DT-ROBOT

Line Follower Base

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1. INTRODUCTION

A line-following robot, also called line follower, is very common and often made by robot hobbyists. A lot of robotic competitions are in the form of line following race. The line or path followed is usually a dark line on a bright surface or vice versa. The robot detects the line by measuring the intensity of light reflected from the surface of its path. The intensity of light reflected by dark surface is less than the light reflected from brighter colored surface.

DT-ROBOT LINE FOLLOWER BASE is a robot controller module suitable as a learning tools about the line follower robot for beginner to advanced programming level.

For beginner level, DT-ROBOT LINE FOLLOWER BASE is equipped with a standard line following algorithm that has been tested on various models of line following tracks, ranging from simple to difficult path. Beginner level users can experiment with setting the parameters available in the included GUI software.

For intermediate level, we provide a sample program of the line follower robot that has been tested with DT-ROBOT LINE FOLLOWER BASE. The user can learn about the robot line follower programming with the assistance from the framework of existing programs. The user can experiment with the line following algorithm, create or add a variety of algorithms themselves so that their line follower robots becomes more intelligent.

For advanced level, the whole series of electronics and components of the DT-ROBOT LINE FOLLOWER BASE will be explained in detail so that the robot and electronics enthusiasts can be creative and experiment freely with it. DT-ROBOT LINE FOLLOWER BASE could be developed for robot with different functions, sensors, or motor movements. There are also available optional components of DT-ROBOT LINE FOLLOWER BASE such as motors and sensors that sold separately.

1.1. DT-ROBOT LINE FOLLOWER BASE SPECIFICATION

DT-ROBOT LINE FOLLOWER BASE specification is as follows:

- Uses 6 x AA batteries (@1.2 – 1.5 VDC) as the power supply.
- Based on ATmega168.
- Uses SN754410 motor driver IC with dual full H-Bridge configuration and 1 A continuous current capacity for each driver.
- Equipped with 8 x 2 characters LCD.
- 2 tactile switches as inputs and 1 tactile switch for reset are available.
- Communication line uses the UART RS-232 interface.
- Input/Output pins are compatible with TTL and CMOS voltage level.

1.2. SUGGESTED SYSTEM

Suggested system for DT-ROBOT LINE FOLLOWER BASE is:

Hardware:

- PC™ AT™ Pentium® IBM™ Compatible with COM/USB serial port.
- DVD-ROM Drive and Hard disk.

Software:

- Windows® XP operating system.
- CodeVisionAVR©.
- Program CD/DVD contents:
  default.hex, default.eep, GUI folder, testing folder, CodeVisionAVR Evaluation folder, datasheets, and DT-ROBOT Line Follower Base Manual.

1.3. DT-ROBOT LINE FOLLOWER BASE MOVEMENTS

DT-ROBOT LINE FOLLOWER BASE has a driver to control two wheels driven by motors (Differential Drive). Therefore there are at least 9 kinds of movement can be done by the robot as shown in the following table.

Movement	Description
Straight	Left and right motor drives forward with the same speed
Turn Left	Left and right motor drives forward with the right motor faster than the left
Turn Right	Left and right motor drives forward with the left motor faster than the right
Sharp Turn Left	Left motor stops while right motor drives forward with a certain speed
Sharp Turn Right	Right motor stops while left motor drives forward with a certain speed
Spin Left	Left motor drives backward and right motor drives forward
Spin Right	Left motor drives forward and right motor drives backward
Reverse	Left and right motor drives backward
Stop	Left and right motor stop

1.4. LINE FOLLOWING ALGORITHM

If the line sensor module mounted on DT-ROBOT has 4 sensors, then robot's movements are determined by reading the results of those sensors. As an example, if a sensor is located directly above the line then its reading will have a value of 1 and if the sensor does not detect the line then the reading value is 0. The decisions can be taken based on sensors reading value can be seen in the following table.

Sensor Result	Example of Decisions Taken
0110	The line is right on the middle. Robot moves straight.
0010	The line deviates slightly to the right. Robot turns right.
0011	The line deviates to the right. Robot makes sharp turn to the right.
0001	The line is in the far right. Robot spins right.
0111	There is a possible right turn. Robot spins right.
0100	The line deviates slightly to the left. Robot turns left.
1100	The line deviates to the left. Robot makes sharp turn to the left.
1000	The line is in the far left. Robot spins left.
1110	There is a possible left turn. Robot spins left.
1111	There is a possible crossroads. Robot moves straight.
0000	Robot is off track. Run the algorithm to get back on track.
Others	Robot moves the way it was before.

