

Utilizing Raspberry Pi Pico microcontroller board in teaching and training students

Ứng dụng bo mạch vi điều khiển Raspberry Pi Pico trong giảng dạy và đào tạo sinh viên

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Abstract: This research aims to study and utilize a new kind of microcontroller, Raspberry Pi Pico, to create applications related to electronic and automation control to teach students in the university. First, the structure and function of the Raspberry Pi RP2040 microcontroller chip and Raspberry Pi Pico board were introduced in general. Second, the author introduces how to connect Raspberry Pi Pico to a computer and how to control and program it. Then, real applications using Pi Pico were developed to demonstrate interesting things that can be created with Pi Pico including turning the light on and off automatically using ADC and photoresistor, displaying the real-time clock and temperature values on an LCD, showing text and images on a TFT screen, and controlling Pico W via the internet. Those real demonstrations show that Pi Pico is an easy and interesting kind of microcontroller for students and people to use, to make real applications. It is worth learning and applying this interesting microcontroller board in students' theses, projects, and future jobs.

Keywords: *Automation; IoT; microcontroller; IoT; automation; Raspberry Pi Pico*

Tóm tắt: Nghiên cứu này tìm hiểu và ứng dụng một loại vi điều khiển mới, Raspberry Pi Pico, để thiết kế, chế tạo các ứng dụng liên quan đến lĩnh vực điện tử và điều khiển tự động để giảng dạy sinh viên ở trường đại học. Trước tiên, cấu trúc và chức năng của chip vi điều khiển Raspberry Pi RP2040 và board Raspberry Pi Pico được giới thiệu tổng quát. Kế tiếp, tác giả trình bày cách thức kết nối bo mạch Raspberry Pi Pico với máy tính và cách thức để điều khiển và lập trình cho Pi Pico. Sau đó, các ứng dụng thực tế sử dụng Pi Pico được xây dựng để minh họa các công việc lý thú mà Pi Pico có thể thực hiện bao gồm điều khiển bật tắt đèn tự động sử dụng quang trở và bộ biến đổi tương tự - số sẵn có, đồng hồ hiển thị thời gian thực và nhiệt độ trên màn hình LCD, hiển thị hình ảnh, chữ viết trên màn hình TFT, và điều khiển Pi Pico W thông qua kết nối internet. Các ứng dụng minh họa này cho thấy Pi Pico là bo mạch vi điều khiển hấp dẫn và dễ dàng cho sinh viên và mọi người yêu thích sử dụng để ứng dụng thực tế trong công việc, cuộc sống. Pi pico phù hợp cho sinh viên sử dụng cho mục đích học tập và ứng dụng trong việc thực hiện khóa luận tốt nghiệp, đề án của sinh viên cũng như cho công việc nghề nghiệp trong tương lai.

Từ khóa: *điều khiển tự động; IoT; Raspberry Pi Pico; tự động hóa; vi điều khiển*

1. Introduction

Microcontroller boards have been widely used to create many interesting applications, bringing benefits to people's lives. During the training

program in the university, students majoring in electronics, mechatronics, and automatic control have studied microcontrollers through modules such as microcontrollers, embedded systems, and projects. Students can apply

microcontrollers during their learning process, making projects, graduation theses as well as solving automation problems in reality.

Raspberry Pi Ltd, an innovative company that manufactures interesting tiny computer board Raspberry Pi, recently designed and manufactured their first microcontroller chip, the RP2040 chip, and introduced the Raspberry Pi Pico microcontroller board [1], [2]. Besides Arduino microcontrollers which are used popularly, now the community of people who like automatic control and IoTs can learn and use the RP2040 microcontroller in their creative and attractive activities. To better understand as well as to introduce to students the practical application of Pi Pico in automatic control applications, IoT, the author studies the structure, functions, and applications of Pico, and designs several simple but practical applications with Pi Pico for students to get familiar with a new kind of microcontroller, Pico. This report introduces the RP2040 microcontroller chip, the characteristics, and features of the Raspberry Pi Pico board [1], the MicroPython programming language [3], [4], and practical experience of some specific applications of the Raspberry Pi Pico in automatic control and IoTs.

