CEC Continuing Education Center

DesignNews

DC Motor Controls with the RP2040 Pico

DAY 1 : RP2040 Pico Basics

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Webinar Logistics

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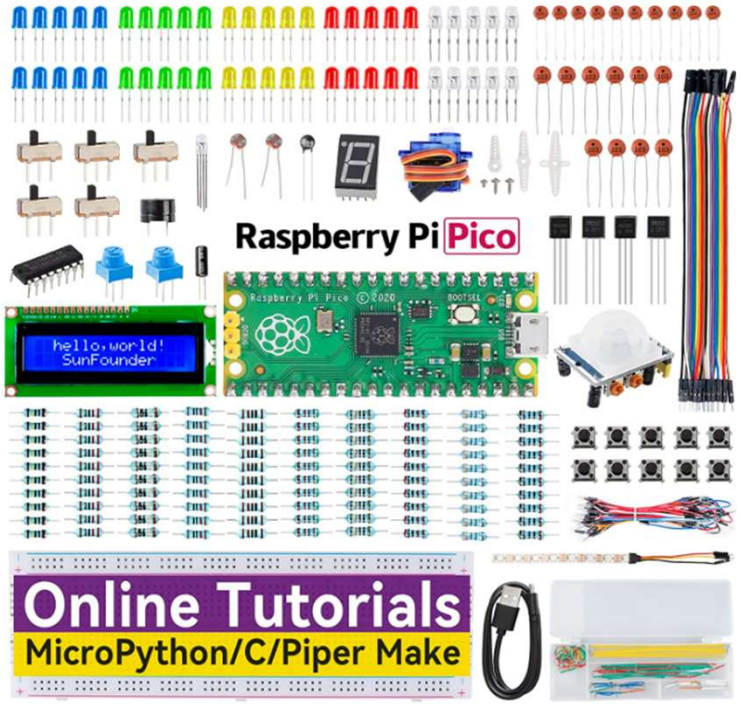
Dr. Don Wilcher

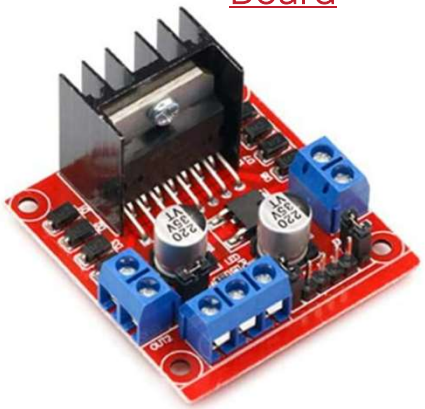
Visit ‘Lecturer Profile’ in your console for more details.

Course Kit and Materials

SunFounder Raspberry Pi Pico Starter Kit



L298N Motor Drive Controller Board



1 Channel Relay Module

ULN2003 4-Phase Stepper Motor with 5V Drive Board

1-5V – 6VDC Motor

Agenda:

- Raspberry Pi Pico Overview
- RP2040 Microcontroller System Architecture
- The transistor electromechanical relay basics
- Lab: Wiring and Testing a Transistor Relay Module

Raspberry Pi RP2040 :

"Raspberry Pi RP2040 SoC, a surprisingly powerful yet radically low-cost microcontroller packing dual Arm Cortex-M0+ processors, the most energy-efficient Arm processor available" (Adams, 2021).

Raspberry Pi Pico Overview

Raspberry Pi Pico is a microcontroller board based on the Raspberry Pi RP2040 microcontroller chip.

Raspberry Pi Pico has been designed to be a low-cost yet flexible development platform for RP2040, with the following key features:

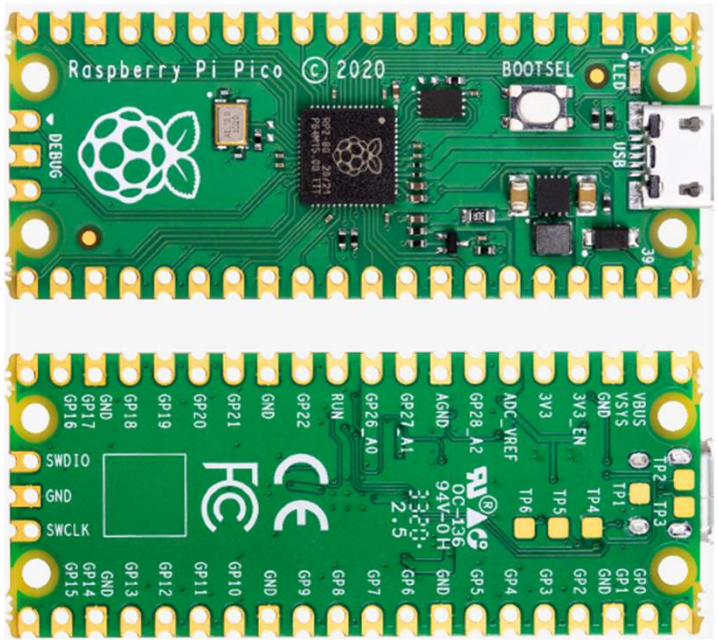
- RP2040 microcontroller with 2MByte Flash
- Micro-USB B port for power and data (and for reprogramming the Flash)
- 40 pin 21x51 'DIP' style 1mm thick PCB with 0.1" through-hole pins also with edge castellations
  - Exposes 26 multi-function 3.3V General Purpose I/O (GPIO)

Raspberry Pi Pico Overview. . .

23 GPIO are digital-only, and 3 are ADC capable
- Can be surface mounted as a module
- 3-pin ARM Serial Wire Debug (SWD) port
- Simple yet highly flexible power supply architecture
- Various options for easily powering the unit from micro-USB, external supplies, or batteries
- High quality, low cost, high availability
- Comprehensive SDK, software examples, and documentation

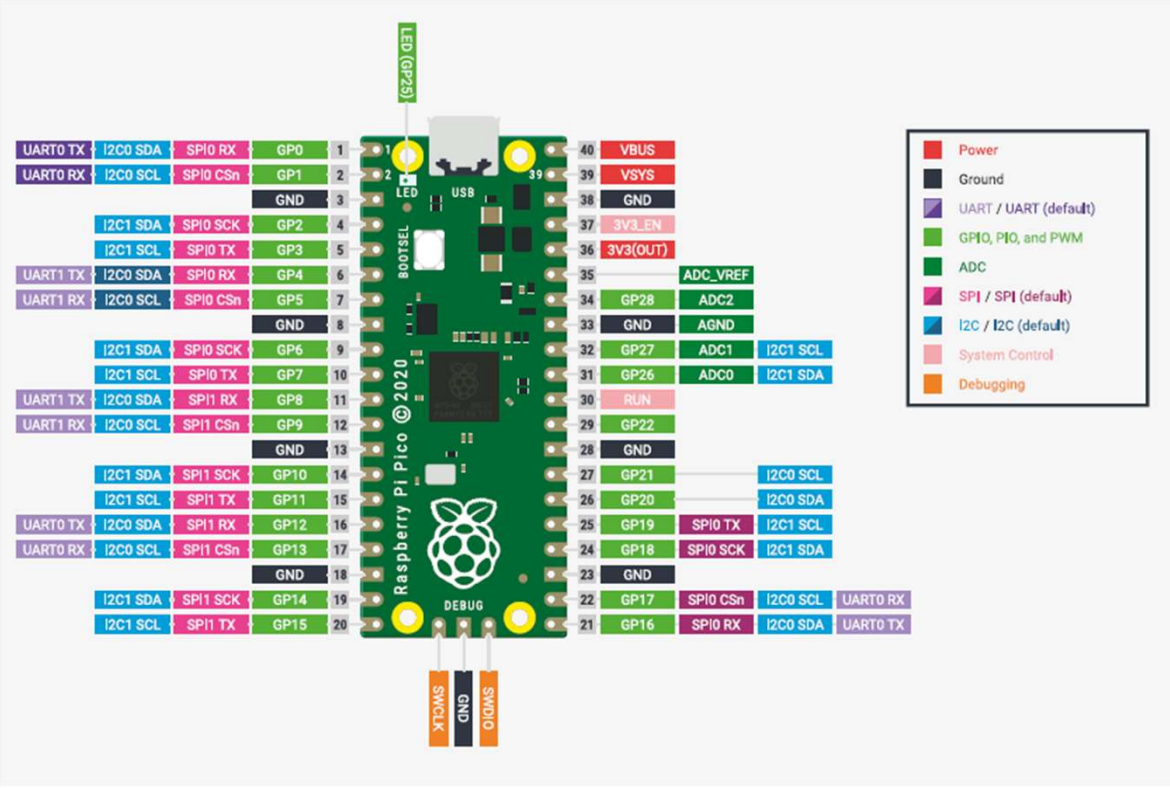
Raspberry Pi Pico Overview. . .

