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Intel

I'm a software engineer. My professional path I started from maker. In 2013 I developed a model of the self-driving car, and presented it during the Maker Faire 2014 in Italy. After that, I continued to develop robots, and program them. One of my projects was development of the robot avatar in 2014. That project was noticed by Intel, and I presented it during the developers conference in Russia at the Intel's booth.
<https://dumash.intel.com/projects/robot-avatar>

VIDEO



Zephyr* RTOS Juicy Features

Using simple evaluation boards and robots

Maksim Masalski /
Software engineer, Intel

#osummit @twitterhandle

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A Disciplined....pptx

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Agenda

Part I Zephyr* Introduction

- The Zephyr Project Overview
- Key points of the Zephyr RTOS

Part II Robotics

- How do you write code for a robot?
- Micro:bit* board description
- Robotics expansion platforms
- Line-following robot
- Run samples on Zephyr
- Reverse engineering of the MakeCode* program
- Create Zephyr application
- Building an application
- Setup Zephyr application
- Coding Zephyr application
- Build and upload Zephyr binary
- Running application



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The Zephyr* Project Overview

It is an open-source, little in size, real-time operating system, developed to support multiple architectures, and to be used on resource-constrained devices.

- An open-source real-time operating system
- The software is a perfect choice for simple connected sensors, LED wearables, modems, and small wireless gateways
- Linux Foundation hosted Collaboration Project
- Permissively licensed – Apache* 2.0
- Managed on Github* <https://github.com/zephyrproject-rtos/zephyr>
- Built to be secure and safe
- Great community support (Github, Slack, Open Weekly Meetings about Zephyr development)
- The cross-architecture with broad SoC and development board support <https://docs.zephyrproject.org/latest/boards/index.html>
- Vendor Neutral governance
- Complete, fully integrated, highly configurable; modular for flexibility
- Product development-ready using LTS includes security updates

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Key points of the Zephyr* RTOS

Developing with Zephyr

- Code on Github, contributions through pull requests
- Linux*, MacOS*, and Windows* SDKs supported
- Lots of sample applications in the source tree
- Flashing boards usually just "make flash"

Supported Boards

x86 Boards
ARM Boards
ARC Boards
MIPS Boards
XTENSA Boards
POSIX/NATIVE Boards
RISC-V Boards
Shields

41252

boards

687

components

37

applications

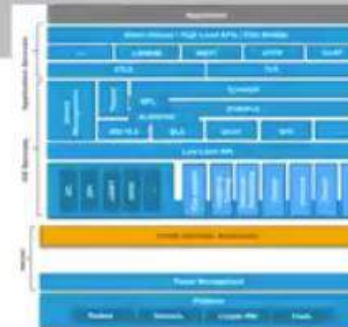
16334

pull requests (since)

As of June 1, 2020

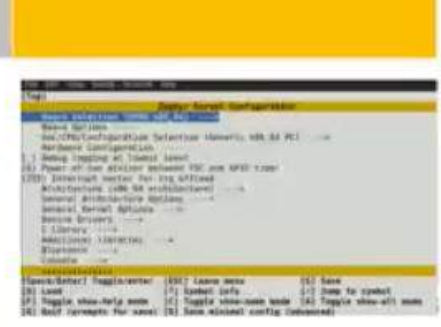
Architecture

- Modular and configurable
- Two types of threading: cooperative and preemptive
- Memory resources are statically allocated
- Has integration of device driver interface
- Stack overflow protection, thread isolation
- Kernel object, device driver permission tracking
- Native and optimized IP stack
- BLE, BLE Mesh



Small Linux brother

- Familiar to Linux developers
- Kconfig-based build configuration
- Linux coding style
- Device-tree used for board definitions
- Integrated Qemu support



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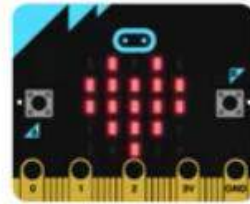
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<https://devmesh.intel.com/projects/robot-avatar-sensedrive-symbiosis-of-human-mechatronics-and-virtual-reality> Also that project my team presented during the Microsoft Imagine Cup in Minsk, Belarus in 2016. During that period 2013-2019 I had various speaking experience mostly on robotics topics in my home country as Intel Software Innovator (independent developer supported by Intel). In 2019 I became an Intel software engineer and currently I'm based in Shanghai, China. Now I'm involved into development of the open-source real-time operating system called Zephyr.
<https://www.zephyrproject.org/>

VIDEO

Program a robot using Zephyr*

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Does zephyr supports 802.15.4?