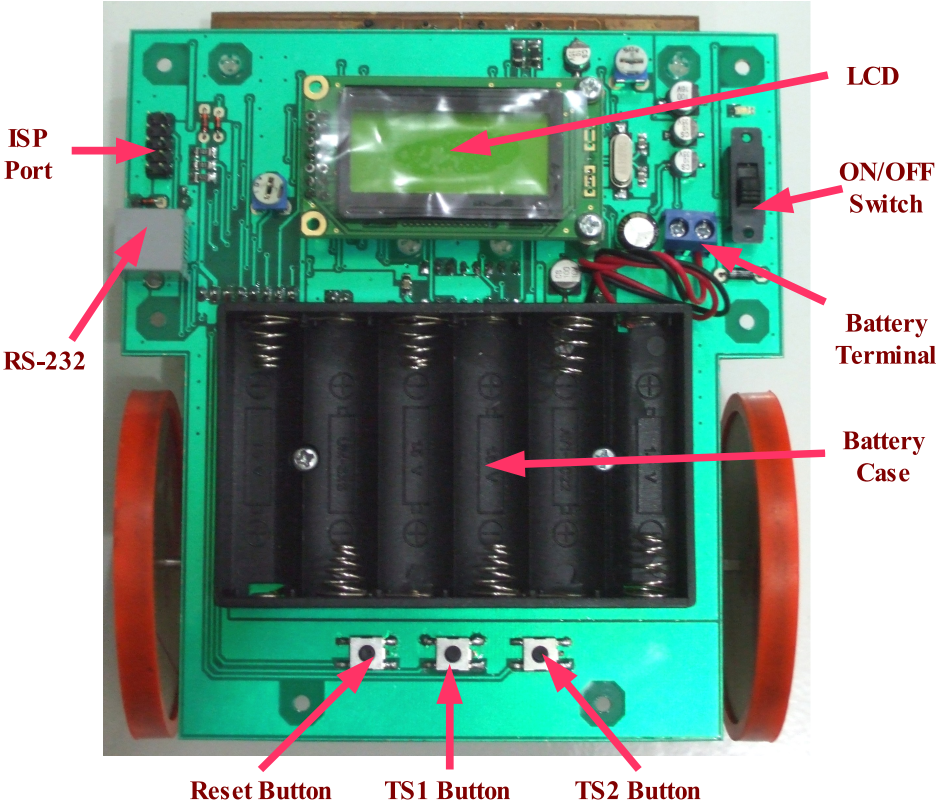
If all of the sensors does not detect the line which results in “0000”, then the robot must run the algorithm to get back on track. There are various algorithms that can be used to find the line. One simple algorithm is to store the results of last decisions of the robot. For example if previously the robot is trying to do a sharp turn left before getting off track, then when the line disappears the robot can be ordered to spin left to go back to the line. Else if the robot have tried to do a sharp right turn before getting off track, then the robot can be ordered to spin right. If the robot is moving straight forward and the lines disappear, then the robot can be ordered to move backward.

2. OPERATING DT-ROBOT LINE FOLLOWER BASE

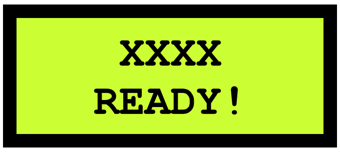
2.1. DEFAULT TESTER PROGRAM

DT-ROBOT LINE FOLLOWER BASE is equipped with a standard line following algorithm that has been tested on various models of line following tracks, ranging from simple path to a difficult path. Beginner level users can experiment by setting the parameters that are available through the included GUI software.

The algorithm is already programmed in the robot. Inside the DVD, the default algorithm is stored with the file name "**default.hex**" for the program and "**default.eep**" for the initial parameters.

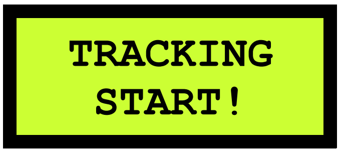


At the time DT-ROBOT LINE FOLLOWER BASE was first turned on, LCD will show a **Tracking Menu** marked with the string "**READY**" on the bottom line and digital combination of sensors reading value on the top line.



```
XXXX
READY!
```

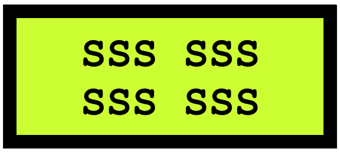
If **TS1 Button** is pressed, then DT-ROBOT LINE FOLLOWER BASE will start the line following and LCD will show this text.



TRACKING
START!

To stop the line following, press **TS2 Button** so that DT-ROBOT LINE FOLLOWER BASE returns to **Tracking menu.**

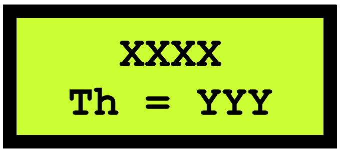
If DT-ROBOT LINE FOLLOWER BASE is in **Tracking Menu**, and **TS2 Button** is pressed for 2 seconds, then DT-ROBOT LINE FOLLOWER BASE will switch to the next menu which is **Raw Data Menu**.



SSS SSS
SSS SSS

If SENSOR PORT (J4) is connected to DT-SENSE LINE TRACKING CDS/SFH 4 SENSOR, then on this **Raw Data Menu,** the LCD will show sensors reading values so that users can adjust the variable resistor on each sensor and record the value of the sensor when it's on top of the track and off the track.
Moving from **Raw Data Menu** to the next menu can be done by pressing **TS2 Button** for 2 seconds.

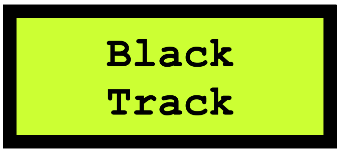
The next menu is **Threshold Menu** which is marked with an LCD display that resembles the following display.



