Rapid Embedded Systems Prototyping Redefined: TARS Plug and Play Electronics for Industry, Scientific, and Education

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Abstract: This article marks the inception of the TARS Electronic board series, addressing the challenges inherent in Internet of Things (IoT) and embedded systems development. Traditional approaches often consume significant human-hours in addressing issues like breadboard errors, coding, and soldering during prototype realization. TARS plug-and-play electronic modules emerge as a transformative solution, minimizing time and effort while offering an ideal platform for micro and small-scale enterprises, students, and researchers. Featuring the capability to integrate over fifty sensors and various electronic components, including HDMI, Bluetooth, ZigBee, and IEEE 802.11 Wi-Fi, this board transforms into a cluster of IoT systems, streamlining development processes and fostering innovation. Additionally, it serves as an excellent platform for skill development of the electronics engineering workforce, enhancing proficiency and expertise in emerging technologies.

Keywords: IoT; WIFI; ZigBee; Embedded Systems; Bluetooth, HDMI, Electronics

Introduction & Background

There are numerous research articles that have dedicated a significant part of their research to resolving issues arising in breadboards also known as “the bug”. The article by Drew et al 2016, have noted that troubleshooting circuits continues to pose a challenging and time-intensive endeavor [1]. Therefore, they developed a “toastboard” to locate the faults and troubleshoot the issues on a web interface. Likewise, it was observed by Karchemsky et al in 2019 that students spend a lot of time locating and fixing the bugs on their circuits, they may not always have expert teachers and instructors to inspect their electronic circuits while prototyping them. To address this issue, they developed a testbench “Heimdall” to remotely visualize and inspect the circuits built by the students and no-voices [2,3]. Booth et al., in 2016 conducted an empirical study observed end-user developers connecting a temperature sensor to an Arduino. Most fatal faults stemmed from incorrect circuit construction. Limited support exists for physical computing tasks, urging the development of appropriate tools [4]. A study by DesPortes et al in 2019, analyzed 31 novices' experiences with Arduinos, revealing common breakdowns and tool impacts [5].

The Psychological Impact of Time Loss on Learning Efficiency

Ample research exists on the psychological impact of time loss and failure to achieve learning goals. Studies have shown that experiencing failure in one area can negatively affect performance in a different area that is unrelated to the initial failure. This effect occurs because the failure challenges one's self-perception or self-concept, impacting subsequent tasks even if they are unrelated to the initial failure [5]. At the same time the study also showed that intermittent validation of their desired self-image helped mitigate the negative impact of failing to define themselves as they wished [6].

Table 1. Psychological effects on time, progress and outcomes on learning

Study	Negative effects	Correctional measures and outcomes
[6]	The failure challenges one's self-perception or self-concept, impacting subsequent tasks even if they are unrelated to the initial failure	That intermittent validation of their desired self-image helped mitigate the negative impact of failing to define themselves as they wished.
[7]	Performance goals, where individuals strive for positive evaluations of their skills or to evade negative assessments, were anticipated to foster **avoidance of challenges** and *the development of learned helplessness* when perceived ability was low.	The study examined a framework proposing goals as key factors in shaping achievement patterns. It anticipated that learning goals, focusing on enhancing competence, **would encourage seeking challenges** and adopting **a mastery-oriented approach towards failure**, independent of perceived ability.
[8]	The study examines various psychological phenomena, including computer anxiety, which exhibits a negative correlation with computer confidence and a moderate positive correlation with mathematics anxiety. Males demonstrate higher trait anxiety than females. Those with limited prior experience with mechanical devices tend to harbor negative attitudes toward computers. Technostress pervades contemporary society. For many, "success" is equated with possessing high levels of technological competence, a notion that psychology views differently.	Amidst the pervasive influence of advanced technology in our surroundings, the imperative lies in crafting educational systems that are both user-friendly and efficient, while also instilling a positive self-image in all individuals who interact with them.