Yes, it does.

<https://docs.zephyrproject.org/latest/reference/networking/ieee802154.htm>

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How do you write code for a robot?

- Can be difficult for an Arduino* developer
- Chance to level up your DIY robots development skills

**Using Zephyr* RTOS
for your maker project**

ARDUINO

- ARM* Arduino boards are supported by Zephyr like Arduino Due, Arduino Zero too.
- There is an extension to develop with Arduino API with using Zephyr RTOS as base system.
<https://github.com/soburi/arduino-on-zephyr>

**Still playing with
Arduino* IDE?***Other names and brands may be claimed as the property of others.

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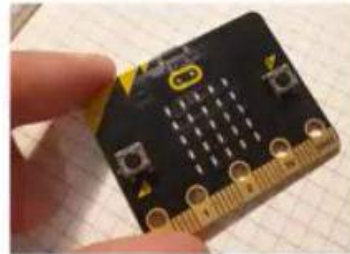
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Micro:bit* board description



- Has enough built-in features like gyroscope, accelerometer, 2 buttons, temp sensor, LED matrix
- Doesn't take much space at your desk
- In the evening, you can use it to teach kids coding using simple programming languages like Scratch*, MakeCode*, or even Python*
- When kids go to sleep, run Zephyr on it and play with robots, and IoT prototypes
- Cheap enough to buy one more, if you burn it during robotics experiments

Technical data:

1. Size 4 x 5cm (1.6 x 2 inch)
2. Has 2 programmable buttons
3. 3 digital/analogue input/output pins
4. 25 individually programmable LEDs
5. 32-bit ARM* Cortex* M0 CPU 16K RAM 16Mhz with Bluetooth* LE
6. Accelerometer, compass, temperature sensor
7. 20 pin edge connector
8. Micro USB* connector



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Robotics expansion platforms

A big number of expansion boards and platforms makes it simple to create a robot of any type and purpose. Just insert micro:bit into the platform and you can control it.

And finally, drive your robot by Zephyr*!

Micro:bit* has next expansion platforms:

1. Drones
2. Robotic Arms
3. Various car chassis
4. Biped robots



*Image above used by permission Yatbacon Technology



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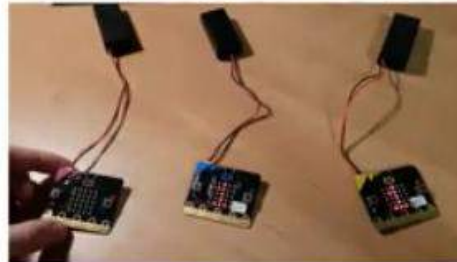
<https://docs.zephyrproject.org/latest/reference/networking/ieee802154.htm>

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Run samples on Zephyr*



- If you have three micro:bit boards you can try to run the Bluetooth® Mesh sample from the Zephyr code repo.
- Detailed Bluetooth Mesh project description here:
https://docs.zephyrproject.org/latest/samples/bluetooth/mesh_demo/README.html



- The most popular and easiest-to-implement are line-follower robots.
- I will guide you how to program line-following function of the robot using Zephyr RTOS.
- Video of the robot following a line:
<https://www.youtube.com/watch?v=tlvoHQjo8a4>



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Line-following robot



3x3 inches tiny robot is capable of performing various tasks, fits on your desk, and provides fun during quarantine at home.