Raspberry Pi Pico PCB: Top and Bottom views



Raspberry Pi Pico Overview. . .

Raspberry Pi Pico pinout



Question 1

Adams(2021) stated that the "Raspberry Pi Pico RP2040 _____ is a surprisingly powerful yet radically low-voltage microcontroller".

a) CoS
b) Sock
c) SoC
d) PSoc

RP2040 Microcontroller System Architecture

Why is the microcontroller called RP2040?

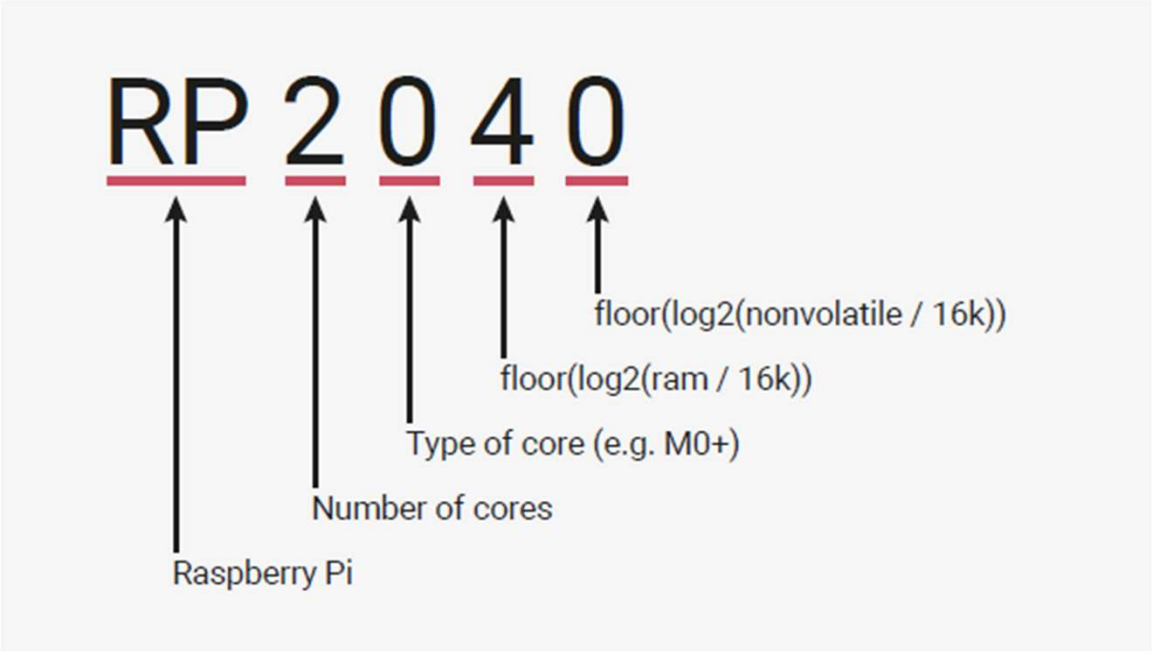
The post-fix numeral on RP2040 comes from the following

1. Number of processor cores (2)
2. Loosely which type of processor (M0+)
3. floor(log2(RAM / 16k)): use to calculate a number representing SRAM which equates to 4
4. floor(log2(Nonvolatile /16k): equates to 0 if no onboard nonvolatile storage

RP2040 Microcontroller System Architecture. . .

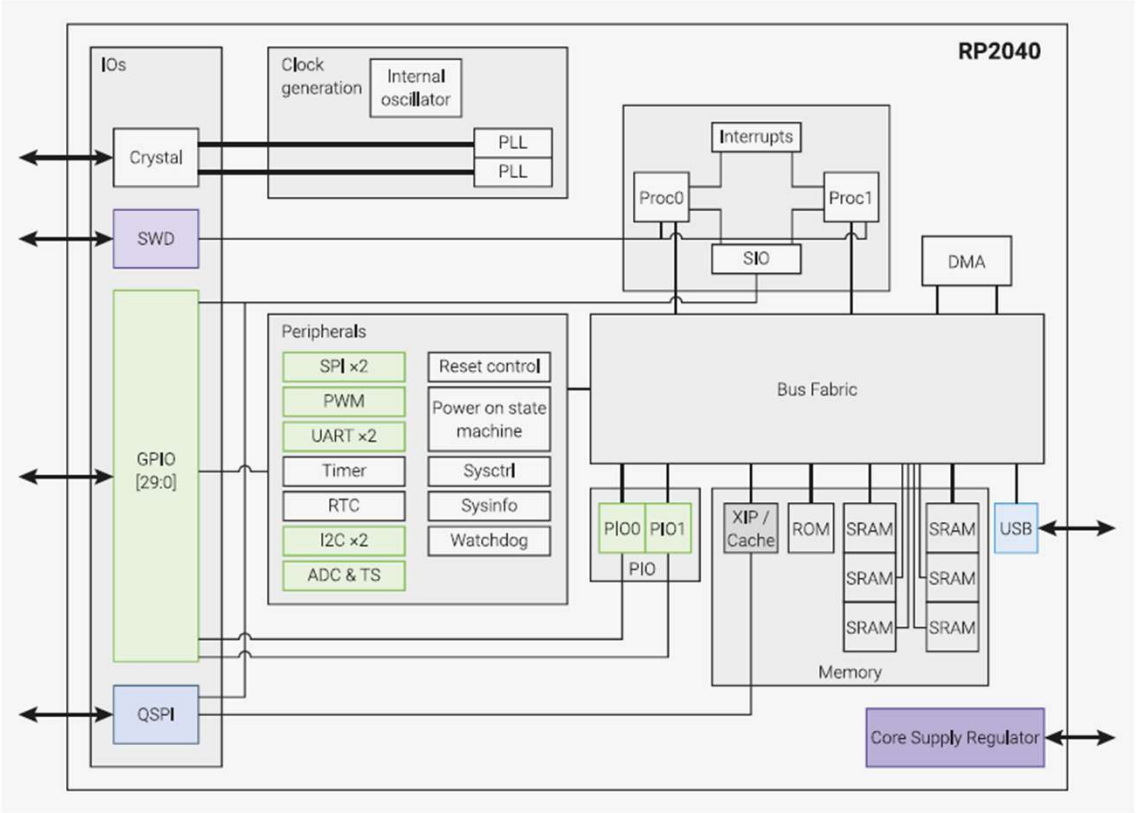
Why is the microcontroller called RP2040?

RP2040 part number configuration



RP2040 Microcontroller System Architecture. . .

RP2040 System Architecture



RP2040 Microcontroller System Architecture. . .

RP2040 Microcontroller's Programmable I/O (PIO) uses state machines to execute short binary programs.

Squarewave Example State machine

```
 7 .program squarewave
 8     set pindirs, 1   ; Set pin to output
 9 again:
10     set pins, 1 [1]  ; Drive pin high and then delay for one cycle
11     set pins, 0      ; Drive pin low
12     jmp again        ; Set PC to label `again`
```

RP2040 Microcontroller System Architecture. . .

RP2040 microcontroller dedicated hardware interfacing support:

- GPIO pins can be driven directly or from various dedicated logic functions.
- Dedicated hardware for fixed functions such as SPI, I2C, and UART.
- Flexible, configurable PIO controllers can be used to provide a wide variety of IO functions.

