

KILOBOT

user manual



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Trademark Acknowledgements:

IBM PC : International Business Machines Corp.
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LabVIEW : National Instruments Corp.
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Webots : Cyberbotics Ltd
Logitech : Logitech Int. SA
Gumstix : Gumstix Inc.
Khepera : K-Team SA
V-REP : Coppelia Robotics

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- The contents of this manual are subject to change without notice
- All efforts have been made to ensure the accuracy of the content of this manual. However, should any error be detected, please inform K-Team.
- The above notwithstanding, K-Team can assume no responsibility for any error in this manual.

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1. INTRODUCTION

Thank you for buying Kilobot robots!

Kilobots are low cost robots designed at Harvard University's Self-Organizing Systems Research Lab <http://www.eecs.harvard.edu/ssr>. The robots are designed to make testing collective algorithms on hundreds or thousands of robots accessible to robotics researchers.

Though the Kilobots are low-cost, they maintain abilities similar to other collective robots. These abilities include differential drive locomotion, on-board computation power, neighbor-to-neighbor communication, neighbor-to neighbor distance sensing, and ambient light sensing. Additionally they are designed to operate such that no robot requires any individual attention by a human operator. This makes controlling a group of Kilobots easy, whether there are 10 or 1000 in the group.

You can find more information directly on the designer website:

<http://www.eecs.harvard.edu/ssr/projects/progSA/kilobot.html>

1.1 How to use this handbook

This handbook introduces the Kilobot and its various operating modes. For a quick start, jump to chapter 4 "USAGE".

If this handbook does not answer one of the problems you wish to solve, please consult the K-Team web site (<http://www.k-team.com>) and especially the Forum and the FAQs.

- **Unpacking and Inspection** : Kilobot package description and first use.
- **Description** : Kilobot description.
- **Usage** : Kilobot usage descriptions.
- **Annexes** : Examples of source code.

1.2 Safety precautions

Here are some recommendations on how to correctly use the Kilobot:

- **Keep the board away from wet area.** Contact with water could cause malfunction and/or breakdown.
- **Store your board in a stable position.** This will avoid the risks of falling, which could break it or cause damage to a person.
- **Do not plug any connectors while the board is powered on.** To avoid any damage, make all connections when the board power is off.
- **Keep the board away of conducting materials.** To avoid any short-circuit and damage to the robots, avoid contact with metallic lonely wires and other conducting materials.

1.3 Recycling

Think about the end of life of your product! Parts of the board can be recycled and it is important to do so. By recycling you can help to create a cleaner and safer environment for generations to come. For those reasons please take care to the recycling of your product at the end of its life cycle, for instance sending back the product to the manufacturer or to your local dealer.

Thanks for your contribution to a cleaner environment!

1.4 Specifications

The main specifications of the Kilobot robot are listed below:

- Processor : ATmega 328p (8bit @ 8MHz)
- Memory :
 - 32 KB Flash
 - 1KB EEPROM
- Battery/ autonomy: Rechargeable Li-Ion 3.7V / 3-10 hours continuously, 3 months in sleep mode
- Charging : Kilobot charger for 10 robots simultaneously (optional)
- Communication : IR (up to 7cm, up to 32kb/s and 1kbyte/s with 25 robots), serial (256000 baud)
- Sensing : 1 IR and 1 light intensity
- Movement : forward, rotation (1cm/s , 45deg/s)
- Light : one RGB led
- Software : Kilobot Controller software for controlling the robot
- Programming : C language with WinAVR compiler combined with AvrStudio
- Dimensions : diameter: 33 mm, height 34 mm (including the legs, without recharge antenna).

2. UNPACKING AND INSPECTION

2.1 Package Contents

They are 3 different packages sold separately. They are containing the following items:

- The robot package:
 - 1 CD-ROM*
 - 10 Kilobot robots
- The overhead controller package:
 - 1 overhead controller
 - 1 CD-ROM*
 - 3 cables (1 usb, a 6-wire cable and a 2-wire cable)
- The charger package:
 - 1 charger
 - 1 transformer
 - 1 CD ROM*

* If multiple packages are ordered together, only one CD-ROM will be shipped.

2.2 Inspection

The material should be checked after unpacking.

For the Kilobots robots, check that their legs are not bended. The charging tab also must not be bended. The jumper and the battery should be present (see figure 3.1). The battery should be plugged with the negative on top (opposite of the battery holder +/- marks).

For the Overhead controller, check that the LEDS are not bended or broken. The jumper for firmware programming should be present (see figure 3.2).

3. DESCRIPTION

3.1 Overview

3.1.1 Kilobot robot

An overview of the Kilobot hardware is depicted in the Figure 3.1. The locations of various key elements are indicated for later references.

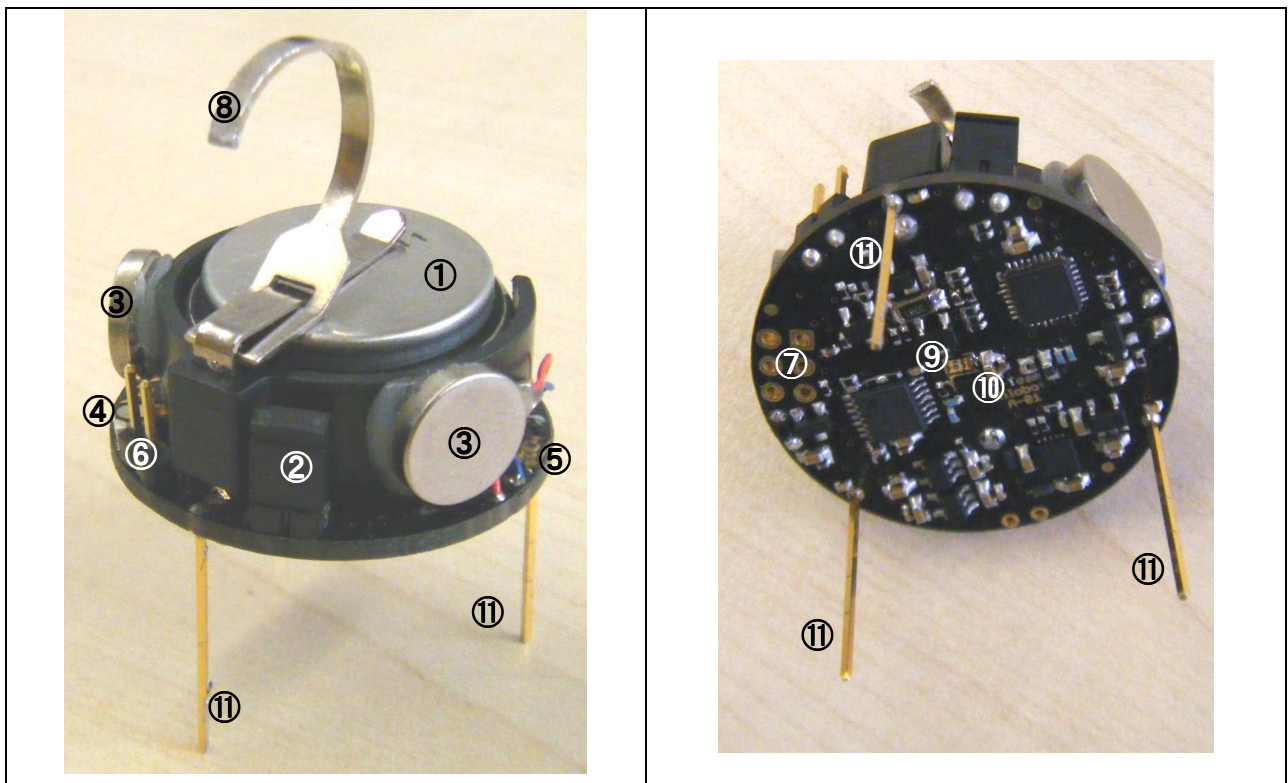


Figure 3.1: Kilobot overview

- | | |
|-----------------------------------|-----------------------------|
| ① 3.7-Volt Battery (- up, + down) | ⑦ Direct programming socket |
| ② Power jumper | ⑧ Charging Tab |
| ③ Vibration motors | ⑨ IR Transmitter |
| ④ LED (Red/Green/Blue) | ⑩ IR Receiver |
| ⑤ Ambient light sensor | ⑪ Robot leg |
| ⑥ Serial output header | |

3.1.2 Overhead controller (OHC)

An overview of the Kilobot Overhead controller (OHC) is depicted in the Figure 3.1. The locations of various key elements are indicated for later references.