XXXX
Th = YYY

Threshold or **Limit** is a value that is used to categorize whether the sensor is above the line or not. For the **Black Track** mode which is dark lines on a brighter surface, if the value is higher than the **Limit** then it will be categorized as a line (has a value of 1). While for **White Track** mode, which is bright line on a dark surface, if the value is lower than the **Limit** then it will be categorized as a line (digital data has a value of 1).
Raising the **Limit** value can be done by pressing the **TS1 Button** while lowering the **Limit** value can be done by pressing the **TS1 Button** and **TS2 Button** simultaneously.
The **Limit** value will be stored in the DT-ROBOT LINE FOLLOWER BASE EEPROM if the user switches to the next menu by pressing **TS2 Button** for 2 seconds.

The next menu is the **Track Mode Menu** which is marked with an LCD display that resembles the following display.



Black
Track

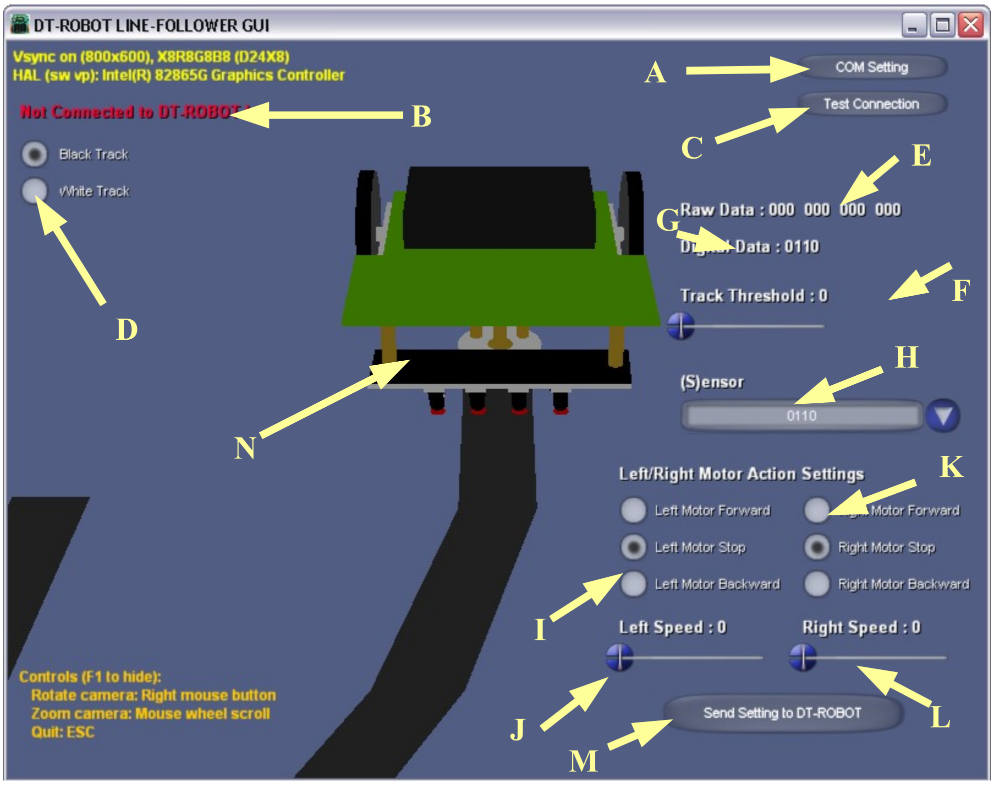
On the **Track Mode Menu,** the user can decide whether the line that will be passed by the DT-ROBOT LINE FOLLOWER BASE is in the **Black Track** category, which is a dark line in a bright surface or **White Track** which is a bright line on a dark surface.

Changing the track mode can be done by pressing **TS1 Button**. Track mode will be saved on DT-ROBOT LINE FOLLOWER BASE EEPROM if the user switches to the next menu by pressing **TS2 Button** for 2 seconds.

2.2. DT-ROBOT LINE FOLLOWER BASE GUI

To simplify the experiment of setting the provided line following algorithm parameters, the DT-ROBOT LINE FOLLOWER BASE pack also includes a GUI software, "**DT-ROBOT-LINE-FOLLOWER-GUI**". To set the parameters stored in DT-ROBOT LINE FOLLOWER BASE, connect DT-ROBOT LINE FOLLOWER BASE with a PC through UART communication using the supplied serial cable (UART communication parameters can be seen on the COM Settings).

The following is the interface of the GUI as well as explanations of its functions.



DT-ROBOT LINE-FOLLOWER GUI

Vsync on (800x600), X8R8G8B8 (D24X8)
HAL (sw vp): Intel(R) 82865G Graphics Controller

Not Connected to DT-ROBOT !

● Black Track
○ White Track

Raw Data : 000 000 000 000
Digital Data : 0110
Track Threshold : 0
(S)ensor: 0110

Left/Right Motor Action Settings

○ Left Motor Forward
● Left Motor Stop
○ Left Motor Backward
○ Right Motor Forward
● Right Motor Stop
○ Right Motor Backward

Left Speed : 0
Right Speed : 0

Controls (F1 to hide):
Rotate camera: Right mouse button
Zoom camera: Mouse wheel scroll
Quit: ESC

2.2.1 COM Setting (A)

With this button, the user can select the Serial / COM port. Other parameters of the UART communication used are as follows:

- 115200 bps
- 8 data bits
- 1 stop bit
- no parity bit
- no flow control

2.2.2 Connection Status (B)

This section displays the connection status between the PC and DT-ROBOT LINE FOLLOWER BASE. If the connection is successful then a green colored "Connected to DT-ROBOT" text will appear. And if the connection fails, then a red colored "Not Connected to DT-ROBOT" text will appear. During parameter update, if the update is successful then "Parameter update success !" will appear for 1 second.

