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Engineering Design Project-II
(UTA 024)

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
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Engineering Design Project-II
(UTA 024)
Buggy Lab

Dr. Amit Mishra

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- Objectives
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Engineering Design Project-II (Buggy Lab) (UTA-024)

This is a **Group Project** and it is offered **jointly** by the department of Electronics and Communication Engineering and the department of Computer Science Engineering to the **IInd year students** of **all branch**.

PROJECT GOAL

The aim of this project is to create an autonomous vehicle that is under **wireless supervisory control** from a remote station (see Fig 1) and safely coexists with other trams. In effect, each group is required to design and implement a micro-simulation of the **Lucas** light rail system in Dublin, Ireland or **Tram Bus** rail system in Kolkata, India.

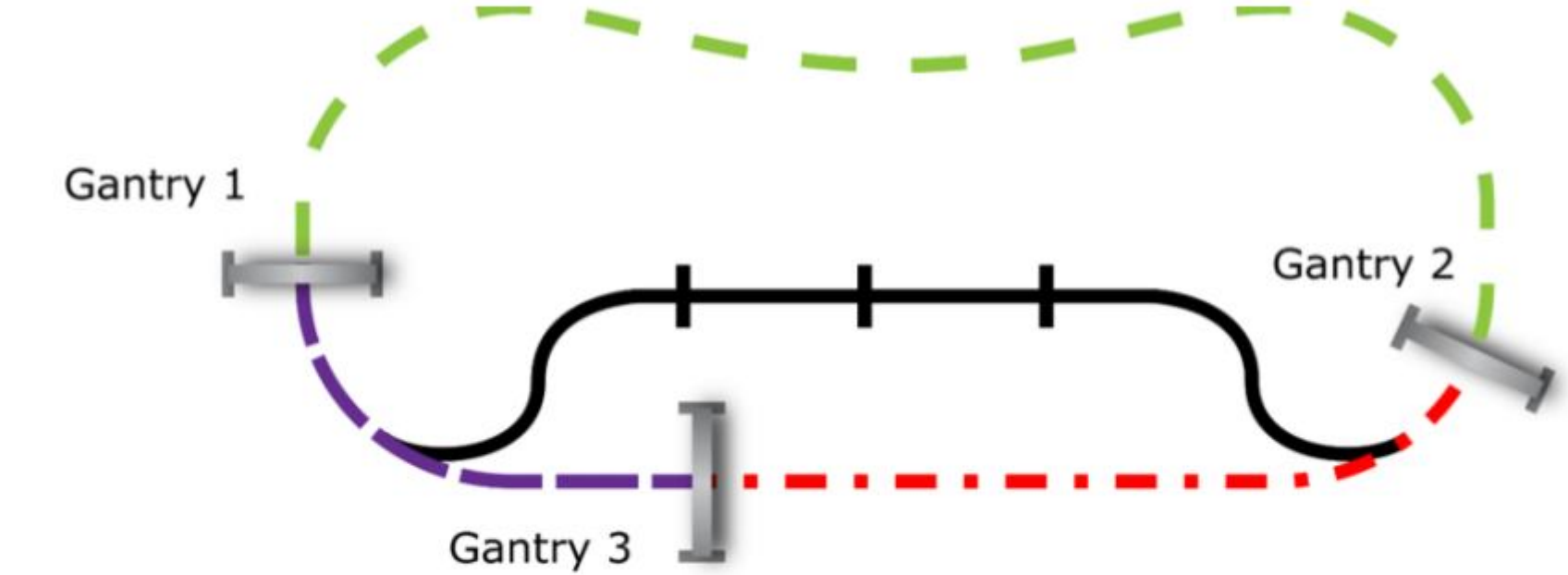
Fig 1

Source: Google

Objective of the Project course

The project will introduce you to the challenge of electronic systems design & integration. The project is an **example of *'hardware and software co-design'*** and the scale of the task is such that it will require teamwork as a coordinated effort. The vehicle (from now on called the "Buggy") must meet a number of progressive design challenges.