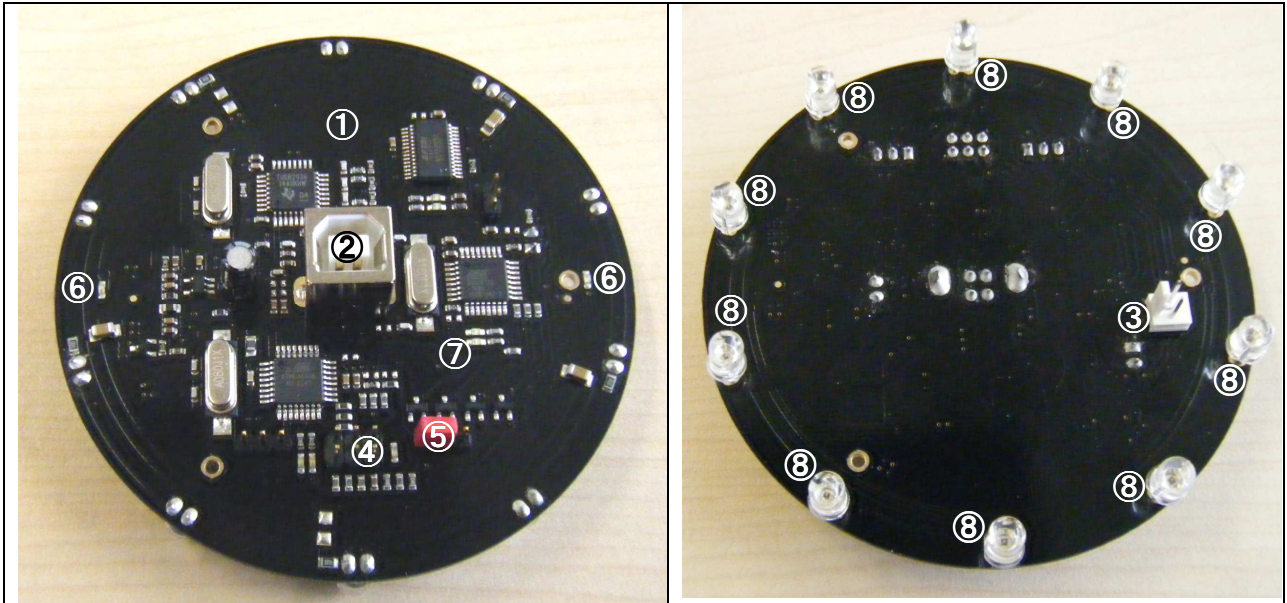


Figure 3.2: Overhead controller overview

- | | |
|--------------------------------------|---------------------------------|
| ① Overhead controller board | ⑤ Firmware programming jumper |
| ② Connector for USB cable | ⑥ Diode for OHC connection test |
| ③ Connector for debug cable | ⑦ Power on LED |
| ④ Connector for firmware programming | ⑧ IR LED |

3.2 Kilobot Hardware

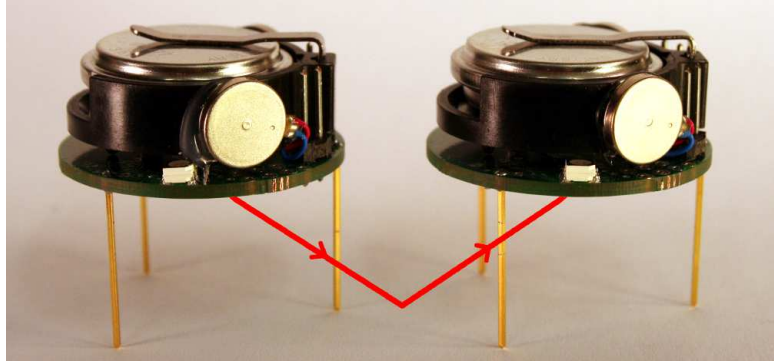
The hardware of the **Kilobot** is described thereafter.

The robot has a microcontroller ATmega 328p (8bit @ 8MHz) as CPU. It contains these following types of memory:

- 32 KB Flash used for both user program and bootloader
- 1KB EEPROM for storing calibration values and other non-volatile data and 2KB SRAM.

Its other features are described in detail below:

- Battery : Rechargeable Li-Ion 3.7V, for a 3 months autonomy in sleep mode. Each Kilobot has a built-in charger circuit, which charges the onboard battery when +6 volts is applied to any of the legs, and GND is applied to the charging tab.
- Charging : Kilobot charger (optional)
- Communication : Kilobots can communicate with neighbors up to 7 cm away by reflecting infrared (IR) light off the ground surface.



- Sensing :
 - When receiving a message, distance to the transmitting Kilobot can be determined using received signal strength. The distance depends on the surface used as the light intensity is used to compute the value.
 - The brightness of the ambient light shining on a Kilobot can be detected.
 - A Kilobot can sense its own battery voltage.
- Movement : Each Kilobot has 2 vibration motors, which are independently controllable, allowing for differential drive of the robot. Each motor can be set to 255 different power levels.

3. DESCRIPTION

- Light : Each Kilobot has a red/green/blue (RGB) LED pointed upward, and each color has 3 levels of brightness control.
- Software : The Kilobot Controller software is available for controlling the controller board, sending program files to the robots and controlling them.
- Programming : For programming, the open source development software WinAVR combined with AvrStudio from Amtel gives a C programming environment. An API with basic functions such as motor speed, led control, distance measurement,... is available and some examples are provided.
- Debug : A serial output header is available on each robot for debugging via computer terminal.

4. USAGE

4.1 Required hardware / software

The required hardware and software to use the board and develop programs are described below.

4.1.1 Required hardware:

- Computer with Microsoft Windows and an USB port (not included)
- Kilobot robot
- Over-head controller (OHC)
- Kilobot charger

4.1.2 Required software:

Required files:

- Microsoft .NET Framework 2.0 Service Pack 2
<http://www.microsoft.com/en-us/download/details.aspx?id=1639>

These files are included in the delivered from the CD_ROM:

- The compiler WINAVR:
software\compiler\WinAVR-20100110-install.exe
- The editor AVR Studio 4:
software\editor\avrstudio4.19setup.exe
- Kilobot controller and programming skeleton project files (VERSION is the version of the files):
software\source_code\KilobotController_VERSION.zip

This archive contains:

- *dev/* development directory
- *dev/default/* compiled object and program directory
- *dev/KilobotSkeleton.aps* AVR Studio editor project configuration
- *dev/KilobotSkeleton.aws* AVR Studio editor workspace file

- *dev/KilobotSkeleton.c* source code skeleton where you start programming
 - *dev/libkilobot.c* kilobot library source code
 - *dev/libkilobot.h* kilobot library source code header
 - *FTDI32/* directory for 32 bit driver for USB driver
 - *FTDI64/* directory for 64 bit driver for USB driver
 - *STK500/* directory for Atmel AVR Flash
 - *Controller.hex* controller normal firmware
 - *KiloBot Controller.exe* Kilobot Controller program
 - *KilobotFirstFirmware.hex* robot first firmware
 - *Kilobot_motor_cal.hex* robot calibration program
 - *OHC_motor_cal.hex* controller "motor calibration" firmware
 - *Program.hex* copied current robot program
 - *Readme.txt* readme
-
- RealTerm terminal for debugging:
software\terminal\Realterm_2.0.0.70_setup.exe

4.2 Installation

The following sub-chapters explain the software and installations.

4.2.1 Install the software

1. Install WINAVR compiler if not already done.
2. Install also AVR Studio 4 editor.

If you did not install WINAVR in the default install directory (*C:\WinAVR-20100110*), you will have to tell AVR studio where is the compiler and the maker:

In AVR Studio “Project” menu, select “Configuration Options” sub-menu and choose the “Custom Option”. Under “External tools”, with the button on the bottom right, select for *avr-gcc* the file *avr-gcc.exe* in the *WinAVR-20100110\bin* directory and for *make* the file *make.exe* in the directory *WinAVR-20100110\utils\bin* .

3. Decompress *KilobotController_VERSION.zip* in *c:*

4.2.2 Overhead Controller (OHC) Software Installation

1. Open *KilobotController.exe* from *c:\KilobotController*.
2. In the Help menu of *KilobotController.exe*, select “Installation and programming” and follow the instructions to install the software and drivers (Fig 4.1).