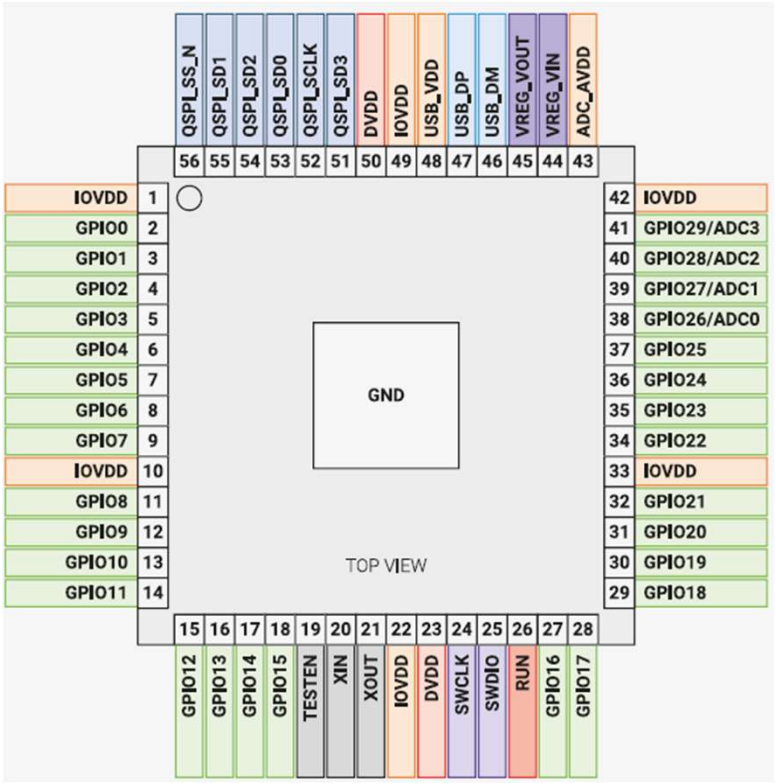
Question 2

The PIO state machine executes short _____ programs.

a) assembly
b) Embedded C
c) binary
d) machine code

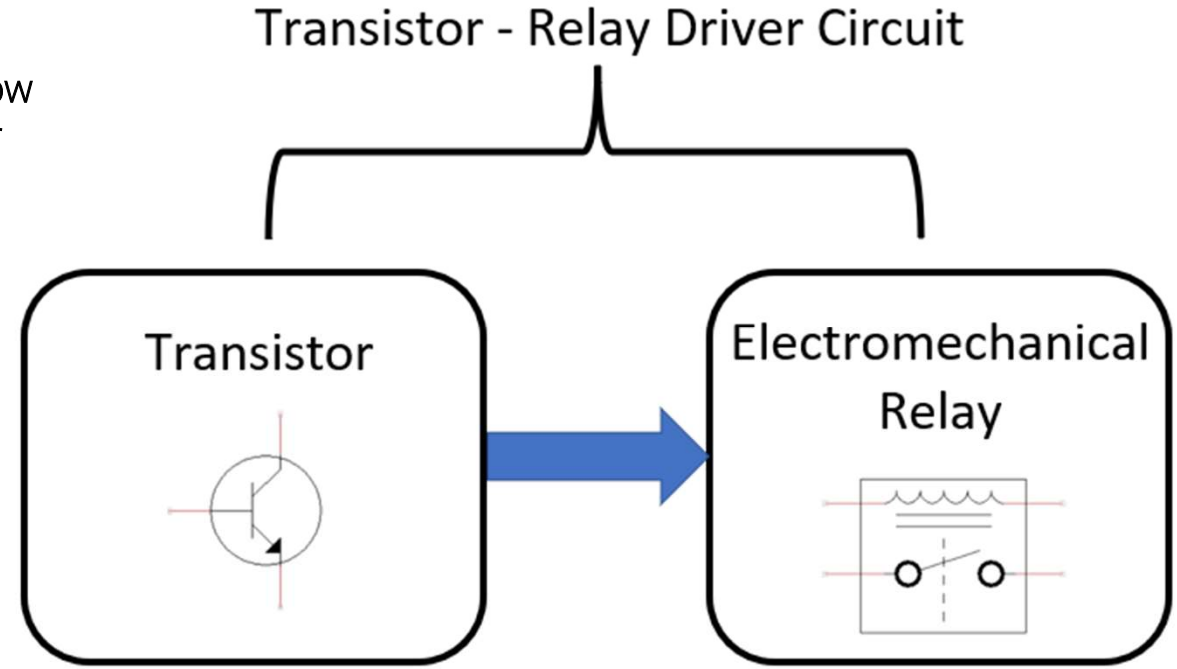
RP2040 Microcontroller System Architecture. . .

RP2040 Pinout
Chip packaged in a Quad Flat-No Lead Package (QFN) – 56 pins: 7x7mm



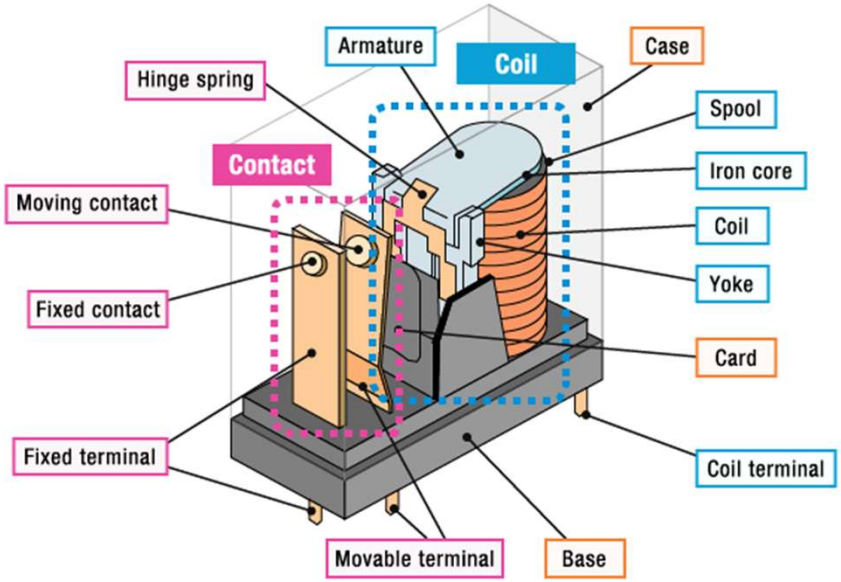
The transistor - electromechanical relay basics

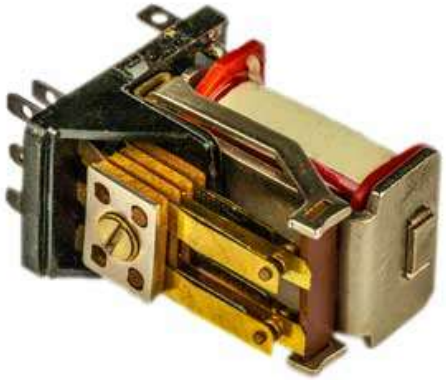
The transistor and electromechanical relay allow the RP2040 microcontroller to easily control a DC or AC motor!



Electromechanical Relay Construction

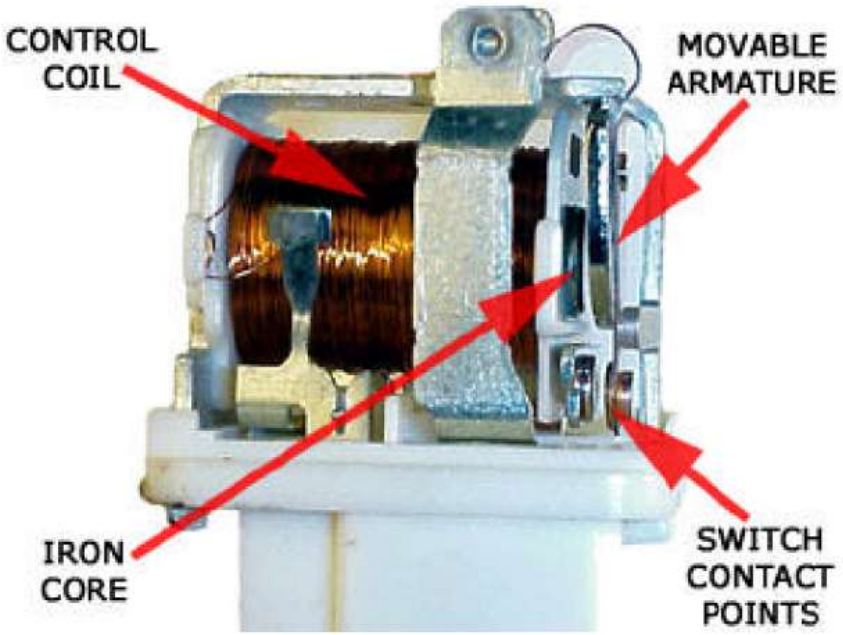
An electromechanical switch that can be turned ON and OFF by a low current signal is called an electromechanical relay.





