IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

Scientific Instrumentation Techniques using Open-Source Hardware Platforms like Arduino and Raspberry-Pi: A Review

Thirumalesh[*1], Ashok A S[1], Sujatha V[1], Kavya S R[1], Mahesh Kumar K L[1], Govindaraju K G[1]
R L Jalappa Institute of Technology, Doddaballapur, Bangalore, India[1]
Corresponding author:thirumalesh@rljit.in[1]

Abstract: *The field of scientific instrumentation is constantly evolving due to technological advancements, leading to the development of more sophisticated instruments capable of achieving highly accurate measurements. However, despite these advancements, there are situations where researchers require simple specific intelligent setups that may not be easily accessible by the existing high end instruments due to cost constraints or limited project budgets. In such cases, open-source hardware platforms like Arduino and Raspberry Pi present an attractive solution. These compact and versatile boards offer the capability to perform accurate measurements and carry out tasks that would otherwise require expensive specialized instruments. The open-source nature of Arduino and Raspberry Pi fosters collaboration and innovation within the scientific community. Researchers can tailor and customize the hardware and software to suit their specific experimental needs, enabling the development of low-cost yet effective scientific instruments. This review article aims to explore the potential applications of Arduino and Raspberry Pi in scientific instrumentation. It will discuss various ways in which these open-source platforms can be utilized to address research challenges, and it will showcase prominent works that have leveraged Arduino and Raspberry Pi to achieve significant scientific advancements. By presenting practical examples and use cases, this review seeks to inspire researchers to harness the capabilities of open-source hardware platforms to enhance scientific experimentation, especially in projects with limited financial resources. Ultimately, embracing these versatile boards can foster a more inclusive and accessible approach to scientific research, benefiting the scientific community as a whole*

Keywords: Scientific instrumentation, Arduino, Raspberry Pi, Open-source instrumentation

REFERENCES

[1]. Daniel K, Fisher, and Gould Peter J. "Open-source hardware is a low-cost alternative for scientific instrumentation and research." *Modern instrumentation* 2012 (2012).
[2]. El Hammoumi, Aboubakr, Saad Motahhir, Abdelilah Chalh, Abdelaziz El Ghzizal, and Aziz Derouich. "Low-cost virtual instrumentation of PV panel characteristics using Excel and Arduino in comparison with traditional instrumentation." *Renewables: wind, water, and solar* 5, no. 1 (2018): 1-16.
[3]. Pearce, Joshua M. "Building research equipment with free, open-source hardware." *Science* 337, no. 6100 (2012): 1303-1304.
[4]. Arduino: https://www.arduino.cc/
[5]. Raspberry Pi:https://www.raspberrypi.com/
[6]. Zlatanov, Nikola. "Arduino and open source computer hardware and software." *J. Water, Sanit. Hyg. Dev* 10, no. 11 (2016): 1-8.
[7]. Koenka, Israel Joel, Jorge Sáiz, and Peter C. Hauser. "Instrumentino: an open-source software for scientific instruments." *Chimia* 69, no. 4 (2015): 172-172.
[8]. Thirumalesh K, Raju SP, Somashekarappa HM, Swaroop K. Shock tube data processing tools using open source hardware and software platforms. *Engineering Reports*. 2020;e12353, https://doi.org/10.1002/eng2.12353

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

[9]. Deshmukh, Akshay D., and Ulhas B. Shinde. "A low cost environment monitoring system using raspberry Pi and arduino with Zigbee." In *2016 International Conference on Inventive Computation Technologies (ICICT)*, vol. 3, pp. 1-6. IEEE, 2016.

[10]. Benítez, Alfredo, Ulises Santiago, John E. Sanchez, and Arturo Ponce. "Design of a cathodoluminescence image generator using a Raspberry Pi coupled to a scanning electron microscope." *Review of Scientific Instruments* 89, no. 1 (2018).

[11]. Vujović, Vladimir, and Mirjana Maksimović. "Raspberry Pi as a Sensor Web node for home automation." *Computers & Electrical Engineering* 44 (2015): 153-171.

[12]. Othman, Nor Azlan, Muhammad Riduan Zainodin, Norhasnelly Anuar, and Nor Salwa Damanhuri. "Remote monitoring system development via Raspberry-Pi for small scale standalone PV plant." In *2017 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, pp. 360-365. IEEE, 2017.