Table 2. Learning Barriers in Electronics

Study	Barriers	Solutions
[9]	Sample size of 1677 students. At the beginning of the course, certain students were found to be at a disadvantage because they had little practical experience and were not familiar with the technical terms used in electronics.	Adopted new techniques and tools to teach electronics significantly improved the learning outcomes.
[10]	The study identified several concerning aspects: Elevated failure rates in introductory-level linear circuit analysis courses, averaging 23% and	Targeted learning techniques were adopted to teach all concepts instead of focusing on teaching how to learn clever problems.

	varying significantly among instructors and sections. Student challenges stemming from insufficient mathematical skills, limited active learning strategies, and varying motivation levels, particularly among non-major students. A gap in systematically teaching students all essential principles for solving circuit problems and addressing qualitative misconceptions. Pre-test scores indicating a baseline conceptual understanding of basic DC electricity concepts around 49%. Limited improvement in post-test scores, typically reaching only 57% across multiple instructors, suggesting conventional instruction inadequately tackles qualitative misunderstandings. Persistent misconceptions among students, like the belief that batteries function as current sources, highlighting the need for targeted instruction to rectify these misconceptions.	Statistically significant effects on student performance, with post-test scores reaching as high as 77%, demonstrating the impact of innovative teaching approaches on learning outcomes.
[11]	The research examined how two types of electrical circuit representations influenced elementary and high school students' perceptions and learning in outreach programs. Concrete representations, using familiar circuit elements, resulted in better understanding and lower cognitive load for elementary students, with no notable difference in learning outcomes. For high school students, representation types showed no significant distinctions in perceptions or learning outcomes. However, male high school students showed greater interest, understanding, and lower cognitive load compared to females, despite similar learning outcomes. Elementary students reported enjoying the activity more but experienced higher cognitive load compared to high school students.	The study used electronic kits to teach students and found that student engagement and enjoyment of learning was high.
[12]	Deployed open-source embedded systems laboratory kits to teach students. The development and creation of an educationally focused MCU kit were undertaken with the objective of crafting a versatile training board capable of accommodating a variety of experiments across different subjects. This endeavor led to the integration of a diverse array of peripherals. Additionally, the kit was complemented by student-centered lab manuals,	The quantitative findings demonstrate statistically significant evidence that utilizing a virtual embedded systems lab for preparation leads to superior learning outcomes.

	training exercises, video resources, and virtual MCU experiments.	

Tables 1 and 2 unequivocally demonstrate the essential need to embrace new techniques and tools for effectively instructing students, electronics enthusiasts, and innovators through an object-oriented learning approach. This is where we introduce the TARS Electronic modules.

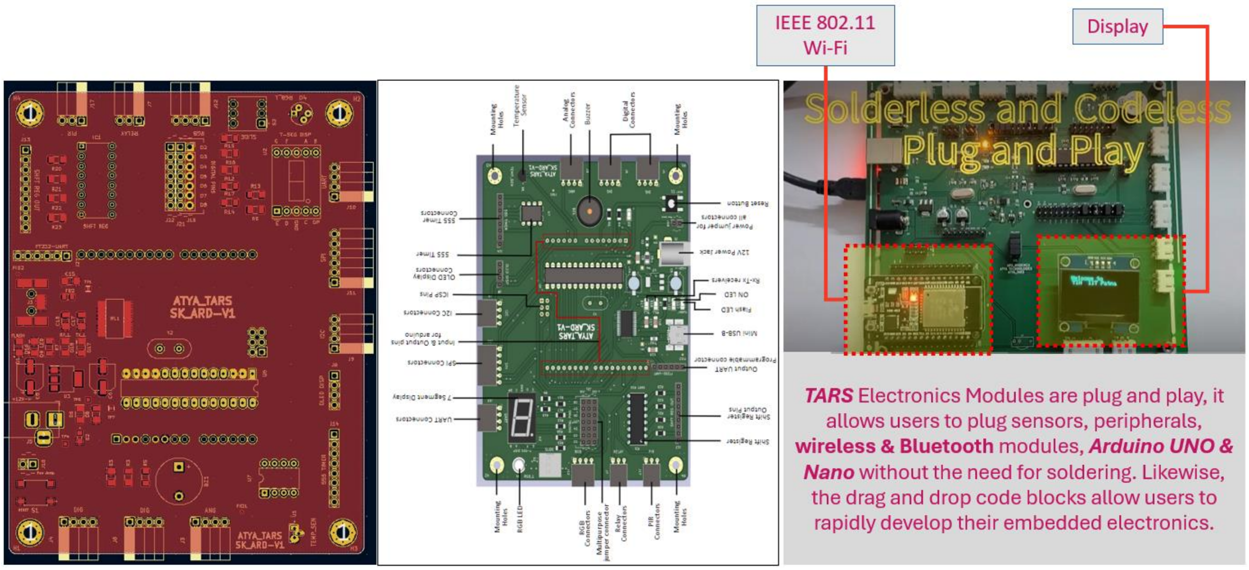

Figure 1. TARS Electronics Modules.