2.2.3 Test Connection (C)

This section is used to test the connection between PC and DT-ROBOT LINE FOLLOWER BASE. The test results will be displayed on the **Connection Status** section. When this button is pressed, the GUI software will read and display the track mode and threshold settings stored in DT-ROBOT LINE FOLLOWER BASE.

2.2.4 Track Mode (D)

This section is used to set the track mode. Two available track modes are **Black Track** which is a dark line on a bright surface or **White Track** which is a bright line on a dark surface.

2.2.5 Raw Data (E)

When DT-ROBOT LINE FOLLOWER BASE is connected to PC, this section will display sensors readings values.

2.2.6 Track Threshold (F)

This section is used to set the **Limit** value which decides whether the sensor reading value is categorized as a line or not. For **Black Track** mode, a value higher than the **Limit** will be categorized as a line (has a value of 1). While for **White Track** mode, a value lower than the **Limit** will be categorized as a line (digital data has a value of 1).

2.2.7 Digital Data (G)

When DT-ROBOT LINE FOLLOWER BASE is connected to PC, this section will display the comparison results of **Raw Data** and **Track Threshold**.

2.2.8 Sensor (H)

This section is used to choose the sensor reading digital value combinations. If DT-ROBOT LINE FOLLOWER BASE is connected to PC, when a combination is selected (via mouse or the "**S**" key on keyboard), it will display the corresponding action setting stored in DT-ROBOT LINE FOLLOWER BASE. The setting result will be displayed on the **Left/Right Motor Action** section along with each motor's speed setting.

2.2.9 Left Motor Action (I)

This section is used to set the action the left motor will do for the selected digital value combination on **Sensor** section. The available actions are **Forward** (drive forward), **Stop** , or **Reverse** (drive backward).

2.2.10 Left Motor Speed (J)

This section is used to set the left motor speed (PWM value) for the selected digital value combination on **Sensor** section. The allowed value is ranging from **0** to **1023**. The bigger the value, the faster the left motor will spin.

2.2.11 Right Motor Action (K)

This section is used to set the action the right motor will do for the selected digital value combination on **Sensor** section. The available actions are **Forward** (drive forward), **Stop** , or **Reverse** (drive backward).

2.2.12 Right Motor Speed (L)

This section is used to set the right motor speed (PWM value) for the selected digital value combination on **Sensor** section. The allowed value is ranging from **0** to **1023**. The bigger the value, the faster the right motor will spin.

2.2.13 Send Setting to DT-ROBOT (M)

This button is used to send the **Mode Track, Track Threshold, Left/Right Motor Action,** and **Speed** parameter settings from PC to DT-ROBOT LINE FOLLOWER BASE. The above parameters will be sent to DT-ROBOT LINE FOLLOWER BASE when the software has been connected to DT-ROBOT LINE FOLLOWER BASE and the "**Send Setting to DT-ROBOT**" button is pressed. If the parameter update is successful then “Parameter update success !” will appear for 1 second on **Connection Status** section.

2.2.14 DT-ROBOT LINE FOLLOWER Model (N)

This section is used to give an illustration for the possible positions of DT-ROBOT LINE FOLLOWER BASE toward the line, based on the selected digital value combination on **Sensor** section.

3. LINE FOLLOWING PROGRAM ROUTINES

For intermediate level, we provide a sample program of the line follower robot that has been tested with DT-ROBOT LINE FOLLOWER BASE. Users can learn about the line follower robot programming with the assistance from the framework of existing program. Users can experiment with the line following algorithm, create or add a variety of algorithms themselves so that their line follower robots become more intelligent.

In the DVD, the program example is stored in ”**testing**” folder. The program can be opened using **CodeVisionAVR** evaluation version.

The program has 3 main files, which is : "**testing.c**" that contains the line following main algorithm, "**LCDRoutine.c**" that contains LCD related functions, and "**OtherRoutine.c**" that contains other functions such as directional control and motor speed (PWM values).

There are several procedures and functions on the program that can be used to help the user in programming. The following are some of the procedures and functions used in "**LCDRoutine.c**" and "**OtherRoutine.c**":

3.1 LCD Initialization

Syntax : **void initlcd(void);**

Function : Initializes LCD.

Desc. :

- Call this procedure to perform the LCD initialization process. It's only needed to be performed once at the beginning of program.
- This procedure is used by the **initMain** procedure.

Example : **initlcd();**

3.2 Send Byte to LCD

Syntax : **void putlcd(unsigned char moda, unsigned char comm);**

Function : Sends 1 byte Command or Data to LCD.

Desc. :

- The valid **moda** value is 0 if LCD command is sent and 1 if LCD data is sent.
- The **comm** value is the value of the sent LCD command or data.
- The list of LCD command and data can be seen in the LCD datasheet.

Example : **putlcd(0,0x01);** will clear the LCD screen.

3.3 Display Message to LCD

Syntax : **void lcd_putsf(flash unsigned char *str);**

Function : Displays a string/message on the LCD's current cursor position.

Desc. :

- ***str** contains the message's initial address in the flash memory.

Example : **lcd_putsf("START!");** will display the "START!" text on the LCD.