Source:
https://www.omron-ecb.co.kr/relay-basics/basic

Electromechanical Relay Construction…



Source:

https://www.circuitstoday.com/working-of-relays

Question 3

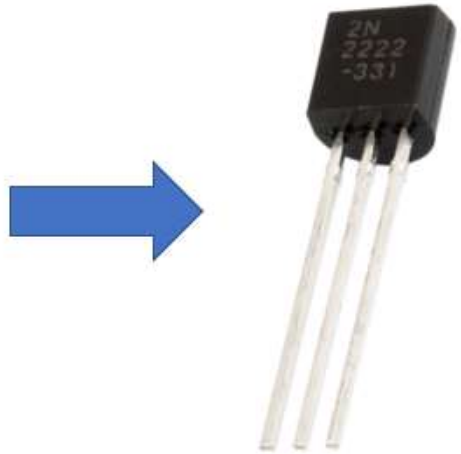
The transistor and electromechanical relay allow the RP2040 microcontroller to easily control a _____

a) DC motor
b) AC motor
c) a & b
d) none of the above

Transistor Basics

Controlling a High Current Electrical Load with Low Current Switching

Low Current Switching Device



Equation 1: $B = \frac{I_C}{I_B}$ or $h_{fe} = \frac{I_C}{I_B}$

Equation 2: $I_C = BI_B$

where:

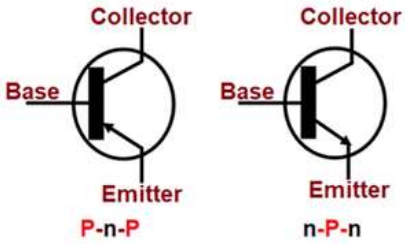
B = Beta

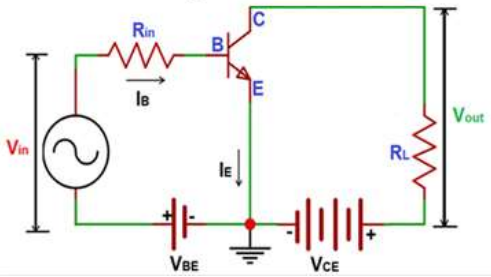
I_c = Collector Current

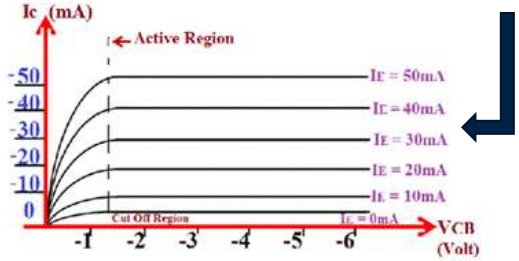
I_B = Base Current

Transistor Basics…

Controlling a High Current Electrical Load with Low Current Switching…







Transistor Family of Curves

Equation 1: $B = \frac{I_C}{I_B}$ or $h_{fe} = \frac{I_C}{I_B}$

Equation 2: $I_C = BI_B$

where:

B = Beta

I_c = Collector Current

I_B = Base Current

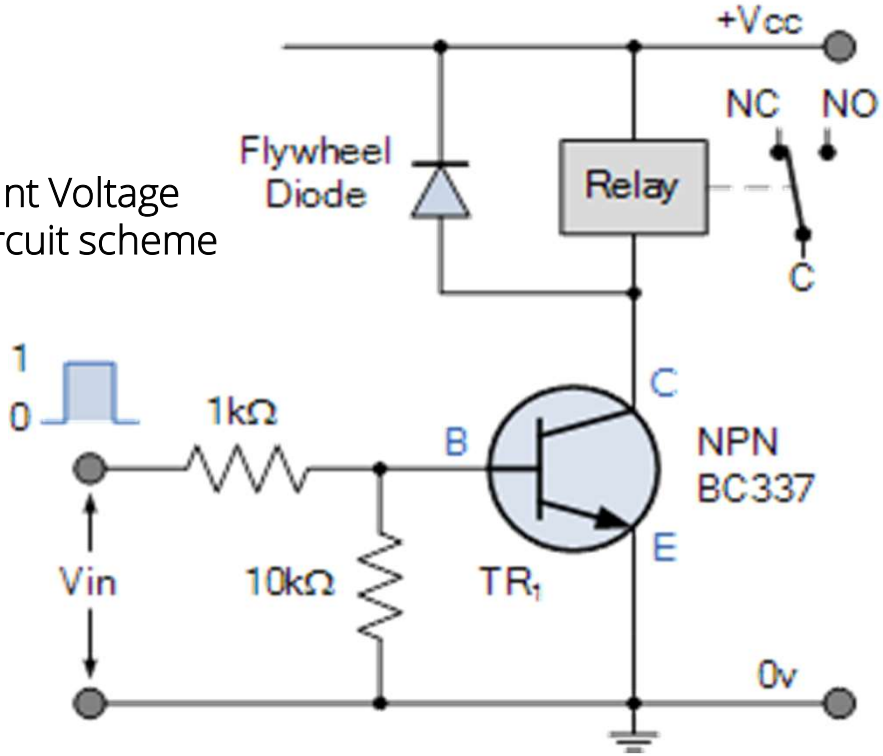
Source:

https://components101.com/articles/understanding-bjt-transistor-and-how-to-use-it-in-your-circuit-designs

Transistor Basics: Transistor Relay Driver Circuit…

Basic Transistor Switching Analysis

Constant Voltage Bias circuit scheme



Equation 3: $v_B = \frac{v_{IN}R}{R_T}$

$$v_B = \frac{5v10k\Omega}{11k\Omega}$$

$$v_B = 4.5\text{V}$$

$v_B > v_{BE}$: $v_{BE} = 0.7v$

Transistor is ON

$$v_B = \frac{v_{IN}R}{R_T}$$

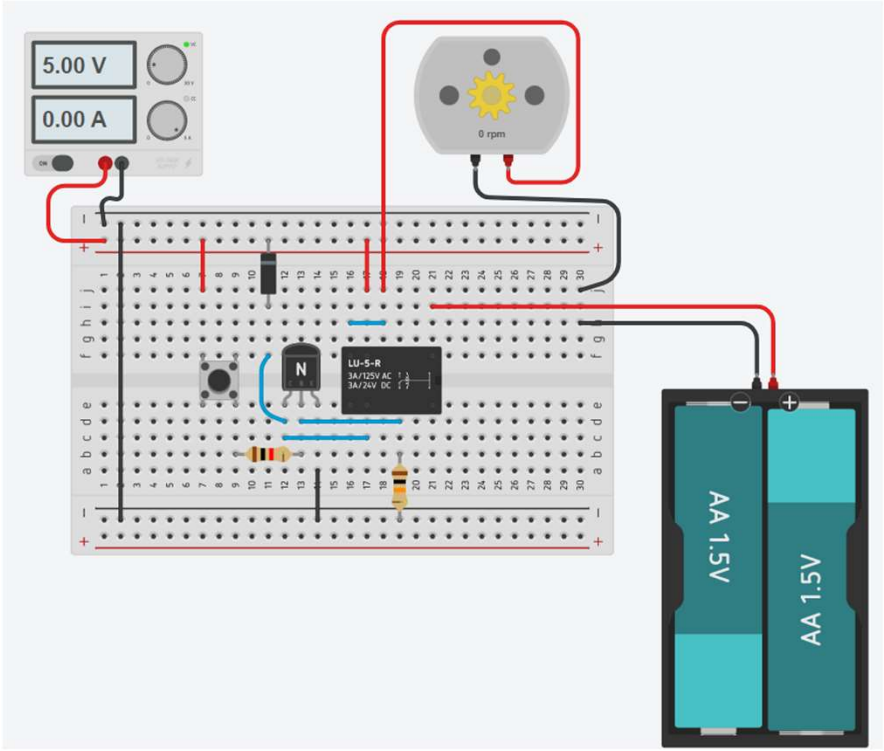
$$v_B = \frac{0v10k\Omega}{11k\Omega}$$

$$v_B = 0\text{V}$$

$v_B < v_{BE}$:

Transistor is OFF

Transistor- Electromechanical Basics: Tinkercad Circuits Transistor Relay Driver Model. . .