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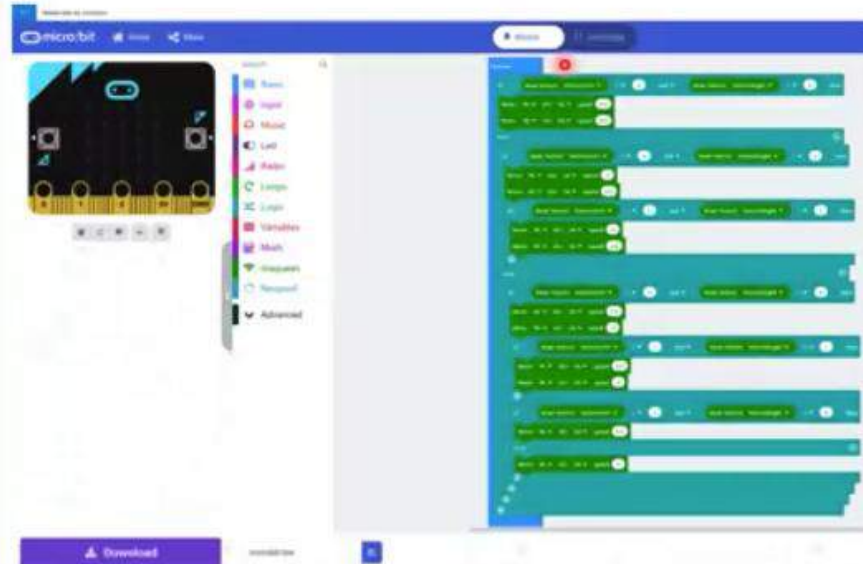
<https://docs.zephyrproject.org/latest/reference/networking/ieee802154.htm>

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Reverse engineering the MakeCode* program



- MakeCode program
- Looks like LEGO* bricks
- Easy to code, but for our task necessary to understand how that program is interpreted to be executed by the robot
- Need to investigate what drivers and principle of motors control
- Need to investigate what drivers and principle of line sensors data reading



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Reverse engineering of the MakeCode* program



Block to control motor speed of the robot

MakeCode/JavaScript

Return nothing, only accepts motor speed value from 0 to 255

```
maqueen.MotorRun(maqueen.aMotors.M1, maqueen.Dir.CW, 255)
```



Block to read data from line sensor

MakeCode/JavaScript

Returns value 0 or 1

```
maqueen.readPatrol(maqueen.Patrol.PatrolLeft)
```

For kids, the blocks are "black boxes", but for me it was necessary to dig in and understand how they are implemented to use that code in my Zephyr* application.



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Reverse engineering of the MakeCode* program

Found library on Github*

- Typescript file (.ts) had all definitions and control code for motor and also code for reading data from the sensors.

Motor driver information:

- Motor driver is I2C
- In code found correct device address value (0x10)
- In code found commands responsible for setting motors speed value

Line sensor information:

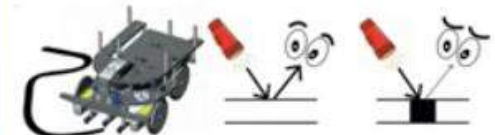
- Robot has two line sensors.
- Line sensors are binary. They use infrared LED to measure the amount of the reflected light from the surface.
- Found ping on the micro:bit board responsible for reading sensor data (pin 22, pin 23). One pin for each sensor.

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Two motor drivers.
One for each motor.
Both controlled by one I2C chip.



Line sensors working principle:





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Does Zephyr support time sensitive networks?

Yes, gPTP, 802.1Qav in upstream
<https://www.zephyrproject.org/wp-content/uploads/2020/01/Zephyr-industrial-networking.pdf>

What's the model of this robot used?