2. Raspberry Pi Pico board and its functions

2.1. RP2040 Microcontroller

RP2040 is a low-cost, high-performance microcontroller chip with a variety of digital communication protocols.

RP2040 is designed based on ARM's Cortex M0+ architecture with a dual-core processor, up to 133 MHz, 264 kB built-in SRAM memory arranged in 6 blocks, 30 general purpose input-output (GPIO), specialized hardware for common peripheral interfaces, programmable I/Os to support extended peripherals, 4 analog-to-digital converters (ADCs) 12-bit with a sampling rate of 500 kilosamples per second (ksp/s) (Figure 1). In addition, the RP2040 also has a built-in temperature sensor inside the chip and a real-time clock (RTC) [1], [2].

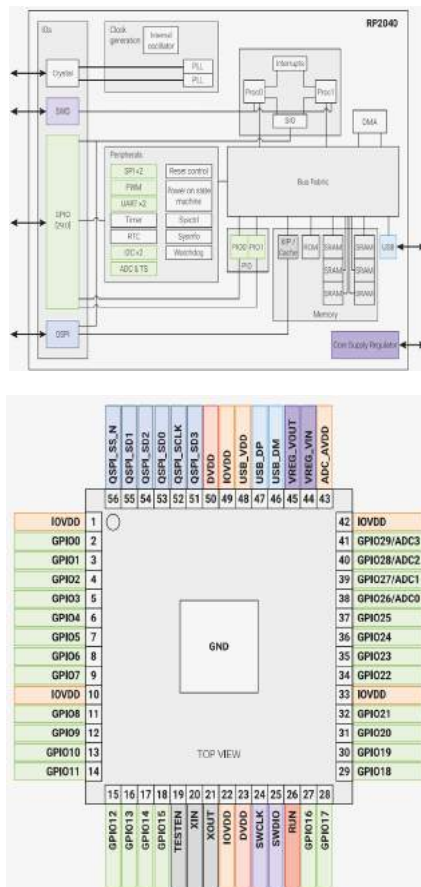


Figure 1. A system overview of the RP2040 microcontroller chip and its pinout diagram [1]

2.2. Raspberry Pi Pico and Pico W boards



Figure 2. Raspberry Pi Pico board with RP2040 chip

The Raspberry Pi Pico board, uses a RP2040 microcontroller, has a compact size of 21 x 51 mm, is designed with 40 GPIO pins, arranged in DIP format, including 2 rows of pins, each side has 20 pins [4]. The circuit board is equipped with a micro-USB type B port used for power supply and data transfer (flash memory programming) (Figure 2). Therefore, people can utilize this board to control many applications with different kinds of electronic components and kits.

The Raspberry Pi Pico W board adds Wi-Fi wireless networking capabilities compared to the Pico board. Raspberry Pi Pico W has 2 MB flash memory, uses an Infineon CYW43439 wireless connection chip operating on the 2.4 GHz band, Wi-Fi 4 standard (802.11n), and 20 MHz bandwidth to help connect devices to Wi-Fi internet network and data transmission. The 40 GPIO pins of the Pico W board are intentionally arranged the same as the Pico board, except that the 3 pins used for debugging purposes (SWD) are arranged in a different location [5]. Therefore, users can replace Pico W for their previous projects that used Pico

board without any changes in hardware design.

Since its introduction, Pico has attracted a lot of users and creators with various interesting applications. Users can easily refer to relevant information while using Pico as well as communicate and receive support from the community of users of this product. There are many interesting applications in automatic control and IoTs to take full advantage brought by this board.

2.3. Controlling Raspberry Pi Pico

To control Pico, users can write control programs in MicroPython or C/C++ programming language. MicroPython, a programming language that is friendly and easy to learn and use, was developed to program small, simple microcontrollers with little memory capacity [3], [4]. The MicroPython programming language is compatible with the Python language, including the functions of the Python language and adding new functions to take advantage of the components on the microcontroller. Thonny is an integrated development environment (IDE) commonly used to program with the MicroPython language [6]. The control program is loaded into Pico via the USB interface. GPIO input and output pins help Pico connect and control peripheral devices.