3.4 Display Decimal to LCD

Syntax : **void lcd_putInt(unsigned int value,unsigned char dispNum);**

Function : Displays the input values in decimal to the LCD's current cursor position.

Desc. :

- **value** is the value to be displayed.
- **dispNum** value contains the number of characters that will be displayed.
- The valid **dispNum** value is 1 up to 5.

Example : **lcd_putInt(1234,4);** will write 1234 on the LCD.
lcd_putInt(number,3); will write the contents of the number variable on the LCD as many as 3 characters (hundreds, tens, units).

3.5 Display Binary to LCD

Syntax : **void lcd_putBin(unsigned char value,unsigned char dispNum);**

Function : Displays the input values in binary to the LCD's current cursor position.

Desc. :

- **value** is the value to be displayed.
- **dispNum** value contains the number of characters to be displayed.
- The valid **dispNum** value is 1 up to 8.

Example : **lcd_putBin(12,4);** will write 1100 on the LCD.
lcd_putInt(number,5); will write the contents of the number variable on the LCD as many as 5 characters.

3.6 Move Cursor Position

Syntax : **void locate(unsigned char lines, unsigned char cols);**

Function : Arranges the cursor position so that it will be placed in a certain line and column.

Desc. :

- The **lines** value is the line position. The valid value is 1 up to 2 for an 8x2 character LCD.
- The **cols** value is the column position. The valid value is 1 up to 8 for an 8x2 character LCD.

Example : **locate(1,1);** will place the cursor in the 1st line and 1st column (upper left corner).

3.7 Read ADC

Syntax : **unsigned char read_adc(unsigned char adc_input);**

Function : Reads the sensor voltage value.

Desc. :

- **adc_input** is ADC channel number. The valid value is 4 up to 7.

Example : **read_adc(4);** will read the leftmost sensor's voltage value.
read_adc(5); will read the 2nd from the left sensor's voltage value.
read_adc(6); will read the 3rd from the left sensor's voltage value.
read_adc(7); will read the rightmost sensor's voltage value.

3.8 DT-ROBOT LINE FOLLOWER BASE Initialization

Syntax : **void initMain(void);**

Function : Initializes all I/O ports and DT-ROBOT LINE FOLLOWER BASE peripherals including LCD.

Desc. :

- Call this procedure to perform the LCD initialization process. It's only needed to be performed once at the beginning of program.

Example : **initlMain();**

3.9 Left Motor Control

Syntax : **void motorKiri(unsigned char arah,unsigned int speed);**

Function : Arranges the speed and spin direction of the left motor.

Desc. :

- **arah** can have a value of 0 for forward, 1 for reverse, or 2 for stop.
- **speed** is the speed of the motor (PWM value). The valid value is 0 to 1023. The greater the **speed** value the faster the motor spins.

Example : **motorKiri(0,500);** will command the left motor to drive forward with a PWM value of 500.

3.10 Right Motor Control

Syntax : **void motorKanan(unsigned char arah,unsigned int speed);**

Function : Arranges the speed and spin direction of the right motor.

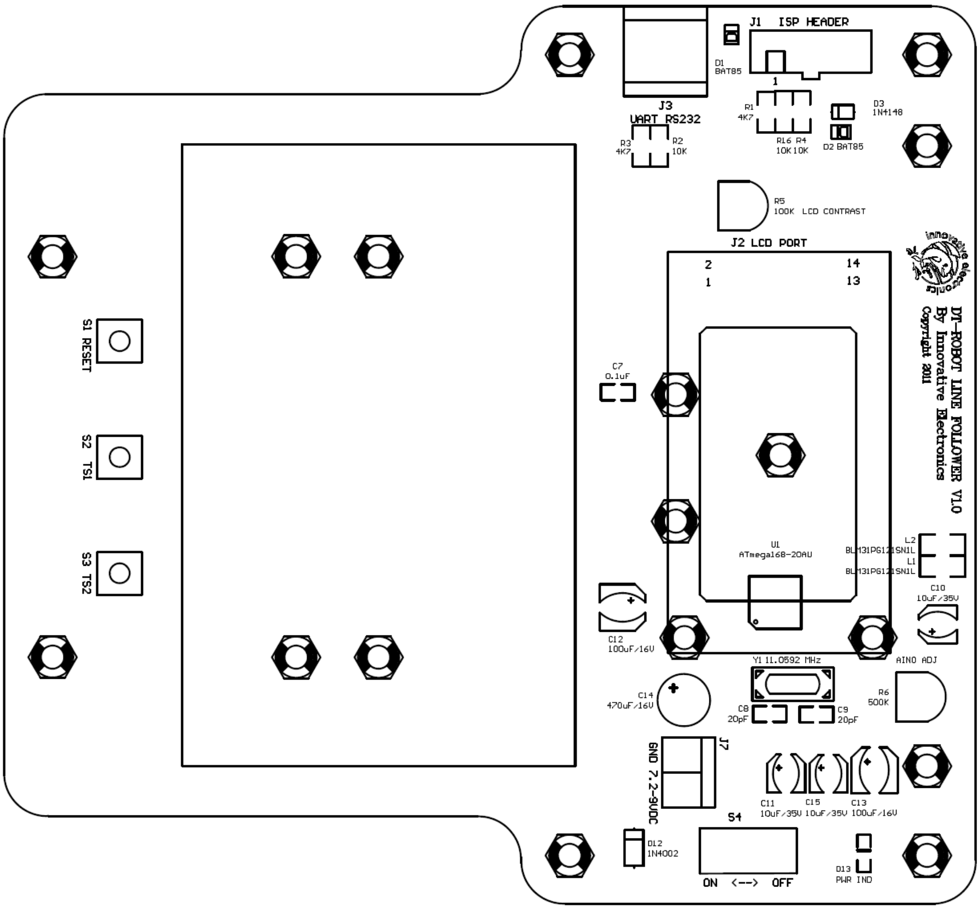
Desc. :

