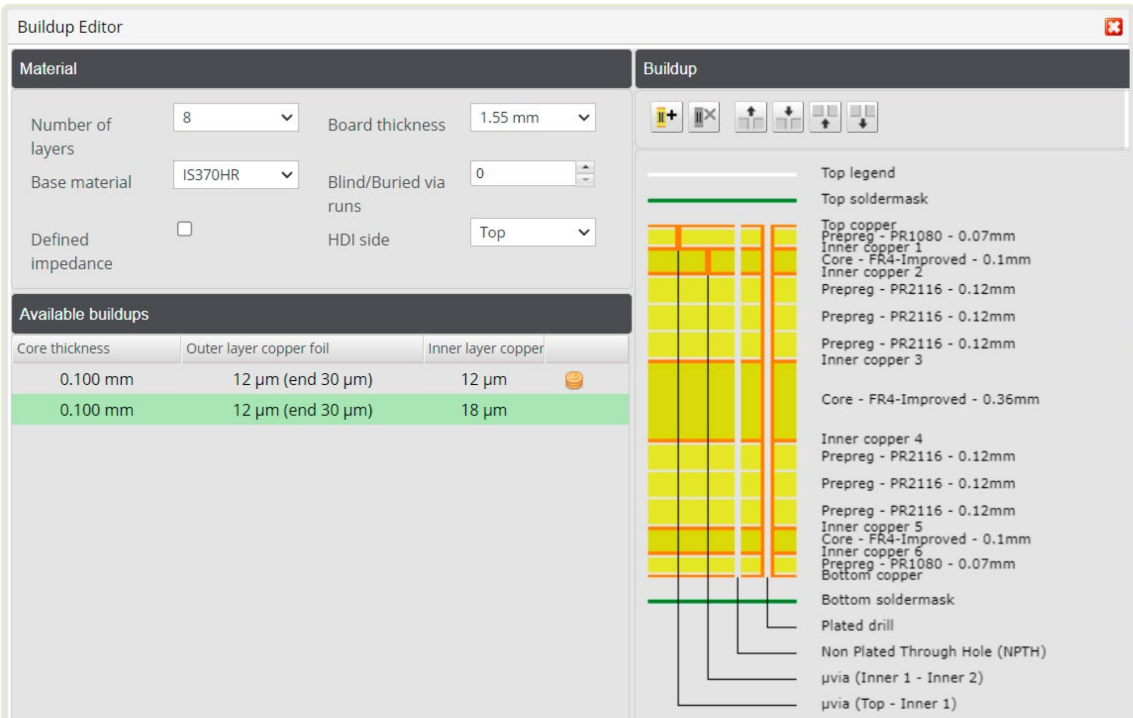


*Figure 1: Our 8-layer HDI pool buildup.*

**Pattern and hole size classification (µm)** Revision 20242808-1

| Pattern classification | | 7 | 8 | 9 |
|---|---|---|---|---|
| **Copper clearance, any layer** | ≥ | 125 | 100 | 90 |
| **Pad diameter, outer layers** Add this value to N/PTH diameter | ≥ | +350 | +300 | +300 |
| **Pad diameter, inner layers** Add this value to N/PTH diameter | ≥ | +350 | +350 | +300 |
| **Clearance from PTH, inner layers** From hole edge | ≥ | 250 | 250 | 250 |
| **Clearance from NPTH, inner layers** From hole edge | ≥ | 200 | 200 | 200 |
| **HDI microvia pad diameter** Available only for layers 1-2 and 2-3 | ≥ | 280 | 230 | 210 |
| **HDI microvia diameter** Available only for layers 1-2 and 2-3 | = | 100 | 100 | 100 |

| Hole diameter classification | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| **Plated through-hole (PTH) diameter** | ≥ | 500 | 350 | 250 | 150 | 100 |
| **Non-plated through-hole (NPTH) diameter** | ≥ | 600 | 450 | 350 | 250 | 200 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Max PCB thickness (mm)** | = | 3.20 | 3.20 | 2.40 | 2.00 | 1.60 |

*Figure 2: The parameters of our Pattern classes for which HDI pool is available (note that Pattern Class 9 isn't poolable.)*

or 8–7 and 7–6, but not both. This lets our customers design with those fine-pitch BGAs, where cost is manageable since the HDI is limited to only a small area and to two microvia 'runs'.

## In Practice

What does this mean in practice? Let's look at Pattern Class 7 with Drill Class E from **Figure 2**, where the smallest pad diameter possible is 0.45 mm (0.1 + 0.35 mm); that won't fit inside most fine pitch BGA pad diameters. However, when we use the same classification together with the HDI pool, the smallest diameter becomes 0.28 mm, which will fit! This allows designers to place vias in the centre of BGA pads without needing to enlarge the pads beyond the manufacturer's recommendations. The smaller microvia pads also mean that using dogbone patterns becomes a possibility.

Obviously, it's impossible to cover all BGA pin arrays and their pin configurations in order to determine which part will be routable and which won't. However, we have configured our pool parameters such that full 8×8 arrays should be fully routable for BGAs down to 0.4 mm pitch. (**Figure 3** shows an example of a fully fanned-out 8×8 0.4 mm pitch part.) But of course, larger arrays are possible too, and it all depends on the array size, pin configuration, and how those pins are used. In many packages, there are *No Connect* pins, and in most designs not all pins of a microcontroller or processor are used, which may ease routing-out large BGA arrays with only two microvia 'runs'.

What now? We invite you to upload your designs to our Visualizer [1] and check them for manufacturability. As always, we welcome your feedback on how this service may solve your manufacturing issues.

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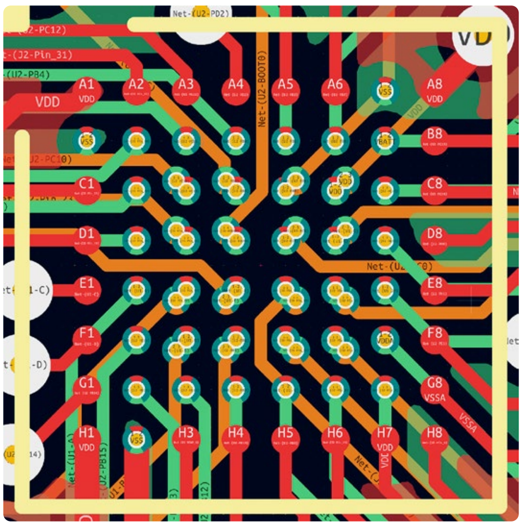


*Figure 3: An example fan-out of an STM32F412 in a WLCSP64 0.4 mm pitch package. The first BGA 'ring' is routed on the top layer (red), the second ring on the second layer (green) using L1–L2 microvias in the centre of pads, and the third and fourth rings are routed on the third layer (orange) using L1–L2 and L2–L3 staggered vias.*

### WEB LINK

[1] http://be.eurocircuits.com/shop/orders/configurator.aspx?loadfrom=web&service=hdipool&lang=en

MIKROE
Time-saving embedded tools

# Remote Access IoT Lab

## One and Only Solution for Remote Learning and Development in Embedded Industry

**Contributed by MIKROE**

MikroElektronika (MIKROE), a pioneer in the embedded solutions industry, has introduced a ground-breaking innovation called Planet Debug, the industry's first hardware-as-a-service platform. Designed to save time, reduce costs, and offer total design flexibility, Planet Debug allows developers, students, and institutions to remotely design, develop, and debug embedded systems.

*Figure 1: Planet Debug's remote stations with 130+ development boards, including MCU cards, peripherals, and displays — no need for costly hardware.*

One of the biggest pain points for embedded system designers is sourcing, waiting for, and assembling hardware components. With Planet Debug, this challenge is eliminated. Instead of purchasing costly hardware, designers can now reserve time on one of Planet Debug's remote stations (**Figure 1**). These stations are equipped with over 130 development boards, including combinations of microcontroller (MCU) cards, peripheral boards, and display configurations.

The process is simple: designers select the hardware configuration they need, and within a day, they can start developing their applications remotely via MIKROE's NECTO Studio Integrated Development Environment (IDE). NECTO Studio allows developers to view real-time images of actual hardware running their code, ensuring they are working with the real thing, not simulations.

For many designers, this flexibility means they can experiment with multiple hardware configurations without committing to an expensive purchase. If they're still exploring different approaches, Planet Debug allows them to *try before buying*, significantly lowering the barriers to entry for those new to embedded systems.

### The Benefits of Planet Debug for Education

The platform is especially valuable for students and universities, enabling remote learning and practical experience with embedded systems, without the need to own hardware. In many educational environments, resources are limited, and not every student can access expensive development kits. With Planet Debug, universities and students can share these remote resources, allowing for hands-on learning from anywhere in the world.

For example, a student in the USA can reserve time on a development board located in Mexico and remotely develop their project, viewing live results in real-time. The ability to access hardware remotely, test code, and debug systems from any location makes it a perfect fit for online courses, especially as remote learning has become the new norm. This flexibility also enhances international collaboration, with students and educators being able to work on joint projects without physical limitations.

### Exploring Aquaculture from Mexico — Learning Beyond the Classroom

One of the standout features of Planet Debug is its global accessibility. Currently, setups are available in Europe, the USA (Minnesota), and Mexico, with plans to expand to other regions, including Asia. In particular, the Planet Debug station in Mexico offers something unique: a

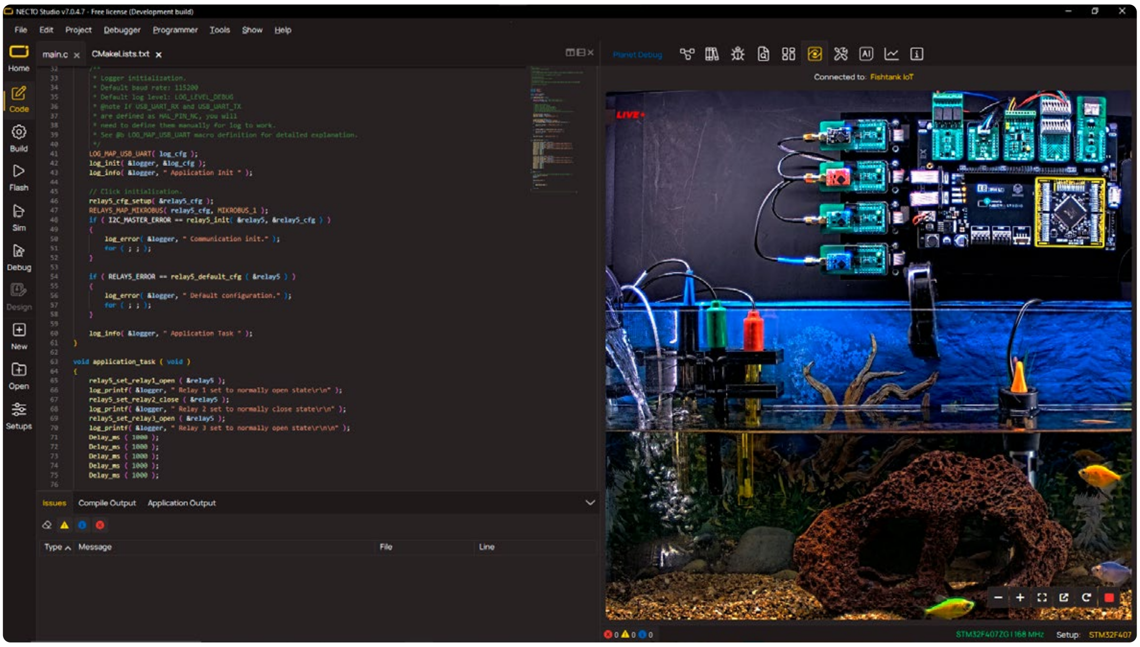


*Figure 2: Planet Debug's Mexico station offers a unique feature: real-time fish tank monitoring alongside live programming.*

real-time view of fish swimming in the tank! Imagine being able to see the movement of marine life while working on your embedded system designs, as shown in **Figure 2**. This setup is perfect for marine biology studies, environmental monitoring, or simply adding an immersive experience to your learning or design process.