The most convenient way to load the program onto the Pico board for the first time is to connect the Pico to the computer as a storage drive. This method allows the user to drag and drop the firmware file to load the program into the Pico board memory. By

pressing and holding the 'BOOTSEL' button on the Pico board, connecting the Pico to the Raspberry Pi or computer via the USB port, and releasing the 'BOOTSEL' button, the computer will recognize the Pico as a storage drive. Download the .uf2 firmware file to your computer, and drag and drop the downloaded firmware onto Pico's drive to install. At this time, Pico will reboot, disconnect itself from the computer as a storage drive, and start running the newly loaded program [3], [4].

3. Designing Real Applications with Raspberry Pi Pico

The Raspberry Pi Pico circuit board is integrated with common communication standards such as I2C, SPI, UART, analog-digital signal converter ADC, temperature sensor, and real-time clock... Users can take advantage of the above features for practical applications.

3.1. Turning the light automatically using ADC and photoresistor

People can use Pico to turn lights on and off automatically based on the light intensity of the environment. To build this application, an integrated analog-digital converter (ADC) of Pico, provided in pins 31 and 32, will be used as a digital comparator circuit. These two input pins receive the environment light intensity sensed by a photoresistor and the signal value adjusted by the potentiometer (Figure 3). These two analog values are converted to digital values by the ADC and Pico is programmed to compare these two values. If the environment light intensity measured by the photoresistor is lower than the value set by the potentiometer, Pico automatically turns on the light and vice versa. The result shows that the design circuit can turn the light on and off automatically depending on how the user changes the value of the potentiometer and light intensity sensed by the photoresistor.

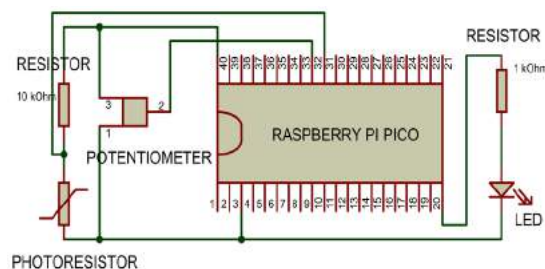


Figure 3. Schematic design and demonstration of turning the light on and off automatically using ADC and photoresistor application

3.2. Displaying the real-time clock and temperature values on a LCD

RP2040 chip is equipped with a temperature sensor on the chip and a real-time clock. The real-time clock is an advantage of Pico which is not equipped on other microcontroller chips. In this application, the board was designed to read the date time, and temperature values, then show those information on the LCD screen. This application uses an LCD screen with I2C communication that can display two lines of text, each line has 16 characters. Two GPIO pins number 4 and 5, which have an I2C communication function,

can be used to transmit data between Pico and LCD. Pico is first programmed to set the reference date and time for the chip, then read the temperature inside the RP2040 chip and the updated date and time in real-time, to display on the LCD screen. The result shows that the temperature value and the real-time date and time were continuously displayed on LCD one after another as designed (Figure 4). During one-week test, the designed board can show the date and time as precisely as a normal clock does. This demonstration promises that people can use Pi Pico to create a real clock to show date and time at their home.