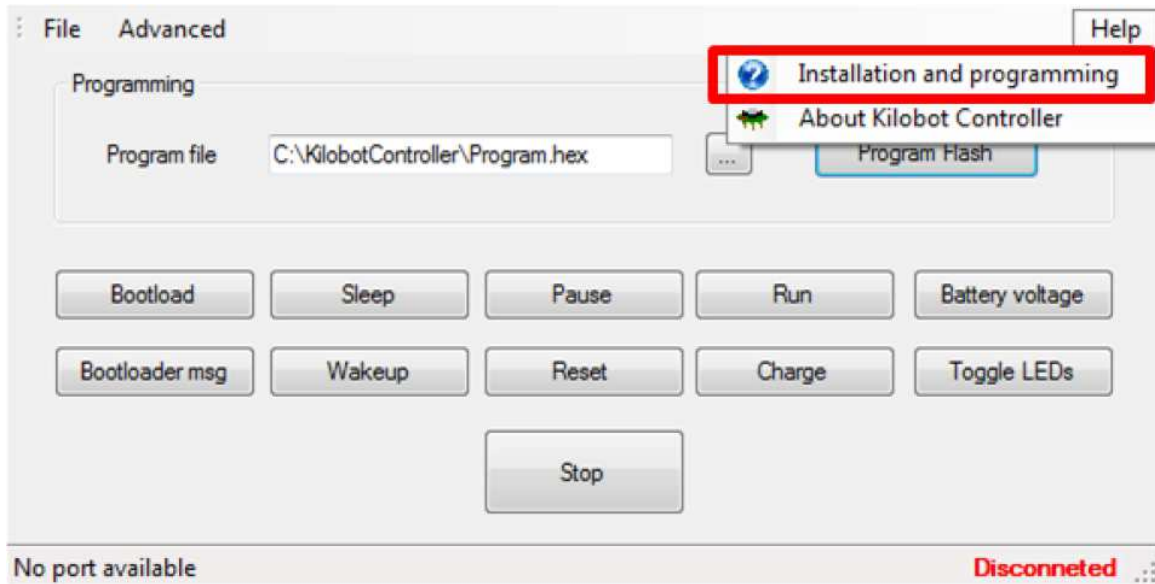


Figure 4.1: OHC software

4.2.3 Overhead Controller (OHC) Hardware Installation

1. Check that the firmware jumper is plugged at the correct place (figure 4.6).
2. Connect the USB cable to the PC; the power LED of the OHC should turn green.
3. Run the *KilobotController.exe* program, and click the “Toggle LEDs” button to test that a connection is made (Fig 4.2). This should blink the red LEDs on the controller.

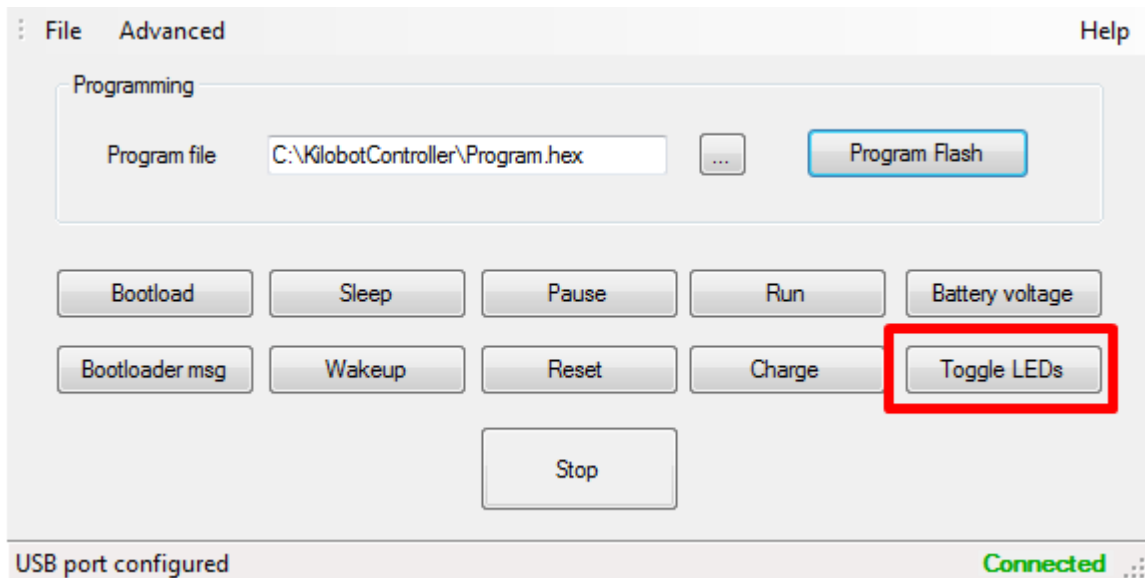


Figure 4.2: OHC software buttons

4.2.4 Kilobot bootloader programming

The Kilobot is delivered with a bootloader already installed. Therefore this step can be **SKIPPED**. But If you would like to reinstall the bootloader or install a newer one, follow the instructions below.

1. In AVR Studio, select Tools->ProgramAVR->Autoconnect .
2. In the window that pops up, under the program tab, in the flash category select the input hex file to be *KilobotFirstFirmware.hex*.
3. Put the firmware programming jumper of the OHC in the “firmware mode” position and connect the firmware cable (figure 4.3).