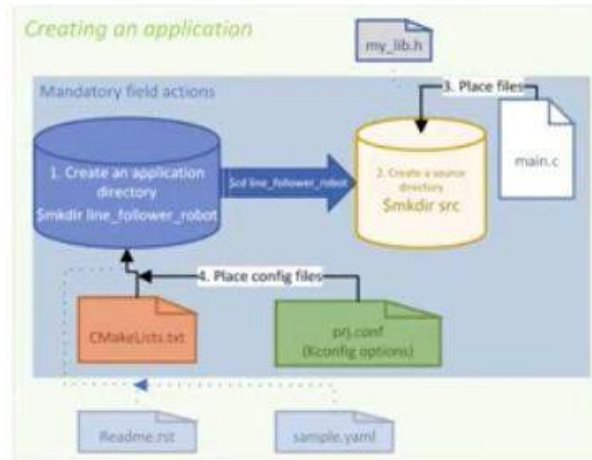
I used DFRobot Maqueen robot.

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Create Zephyr* application



Zephyr's base directory
`/zephyrproject/zephyr`



Application directory

`/zephyrproject/zephyr/samples/boards
/bbc_microbit/line_follower_robot`



1. I created the application directory.



2. Placed all source files there.



3. Readme.rst file with sample description after merging my PR to master will be on the official documentation webpage.



https://docs.zephyrproject.org/latest/samples/boards/bbc_microbit/line_follower_robot/README.html

Official Zephyr page with a comprehensive information about App dev:

<https://docs.zephyrproject.org/latest/application/index.html>



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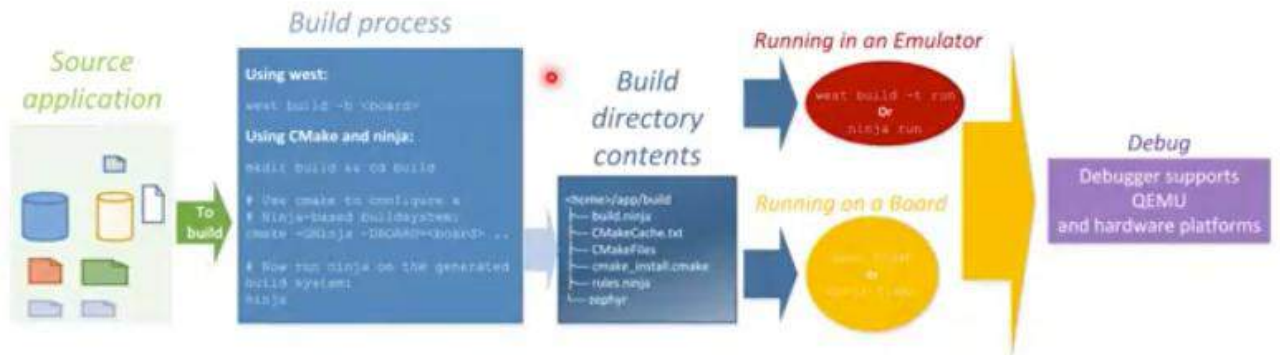
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Building an application

- Zephyr's build system is based on [CMake](#).
- The build system is application-centric and requires Zephyr-based applications to initiate building the kernel source tree. The application build controls the configuration and builds process of both the application and Zephyr itself, compiling them into a single binary. The default build tool in Zephyr is west, Zephyr's meta-tool, which invokes CMake and the underlying build tool (ninja or make) behind the scenes



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What's the model of this robot used?

I used DFRobot Maqueen robot

Why put your application into the Zephyr tree? Is that recommended for all projects, or was it just because this was a first-of-its-kind demo?

[NEW QUESTION](#)**VIDEO**

Setup Zephyr* application

prj.conf

To setup current application necessary to enable vital configuration options. For my application I enabled I2C and GPIO using prj.conf file:

```
CONFIG_GPIO=y
CONFIG_I2C=y
CONFIG_PRINTK=y
```

CMakeLists.txt

```
# SPDX-License-Identifier: Apache-2.0

cmake_minimum_required(VERSION 3.13.1)

find_package(Zephyr REQUIRED HINTS $ENV{ZEPHYR_BASE})
project(robot)

FILE(GLOB app_sources src/*.c)
target_sources(app PRIVATE ${app_sources})
```

Sample.yaml

That file has information for Sanitycheck testing system.