[13]. Arduino Community forum: https://forum.arduino.cc/

[14]. ATmega326P: https://www.microchip.com/en-us/product/atmega328p

[15]. ATmega2560: https://www.microchip.com/en-us/product/atmega2560

[16]. SAMD21:https://ww1.microchip.com/downloads/en/DeviceDoc/SAM_D21_DA1_Family_DataSheet_DS40001882F.pdf

[17]. u-blox® NORA-W106 (ESP32-S3): https://www.u-blox.com/en/product/nora-w10-series

[18]. STM32H747XI: https://www.st.com/en/microcontrollers-microprocessors/stm32h747xi

[19]. Arduino Uno:https://docs.arduino.cc/hardware/uno-rev3

[20]. Arduino Nano:https://docs.arduino.cc/hardware/nano

[21]. Arduino Nano ESP32: https://store-usa.arduino.cc/collections/boards/products/nano-esp32

[22]. Arduino Mega:https://docs.arduino.cc/hardware/mega-2560

[23]. Arduino GIGA R1 WiFi : https://store-usa.arduino.cc/collections/boards/products/giga-r1-wifi

[24]. Raspberry Pi foundation:https://www.raspberrypi.org/

[25]. Richardson, Matt, and Shawn Wallace. *Getting started with raspberry PI.* " O'Reilly Media, Inc.", 2012.

[26]. Raspberry Pi Models: https://www.raspberrypi.com/products/

[27]. Raspberry Pi specifications: https://www.raspberrypi.com/products/raspberry-pi-4-model-b/

[28]. Raspberry Pi OS: https://www.raspberrypi.com/software/

[29]. Wickert, Andrew D., Chad T. Sandell, Bobby Schulz, and Gene-Hua Crystal Ng. "Open-source Arduino-compatible data loggers designed for field research." *Hydrology and Earth System Sciences* 23, no. 4 (2019): 2065-2076.

[30]. Asua, E., V. Etxebarria, J. Feutchwanger, and dan J. Portilla. "High-precision displacement sensor based on resonant cavities through an electronic interface based on Arduino." *Sensors and Actuators A: Physical* 295 (2019): 296-301.

[31]. Sreeshma, D., and K. S. R. Koteswara Rao. "Single thermal scan digital system for deep level transient spectroscopy." *Review of Scientific Instruments* 94, no. 6 (2023).

[32]. Vajpayee, Shivam, Baban Kumar, Ritula Thakur, and Manish Kumar. "Design and development of nano pH sensor and interfacing with arduino." *Int. J. Electron. Electr. Comput. Syst. IJEECS* 8, no. 6 (2017): 66-75.

[33]. Pérez, Israel, José Ángel Hernández Cuevas, and José Trinidad Elizalde Galindo. "Design and construction of a desktop AC susceptometer using an Arduino and a Bluetooth for serial interface." *European Journal of Physics* 39, no. 3 (2018): 035203.

[34]. Iribarren Anacona, Pablo, Jean Paul Luján, Guillermo Azócar, Bruno Mazzorana, Katy Medina, Gonzalo Durán, Ivan Rojas, and Edwin Loarte. "Arduino data loggers: A helping hand in physical geography." *The Geographical Journal* 189, no. 2 (2023): 314-328.

[35]. Mack, A. H., M. K. Trias, and S. G. J. Mochrie. "Precision optical trapping via a programmable direct-digital-synthesis-based controller for acousto-optic deflectors." *Review of Scientific Instruments* 80, no. 1 (2009): 016101.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

[36]. Grinias, James P., Jason T. Whitfield, Erik D. Guetschow, and Robert T. Kennedy. "An inexpensive, open-source USB Arduino data acquisition device for chemical instrumentation." (2016): 1316-1319.

[37]. Patel, Manish, Ahmad Sakaamini, Matthew Harvey, and Andrew James Murray. "An experimental control system for electron spectrometers using Arduino and LabVIEW interfaces." *Review of Scientific Instruments* 91, no. 10 (2020).

[38]. Ta Duc, Tuan, Tuan Le Anh, and Huong Vu Dinh. "Estimating modal parameters of structures using Arduino platform." In *Proceedings of the International Conference on Advances in Computational Mechanics 2017: ACOME 2017, 2 to 4 August 2017, Phu Quoc Island, Vietnam*, pp. 1095-1104. Springer Singapore, 2018.

[39]. Mucciaroni, Luis Ricardo, and Marcelo Gonçalves Vivas. "Efficient yet accessible arduino-based control system for laser microfabrication of photonic platforms." *Lasers in Manufacturing and Materials Processing* 8 (2021): 395-408.