TARS Electronic Modules

Figure 1 shows the TARS electronics module. This kit is designed as an ideal starting point for newcomers, featuring an Arduino-compatible board and an array of additional sensors seamlessly integrated into one PCB design. All modules are connected directly to the Starter Kit through PCB stamp holes. Additionally, the kit offers dedicated Wi-Fi integration capability. However, if preferred, modules can be detached and used with cables for more flexibility. With this Starter Kit, users can explore a variety of projects, from basic to advanced, guided through the fundamentals of using the Starter Kit with the Arduino IDE.

Example Circuit: Speech recognition

The speech recognition software is designed for voice-controlled applications like robots, smart toys, and smart homes. A Nuvoton ISD9160 chip, a microphone, an SPI flash, a connector, a speaker connector, and an LED that may reflect voice instructions are included. It can identify and recognize up to 22 different commands, including "play music," "stop," and "start." It can also detect and return a value, which makes it possible to operate other electronics, such as motors or music players.

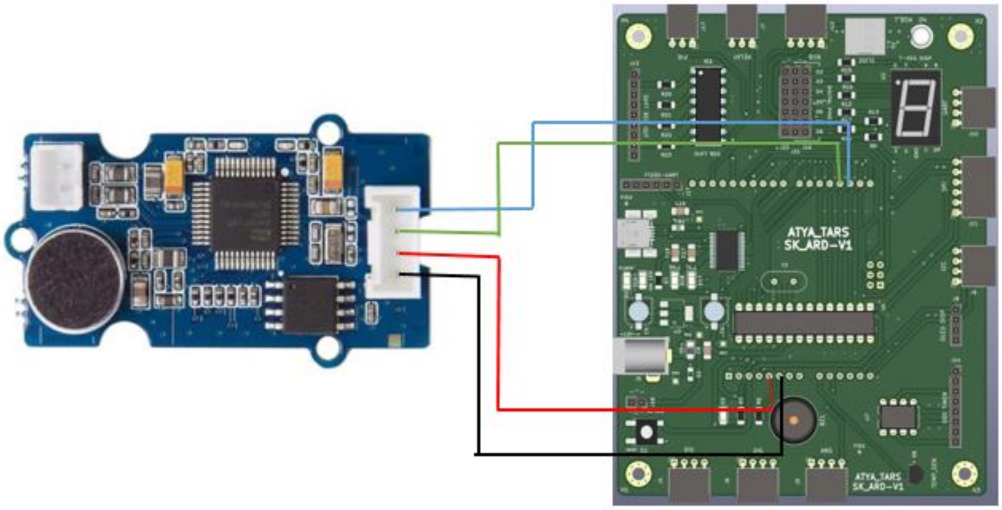

Figure 2. Speech Recognition uses the Nuvoton ISD9160 chip

Example Circuit: Flame Sensor

The flame sensor module has only the necessary parts, including an LM393 comparator IC, an IR photodiode, and complementing passive elements. While the module is powered on, the D0 LED deactivates when it detects a flame, and the power LED lights to indicate operational functionality. The integrated trimmer resistor allows users to fine-tune the sensitivity, providing versatility in the flame detection capabilities.