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[NEW QUESTION](#)**VIDEO**

Coding Zephyr* application

main.c

```
1 /*
2  * Copyright (c) 2019 Maksim Masalski maxxlifrobot@gmail.com
3  * A line follower robot program using DFRobot Maqueen Robot and microbit
4  * SPDX-License-Identifier: Apache-2.0
5  */
6
7 #include <zephyr.h>
8 #include <sys/printk.h>
9 #include <drivers/gpio.h>
10 #include <drivers/i2c.h>
11 #include <device.h>
12
13 #define I2C_SLV_ADDR 0x10
14 #define I2C_LABEL DT_LABEL(DT_NODELABEL(i2c0))
15 #define EXT_P13_GPIO_PIN 23 /* P13, SPI1 SCK */
16 #define EXT_P14_GPIO_PIN 22 /* P14, SPI1 MISO */
17
18 static struct device *gpio;
19 struct device *i2c_dev;
20 unsigned int left_line[1];
21 unsigned int right_line[1];
22 unsigned char buf[3];
23 unsigned char speed_hex[1];
```

Start with license identifier and copyright information

2. Add correct headers to use necessary API

3. Add correct defines to use I2C and correct settings of the GPIO

All pins mappings for the microbit chip
[https://docs.micropython.org/en/latest/microbit-board.html](#)

4. Create device data structures of type struct device



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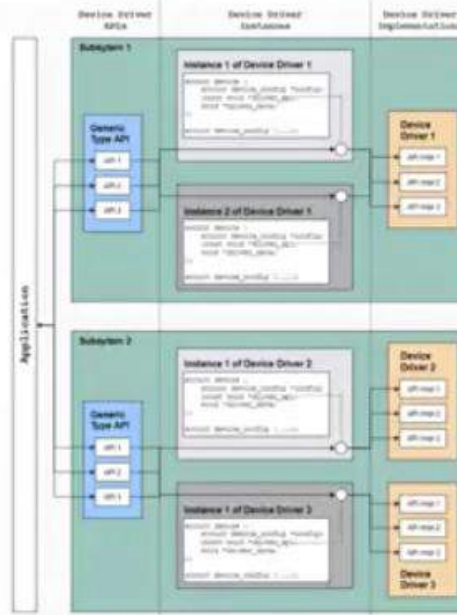
How to use application in the Zephyr

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Device Driver Model



Standard Drivers

- Interrupt controller
- Timer
- Serial communication
- Entropy

Driver Data Structures

The device initialization macros populate some data structures at build time which are split into read-only and runtime-mutable parts. At a high level we have:

```
struct device {  
    const char *name;  
    const void *config_info;  
    const void *driver_api;  
    void *const driver_data;  
};
```

Official Zephyr* page with a comprehensive information about Device drivers:

<https://docs.zephyrproject.org/latest/reference/drivers/index.html>



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Why put your application into the Zephyr tree? Is that recommended for all projects, or was it just because this was a first-of-its-kind demo?

I wanted to merge my application into upstream tree on Github.

Any recommended IDE that can be used with Zephyr? Because main developers like to use IDE for development and debugging.

I'm using VIM, recently started to use VS Code. You can use Eclipse <https://docs.zephyrproject.org/latest/application/index.html> (Eclipse debugging article)

Enter question here...

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Coding Zephyr* application (continued)

main.c

```
25 // Setup gpio of the micro:bit board */
26 static void line_detection(struct device *dev, struct gpio_callback *cb,
27                          uint32_t pins)
28 {
29     left_line[0] = gpio_pin_get_raw(gpio, EXT_P13_GPIO_PIN);
30     right_line[0] = gpio_pin_get_raw(gpio, EXT_P14_GPIO_PIN);
31     /* prints "to turn", left_line[0], right_line[0]; */
32 }
```