[40]. Young, Haley, and Molly T. Soper-Hopper. "Arduino-based instrumentation to monitor greenhouse environmental conditions in metabolomic studies." (2019).

[41]. Rodriguez-Vasquez, Kelly A., Aaron M. Cole, Desislava Yordanova, Rachel Smith, and Nathanael M. Kidwell. "AIRduino: On-demand atmospheric secondary organic aerosol measurements with a mobile arduino multisensor." (2020): 838-844.

[42]. Agudo, Juan Enrique, Pedro J. Pardo, Héctor Sánchez, Ángel Luis Pérez, and María Isabel Suero. "A low-cost real color picker based on arduino." *Sensors* 14, no. 7 (2014): 11943-11956.

[43]. Lockridge, Grant, Brian Dzwonkowski, Reid Nelson, and Sean Powers. "Development of a low-cost arduino-based sonde for coastal applications." *Sensors* 16, no. 4 (2016): 528.

[44]. Ashwindran, S. N., A. A. Azizuddin, and A. N. Oumer. "A Low-Cost Digital Torquemeter Coordinated by Arduino Board." *International Journal of Integrated Engineering* 15, no. 1 (2023): 118-130.

[45]. Kriz, Daniel H., and Lars-Olof Hansson. "Development of a Low-Cost Arduino Based Laser Nephelometric Instrumentation for High Sensitivity determination of the Inflammatory Marker C-Reactive Protein (CRP)." *International Journal of Engineering Research and Science* 4, no. 6.

[46]. Hnatiuk, Michael, Dave Kimball, Elayaraja Kolanthai, Craig J. Neal, Udit Kumar, Tamil Selvan Sakthivel, and Sudipta Seal. "High-throughput and versatile design for multi-layer coating deposition using lab automation through Arduino-controlled devices." *Review of Scientific Instruments* 92, no. 8 (2021).

[47]. Galadima, Ahmad Adamu. "Arduino as a learning tool." In *2014 11th International Conference on Electronics, Computer and Computation (ICECCO)*, pp. 1-4. IEEE, 2014.

[48]. Kuan, Wen-Hsuan, Chi-Hung Tseng, Sufen Chen, and Ching-Chang Wong. "Development of a computer-assisted instrumentation curriculum for physics students: using LabVIEW and Arduino platform." *Journal of Science Education and Technology* 25 (2016): 427-438.

[49]. Hadiati, Soka, Heru Kuswanto, Dadan Rosana, and Adi Pramuda. "The effect of laboratory work style and reasoning with Arduino to improve scientific attitude." *International Journal of Instruction* 12, no. 2 (2019): 321-336.

[50]. Gutiérrez, Samuel T., César I. Fuentes, and Marcos A. Díaz. "Introducing sost: An ultra-low-cost star tracker concept based on a raspberry pi and open-source astronomy software." *IEEE Access* 8 (2020): 166320-166334.

[51]. Chandra P, Bharat, Mayuresh Sarpotdar, Binukumar G. Nair, Richa Rai, Rekhesh Mohan, Joice Mathew, Margarita Safonova, and Jayant Murthy. "Low-cost Raspberry Pi star sensor for small satellites." *Journal of Astronomical Telescopes, Instruments, and Systems* 8, no. 3 (2022): 036002-036002.

[52]. Watanabe, Wataru, Ryoji Maruyama, Hidenobu Arimoto, and Yosuke Tamada. "Low-cost multi-modal microscope using Raspberry Pi." *Optik* 212 (2020): 164713.

[53]. Aidukas, Tomas, Regina Eckert, Andrew R. Harvey, Laura Waller, and Pavan C. Konda. "Low-cost, sub-micron resolution, wide-field computational microscopy using opensource hardware." *Scientific reports* 9, no. 1 (2019): 7457.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

[54]. Ashari, Ahmad, and Mardhani Riasetiawan. "High performance computing on cluster and multicore architecture." *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 13, no. 4 (2015): 1408-1413.

[55]. Pfalzgraf, Aaron M., and Joseph A. Driscoll. "A low-cost computer cluster for high-performance computing education." In *IEEE International Conference on Electro/Information Technology*, pp. 362-366. IEEE, 2014.

[56]. Sharma, Davinder Pal, Keide Samuel, Kris Ramoutar, Takim Lowe, and Isaiah David. "Raspberry Pi Based Real Time Data Acquisition Node for Environmental Data Collection." *Journal of Basic and Applied Engineering Research* 4 (2017): 307-312.

[57]. Nikhila, J. "Web based Environmental Monitoring System using Raspberry Pi." In *2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC)*, pp. 1074-1080. IEEE, 2017.