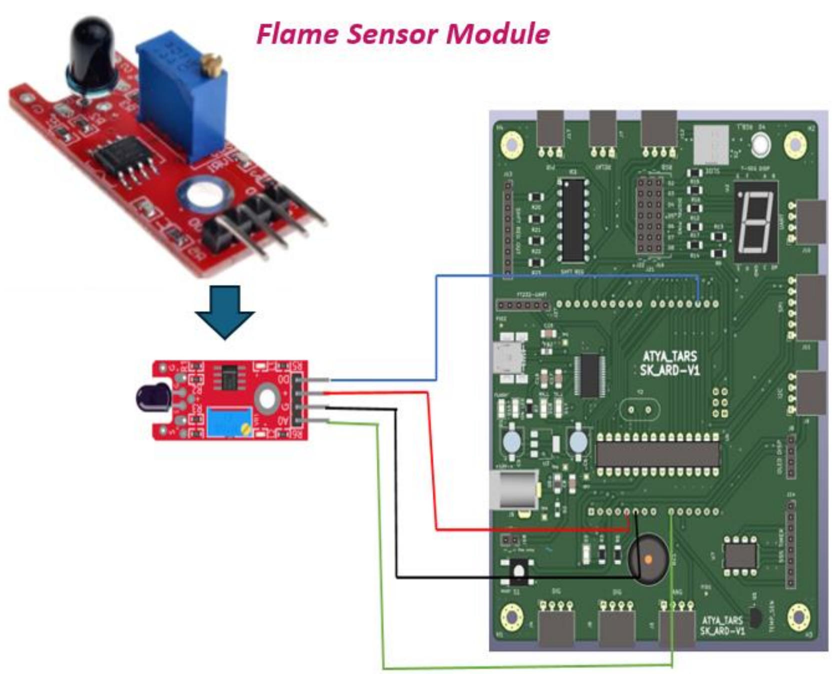

Figure 3. Flame Sensing Circuit

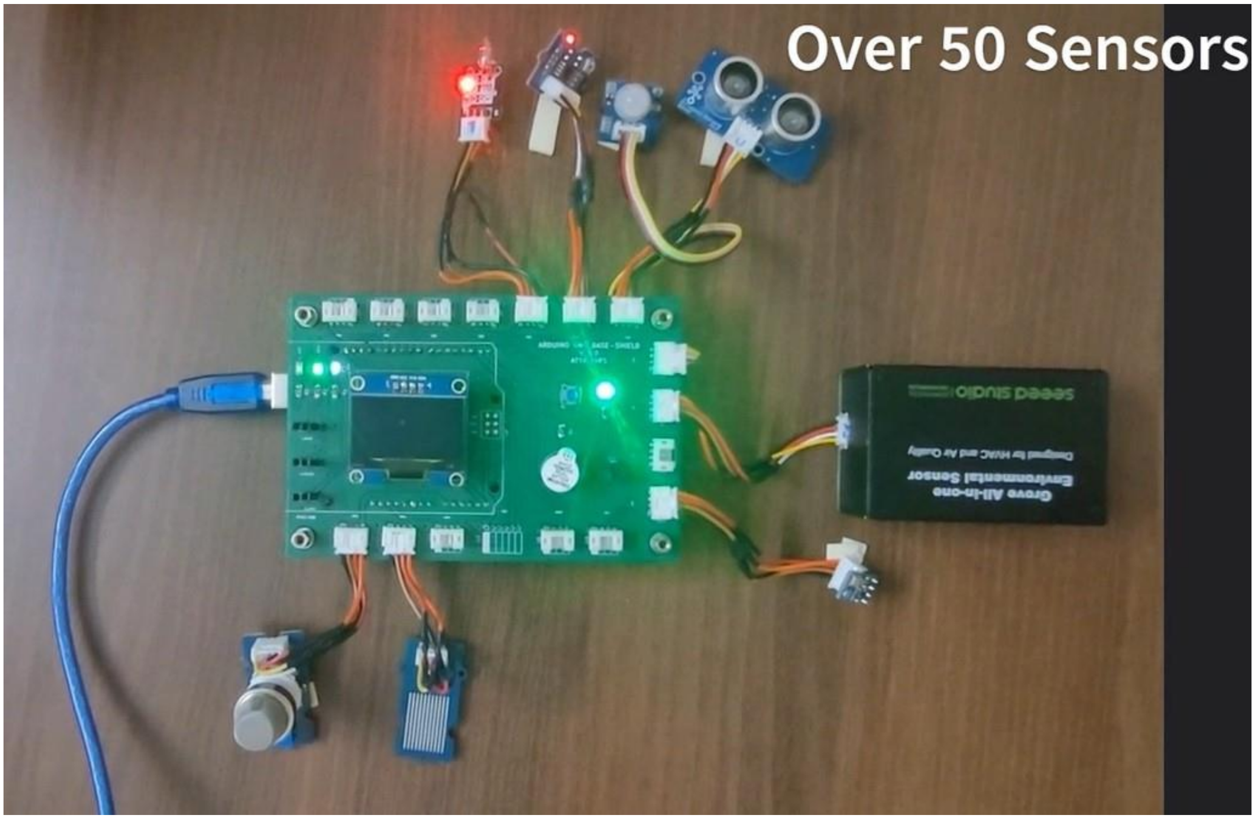

Figure 4. Integrates 50 plus sensors.