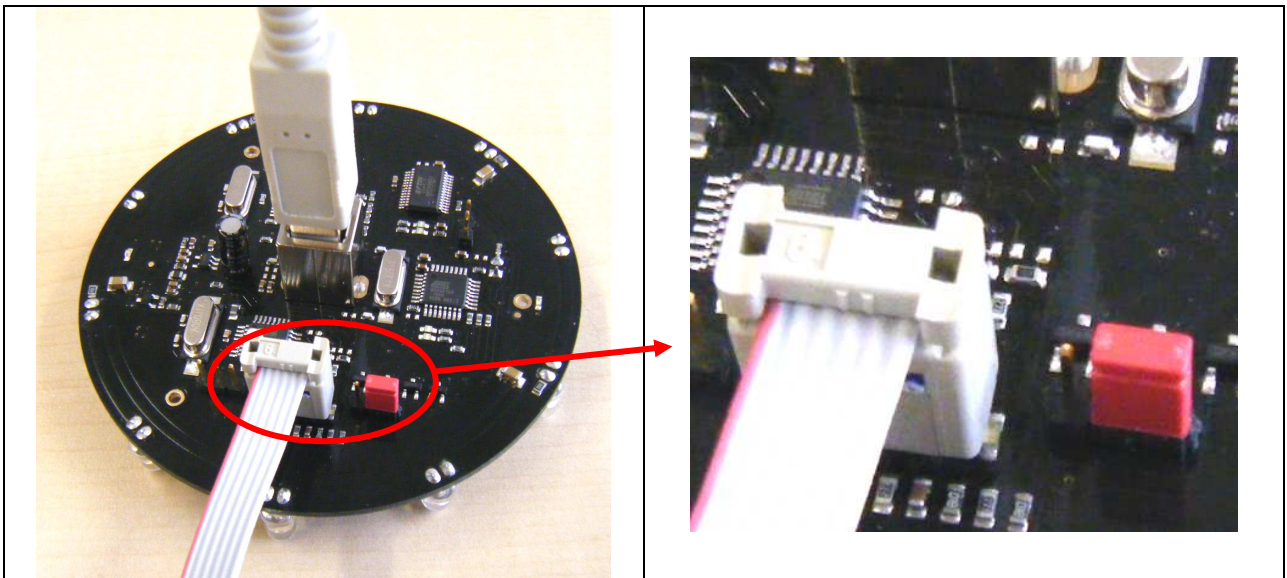


Figure 4.3:firmware cable and jumper in firmware mode

4. Turn on the robot by adding the power jumper as shown in figure 4.4.

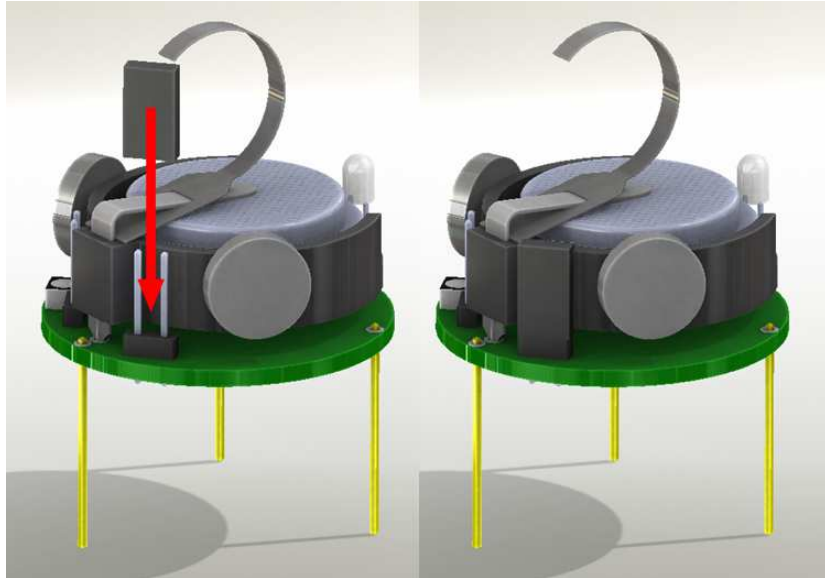


Figure 4.4: power jumper

5. Connect the AVRisp programmer to the robot as shown in figure 4.5. Make sure that the programmer pins do not touch the motor on the back side. Gently press the program cable to the side to ensure a good connection.

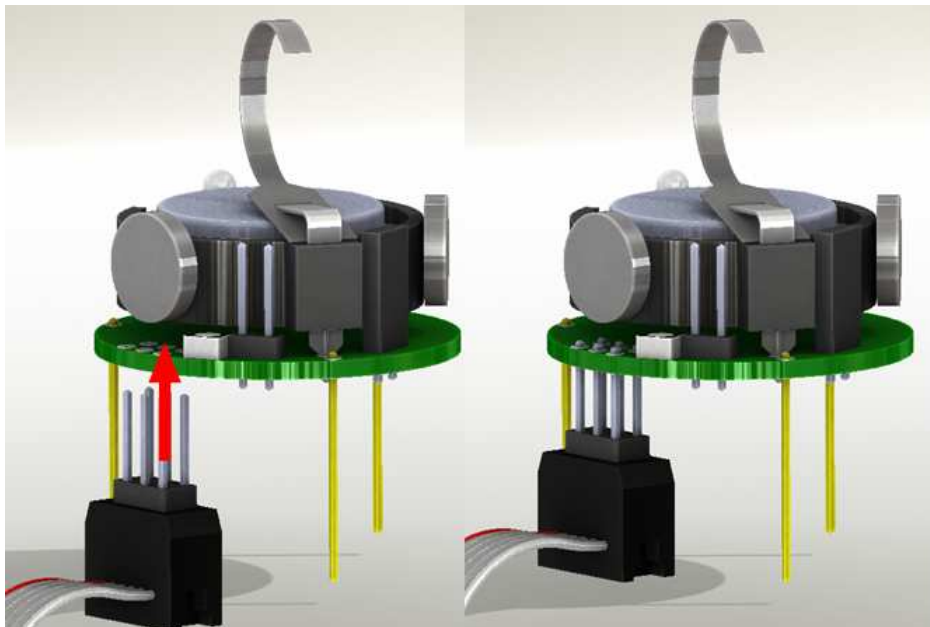


Figure 4.5: communication connector

6. Set robot fuses: In Avr studio AVRISP programming window, go to the fuses tab. Select only the following fuses: spien, EESAVE, BOOTSZ (boot flash size 2048 word, start address = $\$3800$) , SUT_CKSEL (int. RC Osc. 8 MHz; start-up time PWRDWN/RESET: 6 CK/14CK +65 ms). This should result in the following fuse values: extended=0xFF, high=0xD1, low=0xE2
7. In the Autoconnect pop-up window in AVRstudio, press program. It should take a few seconds to program the robot, and the robot may vibrate.
8. Put the firmware programming jumper of the OHC in the back to the standard position.

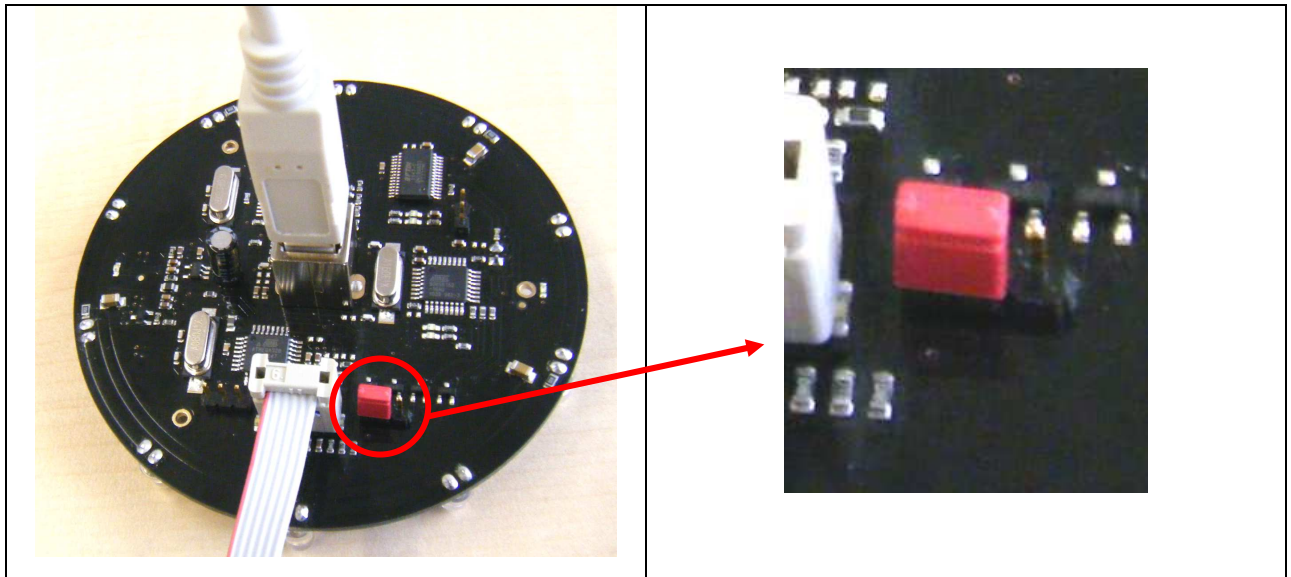


Figure 4.6: firmware jumper: normal mode

4.3 Usage

4.3.1 Programming a kilobot group with a new program

1. In `c:\KilobotController\dev\` double-click on *Kilobot.aps* for opening the project
2. In *KilobotSkeleton.c* locate the following section

```

////////////////////////////////////
//user program code goes here. this code needs to exit in a reasonable amount of time
//so the special message controller can also run
////////////////////////////////////

```

3. Immediately after this is where the user code is written. Note that the user code should not contain long blocking functions; otherwise the robot may not respond to the overhead controller properly.
4. Once program is written, in AVRstudio select Build->build.
5. Run *KilobotController.exe*, click the button to browse for a program file as shown and select the program [.hex] file you just built (located at `c:\KilobotController\dev\default\KilobotSkeleton.hex`).