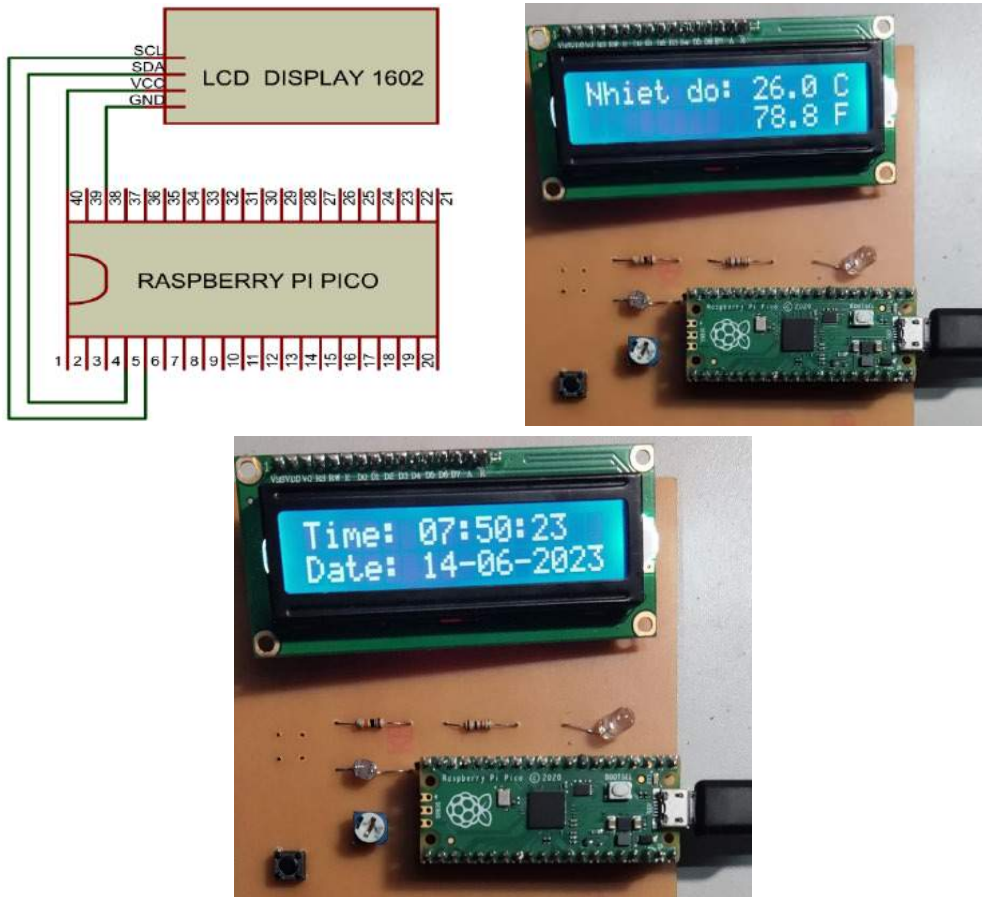


Figure 4. Schematic design and demonstration of reading the real-time clock and temperature values displayed on LCD

3.3. Showing text and images on a TFT screen

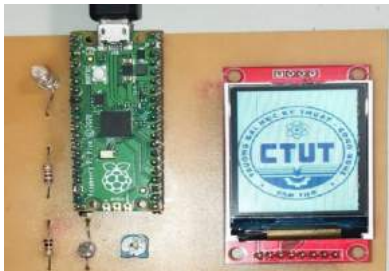
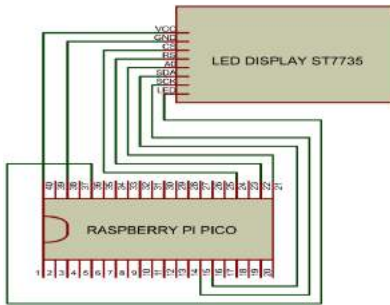


Figure 5. Schematic design and demonstration of displaying text and images on a TFT screen

Displaying images on a screen is an interesting project. With Pico, users can connect to a TFT screen to display text or images on it [7]. There are several libraries available on the internet people can refer to for this purpose. This application imports the CircuitPython libraries to display texts and images on the ST7735 TFT display board [8]. The Pico board is connected to the ST7735 display board via the serial peripheral interface (SPI) connection and is programmed to show several bitmap images on the TFT screen one after another (Figure 5). Through this application, users can create suitable applications such as displaying information in text form or

programming simple games with Pico and screen.

3.4. Controlling Pico W via the internet



Figure 6. Demonstration of using the Anvil to connect and control Pico via the internet

Thanks to the built-in Wi-Fi connection chip of the Pico W board, users can also easily control the Pico W via the internet through the Anvil platform at <https://anvil.works>. Using the Anvil platform, users can design control interfaces with available tools such as labels, buttons, sliders... Based on the designed interface, Anvil will help to generate a basic controlling program for users to connect and control Pico W automatically [9]. This application uses Pico W to connect the Anvil platform to turn on and off LED lights via the internet. Moreover, users can develop this app to control devices that use 220 V power sources for their smart home system.