Through these innovative setups, students and designers can engage with real-world applications while developing their skills in embedded systems, making Planet Debug not just a tool for technical development but also for interactive, real-world learning.

## Planet Debug: A Solution for Design Service Companies

Design service companies, particularly those involved in prototyping and product development, stand to gain significant advantages from Planet Debug. The ability to quickly configure and test various hardware combinations without purchasing multiple development kits is a game-changer for reducing overhead costs.

Time-to-market is crucial for companies, and Planet Debug helps speed up the development process by offering immediate access to hardware without the usual delays associated with shipping and setup. As product requirements change, engineers can quickly reconfigure their development environment remotely, responding to new specifications or market demands without needing to overhaul their setup. This flexibility is invaluable in an industry where agility is key to staying competitive.

## Overcoming the Chip Shortage Challenge

The global semiconductor shortage has affected many industries, causing delays in production and development. However, Planet Debug offers a unique solution to this problem. Since developers are working with remote hardware, chip shortages do not impact their ability to continue developing and testing their applications. The platform ensures that hardware is always available, regardless of supply chain disruptions.

This advantage extends to educational institutions as well, where access to limited resources can delay students' progress. With Planet Debug, universities and students are no longer constrained by hardware availability, ensuring that learning and innovation can continue uninterrupted.

## Future Expansion and Global Accessibility

Currently, Planet Debug stations are available in several locations, including MIKROE's headquarters, various Universities in Europe, and facilities in Minnesota, USA, and Mexico. Plans for expanding to Asia are in the works, further broadening the platform's global reach. The service can be accessed by users from any part of the world, making it a truly global solution for embedded system design.

Nebojsa Matic, a MIKROE's CEO, and founder of Planet Debug, sums it up perfectly: "Hardware-as-a-service is the future of design. It's hard for people to grasp right now because there are so many pieces to the puzzle: the Click peripheral boards and SiBRAIN MCU cards based on standard sockets; the Fusion development boards, CODEGRIP and NECTO. But the logical end-game for us was always to combine them in the Planet Debug platform. It will revolutionize embedded design."

## A New Era for Embedded Design and Remote Learning

Planet Debug represents a significant shift in how embedded systems are designed, developed, and taught. Its unique hardware-as-a-service model offers unparalleled flexibility, cost savings, and accessibility for designers, students, and universities worldwide. By removing the need for costly hardware purchases and providing remote access to high-end development tools, MIKROE has created a platform that empowers users to focus on innovation and creativity, rather than logistics and hardware constraints.

For students and universities, it's a perfect solution for remote learning and hands-on experience, ensuring that education keeps pace with technological advancements. For companies, it's a cost-effective way to streamline the design process, reduce time-to-market, and stay competitive. And for marine biologists or any field requiring remote observation, Planet Debug opens new doors for exploration and discovery.

The future of embedded design is here, and it's more accessible, flexible, and innovative than ever before.

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OpenAI and studio Elektor

Guest-Edited Editions of Elektor:

# Collaborations That Drive Electronics Innovation

**By The Elektor Content Team**

When it comes to electronics and engineering, there is power in collaboration. With guest-edited editions of *ElektorMag*, we've partnered with leading industry innovators like Arduino, Espressif, and SparkFun to bring creative electronics projects and in-depth engineering tutorials to the global electronics community.

What happens when Elektor teams up with some of the most pioneering companies in the electronics world? You get a dynamic fusion of creativity, expertise, and forward-thinking technology in the pages of *ElektorMag*. Over the past few years, Elektor has collaborated with trailblazers like SparkFun, Arduino, and Espressif to co-create exclusive editions of *ElektorMag* filled with innovative electronics projects, in-depth engineering tutorials, and helpful insights from top engineers. These special issues have captivated and inspired the global community of engineers, makers, and tech enthusiasts.

To reach the widest audience, the guest-edited magazines were published (in print and digital) and promoted in the English, German, Dutch, and French markets. The initiative enabled both our guests and Elektor to showcase their brands in new markets to promote their products to new audiences. We promoted each magazine with a free digital bonus edition, each packed with extra projects and articles, as well as with well-attended webinars and videos. The results have been remarkable, with each edition and all the subsequent content reaching hundreds of thousands of enthusiastic engineers and makers.


"First, many thanks to Elektor for letting us co-host an issue of this incredible magazine! We're very excited to share more about SparkFun through interviews, projects, and articles with the Elektor community. We have truly enjoyed working with the Elektor team to produce this publication — truly professional and exceptionally talented."

*Nathan Seidle (Founder, SparkFun) & Glenn Samala (CEO, SparkFun)*

## The SparkFun Guest-Edited Edition

In 2021, Elektor launched the first guest-edited edition of Elektor Magazine. Together with our first special guest, SparkFun, we created and published a magazine packed with in-depth engineering tutorials, electronics projects featuring SparkFun products, exclusive content, and insights from SparkFun's founder, its executives, and its engineers. How did this come about? The edition was a few years in the making. While attending the May 2019 Maker Faire in San Mateo, California, Don Akkermans (Elektor) and C. J. Abate (Elektor) met up with SparkFun to discuss possible collaborations on content and products. During their meeting over espresso, they quickly found that the two companies had a lot in common: talented in-house engineering teams, widely popular online electronics stores, a serious passion for fun DIY electronics projects, and fast-growing communities of curious engineers and makers. Discussions in the months following that initial meeting sparked some first ideas for collaboration that organically grew from products to projects to articles and finally an entire edition of *ElektorMag*. The result was a collector's item!

**Check out the SparkFun Guest-Edited edition of ElektorMag (2021)!**


"This special issue of Elektor Magazine is a homage to our community, to everyone who ever took an Arduino in their hands to make a project, to those who spent their time teaching others about the importance of digital technology, to the artists, designers, engineers, and scientists aiming at making a great job by means of an Arduino board, and to the Elektor community who got us in and helped amplify our message throughout the years."

*David Cuartielles (Co-Founder, Arduino)*

## The Arduino Guest-Edited Edition

Following the successful SparkFun edition, we sent a special invitation in 2022 to our friends at Arduino. At the time, they were looking to accentuate the professional capabilities of the Arduino platform, and so we worked closely to develop a unique edition of ElektorMag. Over the course of several months, Elektor's engineers and editors worked closely with David Cuartielles and his colleagues at Arduino to prepare DIY electronics projects, in-depth interviews, and helpful tutorials about many innovative Arduino solutions, from the Arduino UNO to Arduino Cloud to Arduino's professional products, including the Portenta family. In typical Elektor fashion, we worked hard with our friends at Arduino to bring readers a magazine packed not only with innovative do-it-yourself projects like David's soil-monitoring system, but also insights from creative artists such as Jacob Remin who are using Arduino in innovative ways. Magazine articles in the edition included: Getting Started with the Portenta X8, MicroPython Enters the World of Arduino, The New Portenta X8 (with Linux!) and Max Carrier Redefine What's Possible, Arduino Portenta Machine Control and Arduino Portenta H7, MQTT on the Arduino Nano RP2040 Connect, Connected Projects, Simplified: Dive Into the Arduino Cloud, and more.

**Check out the Arduino Guest-Edited edition of ElektorMag (2022)!**


> "We'd like to extend our heartfelt thanks to the fantastic Elektor team and editors for their incredible work and unwavering support in making this publication a reality. It's your contributions that have truly made this all happen."
>
> *Teo Swee Ann*
> *(Founder/CEO, Espressif Systems)*


## The Espressif Guest-Edited Edition

Following the resounding success of both the SparkFun (2021) and the Arduino (2022) collaborations, we were delighted to have Espressif as our guest editor in 2023. With groundbreaking solutions such as the ESP8266 and ESP32, the Espressif team has consistently delivered cutting-edge tools to the world's most innovative professional engineers, serious makers, and forward-thinking students. With this guest-edited *ElektorMag* and the resulting exciting collaboration with Espressif's talented engineers, we put a wide range of examples of the company's solutions and expertise into the hands of Elektor members and engineers around the globe. The magazine was packed with content, from projects to tutorials, on topics including song recognition on an ESP32, embedded development with Rust, ESP32 and ChatGPT, facial recognition with the ESP32-S3-EYE, handy engineering insights, and more. As we did with both Arduino and SparkFun in the previous years, we followed up the edition with a free digital bonus edition, as well as webinars and videos.

**Check out the Espressif Guest-Edited edition of ElektorMag (2023)!**

## Guest-Edited AI Edition

In 2024, we took an unconventional leap forward by inviting AI itself to serve as our guest editor. We consulted various AI programs to suggest key topics, curate content, and even review the numerous projects and articles featured in the edition. While AI did not create the projects and articles (we turned to our in-house engineers as well as our global community for that), it served as a dynamic collaborator, helping to refine ideas, identify emerging trends, and ensure our content remained cutting-edge. This nontraditional approach made perfect sense at a time when AI is rapidly disrupting the electronics industry, transforming everything from design processes to prototyping and beyond. By allowing AI to help shape the special issue, we not only embraced the very technology that's redefining our field but also offered our readers an exciting look at how artificial intelligence can influence creativity, innovation, and the future of engineering. Visit *www.elektormagazine.com/embedded-ai* for more information!

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# Open Vario

## The Open-Source Multifunction Variometer for Paragliding

**By Cedric Jimenez (France)**

Sometimes the best designs arise from an opportunity! Cedric Jimenez, the First Prize winner of the STM32 Wireless Innovation Design Contest, heard about the challenge from a friend and developed an innovative project for variometric flight altitude measurement. Read his full story here.