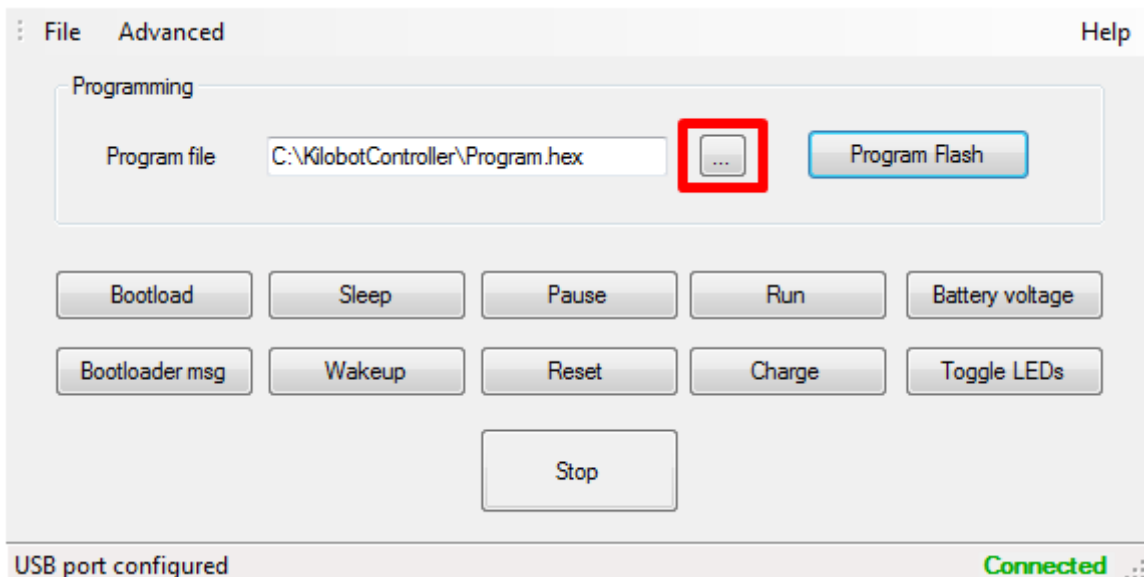


Figure 4.7 : Kilobot Controller software

6. Press the “Program Flash” button to program the OHC (a black window will pop up).
7. Place ALL Kilobot robot in PAUSE mode (LED flashing yellow) underneath the OHC, and press the “Bootload” button in *KilobotController.exe*. The Kilobot will first quickly flash red->green->blue, to indicate it is now in the PROGRAMMING mode. Within 5 seconds, the LED will begin to flash blue and continue flashing while it is receiving the new program. Once the LED has stopped flashing blue and switch to the flashing yellow

of pause mode (approximately 30 seconds), press the “Stop” button in *KilobotController.exe*.

8. To run the program on the robot, press the “Run” button in *KilobotController.exe*. The new program should execute.
9. Press the “Pause” button in *KilobotController.exe* to stop the program. (Note: the robot needs to be in pause mode before programming can begin).

You can find in annex 5.1 examples of source code.

4.3.2 OHC Use

System Setup

Kilobots should be operated on a smooth, flat surface to ensure proper robot mobility. To aid communication, the surface should be glossy or reflective. A mirror or dry-erase whiteboard oriented horizontally is recommended.

The overhead controller should be hung above the Kilobots at a distance of about one meter. The robots beneath the OHC in a about a one meter diameter region will be able to receive communication from the OHC as shown in figure 4.8.

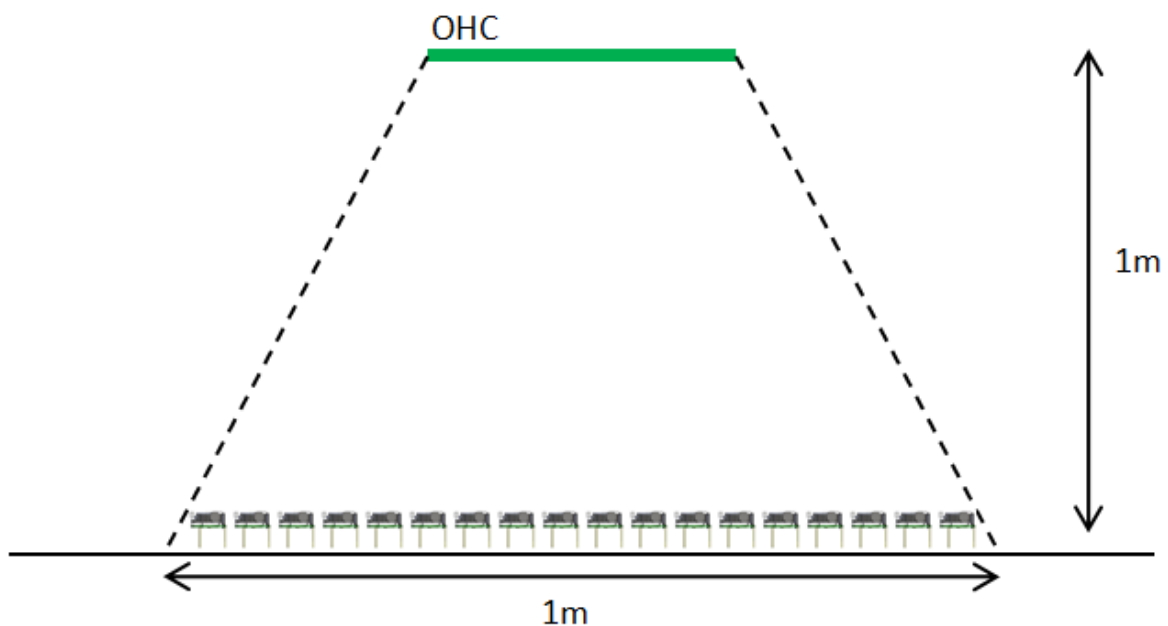


Figure 4.8: System setup

Overhead Controller (OHC) Interface Overview

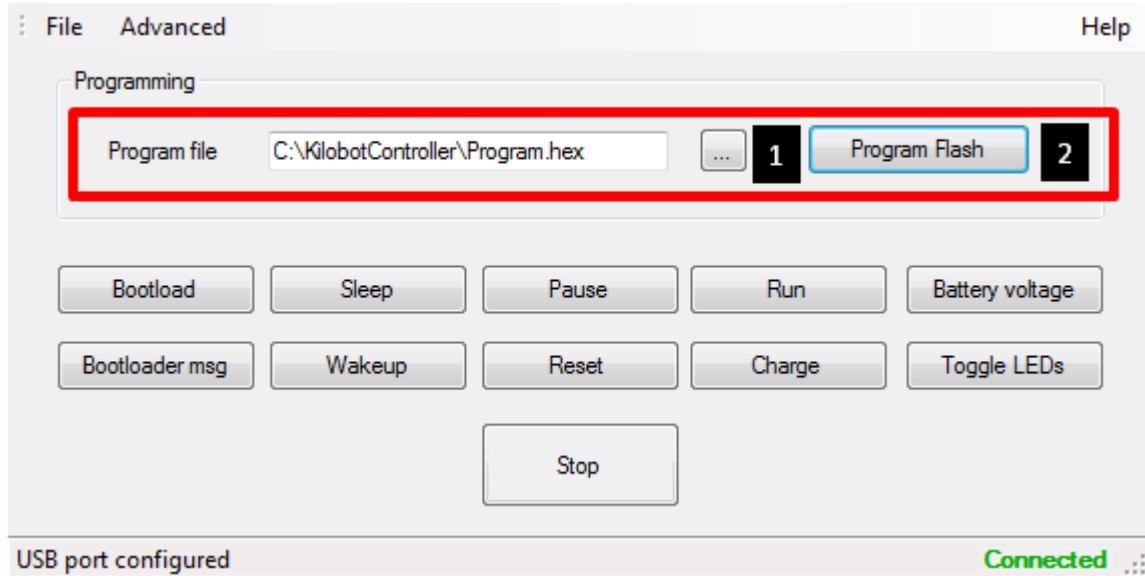


Figure 4.9: Programming Panel

1. Program file: browse for the compiled Kilobot user program [.hex] file to be sent to the Kilobots (usually in `c:\KilobotController\dev\default`).
2. Program Flash: send the program and controller files to the OHC.

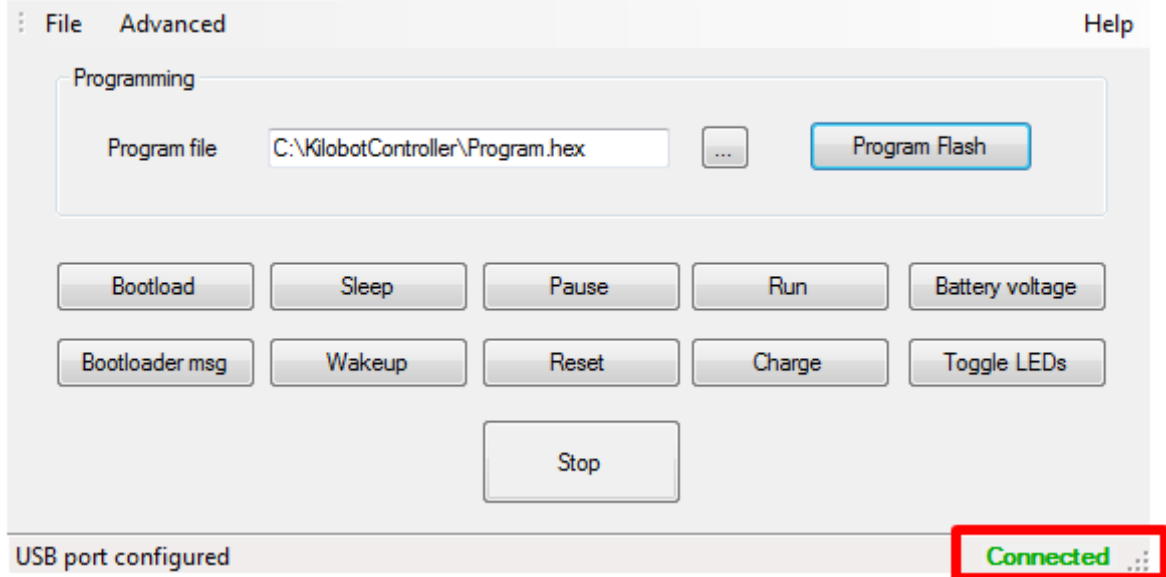


Figure 4.10: Connection Status

You can see if the OHC is connected to the pc or not (fig 4.10).