Besides the Anvil platform, users can also use other platforms such as ThingSpeak (<https://thingspeak.com>) to use Pico W for their IoT applications.

4. Discussion and conclusion

Pico microcontroller board provide users with one more choice to create many innovative and useful applications with electronic components and devices. Raspberry Pi Pico with many built-in functions, communication capabilities, and a large community of users that can support users in getting acquainted with this new kind of microcontroller as well as create a variety of automatic control, and smart IoTs applications.

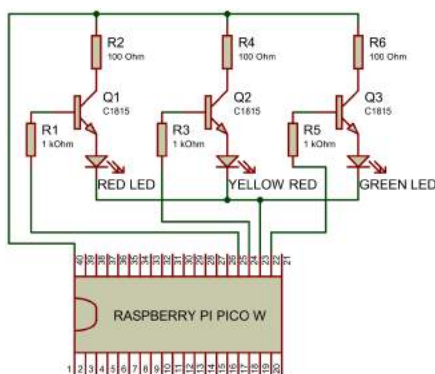


Figure 7. Schematic design and demonstration of controlling the lights via an internet connection with the Anvil platform

Education and training institutions can utilize Raspberry Pi Pico as an efficient tool in their teaching and learning activities for subjects related to microcontrollers. The demonstration projects in this study show that people

can use the Pi Pico board for many interesting applications in the real world. Students majoring in electrical, electronics, mechatronics, and automatic control can apply and take advantage of the RP2040 microcontroller chip and Raspberry Pi Pico board in the implementation of their projects, graduation thesis as well as in their jobs in the future.

The programming codes and libraries used in this study can be refer to at <https://tinyurl.com/vchxjpw7>.

References

- [1] Raspberry Pi Ltd., “RP2040 datasheet: A microcontroller by Raspberry Pi,” Raspberry Pi Ltd., 2023. [Online]. Available: <https://datasheets.raspberrypi.com/rp2040/rp2040-datasheet.pdf>. [Accessed: Sep. 26, 2023].
- [2] Raspberry Pi Ltd., “Hardware design with RP2040: Using RP2040 microcontrollers to build boards and products,” Raspberry Pi Ltd., 2023. [Online]. Available: <https://datasheets.raspberrypi.com/rp2040/hardware-design-with-rp2040.pdf>. [Accessed: Sep. 26, 2023].
- [3] Raspberry Pi Ltd., “Raspberry Pi Pico Python SDK: A MicroPython environment for RP2040 microcontrollers,” Raspberry Pi Ltd., 2023. [Online]. Available: <https://datasheets.raspberrypi.com/pico/raspberry-pi-pico-python-sdk.pdf>. [Accessed: Sep. 26, 2023].
- [4] G. Halfacree and B. Everard, Get started with MicroPython on Raspberry Pi Pico. Cambridge: Raspberry Pi Press, 2021.
- [5] Raspberry Pi Magazine, The MagPi, Issue 119, pages 35-43, July 2022. [Online]. Available:

- <https://magpi.raspberrypi.com/issues/119>. [Accessed: Sep. 26, 2023].
- [6] Thonny, Python IDE for beginners, [Online]. Available: <https://thonny.org>. [Accessed: Sep. 26, 2023].
- [7] CircuitPython, Raspberry Pi Pico Color TFT Tutorial. [Online]. Available: <https://github.com/educ8s/CircuitPython-ST7735-Examples>. [Accessed: Sep. 26, 2023].
- [8] CircuitPython, CircuitPython Libraries. [Online]. Available: <https://circuitpython.org/libraries>. [Accessed: Sep. 26, 2023].
- [9] Anvil, Build Web Apps with Nothing but Python. [Online]. Available: <https://anvil.works>. [Accessed: Sep. 26, 2023].

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