It all started when a friend forwarded me the link to the STM32 Wireless Innovation Design Contest page on Elektor magazine [1]: "Hey! Did you see this contest? It's based on a wireless chip by ST, and they offer an evaluation board!" He knew how to get me interested — since I really enjoy testing new microcontrollers — and I am a big fan of those evaluation boards which allow to quickly set up test projects to discover their features.

### Hardware Choice

I took a quick look at the proposed evaluation boards: two Nucleos (NUCLEO-WBA52CG, NUCLEO-WL55JC) and one Discovery Kit (STM32WB5MM-DK). The latter was, in my opinion, the most attractive as a base for a project because it already embeds plenty of features: display, storage, sensors, USB, extension connectors ... Okay, then I had a board [2], now I needed a project idea.

I'm a paraglider pilot, and I have been thinking for a long time to develop my own flight instruments. I even started to think of a hardware design about five years ago, but I didn't go very far, mainly due to a lack of time. So, I took this contest as an opportunity to transform this idea into a real device which I could use during my flights.

In paragliding, the variometer — also known as a rate of climb and descent indicator (RCDI) — is the most precious device! The climb rate expressed in meters or feet per second helps to look for the thermal streams which will allow the glider to climb up and thus to stay in the air, allowing multiple hours of flight. Additionally, to the main variometer functionality, the commercial variometers often have other features such as Global Navigation Satellite System (GNSS) tracking and deported display on a smartphone.

### Design Requirements

Based on the features offered by the STM32WB5MM-DK board, I started to list the features I wanted to implement (see **Figure 1**):

- Variometer
- GNSS positioning
- Accelerometer
- Temperature

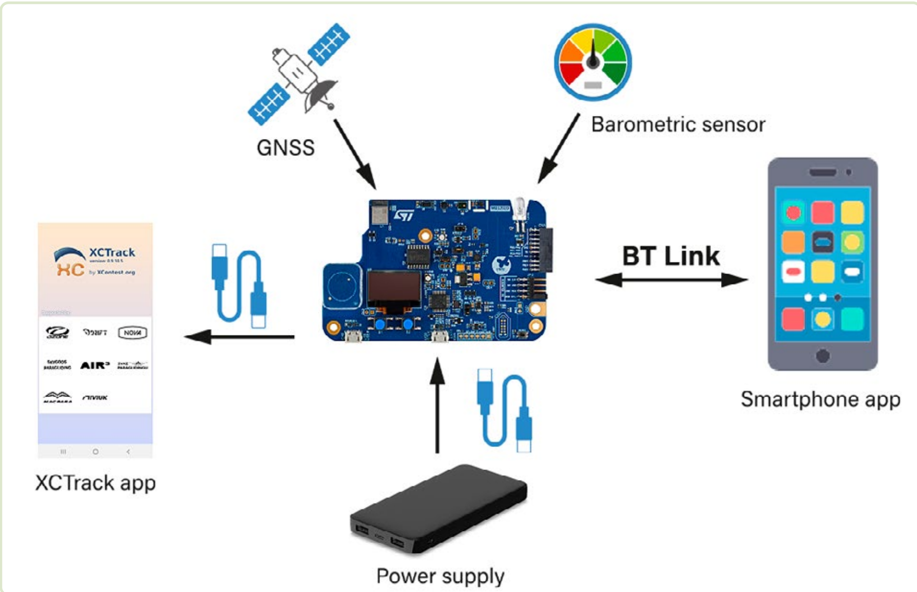


*Figure 1: The STM32WB5MM-DK Development board is at the heart of this project.*

- Glide ratio computation (i.e., the horizontal distance which can be covered for a 1-meter altitude loss)
- Flight data recording (altitude, speed, position…)
- Local HMI to display sensor and flight data
- BLE link to configure parameter and read real-time flight data values
- USB OTG link to connect to the XCTrack smartphone application (well-known application which can be used as a deported display)
- USB device link to connect to homemade PC python tools to export recorded flights

## Extra Hardware Needed

Although the STM32WB5MM-DK board was fulfilling most of the requisites, there were two sensors still missing: a GNSS for retrieving the geo-position of the device and a pressure sensor to compute the climb rate.

The climb rate computation is made by measuring the difference between two measured altitudes multiple time per-seconds. A GNSS doesn't compute a precise enough altitude on its own, so a high-precision barometer/pressure sensor is needed to obtain a 15…30 cm accuracy in altitude measurement.

An additional constraint for the choices of additional sensors was the need for a robust electrical integration with the STM32WB5MM-DK board, which should be able to endure vibrations and shocks during the take-offs, flight turbulences and landings. The form factor of the overall integrated device must also be as compact as possible to be carried easily. This is why I decided to leverage the Arduino UNO-compatible connector on the STM32 board and use MikroE Click Boards plugged on a dedicated shield [3], so that no soldering nor flying wires were needed. MikroElektronika offers a wide range of ready-to use sensor modules (more than 1000!) and I often used them for rapid prototyping.

For the GNSS, I already had a MikroE GNSS 4 Click board [4] featuring the U-blox AM-M8Q module, which embeds an omnidirectional radiation pattern GNSS patch antenna and an UART interface.

For the barometer/pressure sensor, MikroE proposed three high-precision sensors which could be used for my project. I browsed paragliding forums and looked at the provided documentation. In the end, I decided to use the Altitude 2 Clic [5] based on a MS5607 pressure sensor by TE Connectivity, which is used on other variometer projects: it is easy to use and has a good documentation. It can be connected using either I²C or SPI buses.

So, I plugged all this together to see how it was fitting (you may see a block diagram of the system in **Figure 2**) and … bad surprise: neither the I²C nor the SPI bus were available on the pins needed by the barometric sensor module! Okay, this was not really a blocker, I²C bus is not a complex protocol, so I implemented a software bit banging I²C driver as a workaround.

## Software Design

Now that I had my hardware design, I could start thinking about the software part. I like sharing my source code with other people and I also like to be able to re-use other people work. That's why I share most of my code using open-source licenses, and that's why this project should have been open source [6]. I chose the MIT license here to let the maximum flexibility of usage for future contributors/users since this project was not meant to be a commercial one.

For the programming language, I used my favorite one: C++. It offers all the low-level capabilities of C and, additionally, all the features of a modern object-oriented language: type safety, inheritance, templates … Most people think: "Using C++ means using dynamic memory allocation."

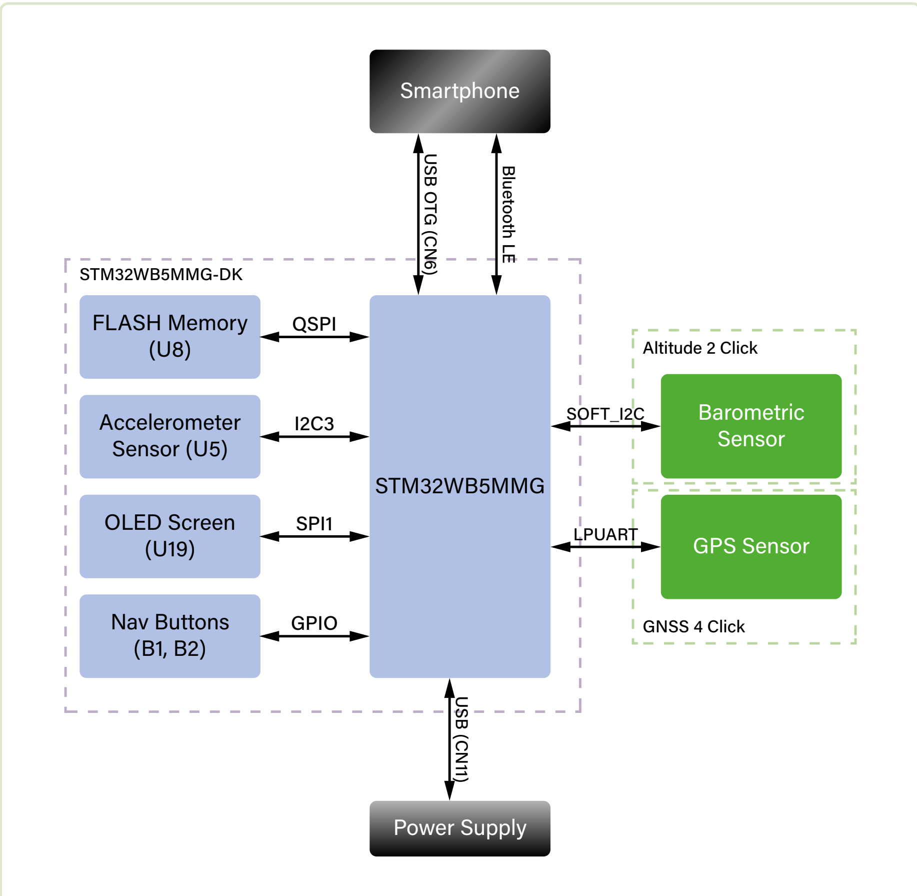


*Figure 2: Functional block diagram of the system, showing the physical interfaces to the external modules.*

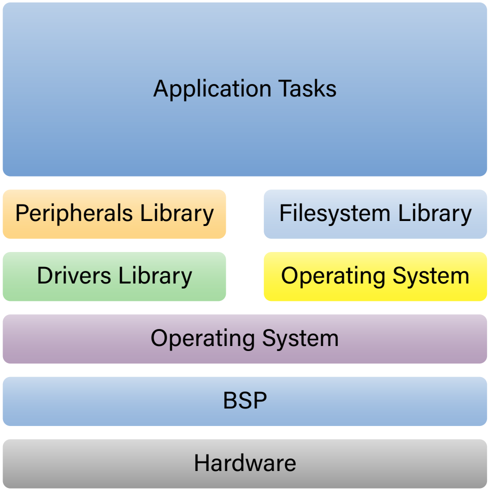


*Figure 3: Block diagram of the layered software architecture used in this project.*

Are `malloc()` and `free()` usage mandatory on a C program? No, neither are `new` and `delete` in C++. It only depends on the subset of the language used, and there are still so many options without dynamic allocations.

ST provides a lot of software tooling for its microcontrollers (STM32CubeIDE, STM32CubeMX ...) and plenty of examples through the device driver HAL and the STM32Cube MCU packages. Even though I really like these tools, which help me speed up small prototypes by generating part of the code and pointing me to the right libraries to use, I preferred using Visual Studio Code IDE with the C/C++ extension for code highlighting and browsing facilities, along with the Cortex-Debug extension for debugging embedded devices using ST-Links or J-Links debug probes.

It offers the same features as the STM32CubeIDE, but it is easier to configure and customize through plugins and JSON configuration files. I also preferred to write my own CMake/Make build system so it was fully independent of the IDE used and had full control on the source tree and the source files (no generated code by ST tools).