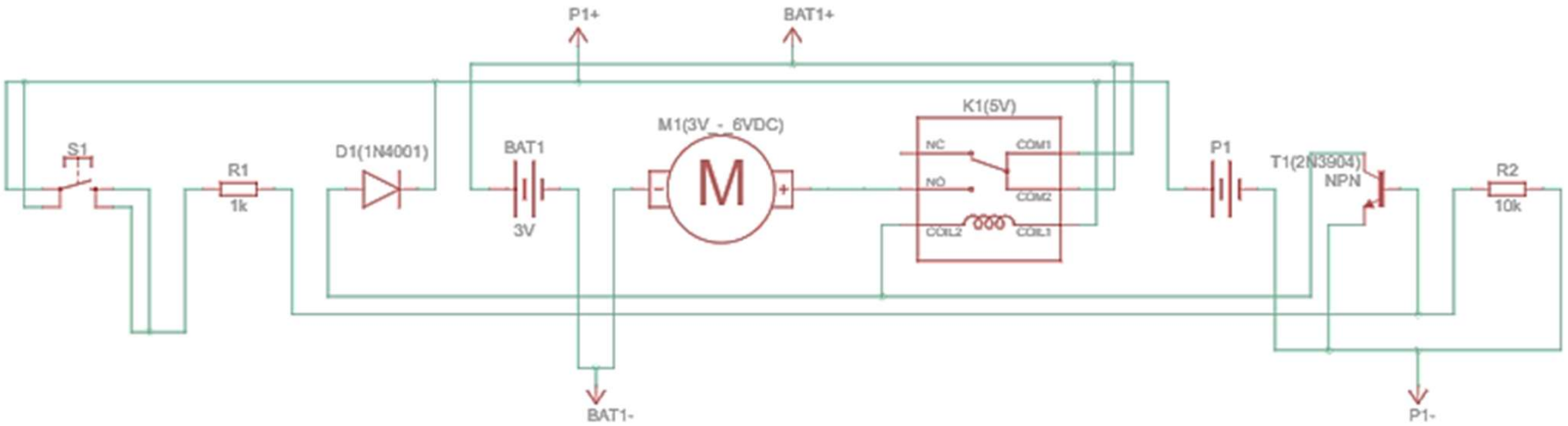


Component List

Name	Quantity	Component
T1(2N3904)	1	NPN Transistor (BJT)
R1	1	1 kΩ Resistor
D1(1N4001)	1	Diode
S1	1	Pushbutton
K1(5V)	1	Relay SPDT
M1(3V - 6VDC)	1	DC Motor
Bat1	1	2 batteries, AA, no 1.5V Battery
P1	1	5 , 5 Power Supply
R2	1	10 kΩ Resistor

Tinkercad Circuits Transistor Relay Driver Model. . .

Electronic Circuit Schematic Diagram

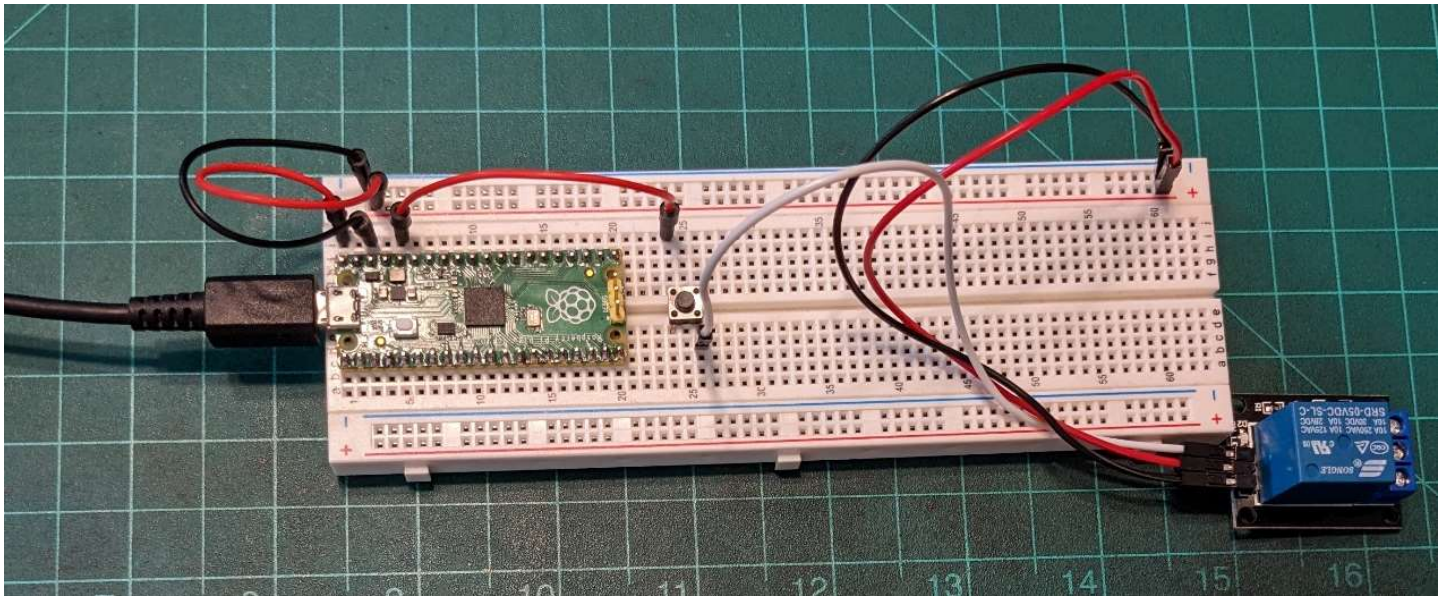


Question 4

What semiconductor device is used to operate the electromechanical relay module?