Function to read line sensors data

```
114 void main(void)
115 {
116     static struct gpio_callback line_sensors;
117
118     gpio = device_get_binding(DT_GPIO_LABEL(DT_ALIAS(sw0), gpio));
119     i2c_dev = device_get_binding(DT_I2C_LABEL());
120     /* Setup gpio to read data from digital line sensors of the robot */
121     gpio_pin_configure(gpio, EXT_P13_GPIO_PIN, GPIO_INPUT);
122     gpio_pin_configure(gpio, EXT_P14_GPIO_PIN, GPIO_INPUT);
123
124     gpio_pin_interrupt_configure(gpio, EXT_P13_GPIO_PIN,
125                               GPIO_INT_EDGE_BOTH);
126
127     gpio_pin_interrupt_configure(gpio, EXT_P14_GPIO_PIN,
128                               GPIO_INT_EDGE_BOTH);
129
130     gpio_init_callback(&line_sensors, line_detection,
131                     BIT(EXT_P13_GPIO_PIN) | BIT(EXT_P14_GPIO_PIN));
132     gpio_add_callback(gpio, &line_sensors);
133
134     while (1) {
135         line_follow();
136     }
137 }
```

Created new struct of type gpio_callback line_sensors

Get binding for the new devices gpio and i2c

Configure pins of the micro:bit board and nrf51 chip to INPUT

Configure interrupts for each pin

Initialize line_detection function to run as a callback



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Coding Zephyr* application (continued)

main.c

Writing function to control motors.

```
41 /* Function to control motors of the DFRobot Maqueen Robot */
42 /* Send value > 0 motor rotates forward */
43 /* Send 0 motor stop */
44 /* Send value < 0 motor rotates backward */
45 void motor_left_control(int left_speed)
46 {
47     if (left_speed < 0) {
48         left_speed = left_speed * (-1);
49         /* Command bits to control I2C motordriver of the robot */
50         buf[0] = 0x00;
51         buf[1] = 0x01;
52         buf[2] = decimal_to_hex(left_speed);
53     } else {
54         buf[0] = 0x00;
55         buf[1] = 0x00;
56         buf[2] = decimal_to_hex(left_speed);
57     }
58     /* Left motor write data*/
59     /* Address of the I2C motordriver on the robot is 0x10 */
60     i2c_write(i2c_dev, buf, 3, 0x10);
61 }
```

Function to control one motor

If function accepted negative value change direction of the rotation.

Make package to send using buf[] array

Else, if function accepted positive value, rotate wheel forward

Send buf[] array to the I2C device



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Coding Zephyr* application (main.c)

```
80 /* Line follower algorithm for the robot */
81 void line_follow(void)
82 {
83     if ((left_line[0] == 0) && (right_line[0] == 0)) {
84         motor_left_control(200);
85         motor_right_control(200);
86     } else {
87         if ((left_line[0] == 0) && (right_line[0] == 1)) {
88             motor_left_control(0);
89             motor_right_control(200);
90             if ((left_line[0] == 1) && (right_line[0] == 1)) {
91                 motor_left_control(0);
92                 motor_right_control(200);
93             }
94         } else {
95             if ((left_line[0] == 1) && (right_line[0] == 0)) {
96                 motor_left_control(200);
97                 motor_right_control(0);
98                 if ((left_line[0] == 1) &&
99                     (right_line[0] == 1)) {
100                     motor_left_control(200);
101                     motor_right_control(0);
102                 }
103             }
104             if ((left_line[0] == 1) &&
105                 (right_line[0] == 0)) {
106                 motor_left_control(200);
107             } else {
108                 motor_right_control(0);
109             }
110         }
111     }
112 }
```

Function to follow the line

If both sensors detected black line, go forward

Else, if right sensor detected white, and left is still on black, turn left

If data changed fast and sensors now both on black line, then continue turn left

Else, if left sensor detected white, and right is still on black line, turn right

If data changed fast and sensors now both on black line, then continue turn left

If left sensor is still detecting white, and right is still on black line, turn right using only left motor

Else, stop only right motor



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Build and upload Zephyr* binary