Aside the *STM32 HAL*, *STM32 USB* device library and, of course, the *STM32 WPAN* stack for Bluetooth, I decided to use the following third-party libraries (all available on github):

- FreeRTOS 10.6.2: Real-time operating system (I find easier to use one instead of a single loop design when resources are not too constrained)
- Little-FS 2.81: Easy to use, low footprint, power outage resilient filesystem for NOR memories
- YACSGL/YACSWL 0.0.1: Low footprint graphical library tailored for black and white OLED and/or ink paper screens

First, I did a C++ wrapper for all these libraries, so that they will be easier to integrate with C++ code. And, for some of them like the `mutex` class, I did mimic the standard C++ `std::mutex` behavior so that code can be easily written when using C++ otherwise. Then I decided to implement a "classical" but still efficient layered software architecture (see **Figure 3**). On top of it, I used what I called a "board abstraction pattern," which defines an interface allowing me to retrieve all my objects handling peripherals and device drivers through, of course, abstract interface. Ok, that's a lot of theory, so now let's take a look at the code in **Listing 1,** also available at GitHub [6].

Using this interface, in my application tasks I could easily access to the hardware peripherals and drivers without worrying at all about their implementation. This allowed me, for example, to easily stub sensors outputs to speed up the development of the algorithms in the application task. On another project, I used the same pattern to abstract the hardware and allow the same software to run on multiple different kinds of boards.

## Testing

The final step was now to test my device in real flight conditions. From simulated inputs, I knew that my algorithms were computing valid values and were behaving correctly when I changed the parameter of their filters. But in paragliding, everything is about feelings; therefore, I had to adjust these parameters during real flights so that the device behaves with my way of flying, and also to provide a way to easily configure them so that another pilot can adjust them.

I couldn't directly expose the device to open air due to the impact of direct sun exposition (and relative airflow) on the very sensitive pressure sensor. Instead, I had to use my smartphone to visualize data and control the parameters. There are two options to connect the STM32 board to a smartphone, Bluetooth and the USB-OTG connection, and I used both of them.

The Bluetooth link is exposing all the parameters in various services and characteristics. (See the document I put on the Elektor Labs webpage for this project [7].) Sadly, I didn't have an opportunity to develop a dedicated smartphone app with a fancy UI, but they are still easily modifiable using free generic BLE apps like BLE Scanner (see **Figure 4**).

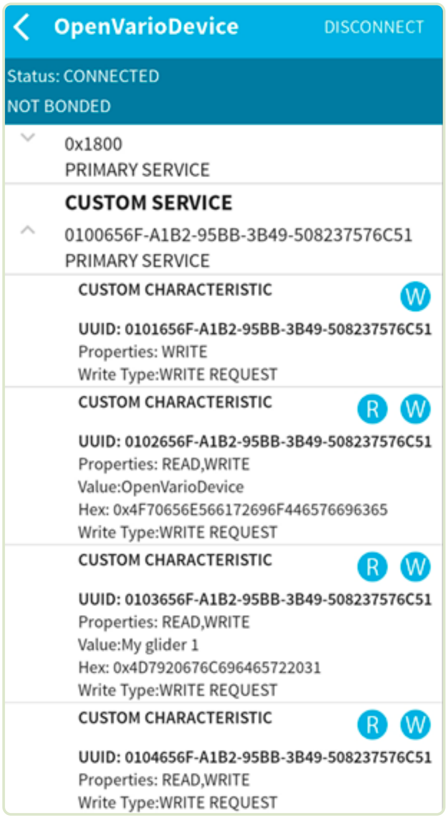


*Figure 4: Screenshot of the BLE Scanner app, used to customize the running services.*


*Figure 5: A commercial variometer was used to compare measurements made with my Open Vario.*

Another option to use the smartphone screen when flying: the XCTrack smartphone application — commonly used among paragliders — using the OTG link of the Discovery Kit. This allowed me to visualize the flight data computed by my device on my smartphone. I also added to my setup the "commercial" variometer that I usually utilize to compare the computed values, as shown in **Figure 5**.

During the flights I record periodically (default is 1 s) all the outputs of my sensors and algorithms aside with my GNSS position. Each flight is stored in a separated file of the QSPI NOR Flash. With the default settings, I can record up to nearly 24 hours of flight, which is plenty enough. I developed Python scripts to retrieve these files on a PC using the USB device link of the Discovery Kit and store them as CSV file so that they can be easily analyzed using Excel (see **Figure 6**) and also visualized as KML file in Google Earth application to review my flight in 3D, as illustrated in **Figure 7**.

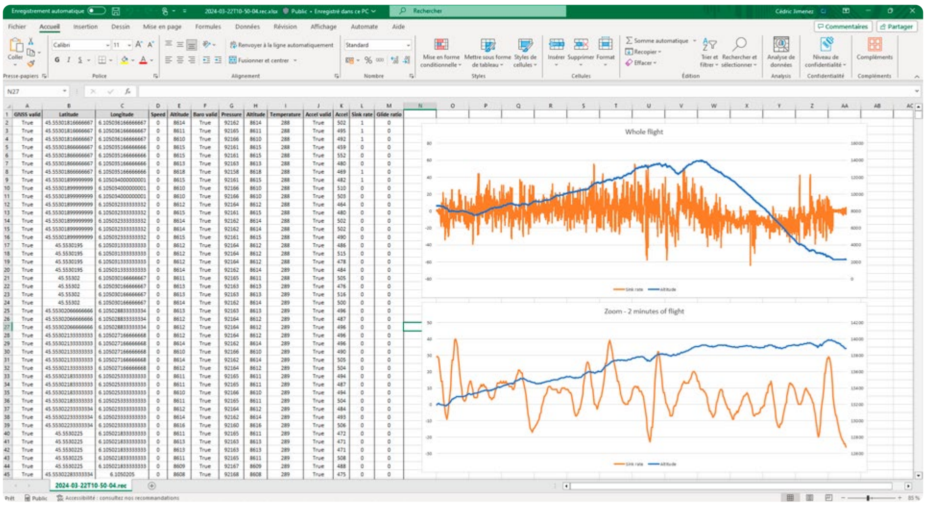


*Figure 6: The acquired data, stored in a .csv file, analyzed and displayed through Excel.*

## Plenty of Opportunities

So, I think that you have already figured out that I really enjoyed participating in this contest, even if it was a bit time-consuming (5...10 h per week)! It gave me plenty of opportunities: discovering a new microcontroller, developing a project I never took time to develop, mixing two of my favorite hobbies and discovering other exciting projects using the same hardware.

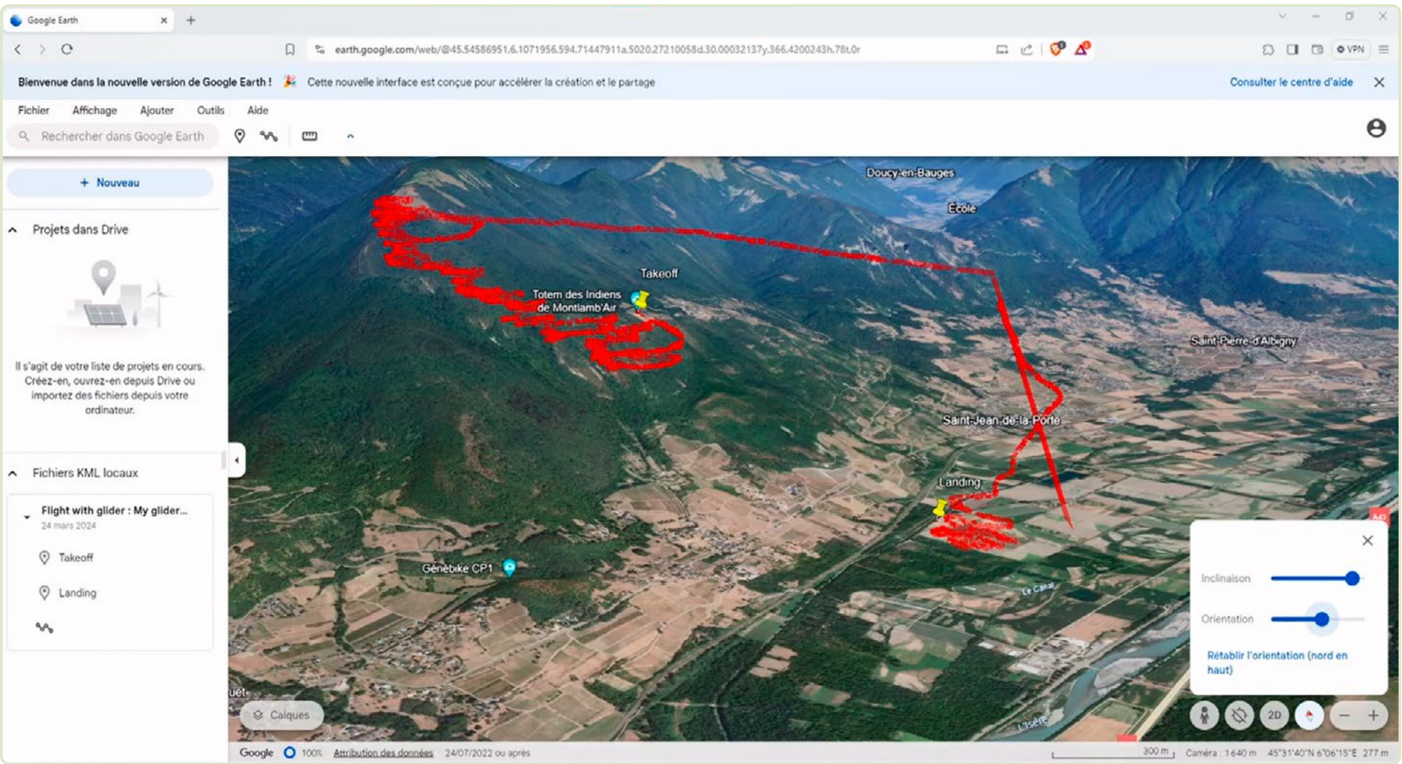


*Figure 7: 3-D visualization of flight data (as a KML file) in Google Earth.*

Also, the limited time frame for the contest (thanks for the time extension, by the way) was very challenging: every project comes with a lot a technical issues to overcome and at the end the project should propose an attractive number of features and be functional. I think that my job as an embedded software engineer helped me a lot on this part, since that's the kind of constraint I encounter on a regular basis.

Thank you, Elektor Magazine and ST Microelectronics, for the organization of this contest: I hope that you will organize others in the future!