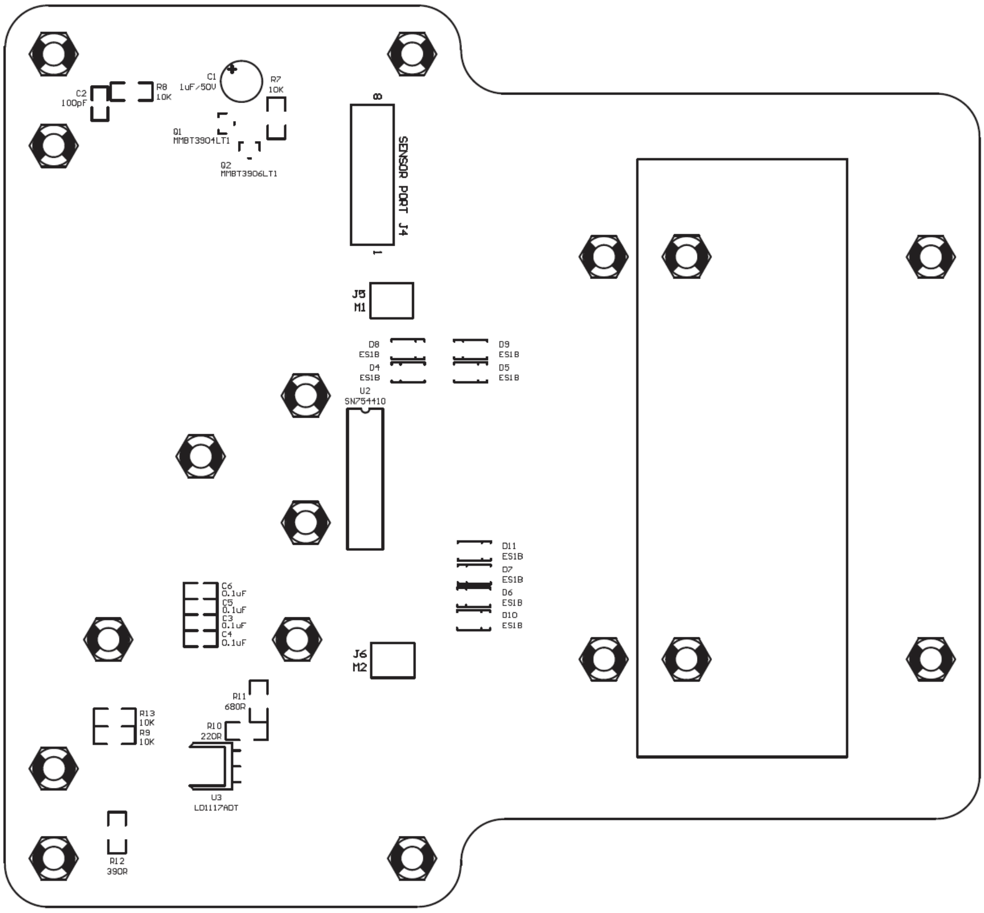
- **arah** can have a value of 0 for forward, 1 for reverse, or 2 for stop.
- **speed** is the speed of the motor (PWM value). The valid value is 0 to 1023. The greater the **speed** value the faster the motor spins.

Example : **motorKanan(2,0);** will command the right motor to stop.

4. DT-ROBOT LINE FOLLOWER BASE HARDWARE

4.1. DT-ROBOT LINE FOLLOWER BASE COMPONENT LAYOUT





4.2. CONNECTORS AND COMPONENTS FUNCTIONS

The J7 blue terminal is the connector for power supply.

Pin	Name	Function
1	GND	Ground reference for power supply input
2	7.2-9VDC	Connected to power supply for input (7.2 – 9 Volt)

UART RS232 (J3) RJ11 connector is the connector for UART RS-232 interface.

Pin	Name	Function
1	NC	Not connected
2	SGND	Ground reference
3	TX	RS-232 serial output from DT-ROBOT LINE FOLLOWER BASE
4	RX	RS-232 serial input to DT-ROBOT LINE FOLLOWER BASE

ISP HEADER (J1) header is the connector for ISP programming.

Pin	Name	Function
1	MOSI	Connected to microcontroller's MOSI pin
2	VCC	5 volts output voltage from DT-ROBOT LINE FOLLOWER BASE
3	NC	Not connected
5	ISP_RST	Connected to microcontroller's RESET circuitry
7	SCK	Connected to microcontroller's SCK pin
9	MISO	Connected to microcontroller's MISO pin
4,6,8,10	GND	Ground reference

SENSOR PORT (J4) connector is the connector for the sensor module.