Below in figure 4.11 is the Button Panel with a description of the buttons functionality.



Figure 4.11: Button Panel

1. **Bootload:** transmit the kilobot user program from the OHC to the Kilobots, which takes about 30 seconds. Ensure all robots are in pause mode before bootloading.
2. **Sleep:** put Kilobots in low-power SLEEP mode. They will wake up briefly every 60 seconds to check if a wakeup message is being sent. The robots conserve energy in this mode and can stay in sleep for months without recharging.
3. **Pause:** put Kilobots in idle PAUSE mode, and is also used to prepares robots to be reprogrammed.
4. **Run:** initiates Kilobots user program.
5. **Battery Voltage:** instructs Kilobots to indicate their battery voltage through the LED. where green indicates a battery voltage over 4V, blue indicates a voltage between 3.75 and 4, yellow indicates a voltage between 3.5 and 3.75, and red indicates a voltage under 3.5 volts .
6. **Bootloader msg:** sends a message for all robots to exit their program and jump to the bootloader.
7. **Wakeup:** take Kilobots out of low-power SLEEP mode. This message will transmit until stop is pressed. It will take a minute or two for all the robots to wake up.
8. **Reset:** restarts the Kilobot program.
9. **Charge:** instructs Kilobots to enter CHARGE mode for battery recharging. The robots will stop the user program and blink red if they are actively charging, if not, the RGB led will turn off.
10. **Toggle LEDs:** flashes the LEDs on the OHC.
11. **Stop:** stops whatever the OHC is doing. This can be used to stop functions that are continuous such as wakeup or bootloading.

4.3.3 Charger

A charger for up to 10 Kilobots is available as an optional item.

1. Put the Kilobots charger on a flat surface, having the bar with the red indicator below and the black above.
 WARNING: if the color position is not respected, that will not work and may damage the charger or the robots.
2. Plug the Kilobots charger transformer to the charger and to a power socket. Pay attention to the polarization (+ outside, - inside).
 WARNING: if the polarization is not respected, that will not work and may damage the charger or the robots.
3. Switch the Kilobots on (put the power jumper as in figure 4.4).
4. Pay attention to respect the bar side and the cable polarization as explained above in 1) and 2), Then hang the Kilobots as specified in the figure below. The bar with the red indicator is in contacts of the legs of the robots and is the positive.
5. With the Kilobot Controller, push the **Charge** button. The robot will stop the current program and enter in charge mode indicated by a blinking red. If the charge is done, the RGB led will turn off.
6. After the charge is finished, you can remove the robots from the charger and use them as normal with the Kilobot Controller (push the **Pause** button to go back to pause mode).

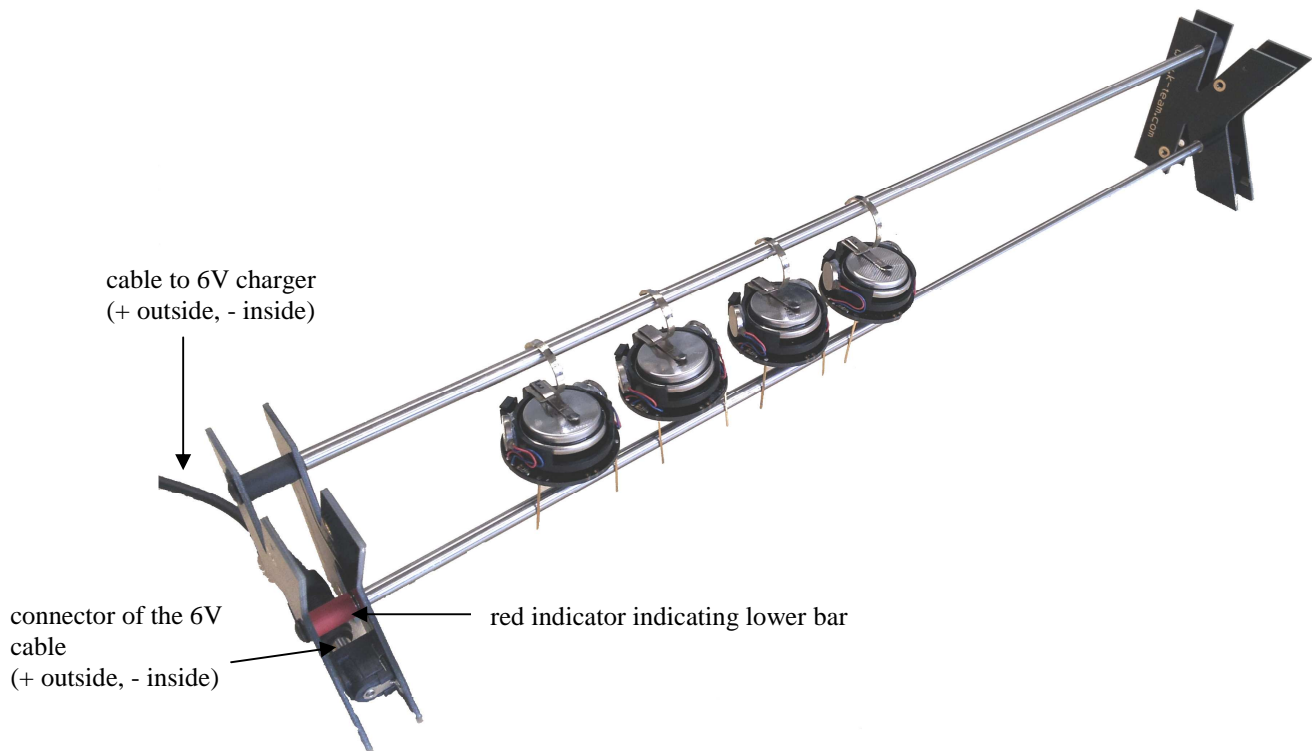


Figure 4.12: Kilobots on charger

4.3.4 Debugging

With the *kprinti()* and *kprints()* functions, you can get a feedback from the robot. You must connect the robot to the OHC with the 2-wire cable, respecting the polarity on the robot as shown in the figure below (see figures 3.1 and 3.2 for the connectors place).