240325-01

*Editor's note: This article first appeared in Elektor September/October 2024.*

## About the Author

Cedric Jimenez is 40 years old and the happy father of an 8-year-old daughter. He lives in the French Alps, where he does a lot of mountaineering activities (climbing, paragliding). Cedric is a big fan of software engineering on embedded systems. He started programming in Basic language at the age of 9 on a Thomson TO7/70 and moved to C++ a few years later.
Although he learned a lot of programming languages (VB, C#, C, Pascal, FORTRAN, Python, Ruby...), C++ is still his favorite one. He holds a Master's degree in computer sciences with a specialty in Real-Time Embedded Systems. He's been working for more than 15 years as a subcontractor in various domains (railway/subway, cranes, medical devices...), and actually works as an embedded software architect for Schneider Electric.

## Questions or Comments?

Do you have technical questions or comments about this article? You may write to the author at cjz.73fr@gmail.com or to the editorial team of Elektor at editor@elektor.com.

### Listing 1: A board abstraction class.

```
/*
 * Copyright (c) 2023 open-vario
 * SPDX-License-Identifier: MIT
 */
#ifndef OV_I_BOARD_H
#define OV_I_BOARD_H
#include "i_accelerometer_sensor.h"
#include "i_barometric_altimeter.h"
#include "i_ble_stack.h"
#include "i_button.h"
#include "i_display.h"
#include "i_gnss.h"
#include "i_serial.h"
#include "i_storage_memory.h"
#include "i_usb_cdc.h"

namespace ov
{

/** @brief Interface for boards implementations */
class i_board
{

  public:
    /** @brief Destructor */
    virtual ~i_board() { }

    /** @brief Reset the board */
    virtual void reset() = 0;

    /** @brief Get the debug serial port */
    virtual i_serial& get_debug_port() = 0;

    /** @brief Get the USB CDC port */
    virtual i_usb_cdc& get_usb_cdc() = 0;

    /** @brief Get the storage memory */
    virtual i_storage_memory& get_storage_memory() = 0;

    /** @brief Get the display */
    virtual i_display& get_display() = 0;

    /** @brief Get the 'Previous' button */
    virtual i_button& get_previous_button() = 0;

    /** @brief Get the 'Next' button */
    virtual i_button& get_next_button() = 0;

    /** @brief Get the 'Select' button */
    virtual i_button& get_select_button() = 0;

    /** @brief Get the BLE stack */
    virtual i_ble_stack& get_ble_stack() = 0;

    /** @brief Get the GNSS  */
    virtual i_gnss& get_gnss() = 0;
```

```
    /** @brief Get the barometric altimeter */
    virtual i_barometric_altimeter& get_altimeter() = 0;

    /** @brief Get the accelerometer */
    virtual i_accelerometer_sensor& get_accelerometer() = 0;
};

} // namespace ov

#endif // OV_I_BOARD_H
```

**Related Product**

- Majid Pakdel, *Advanced Programming with STM32 Microcontrollers*, Elektor, 2020
  www.elektor.com/19527


## WEB LINKS

[1] STM32 Contest Webpage: https://tinyurl.com/bdenyy24
[2] STM32WB5MM-DK Evaluation Tool Webpage: https://tinyurl.com/4dp83f8h
[3] MikroElektronika Arduino Uno Click Shield: https://www.mikroe.com/arduino-uno-click-shield
[4] MikroElektronika GNSS 4 Click Board: https://www.mikroe.com/gnss-4-click
[5] MikroElektronika Altitude 2 Click Board: https://www.mikroe.com/altitude-2-click
[6] Author's Gihub page for Vario: https://github.com/open-vario/open-vario
[7] Elektor Labs webpage for this project: https://tinyurl.com/4rmn5j28

eeNews EUROPE

CTO Interview:
# The Geopolitics of GaN

Source: IQE

**By Nick Flaherty (eeNews Europe)**

Rodney Pelzel, CTO of IQE, talks to *eeNews Europe* about its plans for expanding gallium nitride (GaN) into power and microLED applications.

IQE is a supplier of epitaxial wafers in the UK for many applications, from VCSEL vertical lasers to GaN-on-silicon for RF applications. The shifting geopolitical landscape is driving more attention on supplying GaN wafers and power devices in the US and Europe rather than Taiwan or China.

"IQE has a very long history with GaN as a material system, starting in the US 20 years ago on military RF applications and that grew into a successful product offering that we have today, and we have experimented with all kinds of substrates and architectures.

"We've had power on our roadmap for quite a while, but it has been stop and start. With GaN on Silicon we are in customer development and qualification. GaN is very interesting as it needs a proprietary buffer. We own that and guard that under lock and key."

"We have 650 V for both enhanced mode and depletion mode GaN on 6in and 8in wafers and we used a lot of our knowhow to get to where we are today. We have relationships with IDMs, fabless, foundries, and We are also designing our own reference structure to sample numerous customers at 650 V.

"It is key to our diversification strategy that has two thrusts with power and microLED. Today we manufacture GaN on Silicon in Massachusetts and have recently added two G5 reactors from Aixtron. We also have the original G5 for the group in St Mellon in Wales in a European Space Agency (ESA) programme and engaged with imec programmes as well."

The Newport magafoundry was put in place for GaAS VCSELs with ten G4 Aixtron reactors and two G5s for GaN coming online in October. "We are setting up very deliberately to have a very significant capability in the UK and US, to give us global reach."

"The geopolitical landscape is getting more complex," he said. This is leading to a peculiar situation with isolated development teams.

"Different GaN teams in the regions for entirely independent developments," he said.

"I don't think the supply chain has really shaken out. It does remind me of the RF GaAs landscape. I think it will be a complex model because of where the IP sits. 60 to 80% of the value sits in the epi which sets the performance, and you can run that through an 8in depreciated fab and get leading edge performance. The line widths are nothing special for a fab today. The epi is really the key part to that."

The current planar GaN epitaxial process does not need an engineered wafer, which IQE also develops.

"At 650 V, engineered not so much — with 1200 V the verdict is out. We have started to dabble in 1200 V and have a roadmap. My feeling is that there is a play for engineered substrates of some sorts as you go to higher voltage nodes, also as the demands for 650 V shift with the RF behaviour which is determined by the buffer and the defects."

*The choice of GaN structure, whether planar or vertical trench, is up to the customer.*

The choice of GaN structure, whether planar or vertical trench, is up to the customer, he says, rather than the depth of the epitaxial layer. "Trench is more for the customer, but it's not too far a leap to have the capability. When I think about the problem, what I am really engineering is how does the epi layer behave with silicon and function with rogue silicon and that's where the value of the epi comes through to be able to have iterative designs in less than a year."

The rise of more integrated devices is also important.

"As you start to integrate various capabilities that does change the epi, but we are not seeing that right now. The interesting thing is in the design side. That's where the foundry model and fabless companies can really go much quicker than the vertically integrated suppliers as you are leveraging all the core capabilities rather than having to have them all in house.

"When you start factoring in the geopolitics and regional restrictions, it depends on the ramp at 650V and who wins. There is a need for more GaN capacity in this region," he said. This is leading to expansion in the US and Europe and IQE is also preparing an application for funding under the US Chips Act to expand its GaN epitaxial wafer production

"We have actively engaged with them on compound semiconductors, but there was an education issue first on compound semiconductors and the supply chain," said Pelzel.

It is also looking at a European site with backing from the EU Chips Act. "We have discussion with two of the major locations. For us, we don't need multiple facilities, we need a location in the UK or EU that enables us to progress and continue with the strategy of having manufacturing and development in the region," he said.

The available talent pool is also key for a location. "That is the major concern with where you put facilities these days, because the innovation is in a different area the skill set is subtly different. Epitaxy is different enough that hiring someone from a silicon fab can be a challenge in some areas."

"We have plans to process 300 mm wafers. We don't have in house yet today but it will go there. For me, GaN for power has a long runway but GaN for microLED is a really big opportunity. The explosion of AI is going to help microLED and 300 mm as it will drive the creation of additional 300 mm fabs for the economics and the backplane for microLED AR displays will take more sophisticated devices."

It's not just about the additional size of the equipment for the 300 mm wafers but how they are clustered for efficiency, he says.

"When you start factoring in the geopolitics and regional restrictions, there is a need for more GaN capacity in this region," he said.

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**WEB LINK**

[1] IQE: https://www.iqep.com

**Editor's Note**

*eeNews Europe* first published this article on June 25, 2024. Visit *www.eenewseurope.com* for more news and interviews.

Source: Adobe Stock

# Paragraf Gears Up for Next Phase of Graphene Development

**By Peter Clarke (eeNews Europe)**

Andy MacInnes, chief development officer of Paragraf Ltd. (Somersham, England), discusses the next steps for the UK developer of graphene electronics.

Graphene is a single atomic layer material that holds the promise to produce devices and components with market-leading specifications. Paragraf's position is based on its ability to lay down contamination-free graphene without the use of a copper catalyst. Paragraf's techniques have already produced chemical and magnetic sensors with enhanced sensitivity and could be extended to produce graphene-based transistors superior to silicon equivalents.

The company is approaching its ninth birthday and has a couple of products in the market, a Hall-effect sensor of exceptional sensitivity and a graphene FET (GFET) that can be used for molecular sensing in biological, health, agricultural and other applications. The molecular sensor comes courtesy of Paragraf's acquisition of Cardea Bio Inc. in May 2023 (see Graphene pioneer Paragraf acquires bio-sensor startup Cardea).[1]

MacInnes said Paragraf's Hall-effect sensor has potential in automotive applications and in quantum computing, but he admits graphene electronics, "has not really gained traction in the market yet." As chief development officer, it would seem to be MacInnes job to help make that happen.

"I worked at TriQuint Semiconductor in the 1990s, now part of Qorvo, on gallium arsenide. Back then gallium-arsenide was always the technology of the future. Its future never seemed to arrive but eventually gallium arsenide found market entry in the communications domain," said MacInnes.

"That's where graphene is right now. Automotive has a strict and lengthy qualification process, so adoption into volume production will take some time," he added.

Automotive applications include battery management systems where Paragraf's sensors can be used to monitor individual battery cells, operating accurately over broad temperature ranges. The same sensors, which in essence link voltage, current and magnetic field strength, can be used for steer-by-wire systems. Here the advantage is a high signal-to-noise ratio over a broad dynamic and temperature range. Conventional Hall-effect sensors are already in use here, but graphene-based devices have the opportunity to reduce the number of components required, MacInnes said.

"But it's got to prove itself," said MacInnes. "We've got to start delivering the widgets that applications need."

## Quantum Computing

"In quantum computing it's not the same challenge. There isn't an established qualification process and it's more of a blank canvas. Here the cryogenic capabilities of graphene mean it can measure magnetic fields at milliKelvin temperatures," MacInnes said.