Pin	Name	Function
1	SI3	Input, connected to microcontroller's internal ADC channel 7
2	SI2	Input, connected to microcontroller's internal ADC channel 6
3	SI1	Input, connected to microcontroller's internal ADC channel 5
4	SI0	Input, connected to microcontroller's internal ADC channel 4
5	SEN	Output to turn on or off the LED on the sensor module
6	NC	Not connected
7	VCC	5 volts output voltage from DT-ROBOT LINE FOLLOWER BASE
8	PGND	Ground reference

M1 (J5) connector is the connector for the left motor.

Pin	Name	Function
1	M11	Output to the 1st left motor pin
2	M12	Output to the 2nd left motor pin

M2 (J6) connector is the connector for the right motor.

Pin	Name	Function
1	M21	Output to the 1st right motor pin
2	M22	Output to the 2nd right motor pin

S4 slide switch is used as an ON/OFF switch with LED PWR IND (D13) as its indicator.
VR LCD CONTRAST (R5) is used to set the LCD contrast.
VR AIN0 ADJ (R6) is connected to AIN0. This VR can be used for Analog Comparator Multiplexed Input.
Tactile switch RESET (S1) is connected to the reset circuitry.
Tactile switch TS1 (S2) is connected to PortD.7, can be functioned as input.
Tactile switch TS2 (S3) is connected to PortB.5, can be functioned as input.

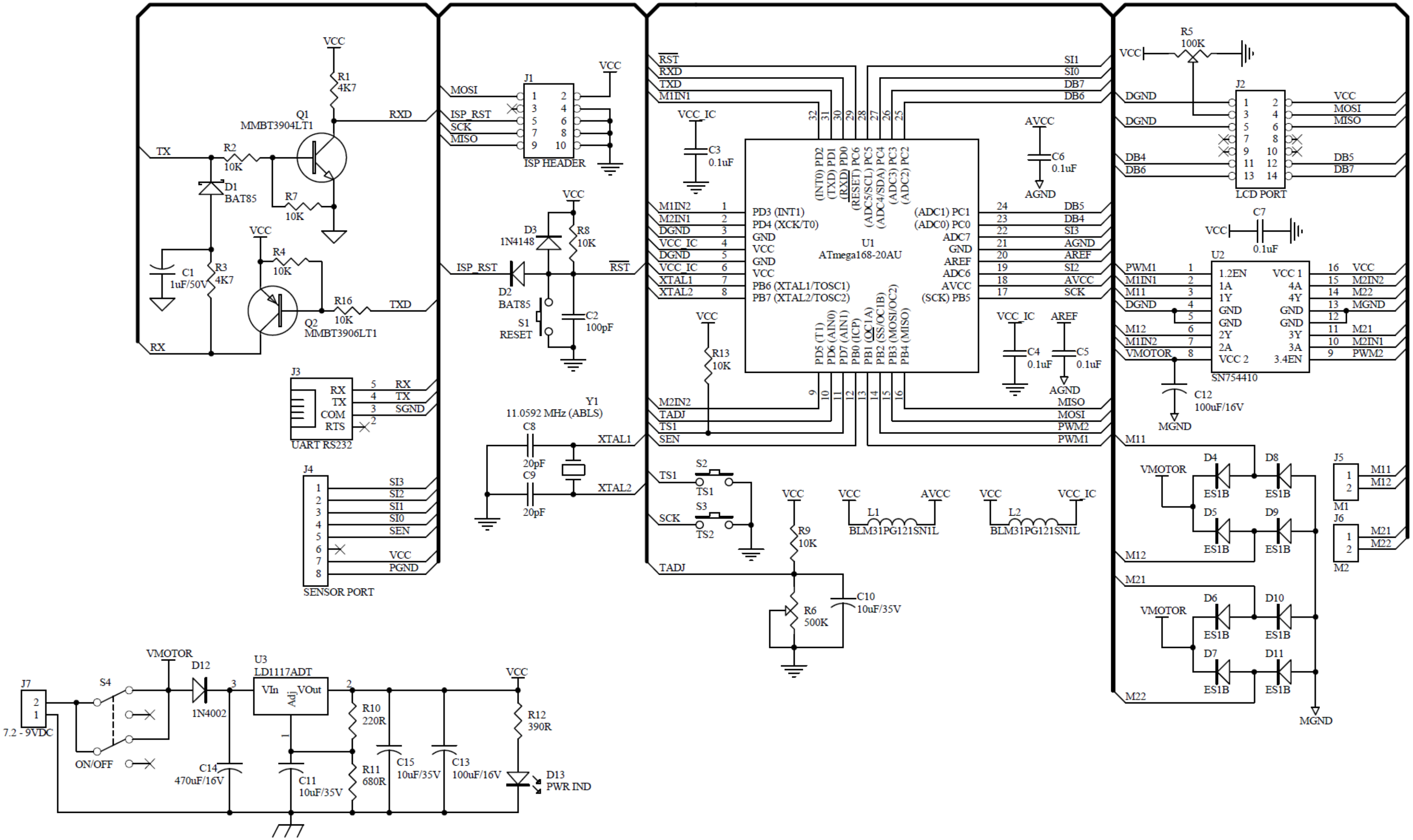
LCD and motor driver connection can be seen in the schematics attachment.