[58]. Zimmers, Zackary A., Alexander D. Boyd, Hannah E. Stepp, Nicholas M. Adams, and Frederick R. Haselton. "Development of an automated, non-enzymatic nucleic acid amplification test." *Micromachines* 12, no. 10 (2021): 1204.

[59]. Pramudita, Brahmantya Aji, Muhammad Irfan Falih Mahdika, Ni Kadek Riyastika Pradnyandari Putri, Aris Hartaman, and Irham Mulkan Rodiana. "Monitoring And Controlling System Of Chili Aquaponics Cultivation Based On The Internet Of Things." In *2022 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob)*, pp. 1-6. IEEE, 2022.

[60]. Mehra, Manav, Sameer Saxena, Suresh Sankaranarayanan, Rijo Jackson Tom, and M. Veeramanikandan. "IoT based hydroponics system using Deep Neural Networks." *Computers and electronics in agriculture* 155 (2018): 473-486.

[61]. Özcebe, Ali Güney, Alexandru Tiganescu, Ekin Ozer, Caterina Negulescu, Juan Jose Galiana-Merino, Enrico Tubaldi, Dragos Toma-Danila et al. "Raspberry Shake-based rapid structural identification of existing buildings subject to earthquake ground motion: the case study of Bucharest." *Sensors* 22, no. 13 (2022): 4787.

[62]. Suparno, Supriyanto, Hamdan Akbar Notonegoro, Britantyo Wicaksono, and Abdurrahman Azzam Akbar. "Raspberry-Pi Zero-Based Reflection Seismic Logger Design with Network Time Protocol Synchronization." *FLYWHEEL: Jurnal Teknik Mesin Untirta* (2022): 37-42.

[63]. Benhadhria, Saifeddine, Mohamed Mansouri, Ameni Benkhlifa, Imed Gharbi, and Nadhem Jlili. "Vagadrone: Intelligent and fully automatic drone based on raspberry pi and android." *Applied Sciences* 11, no. 7 (2021): 3153.

[64]. Saha, Arnab Kumar, Subhronil Roy, Aranya Bhattacharya, Prabhat Shankar, Anindya Kumar Sarkar, Himadri Nath Saha, and Pratanu Dasgupta. "A low cost remote controlled underwater rover using raspberry Pi." In *2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)*, pp. 769-772. IEEE, 2018.

[65]. Subramaniyan, Dinesh Kumar. *A Mixed Aquatic and Aerial Multi-Robot System for Environmental Monitoring*. The University of Toledo, 2020.

[66]. Arshad, Jehangir, Rizwan Tariq, Saqib Saleem, Ateeq Ur Rehman, Hafiz Munir, Noorbakhsh Amiri Golilarz, and Aamir Saleem. "Intelligent greenhouse monitoring and control scheme: An arrangement of Sensors Raspberry Pi based Embedded System and IoT platform." *Indian Journal of Science and Technology* 13, no. 27 (2020): 2811-2822.

[67]. Shelvane, Saraswati, Madhuri Shedage, and Akshada Phadtare. "Greenhouse monitoring using Raspberry Pi." *International Research Journal of Engineering and Technology (IRJET)* 6, no. 04 (2019).

[68]. Zhu, Lin, Shuwei Yang, Huachuan Huang, Keding Yan, Zhilong Jiang, Xiaoliang He, Yan Kong, Cheng Liu, and Shouyu Wang. "Portable Raspberry Pi Based Spectrometer for Rapid On-Site Spectral Testing." *Available at SSRN 4187597*.

[69]. Sangjan, Worasit, Arron H. Carter, Michael O. Pumphrey, Vadim Jitkov, and Sindhuja Sankaran. "Development of a raspberry pi-based sensor system for automated in-field monitoring to support crop breeding programs." *Inventions* 6, no. 2 (2021): 42.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

[70]. Tovar, Jose C., J. Steen Hoyer, Andy Lin, Allison Tielking, Steven T. Callen, S. Elizabeth Castillo, Michael Miller et al. "Raspberry Pi–powered imaging for plant phenotyping." *Applications in Plant Sciences* 6, no. 3 (2018): e1031.

[71]. Ferdoush, Sheikh, and Xinrong Li. "Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications." *Procedia Computer Science* 34 (2014): 103-110.

[72]. Barik, Lalbihari. "IoT based temperature and humidity controlling using Arduino and Raspberry Pi." *International Journal of Advanced Computer Science and Applications* 10, no. 9 (2019).