He explained that for many approaches to quantum computing it is necessary to subtract stray magnetic fields at temperatures near absolute zero as part of the method of detecting the quantum state of qubits. "We are sampling products. It's a niche area where we have traction, and we are gaining a lot of learning." In this case, the market is more immediate, but it is essentially one of relatively high value but low volume.

*Automotive applications include battery management systems where Paragraf's sensors can be used to monitor individual battery cells.*

And then there are the molecular sensors. "We've opted to sell the GFET base unit and allow customers and third parties develop the intermediate layers used to capture a specific molecule such as methane or biological markers," said MacInnes. He pointed out that in the area of health applications there are long and expensive qualification processes that the company has opted not to take on.

At the same time, Paragraf remains committed to researching devices aimed at other applications that can take advantage of graphene's 2D-material characteristics. Here the challenges may come from how to transfer the mono-layer graphene into part-processed devices, said MacInnes. "We probably need to grow the graphene in situ; to grow-in the quality," he said.

This background — and the fact that Paragraf took possession of a 43,000-square-feet manufacturing site in Huntingdon in February 2023 — points to Paragraf being a manufacturing company (Paragraf opens second UK graphene electronics manufacturing site).[2]

*Andrew MacInnes, CDO of Paragraf Ltd. (Source: eeNews Europe)*

## Make First, License Later

"The general concept right now is that we have to develop our own standard products to establish the market for graphene electronics," said MacInnes. "We have a development fab and we will be in Huntingdon soon to allow general manufacturing. We do expect to outgrow the Huntingdon site. At that point, we would be better placed to license the process to other foundries."

MacInnes added that the pathway depends on the degree of maturity of the process. "The back-end, packaging, we already outsource," he added.

But being a manufacturing company also means that Paragraf needs funds for capital expenditure. The company closed a Series B round of financing worth US$60 million in 2022 (see Paragraf raises $60 million for graphene).

In Paragraf's full accounts for the year ending December 31, 2022, which were signed off on June 2, 2023, it was stated that the company was engaged in a Series C round of venture capital financing that was expected to complete in the coming months. MacInnes did not comment on this except to agree further funding is necessary to propel Paragraf forward. "If we were a fabless chip company it would be different, but we are not," he said.

As a pioneer of the graphene electronics sector, Paragraf is carrying a lot of expectations and the possibility of long-term returns on its shoulders. The size of that Series C – and how soon it is announced – will be an indication of how aggressively Paragraf can engage in the next phase of its development.

240523-01

**Editor's Note**
*eeNews Europe* first published this article on August 22, 2024. Visit *www.eenewseurope.com* for more news and interviews.

## WEB LINKS

[1] P. Clarke, "Graphene pioneer Paragraf acquires bio-sensor startup Cardea," eeNews Europe, May 2, 2023: https://www.eenewseurope.com/en/graphene-pioneer-paragraf-acquires-bio-sensor-startup-cardea/
[2] P. Clarke, "Paragraf opens second UK graphene electronics manufacturing site," eeNews Europe, February 21, 2023: https://www.eenewseurope.com/en/paragraf-opens-second-uk-graphene-electronics-manufacturing-site/
[3] Paragraf: http://www.paragraf.com

# ECINews Covers Electronics Industry News for the French Market

## A Magazine, Website, and Newsletter Dedicated to Electronics


**By Nicolas Feste and Daniel Cardon (ECI News, France)**

Discover how ECI News keeps French-speaking electronics professionals informed. With a magazine, a dynamic website, and a newsletter, ECI News ensures coverage of the latest industry developments, from automotive tech to AI innovations and more.

Published in French, ECI News magazine, which is part of the Elektor publishing family, has been present in the French electronic press market for over 20 years. Initially, there was only the paper magazine, accompanied by various direct marketing products (bulk mailing, mailing list rental). Over time, and with the advancement of communication technologies, in addition to the printed magazine and to meet the demand of a new generation of subscribers, a digital version was launched with the arrival of the website.

### Wide Distribution

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# ECI News: Providing Insights Into the Latest Tech Trends and Innovations




















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# Touch Sensing Made Simple

## A DIY Guide for Any Microcontroller

By Michael J. Bauer (Australia)

Not all microcontrollers have touch-sensitive GPIOs built-in. This article outlines a method to enable capacitive touch sensing using general-purpose I/O pins on devices like the AVR ATmega328P. It covers configuring pins to detect changes in capacitance and reveals code developed with Microchip Studio.

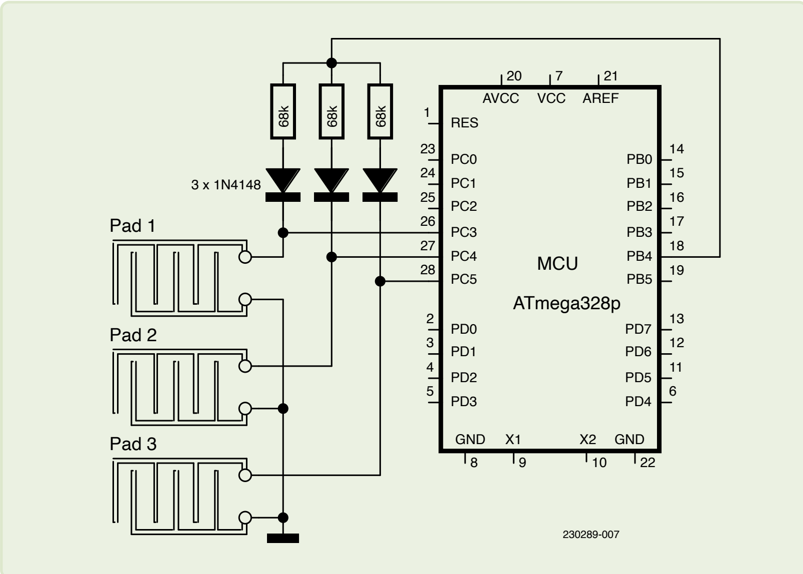


*Figure 1: Schematic of touchpad connections to the microcontroller.*

Some microcontroller devices have on-chip hardware to support reading of capacitive touchpads. These devices provide "automatic" measurement of capacitance between an I/O pin and earth (GND). However, a change in capacitance on an (analog) input pin can be detected easily without any special on-chip wizardry. The technique presented here relies on the measurement of the charge rate of a capacitor (in form of a touchpad). To be more precise, the voltage on the capacitor after a fixed charge time is measured. While a pad is touched, its effective capacitance is higher; the charge rate will be lower and so the end voltage will be lower.

### Principle

The microcontroller must have I/O pins that can be configured as either digital (GPIO) or analog (ADC inputs). One such pin is required for each touch input. The number of touchpads may be increased above the number of available ADC inputs by using an external analog multiplexer IC. One digital output is required to provide a "current source." Actually, it's a voltage source, but a high-value resistor (one for each touch input) turns it into a current source. Refer to **Figure 1** for the schematic diagram showing how the touchpads are connected to the microcontroller.

Touchpads may be etched into a PCB with signal and ground traces inter-meshed to form a capacitor. When touched with a finger, the capacitance between the signal and ground traces will increase. Alternatively, touchpads may be just bare-metal objects such as a screw head, rivet or piece of metallic tape.

The human body acts a large capacitance to earth when it contacts a touchpad. But touch-sensing is more effective if the body is connected to the microcontroller system's ground (GND) somehow.

Initially, the current source drive (PB4) is switched off and the touchpad pins (PC3, PC4, PC5) are configured as outputs and set to low (0 V). This discharges the pads. Each pad is "serviced" in turn, one by one. At the start of the service routine, the pad I/O pin is configured as an analog input. The pad is charged from the current source (resistor and diode) for a fixed duration, typically a few microseconds.

At the end of the charge time, the current source is switched off. The diode prevents discharge while the pad voltage is measured

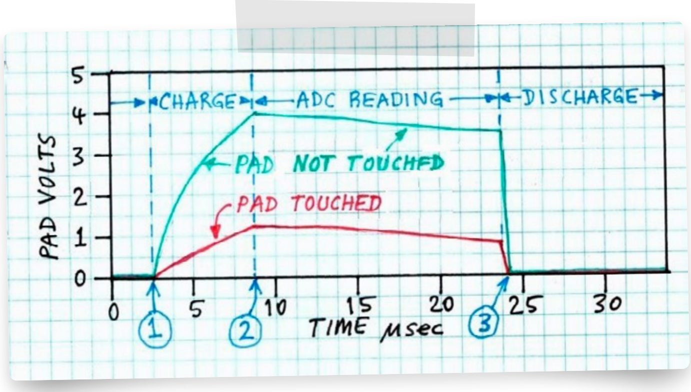


Figure 2: Voltage vs. time for an untouched touchpad.

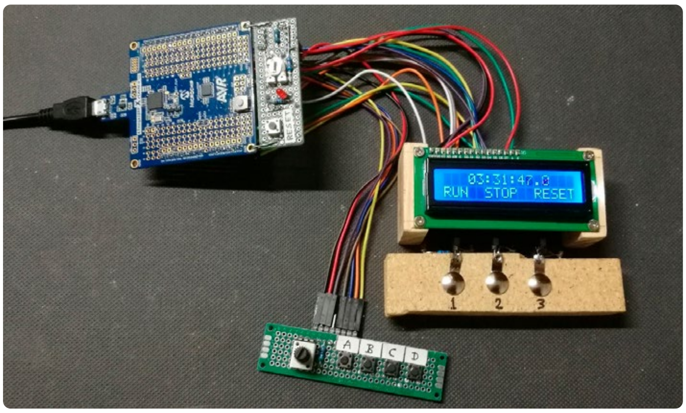


Figure 3: Test & Demo Setup with AVR X-mini board.

by the ADC. When the ADC conversion is complete, the result is read out and the pad I/O pin is re-configured as a digital output and set low to discharge the pad.

See **Figure 2** for the graph illustrating the pad signal voltage versus time during the reading sequence. The green trace is the pad voltage, with the pad not touched. The pad capacitance is very low, so it charges rapidly and reaches a relatively high voltage. At timing point 2, the current source is switched off and the ADC conversion sequence is started. There will be a slow discharge due to current leakage in the diode and in the ADC inputs. This is not a problem because the ADC samples the voltage at the start of conversion (point 2) and holds it constant during conversion. At the end of the conversion sequence (point 3), the ADC value is read out and saved in an array. Finally, the touchpad is discharged, in preparation for a subsequent reading.

Depending on your specific application requirements, the interval between calling the touchpad "service routine" may be anywhere in the range of 100 µs up to 5 ms, or more. Execution time of the service routine itself is typically under 30 µs for each touch input. Thus, the processing overhead to service the touchpads is very low. Interrupts must be disabled during execution of the service routine because the timing is critical. For most embedded applications, a delay of under 30 µs occurring once every millisecond (more or less) would not be regarded as "process blocking."