a) diode
b) resistor divider circuit
c) transistor
d) none of the above

Lab: Wiring and Testing a Transistor-Relay Module

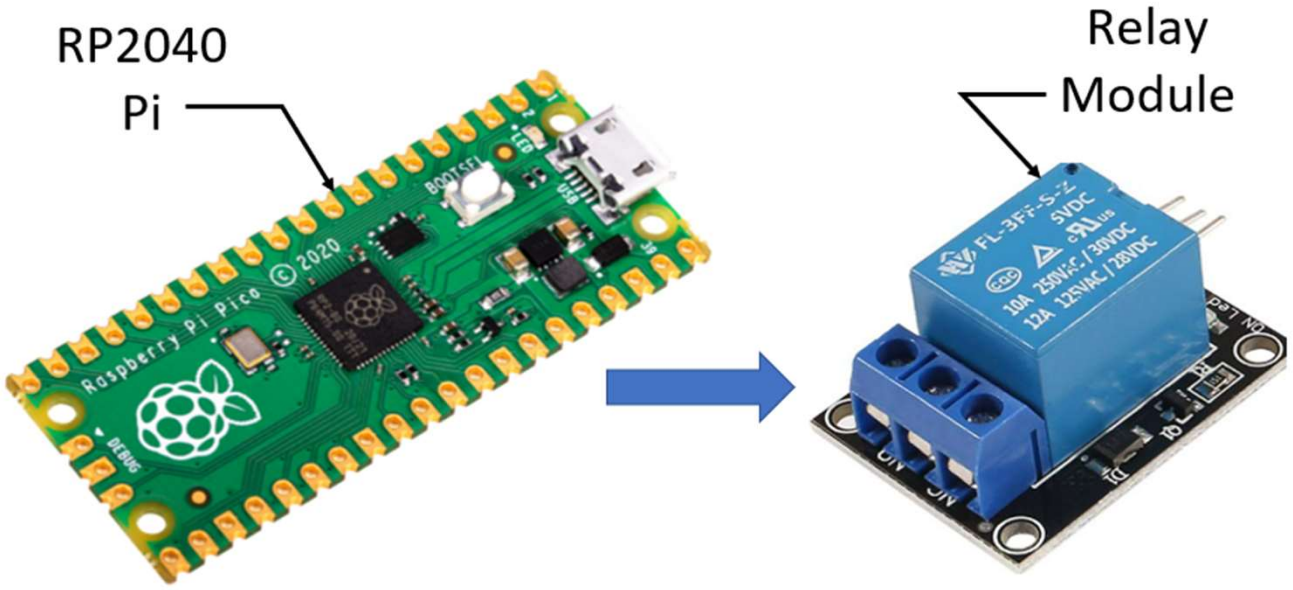


Lab: Wiring and Testing a Transistor-Relay Module

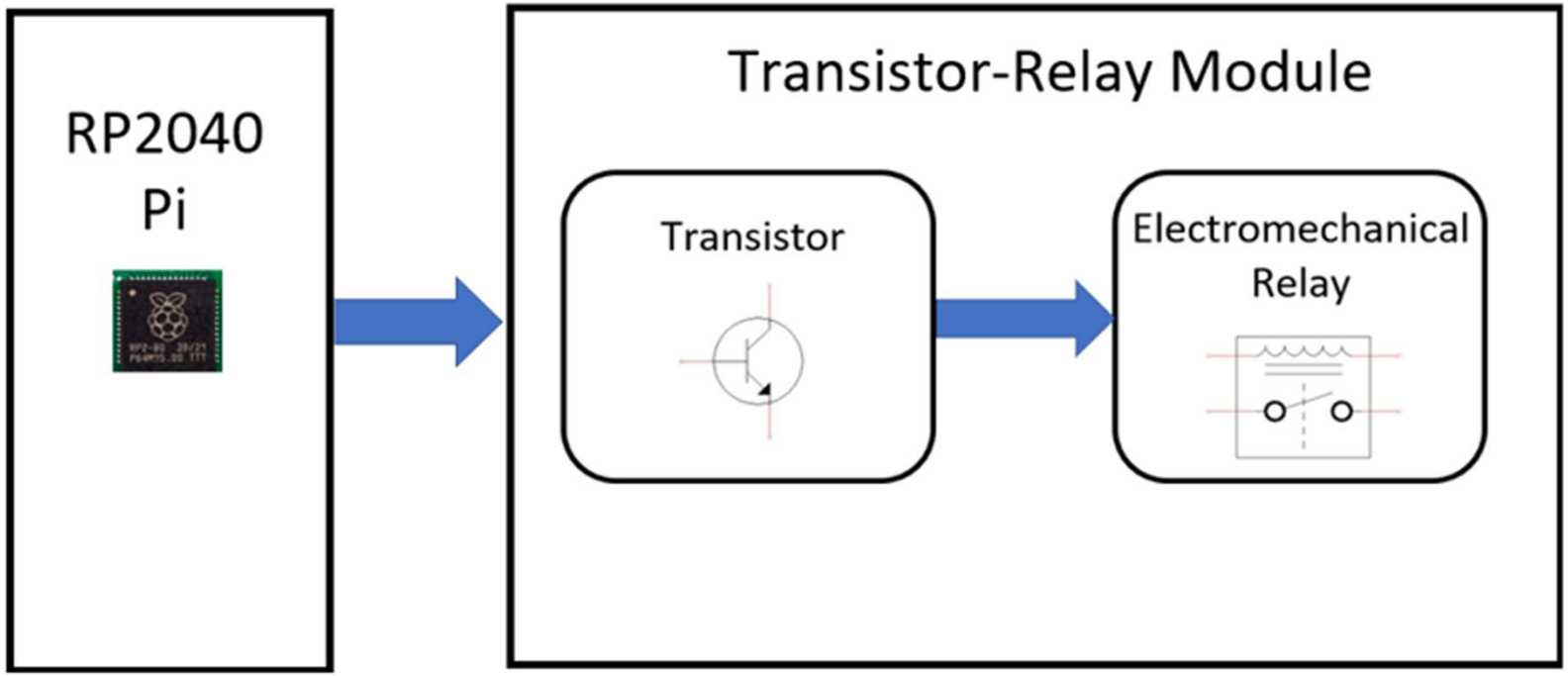
Big IDEAS (Learning Objectives):

1. The participant will be able to wire a transistor-based electromechanical relay module to Raspberry Pi Pico's Power Supply pins.
2. The participant will be able to test the transistor-based electromechanical relay module using a wired test switch.
3. The participant will be able to build an automated Raspberry Pi Pico transistor-based electromechanical relay module tester circuit using blockly code.