1. Clone the Zephyr repo from Github* and setup development system as described below: https://docs.zephyrproject.org/latest/getting_started/index.html
2. Connect micro:bit to the computer using micro-USB cable.
3. Build application using `$west build` command



```
[maksim@maksim-nuc zephyr]$ pwd
/home/maksim/zephyrproject/zephyr
[maksim@maksim-nuc zephyr]$ west build -p -b bbc_microbit samples/boards/bbc_microbit/line_follower_robot/
```

```
[126/131] Linking C executable zephyr/zephyr_prebuilt.elf
Memory region  Used Size  Region Size  Wago Used
FLASH:         17484 B    256 kB      6.67%
SRAM:          3248 B     16 kB      32.03%
IDT_LIST:       88 B      2 kB      4.36%
[131/131] Linking C executable zephyr/zephyr.elf
```

4. Flash Zephyr image to the micro:bit board using `$west flash` command

```
[maksim@maksim-nuc zephyr]$ west flash
-- west flash: rebuilding
ninja: no work to do.
-- west flash: using runner pyocd
-- runners.pyocd: Flashing file: /home/maksim/zephyrproject/zephyr/build/zephyr/zephyr.hex
[*****] 100%
0003119:INFO:loader:Erased 18432 bytes (18 sectors), programmed 18432 bytes (18 pages), skipped 0 bytes (0 pages)
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```



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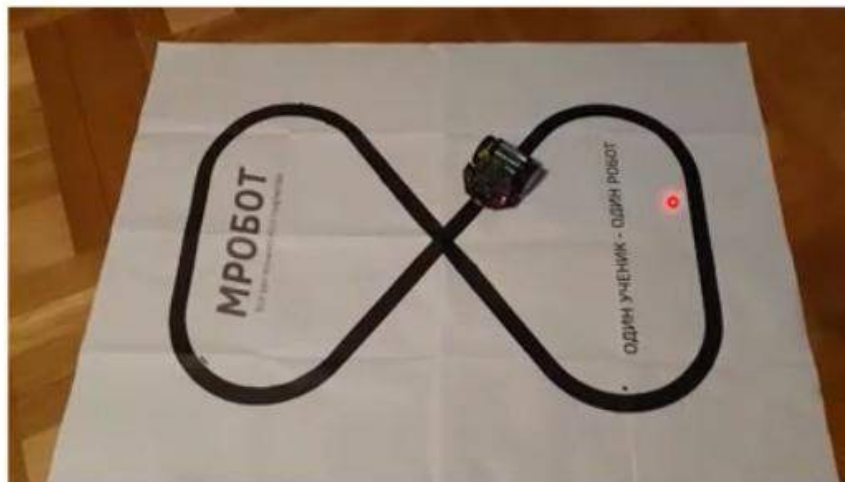
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[NEW QUESTION](#)**VIDEO**

Running the application

Turn on the robot, and place it on the track, it will follow the line as shown in the video below:

<https://www.youtube.com/watch?v=tlvoHQjo8a4>



Join the Zephyr* project:

<https://github.com/zephyrproject-rtos/zephyr>



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Resources

Zephyr* Project Website: <https://zephyrproject.org>

Documentation: <http://docs.zephyrproject.org> (Getting Started Guide)

Source Code: <https://github.com/zephyrproject-rtos/zephyr> is the main repository; <https://elixir.bootlin.com/zephyr/latest/source> contains a searchable index

Releases: <https://github.com/zephyrproject-rtos/zephyr/releases>

Samples and example code: see [Sample and Demo Code Examples](#)

Mailing Lists: users@lists.zephyrproject.org and devel@lists.zephyrproject.org user and developer mailing lists

Nightly CI Build Status: <https://lists.zephyrproject.org/g/builds>

Chat: Zephyr's Slack workspace is <https://zephyrproject.slack.com>. Use this <https://tinyurl.com/y5glwylp> to register.

Issues: <https://github.com/zephyrproject-rtos/zephyr/issues>

Security Issues: Email vulnerabilities@zephyrproject.org to report security issues

Thank you for your attention!

Maksim Masalski
maksim.masalski@intel.com



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