5. TESTING PROCEDURE

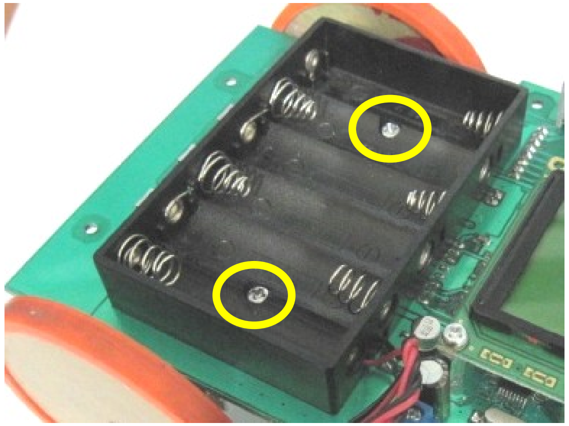
1. Connect DT-SENSE LINE TRACKING CDS/SFH 4 SENSOR or compatible sensor circuitry to SENSOR PORT (J4) connector.
2. Connect DT-ROBOT MINI METAL GEAR HIGH SPEED MOTOR SET/DT-ROBOT MINI METAL GEAR MOTOR SET/DT-ROBOT PLASTIC GEAR MOTOR I SET/DT-ROBOT PLASTIC GEAR MOTOR L SET or compatible motors to M1 (J5) dan M2 (J6) connectors.
3. Connect power supply to J7 blue terminal (from the batteries or other power source).
4. Turn on the DT-ROBOT LINE FOLLOWER BASE using the available ON/OFF switch.
5. LCD will show **Tracking Menu** marked with the inscription "**READY**" on the bottom line and digital combination of sensors reading value on the top line.
6. Press the **TS1Button** so that the DT-ROBOT LINE FOLLOWER BASE will start to perform line-following (left and/or right motor will spin).
7. Press the **TS2 Button** to go back to **Tracking Menu**.
8. Hold the **TS2 Button** for 2 seconds.
9. DT-ROBOT LINE FOLLOWER BASE enter the **Raw Data Menu** and LCD will display the sensors reading values.
10. Place the sensor above a bright or dark surface. The sensor value will change depend on the surface brightness level.
11. Connect DT-ROBOT LINE FOLLOWER BASE and PC using the included serial cable.
12. Run **DT-ROBOT-LINE-FOLLOWER-GUI** software.
13. Set Serial Port configuration via the **COM Setting** button.
14. Press the **Test Connection** button.
15. If the connection is successful, then "**Connected to DT-ROBOT**" will appear on the **Connection Status** section.

ATTACHMENTS

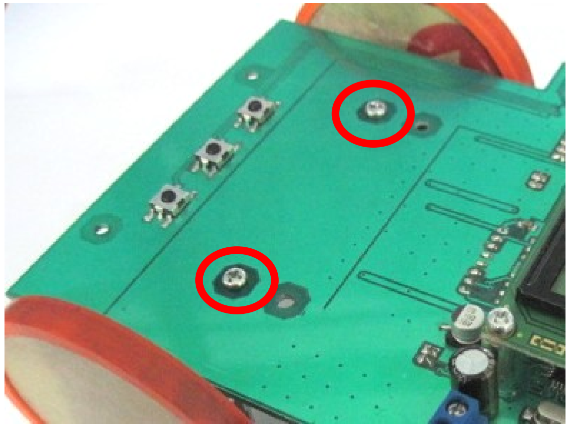
A. DT-ROBOT LINE FOLLOWER BASE SCHEMATICS



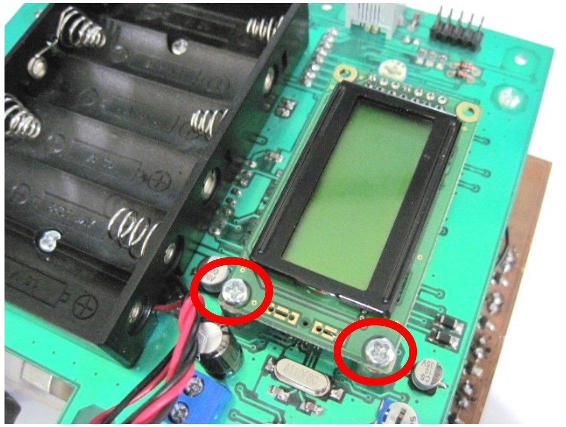
B. DT-ROBOT LINE FOLLOWER BASE PARTS EXPLANATION



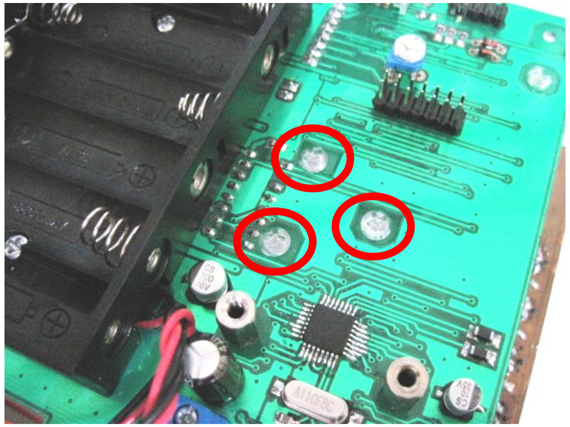
Bolts on battery case, need to be loosened when replacing the bracket (when using different type of motor).



Bolts for bracket (under battery case), need to be loosened when replacing the bracket (when using different type of motor).



Bolts for LCD, need to be loosened when replacing the spacer (when using different type of motor).



Bolts for castor (upper), need to be loosened when replacing the spacer (when using different type of motor).