## "Test & Demo" App

The touch-sense technique has been tested successfully on a "low-end" 8-bit AVR microcontroller, the Atmel ATmega328P, as found in many popular development boards including the Arduino UNO R3 and Nano, and Microchip's ATmega328P (AVR) X-Mini board. I chose the AVR X-Mini because it has an on-board programming tool, it is very cheap (~ €9) and readily available from major suppliers, but primarily because I had one lying around in my unused component box. **Figure 3** shows the configured X-mini board and connected peripherals.

Also, I much prefer Microchip/Atmel Studio IDE for AVR and SAM, compared to the Arduino IDE. My Test & Demo program could be migrated to Arduino IDE, but the MCU pin allocations (for a 1602A LCD module in particular, see below) are incompatible with common Arduino code libraries. Hence, you would need to extract the source code for some peripheral functions from the AVR X-mini library to import into your Arduino sketch.

If you want to run the Test & Demo program on an Arduino UNO or Nano board, the pre-built object code (hex file) can be programmed into the MCU with and without Microchip/Atmel Studio, and without any additional programming tool (please refer to the text box "**How to program an Arduino UNO...**").

Whatever hardware platform and software development tools you are using for your application, the touch-sense technique can be understood by examining the code in the Test & Demo program, in particular the touch-sense "Service Routine." If you want to replicate the application on a compatible AVR hardware platform, connect the LCD and other peripherals as shown in **Figure 4**.

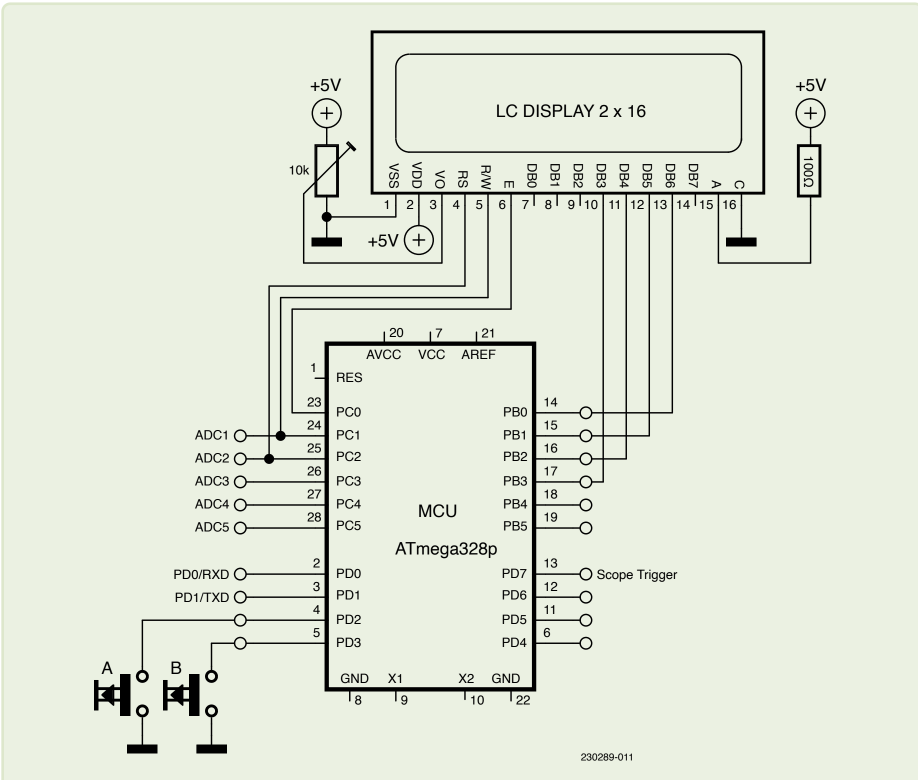


Figure 4: Schematic for Test & Demo application with an ATmega328P.

## How to Program Arduino UNO or Nano

The firmware was developed using Microchip Studio for AVR and SAM Devices (formerly Atmel Studio). One of many reasons for choosing this IDE (Integrated Development Environment) instead of Arduino is that the project hardware design is incompatible with available Arduino code libraries. In particular, the 1602A LCD interface scheme (MCU I/O pin assignment) is not supported by any Arduino library.

Programming the target device (ATmega328P MCU) can be achieved without Arduino IDE and without any hardware programming tool. The UNO and Nano boards have an on-board USB-serial bridge IC and a flash-resident AVR bootloader. A Windows PC application called *AVRdude* talks to the bootloader via USB to program firmware into the MCU flash memory.

Hence you need to download some files to run AVRdude on Windows. You can download these files from the AVRdude GitHub repository [2]. There should be three distribution files: ***avrdude.exe***, ***avrdude.conf*** and ***avrdude.pdb***. Copy these files to a new folder named ***AVRdude*** on your PC local drive, in the root directory (C:\).

Connect your UNO/Nano board to a USB port on your PC. Open Windows *Device Manager* utility and click on *Ports (COM & LPT)*. You should see the UNO/Nano USB-serial device listed. Note the number of the associated COM port. Be aware that the COM port number may change from time to time. This is an annoying USB quirk. Remember to check the allocated COM port when re-connecting the UNO or Nano board to your PC.

You can run AVRdude directly from Microchip Studio, if you create a *Programming Tool* in this IDE:

In Microchip Studio, click in the menu *Tools/External tools*.
You should see a dialog box asking for some parameters, as follows:

In *Title*, write: *Program Nano* or any other name you prefer.
In *Command*, write: *C:\AVRdude\avrdude.exe*
In *Arguments*, write (all on one line):

```
-C "C:\AVRdude\avrdude.conf" -p atmega328p -c arduino -P COM# -b 115200
-U flash:w:"$(ProjectDir)Debug\$(TargetName).hex":i
```

Replace `COM#` (in the Arguments field) with the actual COM port your Nano board is connected to, as found in Windows Device Manager (Example: `COM4`).
Tick the box *Use output window*. Click *OK*.
Done... You should see a new option *Program Nano* in the Tools menu.

After your program code is built, it can be programmed into the Nano board simply by clicking on the item *Program Nano* in the *Tools* menu.

Note: Some cheap Chinese Nano board clones use a non-standard baud rate for the serial bootloader, typically 57600 baud. If Microchip Studio outputs an error message when running the programming tool, try replacing `115200` with `57600` in the arguments field.

Two push-button switches (labelled "A" and "B") are provided for user input in case the touchpads don't work initially. The touchpads are wired as shown in Figure 1. If your application doesn't need the LCD or I²C bus (PC4, PC5), then all (eight) Port C pins may be used for touchpads or other analog inputs.

The touch on/off voltage threshold may need adjustment in the software. Referring to the Test & Demo source code (file ***main.c***), line 29 defines the threshold level to determine whether a pad is touched or not. The default value is 150, which should work for the majority of touchpad physical arrangements. The optimum threshold value can be found by running the program in the *test mode*, selected by button *A*. This will show ADC readings (range 0...255) for the three touchpads. For each pad, note the reading with pad touched and again with pad not touched. The optimum threshold value is about halfway between these two readings.

The program also includes a *demo mode*, which functions as a primitive stopwatch/timer, using the three touchpads to start, stop, and reset the timer. Press button "B" to enter this mode. The demo code is implemented as a state machine with three states: *Reset*, *Running*, and *Stopped*. Touching a pad will change state (if the state machine is not already in the selected state).

## Oscilloscope Screen Captures

**Figure 5** shows the oscilloscope screen captures obtained during the tests, highlighting the touchpad signal behavior. The top (yellow) trace is a test-point output signal. This signal is set high at the start of the service

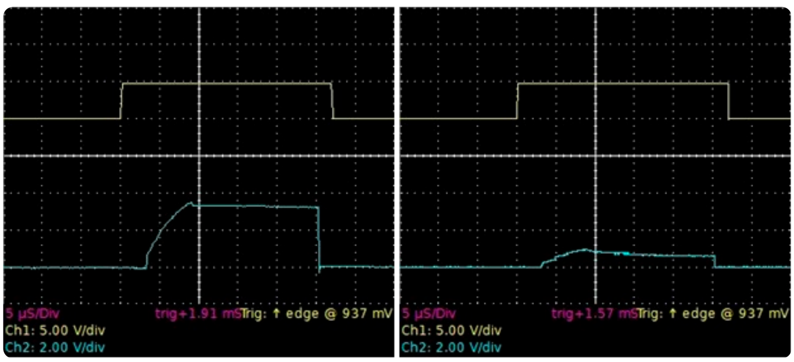


*Figure 5: Result on oscilloscope when pads are not touched (left) vs when pads are touched (right).*

routine and low at the end, just before the function returns. The test-point output (pin PD7) serves two purposes: first scope trigger, and second measurement of service routine execution time.

The bottom (blue) trace is the touchpad signal (ADC input). In these tests, the charge time was set to 6 µs. The current-source resistor value (68 kΩ) and charge time were chosen such that the pad signal reaches almost (but not quite) the ADC reference voltage (+5 V) when the pad is not touched. This results in optimum touch sensitivity.

The screen on the right shows what happens when the pad is touched. The charge rate is much slower, so the voltage on the pad at the end of the charge time is lower. The software defines a voltage somewhere in between to be the "touch ON" threshold.

Note that the ADC conversion time is about 15 µs. This accounts for most of the execution time of the service routine. The ATmega328P ADC clock rate may be increased to reduce the service routine execution time. There is a compromise between ADC speed and conversion accuracy, of course. However, the ADC clock rate used in the test program (2 MHz) gives quite acceptable precision, so perhaps it could be increased further.

## Firmware Development

Should you decide to develop your own application using Microchip/Atmel Studio IDE, assuming you have not used it before, a good place to start is to rebuild my Test & Demo program. Once you have the app running on your target platform, you can then modify and extend the source code for your purposes.

First, download the project files from GitHub [1]. Create a project folder on your computer's local drive and copy all the files into that folder. From the Start Page in Atmel Studio, select *Open Existing Project*. Navigate to your project folder and click on the file named *X-mini-touch-sense.atsln*. This is easier than creating a *New Project* and will ensure that the project has all the required components loaded, in particular the peripheral library files, *lib_avrXmini.**.

Further down the track, if you wish to create a new project using the X-mini library, be sure to attach the library files correctly. This can be checked in the *Solution Explorer* panel on the right side of the IDE editor window.

For detailed programming steps and specific configurations, the Elektor Labs page [3] provides useful guidance.