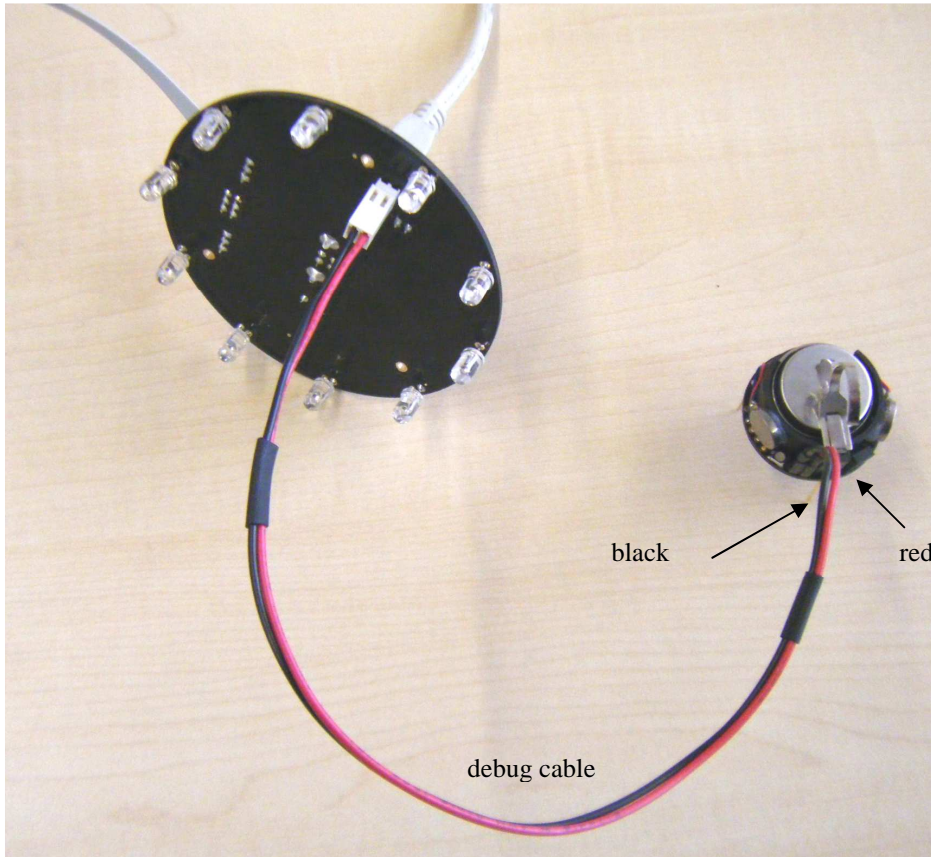


Figure 4.13 Debug settings

1. Install Realterm, a terminal that can use alternate baud rates.
2. Launch your program with the “Run” button of the Kilobot Controller.
3. Close the Kilobot Controller if it is open.
4. Find the USB serial port number used by the OHC in the Device Manager of your computer.
5. Connect Realterm to the number of the USB serial port found above with a baud rate of 256000.

4.3.5 Kilobots API

The different functions specially developed for the Kilobots are explained below. Numerous other functions and AVR-C programming examples can be found on the web.

- **set_motor**(*cw_motor*,*ccw_motor*)

Set motor speed PWM values for motors between 0 (off) and 255 (full on) for *cw_motor* and *ccw_motor*

Examples:

- for moving forward: **set_motor**(*cw_in_straight*, *ccw_in_straight*);
- for turning right: **set_motor**(*cw_in_place*, 0);
- for turning left: **set_motor**(0, *ccw_in_place*);
- **set_motor**(100, 100);

Note that there are 4 calibration values used with the motors

cw_in_place: value for cw motor to turn the robot cw in place (note: ccw motor should be off)

ccw_in_place: value for ccw motor to turn the robot ccw in place (note: cw motor should be off)

cw_in_straight: value for the cw motor to move the robot in the forward direction

ccw_in_straight: value for the ccw motor to move the robot in the forward direction

- **_delay_ms**(*x*)

Busy wait for *x* milliseconds, interrupts can still trigger

//max value for milliseconds = 4000

Example:

```
_delay_ms(250);
```

- **set_color**(*r,g,b*)

Set LED color, values can be from 0(off)-3(brightest)

Example:

```
set_color(1,1,1);
```

- **kprinti**(*int*)

Print integer over serial port - be careful can effect timing!

Example:

```
kprinti(12);
```

- **kprints**(*string*)

Print string up to 10 characters - be careful, can effect timing!

Example:

```
kprints("HelloWorld");
```

- **message_out(tx0,tx1,tx2)**

Set message values to be sent over IR every .2 seconds, 3 bytes *tx0,tx1,tx2* (*tx2 lsb must not be used*).

Example:

```
message_out(0x01,0xFF,0xFE);
```

- **get_message()**

Take oldest message off of rx buffer message. It is only new if *message_rx[5]==1* ! If so, message is in *message_rx[0]* and *message_rx[1]*; distance to transmitting robot (in mm) is in *message_rx[3]*. The distance depends on the surface used as the light intensity is used to compute the value.

Example:

```
get_message();  
if(message_rx[5]==1)  
{  
  data=message_rx[0];  
  distance=message_rx[3];  
}
```

- **enable_tx**

to turn off the transmitter, set *enable_tx = 0*

to turn on the transmitter, set *enable_tx = 1*

Example:

```
if(Want_To_Transmit==TRUE)  
  enable_tx = 1;  
else  
  enable_tx = 0;
```

- **measure_charge_status()**

Measure if battery is charging, returns 0 if no, 1 if yes

Example:

```
if(measure_charge_status())  
  charging = TRUE;  
else  
  charging = FALSE;
```

- **measure_voltage()**

Measure battery voltage, returns voltage in .01 volt units for example if 394 is returned, then the voltage is 3.94 volts

Example:

```
current_voltage = measure_voltage();
```

- **get_ambient_light()**

Returns the value of ambient light

note: will return -1 if there is an incoming message (which also uses a/d)

note: turns off interrupts for a short while to sample a/d

Example:

```
local_brightness = get_ambient_light();
```

4.3.6 Motors calibration

If you see that the robot is no more moving forward and does not rotate well anymore, you can try to recalibrate its motors with the instructions below. But as already said before, the Kilobot should be operated on a smooth, flat surface to ensure proper robot mobility.

1. Upload the motors calibration receiver program *Kilobot_motor_cal.hex* to the robot.
2. Choose the calibration transmitter program *OHC_motor_cal.hex* to the OHC with the advanced menu “Select alternative controller file” and push “Program flash button to reprogram the Kilobot Controller in motor calibration mode (Figure 4.14).
3. In the OHC software, select the “Motor calibration” sub-menu of the advanced menu.

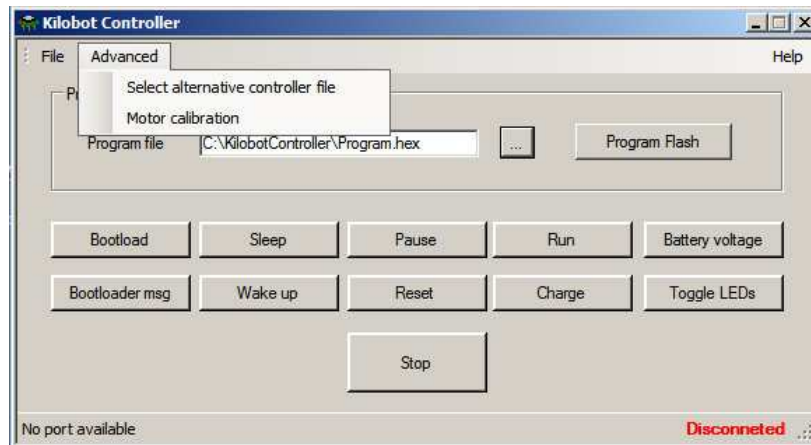


Figure 4.14: Advanced menu

4. Place the Kilobot under the OHC, and push the button "More cw" or "Less cw" to adjust the calibration of the clock wise rotation for the robot.

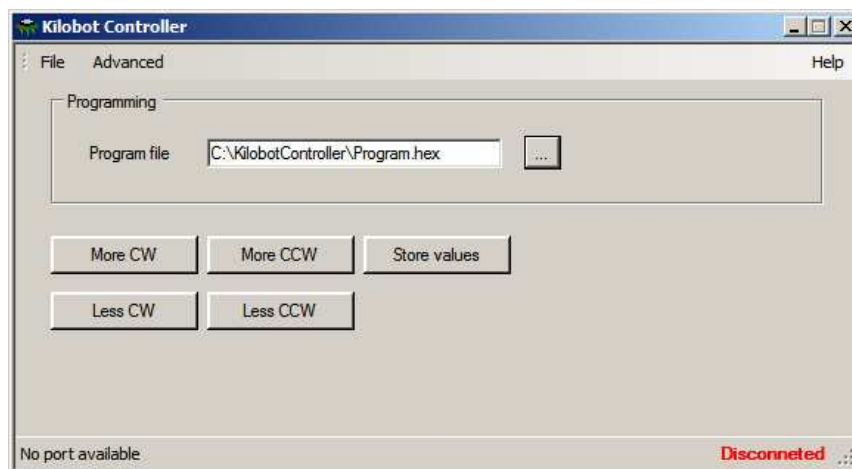


Figure 4.15: Motors calibration

5. When clock wise rotation is good, click "More CCW" once. Now you can use the "more CCW" and the "Less CCW" buttons to calibrate the robots CCW rotation.