Lab: Wiring and Testing a Transistor-Relay Circuit

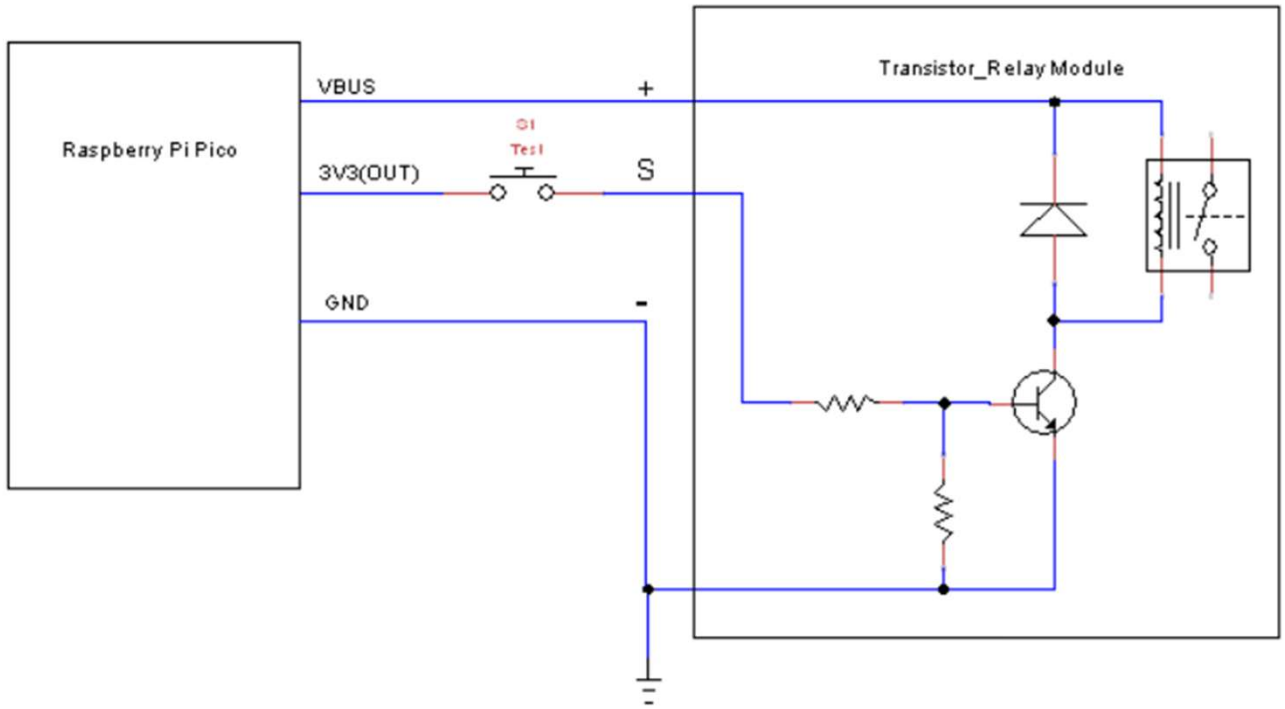


Lab: Wiring and Testing a Transistor-Relay Module



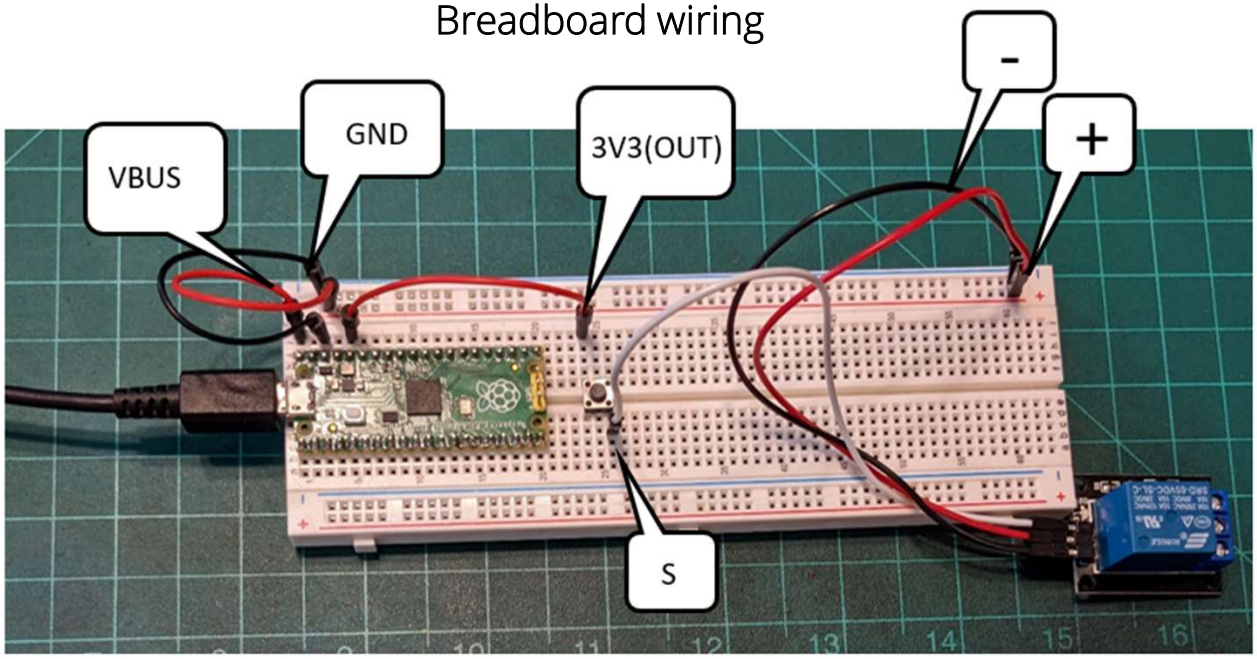
Lab: Wiring and Testing a Transistor-Relay Module

Transistor-Relay Module
Tester Circuit



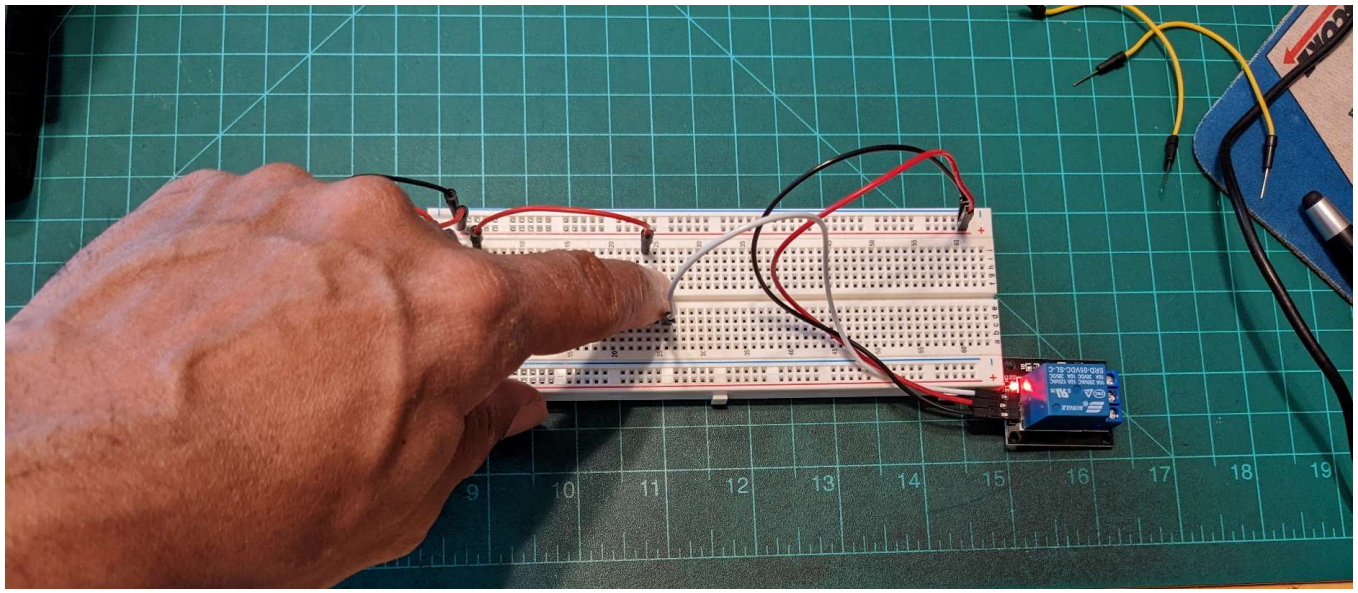
Lab: Wiring and Testing a Transistor-Relay Module

Transistor-Relay Module Tester Circuit (Solderless Breadboard wiring



Lab: Wiring and Testing a Transistor-Relay Module

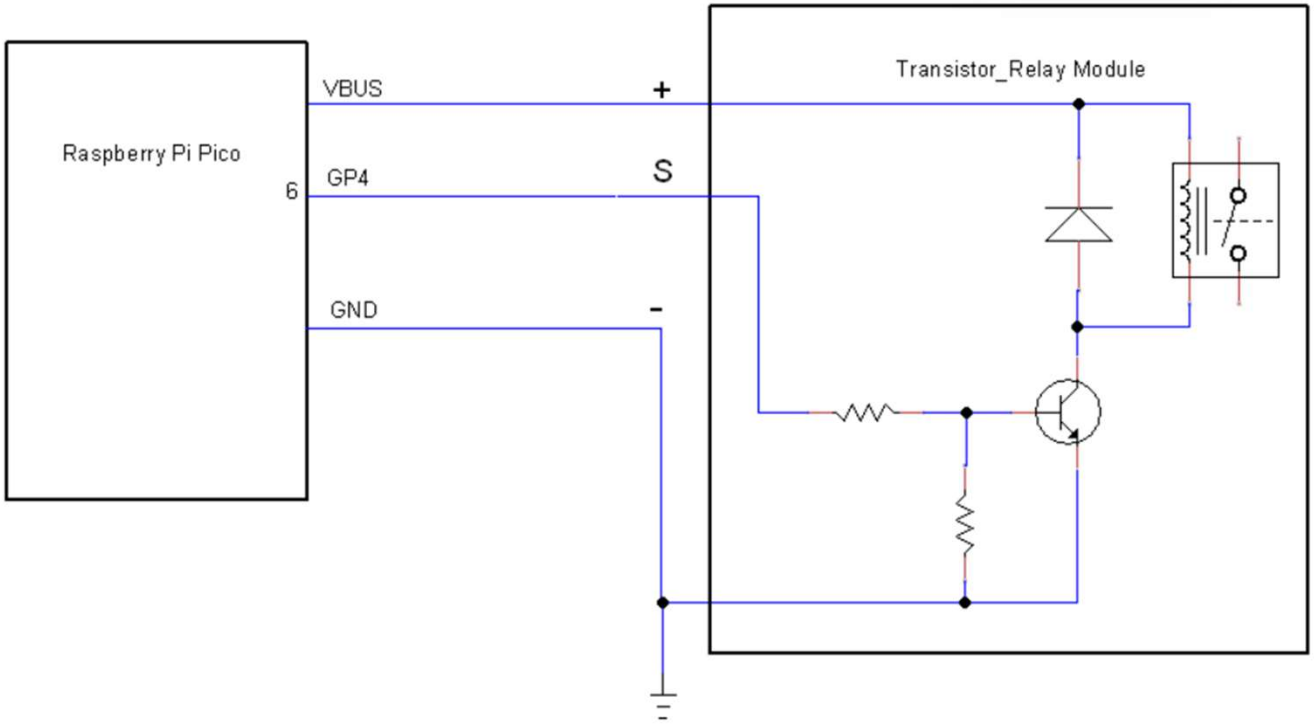
Manual Testing of the Transistor-Relay Module