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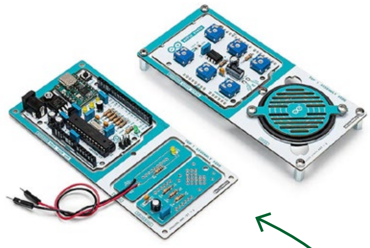
*Editor's note: This article first appeared in Elektor Circuit Special 2024.*

### About the Author

Michael Bauer studied Electrical & Electronic Engineering and later tutored in Computer Science at Deakin University (Australia). Career highlights include co-development of what was perhaps the first commercially viable "smart meter" (MCU-based kWh meter); engineering of control systems for theatre stage automation; electronics design and software development for scientific and biomedical analytical instruments. Now retired, Mike's interests include electronic music technology, cycling and XC skiing. His main claim to fame is a DIY hobby computer project known as the "DREAM-6800" (published in 1979), still popular among vintage micro-computer enthusiasts.

### Questions or Comments?

If you have questions about this article, feel free to email the author at mjbauer@iprimus.com.au, or the Elektor editorial team at editor@elektor.com.



### Related Products

- **Arduino Make-Your-Uno Kit**
  www.elektor.com/20330
- **Seeed Studio Grove LCD RGB Backlight**
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## WEB LINKS


[1] M. J. Bauer | Touch sense on any MCU | Github Repository: https://github.com/M-J-Bauer/Touch-sense-on-any-MCU
[2] AVR Dude | GitHub Repository: https://github.com/mariusgreuel/avrdude/releases
[3] Elektor Labs webpage for this project: https://elektormagazine.com/labs/touch-sense-technique-for-any-mcu

# Vaire Co-Founders Discuss Adiabatic Reversible Computing

*Hannah Earley and Rodolfo Rosini of Vaire Computing (Source: eeNews Europe)*

**By Peter Clarke (eeNews Europe)**

*eeNews Europe* asked Rodolfo Rosini and Hannah Earley, co-founders of Vaire Computing to discuss reversible computing, which is the technical basis of their startup.

Rosini, who serves as CEO of the company, is a serial entrepreneur who has founded companies in AI, gaming and cellphone security. "I decided that developing and introducing a CPU architecture must be one of the most complex tasks in the world; one of the hardest things you can do. I wanted to try," Rosini told ***eeNews Europe.***

Earley gained a PhD from University of Cambridge before co-founding Vaire Computing in 2021 and taking the position of CTO. At Cambridge, her research interests include reversible computing and molecular programming, and she states she is now moving towards the practical implementation of some of these ideas.[1]

Reversible computing is fundamentally different from the "classical" computing that underlies nearly all the commercial computation deployed to date, although the topic has been the subject of academic research since the 1960s.

## Near-Zero Energy

Vaire's goal is to produce an AI processor or accelerator that is approaching 4,000 times more energy efficient than similar devices implemented classically.

"What we can do is make near-zero-energy chips. Our flavour is adiabatic reversible computing. We can operate at room temperature and dissipate almost no power," said Rosini. Earley added: "We are doing this in digital CMOS. The approach is to manage how logic is laid out at the gate level and the speed at which transitions occur."

Adding reversibility to a computation process means that inputs are not lost on the creation of an output. It has been shown in academic research that it is only the destruction of information that sets a fundamental energy limit — the Landauer limit — on computation. Reversible computing would allow that limit to be transcended.

The adiabatic part of the approach is the prevention of the consumption of energy by the movement of charge, through the use of resonant structures. In other words, the work done in classical computing gets turned into heat by dumping charge to ground. If that energy can be recovered within the system, it can be reused for subsequent operations. This together with the reversibility allows for theoretical energy efficiency gains in complex systems of more than three orders of magnitude, according to academic publications.

These are bold claims that have been pursued by a few startups (see Metis emerges with 'data-is-energy' IP).

## Transition Slowly

One of the ways to minimize energy consumption is to allow bit transitions to take place slowly. Classical computing, even at gigahertz clock frequencies, has rapid bit transitions driven by nearly square wave clock signals, which results in high resistance and losses through heating. There are then 'long' waits for the next clock edge. By using trapezoidal waveforms with gentle gradients and by allowing transitions to occupy a greater proportion of a clock period, charge can flow in and out of resonant structures in an adiabatic, or near-adiabatic manner. One of the ways to manage this is by the use of multiple clocks to control the rise and fall of signals.

If transitions were infinitely slow the switching operation would dissipate no energy – and produce no heat – except for that due to leakage currents. Fortunately, the major part of this benefit is seen relatively quickly, meaning that close to conventional clock rates should still be possible, Earley explained.

Earley said that Vaire is using neither a single-rail nor a dual-rail (signal and inverse) logic system. "So, the exact rail system is neither, but the specifics are not yet public. I can say though that single-rail is generally not ideal in reversible computing systems. And yes, we require more clocks than classical CMOS. But our approach requires far fewer clocks than some logic families that have come in the past such as SCRL — 24 or more — or Bennett clocking — arbitrarily many."

The complexities of multiple signal rails and multiple clocks are some of the reasons adiabatic reversible computing has not been adopted in the mainstream; the theoretical benefits come with many overheads and trade-offs. In addition, there is the chicken-and-egg problem of a lack of foundry and EDA software support.

As long as Moore's Law was helping drive performance and to a lesser extent energy efficiency, there was insufficient incentive to jump to reversible computing, Rosini said. However, with the rising awareness of the sustainability challenges around artificial intelligence, Rosini reckons reversible computing's time has come. "AI is reaching the point where suddenly changing to a different paradigm is not only worthwhile, but it is becoming essential," he said.

*Reversible computing is fundamentally different to the "classical" computing that underlies nearly all the commercial computation deployed to date.*

Underlining the point, Earley said: "We are looking to be 4,000x more energy efficient than classical computing." Rosini added: "For 50 years we've had classical computing that was irreversible. I believe we are crossing a threshold to where everything will be reversible."

Earley added that quantum computing is one of the purest forms of reversible computing, and that reversible photonic computation may be adopted eventually for reasons of power efficiency.

## Alternative Gates

However, reversibility requires a 1-to-1 correlation between inputs and outputs, which therefore also requires different types of logic gates internally. For example, the operation of a two-input, one-output NAND gate is destructive of input information and so alternative gate structures and architectures have to be found.

"One-to-one equivalence is not a limitation although it does require consideration," said Earley. "We thought it might require a new instruction set architecture, different fundamental libraries," she added. "We have done a lot of work to develop and optimize our standard cell library and how these cells can be combined into different logical functions."

Rosini added: "But we can isolate any differences within the chip. So, from the outside, it looks like a conventional software target. We don't want to throw away the [software] infrastructure. It is still deterministic computing."

Vaire recently announced that it was intended to have a reversible computing chip out within 12 months (see Startup Vaire says first reversible computing chip due in a year).

Earley confirmed the company's first tape out is being designed for a 22 nm manufacturing process, but declined to name the foundry or the manufacturing process Vaire is targeting. The key choice here would be between planar, FinFET or fully depleted silicon-on-insulator processes. Earley said that Vaire's adiabatic reversible logic is essentially process-agnostic. "We've conducted CAD simulations at many levels of abstraction," said Earley. "What we need to do is validate we can recycle charge at the levels we expect."

This first tape-out is planned to be one of a series of test chips that will progress from gates and simple functions such as adders including resonant structures, up to functional blocks, and culminating in a software-programmable circuit.

## Resonant Structures?

So, what are those resonant structures? Passive LCR circuits would probably be the easiest to integrate, but do they provide the performance and control required? Would active, transistor-based circuitry perform better — but at what cost? And what about MEMS?

Earley declined to provide details. "We are investigating many resonator options, as they each have trade-offs that make sense for different product segments. The difficulty with MEMS is that the development process is a lot less standardized and requires deeper manufacturing expertise than mixed-signal CMOS, and so timelines for prototyping MEMS-based resonators are longer."

Vaire is also looking at the higher levels of the hardware-software stack. Rosini said work on the compilation is underway and that Andrew Sloss, vice president of technology at Vaire Computing, had previously been responsible for a reversible computing research program at processor licensor Arm Ltd. (see Arm engineering veteran joins 'reversible computing' startup). Vaire has also recruited Mike Frank, a prominent researcher in the field of reversible computing at Sandia National Laboratories, as a senior scientist.

Rosini is very clear that he wants to create a fabless chip company with a processing product offering under its own brand. The alternative way forward – of creating functional IP and licensing that to chip companies – does not capture enough of the value created Rosini said. "We've already had companies asking about licensing and politely declined," he added.

But the product business model will require considerably more funding for the company to progress up through the generations of test-chips. Rosini said that he expects Vaire to have a product in the market in 2027.

But can Vaire achieve superiority in terms of performance, energy efficiency and cost, given the additional circuitry, more complex gates and resonant structures required? This is the so-called PPA – performance, power, area – trade off.

## Volumetric Computing

Earley said that chasing advantage in a single planar circuit is not what Vaire's architecture is going to be about. "The performance benefits really come when we pursue multi-layered, volumetric computing," she said. That's because Vaire's energy efficiency will allow circuits to be stacked densely, whereas classical processing circuits cannot do the same, due to thermal considerations.

Earley said that for simple serial computation, especially with strong data dependencies, reversible computing is likely to show little or no benefit over classical computing. "Whilst it IS general purpose, adiabatic reversible logic is far better suited to highly parallel operations," she said.

And that describes the AI sector, where energy consumption is becoming a serious challenge. AI is also a sector where Rosini has already done business. "We want to enter with a generic NPU [neural processing unit] chip for the edge," he said.

Fortunately, Vaire does not necessarily have to create an entire processing system. The easiest point of introduction for adiabatic reversible logic could be within a hybrid architecture.

Earley said: "Our most recently filed patent is, in fact, on exactly this – hybrid irreversible-reversible systems. There are diminishing returns to reversibilizing everything — though these returns do improve as one gets better on the energy recovery side. This is a large part of our roadmap, starting with a chip where the largest energy sinks have been converted to use reversible logic, and then increasing reversible functionality and complexity over time as it makes sense."

> *Vaire does not necessarily have to create an entire processing system.*

Questions remain regarding the introduction of adiabatic reversible computing. Will it have its own ISA or be spliced to an Arm or RISC-V processor in a hybrid implementation? How are active memories implemented and how are they interfaced to non-volatile memory? And much will hinge on the benchmarking of those first prototype chips.

Radical technology change is difficult to achieve in the chip industry but the increasing use and power consumption of AI applications in the datacenter and the need to be frugal with power to perform AI at the edge could make adiabatic reversible computing something that eventually resonates with customers.

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**Editor's Note**
*eeNews Europe* first published this article on July 12, 2024. Visit *www.eenewseurope.com* for more news and interviews.

**WEB LINKS**

[1] P. Clarke, "Startup Vaire says first reversible computing chip due in a year," eeNews Europe, July 2, 2024: https://www.eenewseurope.com/en/startup-vaire-says-first-reversible-computing-chip-due-in-a-year/
[2] Vaire Computing: https://vaire.co/