6. When CCW rotation is good, click the "More cw" button once. Now you can use the "More CCW", "Less CCW", "More CW", "Less CW" buttons to adjust the robots straight calibration value.
7. When the robots straight movement is good, click "Store values". The robot will store calibration values in EEPROM, and then go to sleep. The motors are now calibrated.

WARNING: Don't switch off the robot now otherwise it will go back to calibration mode when rebooting.

8. When done, be sure to load Controller.hex back into the OHC with the Advanced menu "Select alternative controller file".
9. Push wake-up button on the OHC.
10. Program the robot with the *KilobotFirstFirmware.hex* or your program.
11. You can switch off the robot now or put it in sleep mode.

4.3.7 Simulation

You can simulate the Kilobot robot with V-REP, a power physics simulator software. An educational version is available for free at: <http://www.coppeliarobotics.com/downloads.html>

The Kilobot model is already available for V-REP inside the simulator.

All the functions explained in chapter 4.3.5 “Kilobots API” are implemented.

- **get_ambient_light()** function is implemented only in the following because it takes 1.5 more time of simulation:

scene:

http://ftp.k-team.com/V-REP/models/Kilobot/scenes/Kilobots_light_intensity.ttt

model:

http://ftp.k-team.com/V-REP/models/Kilobot/models/Kilobot_light_intensity.ttm

- For the **_delay_ms(x)** function, as it must be non-blocking, you need to implement it like this for example **_delay_ms(50)**: use a state variable (here **substate**).

```
substate=0
```

```
...
```

```
function user_prgm()
```

```
...
```

```
-- wait 50 ms:
```

```
if (substate==0) then
```

```
    delay_start=simGetSimulationTime()
```

```
elseif (substate==1) then
```

```
    if (_delay_ms(50)==1) then
```

```
        -- waited
```

```
        substate=0
```

```
        -----
```

```
        -- here put the following of your code
```

```
        -----
```

```
    end
```

```
...
```


You can find some V-REP scenes with Kilobot examples there:

<http://ftp.k-team.com/V-REP/models/Kilobot/scenes>

- Kilobots_messages.ttt : 5 robots move and display their distances to each others with their led.
- Kilobots_messages.ttt : 4 robots send messages to each other to determinate the one that has the biggest id number.
- Kilobots_around.ttt : robots move around other static robots, keeping distance.

5. ANNEXES

5.1 Examples of source code

These examples of source code have different purposes described in their titles.

5.1.1 Transmits data to neighbors, and blinks led when the message is received:

```
...
message_out(255,255,0);//set message to be sent over IR
enable_tx=1;//enable transmission of message every .2 seconds

//check for message
get_message();
if(message_rx[5]==1)//new message has been received
{
    set_color(1,1,1);//turn RGB LED white
    kprinti(message_rx[0]);//send first byte of received message over serial debug
cable
    kprinti(message_rx[1]);//send second byte of received message over serial debug
cable
    kprinti(message_rx[3]);//send measured distance from transmitting robot over
serial debug cable
    kprints("      ");
    _delay_ms(10);//wait 10 ms
    set_color(0,0,0);//turn RGB LED off
}
```

5.1.2 Non-blocking timed movement:

```
...
static int mode=0;//mode represents state
if(clock<40000)
{
    //clockwise rotation
    if(mode!=0)
    {
```

```

        set_motor(0xa0,0);//spin up cw motor to overcome friction
        _delay_ms(30);
        set_motor(cw_in_place, 0);//set cw motor to calibrated value for good cw
rotation
        mode=0;
    }

}
else if(clock<80000)
{
    if(mode!=1)
    {
        //counter clockwise rotation
        set_motor(0,0xa0);//spin up ccw motor to overcome friction
        _delay_ms(30);
        set_motor(0, ccw_in_place);//set ccw motor to calibrated value for good
cw rotation
        mode=1;
    }

}
else if(clock<120000)
{
    if(mode!=2)
    {
        //move forward
        set_motor(0xa0,0xa0);//spin up both motors to overcome friction
        _delay_ms(30);
        set_motor(cw_in_straight, ccw_in_straight);//set both motor to calibrated
value for good forward movement
        mode=2;
    }
}
else if(clock<160000)
{
    if(mode!=3)
    {
        set_motor(0x00,0x00);//turn off motors
        mode=3;
    }
}
else if(clock<200000)
{
    mode=5;
    clock=0;//reset clock to start cycle over agian
}

```

5.1.3 Random move in see neighbors, stop else

```

static int one_time=0;
if(one_time==0)//if this is the start of the program, only run this if statement once
{
    for(int i=0;i<30;i++)
        randseed+=measure_voltage( );//generate some random sensor data
    one_time=1;//indicate that the first time if statement has now run
    srand(randseed);//seed random variable with some sensor data
}
static int neighbor=0;//1 if i've seen any neighbors, 0 if not
static int movement=0;//1 if moving, 0 if stopped
static int start_move=0;//1 if the movement has changed, 0 if not

//check to see if i have received any new messages, if so, then i have seen neighbors
get_message();
if(message_rx[5]==1)
    neighbor=1;

//if i am currently not moving, and want to start moving
if(start_move==1)
{
    if(movement==0)
    {
        set_motor(0xa0,0xa0);//spin up motors
        _delay_ms(30);
        set_motor(cw_in_straight, ccw_in_straight);//set to move straight
    }
    else if(movement==1)
    {
        set_motor(0, 0xa0);//spin up motor
        _delay_ms(30);
        set_motor(0, ccw_in_place);//set to move ccw
    }
    else
    {
        set_motor(0xa0,0);//spin up motor
        _delay_ms(30);
        set_motor(cw_in_place ,0);//set to move cw
    }
    start_move=2;//mark that i am currently moving
}
else if(start_move==0)//i do not want to move
{
    set_motor(0,0); //stop motors
}
//every 2000 counts of clock, check to see if i've seen any neighbors
//if i have, there is a 20% chance i will change my movement (such as straight to ccw)
if(clock>2000)
{

```

```

if((rand()%100)<20)//update robot movement 20% of the time
{
    int rand_d=rand()%100;
    if(rand_d<25)//if updating robot movement 25% of the time move ccw
    {
        if(movement!=1)
        {
            movement=1;
            if(start_move==2)
                start_move=1;
        }
    }
    else if(rand_d<50)//if updating robot movement 25% of the time move cw
    {
        if(movement!=2)
        {
            movement=2;
            if(start_move==2)
                start_move=1;
        }
    }
    else//if updating robot movement 50% of the time move straight
    {
        if(movement!=0)
        {
            movement=0;
            if(start_move==2)
                start_move=1;
        }
    }
}
//if i've received a message from a neighbor in the last 2000 counts of clock
//and i am not moving, start moving, and turn my rgb led red
if(neighbor==1)
{
    set_color(1,0,0);
    if(start_move==0)
        start_move=1;
}
else
{
    //if i have not received a message from a neighbor in the last 2000 counts of clock
    //stop moving, and turn my RGB led off
    set_color(0,0,0);
    start_move=0;
}
clock=0;//reset clock
neighbor=0;//reset neighbor count
}

```

6. WARRANTY

K-TEAM warrants that the Kilobot is free from defects in materials and workmanship and in conformity with the respective specifications of the product for the minimal legal duration, respectively one year from the date of delivery.

Upon discovery of a defect in materials, workmanship or failure to meet the specifications in the Product during the afore mentioned period, Customer must request help on K-Team Internet forum on <http://www.k-team.com/forum/> by detailing:

- the type of Kilobot used (version)
- the kernel version of the Kilobot
- the programming environment of the robot (standard, version, OS)
- the standard use of Product before the appearance of the problem
- the description of the problem.

If no answers have been received within two working days, Customer can contact K-TEAM support by phone or by electronic mail with the full reference of its order and Kilobot serial number.

K-TEAM shall then, at K-TEAM's sole discretion, either repair such Product or replace it with the equivalent product without charging any technical labor fee and repair parts cost to Customer, on the condition that Customer brings such Product to K-TEAM within the period mentioned before. In case of repair or replacement, K-TEAM may own all the parts removed from the defective Product. K-TEAM may use new and/or reconditioned parts made by various manufacturers in performing warranty repairs and replacement of the Product. Even if K-TEAM repairs or replaces the Product, its original warranty term is not extended.

This limited warranty is invalid if the factory-applied serial number has been altered or removed from the Product.

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