https://youtu.be/u5oISGWFCfs

Lab: Wiring and Testing a Transistor-Relay Module

Automated Testing of the Transistor-Relay Module Circuit Schematic Diagram



Lab: Wiring and Testing a Transistor-Relay Module

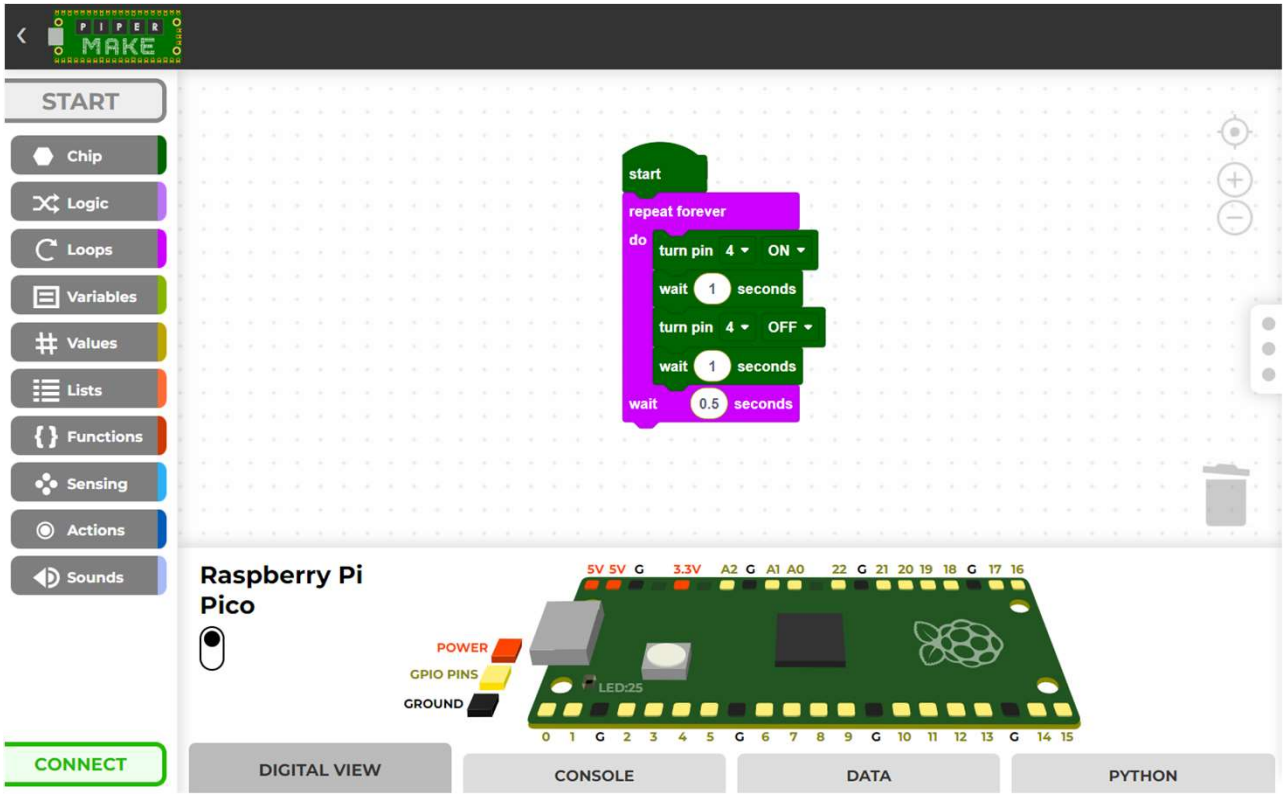
Automated Transistor-Relay Module Tester Code with Piper Make

Online Physical Computing Platform!

https://make.playpiper.com/

Lab: Wiring and Testing a Transistor-Relay Module

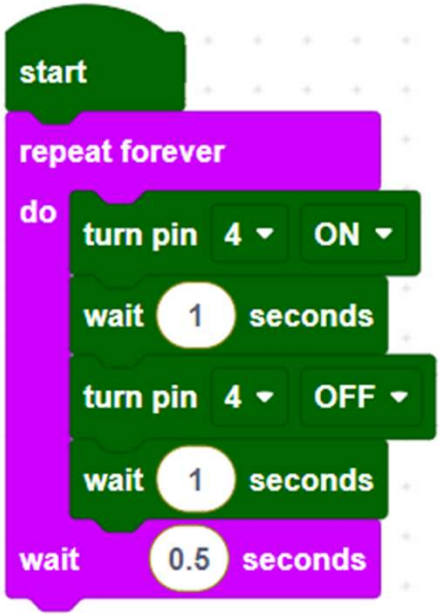
Automated Testing of the Transistor-Relay Module Circuit Schematic Diagram



Lab: Wiring and Testing a Transistor-Relay Module

Automated Testing of the Transistor-Relay Module Blockly Code

NOTE: The blockly code Pin number is the actual GPIO pin.

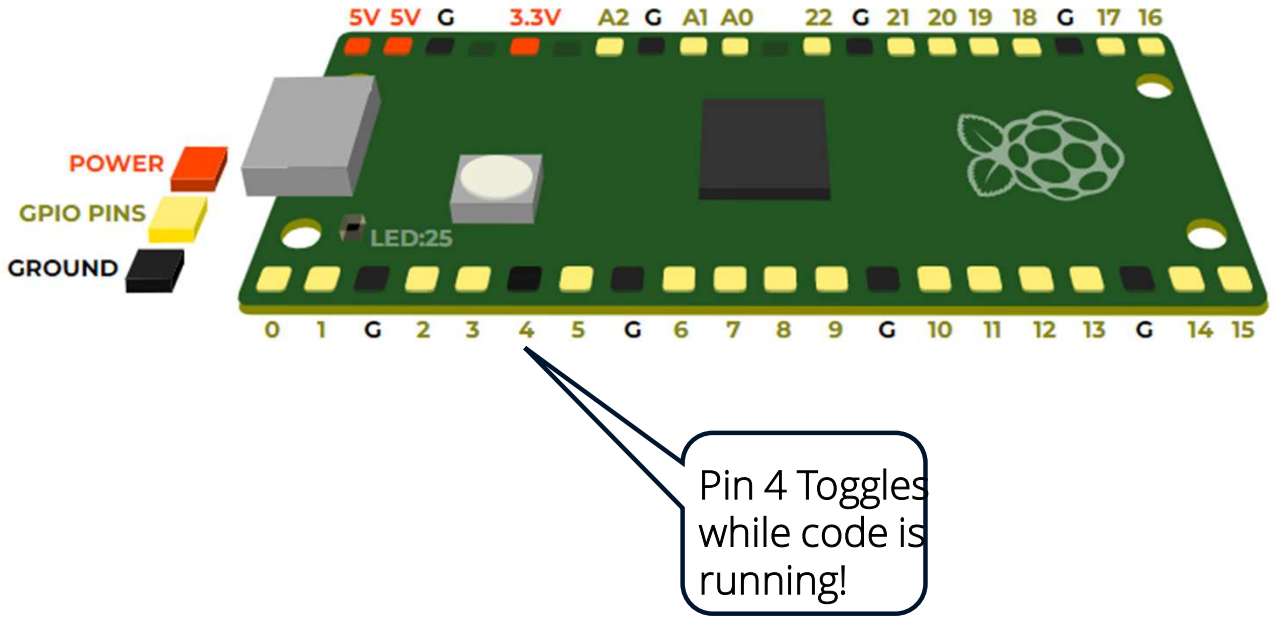


https://youtu.be/0XhBO0dI6_Y

Lab: Wiring and Testing a Transistor-Relay Module

Automated Testing of the Transistor-Relay Module Circuit Schematic Diagram

Raspberry Pi Pico



Question 5

The blockly code Pin Number is the actual GPIO pin.

a) True

b) False

Thank you for attending

Please consider the resources below:

Adams, J. (2021, February 1). *Raspberry pi rp2040: Our microcontroller for the masses*. https://www.arm.com/blogs/blueprint/raspberry-pi-rp2040

RP2040 Datasheet. (2022). RP2040 datasheet: A microcontroller by raspberry pi. https://datasheets.raspberrypi.com/rp2040/rp2040-datasheet.pdf

Raspberry Pi Pico Resources: Raspberry Pi Documentation - Raspberry Pi Pico and Pico W

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