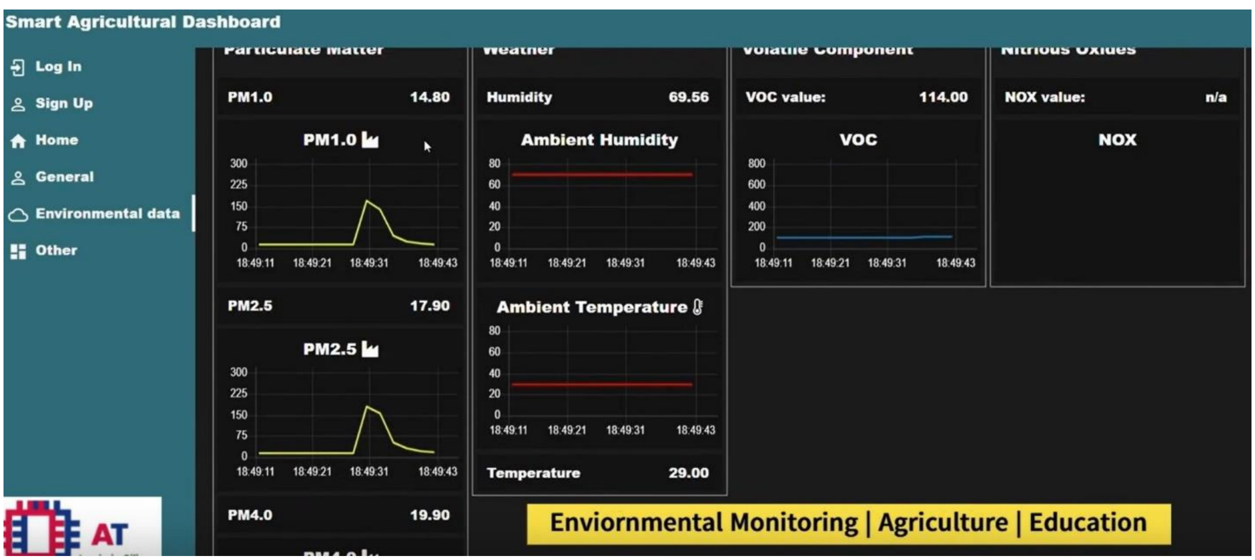

Figure 5. Dashboard for Environmental, Agriculture and Education.

Fostering Entrepreneurship

The TARS electronics plug and play kits are catalyzing innovation and spurring entrepreneurship by providing a versatile platform for integrating circuits into various applications. Entrepreneurs are harnessing these kits to develop solutions for monitoring farmlands, enhancing pharmaceutical facilities, and implementing advanced technologies such as drones and AI-enabled camera modules for surveillance.

In the agricultural sector, entrepreneurs are leveraging TARS kits to create monitoring systems that offer real-time data on soil conditions, weather patterns, and crop health. By integrating sensors and communication modules, farmers can optimize irrigation schedules, minimize resource wastage, and maximize crop yields (figures 4 & 5).

In pharmaceutical facilities, TARS kits are being utilized to develop monitoring systems that ensure compliance with regulatory standards, maintain optimal conditions for drug storage, and track the production process. These systems enhance efficiency, quality control, and regulatory compliance within the pharmaceutical industry.

Furthermore, entrepreneurs are exploring the potential of TARS kits in the field of aerial surveillance. By integrating circuits into drones and AI-enabled camera modules, they are developing sophisticated surveillance systems capable of monitoring large areas, detecting anomalies, and providing real-time insights for security and safety purposes.

Overall, TARS electronics plug and play kits are empowering entrepreneurs to innovate and create solutions that address a wide range of challenges across various industries. Through the integration of circuits into diverse applications, these kits are driving technological advancements and fostering entrepreneurship in fields such as agriculture, pharmaceuticals, and surveillance.

Conclusions

In conclusion, the TARS electronics plug and play kits are revolutionizing the landscape of innovation and entrepreneurship. By providing a versatile platform for integrating circuits into various applications, these kits are empowering students, hobbyists, Engineers, and entrepreneurs to develop solutions that address critical challenges across different industries.

In agriculture, TARS kits are enabling the creation of monitoring systems that offer real-time data on soil conditions, weather patterns, and crop health. This allows farmers to optimize irrigation schedules, minimize resource wastage, and maximize crop yields.

In pharmaceutical facilities, TARS kits are being used to develop monitoring systems that ensure compliance with regulatory standards, maintain optimal conditions for drug storage, and track the production process. These systems enhance efficiency, quality control, and regulatory compliance within the pharmaceutical industry.

Moreover, entrepreneurs are leveraging TARS kits to develop sophisticated surveillance systems for aerial monitoring. By integrating circuits into drones and AI-enabled camera modules, they can monitor large areas, detect anomalies, and provide real-time insights for security and safety purposes.

Overall, TARS electronics plug and play kits are driving technological advancements and fostering entrepreneurship across various sectors. Through the integration of circuits into diverse applications, these kits are fueling innovation and paving the way for transformative solutions in fields such as agriculture, pharmaceuticals, and surveillance.

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