Rules of the Track

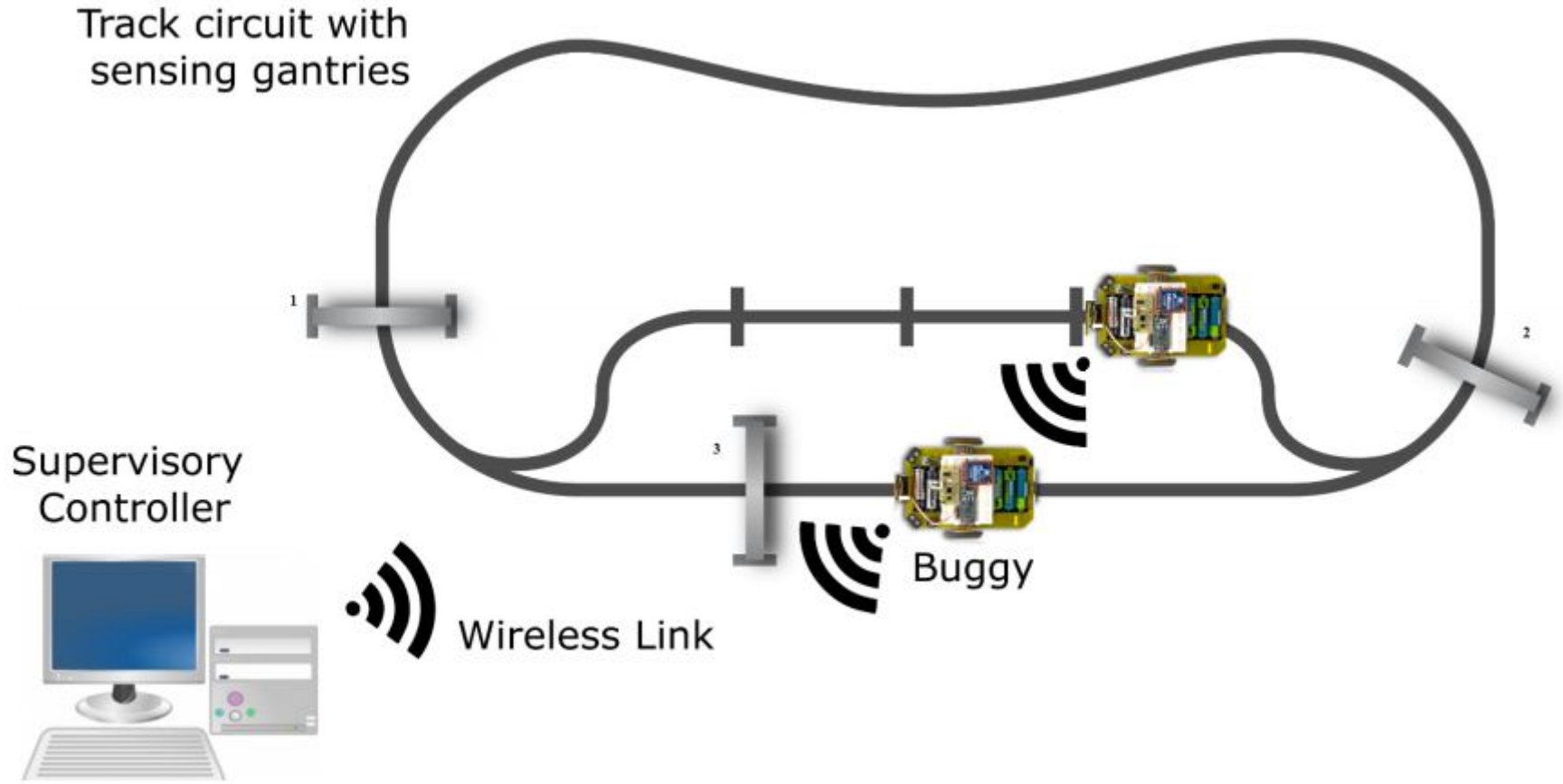


Rules:

- Trams must stop automatically if an obstacle is detected on the track
- Only one tram is permitted in a section
- Trams must wait at Gantries 1, 2 and 3
- Trams that have completed their specified number of laps must park in the parking lane

Courtesy: Trinity College of Dublin

Supervisory control



Courtesy: Trinity College of Dublin

Performance evaluation criterion

Bronze Challenge

Single buggy capable of following main track **twice** in a **clockwise** direction under **full supervisory** control and obeying the **"Rules"** of the track.

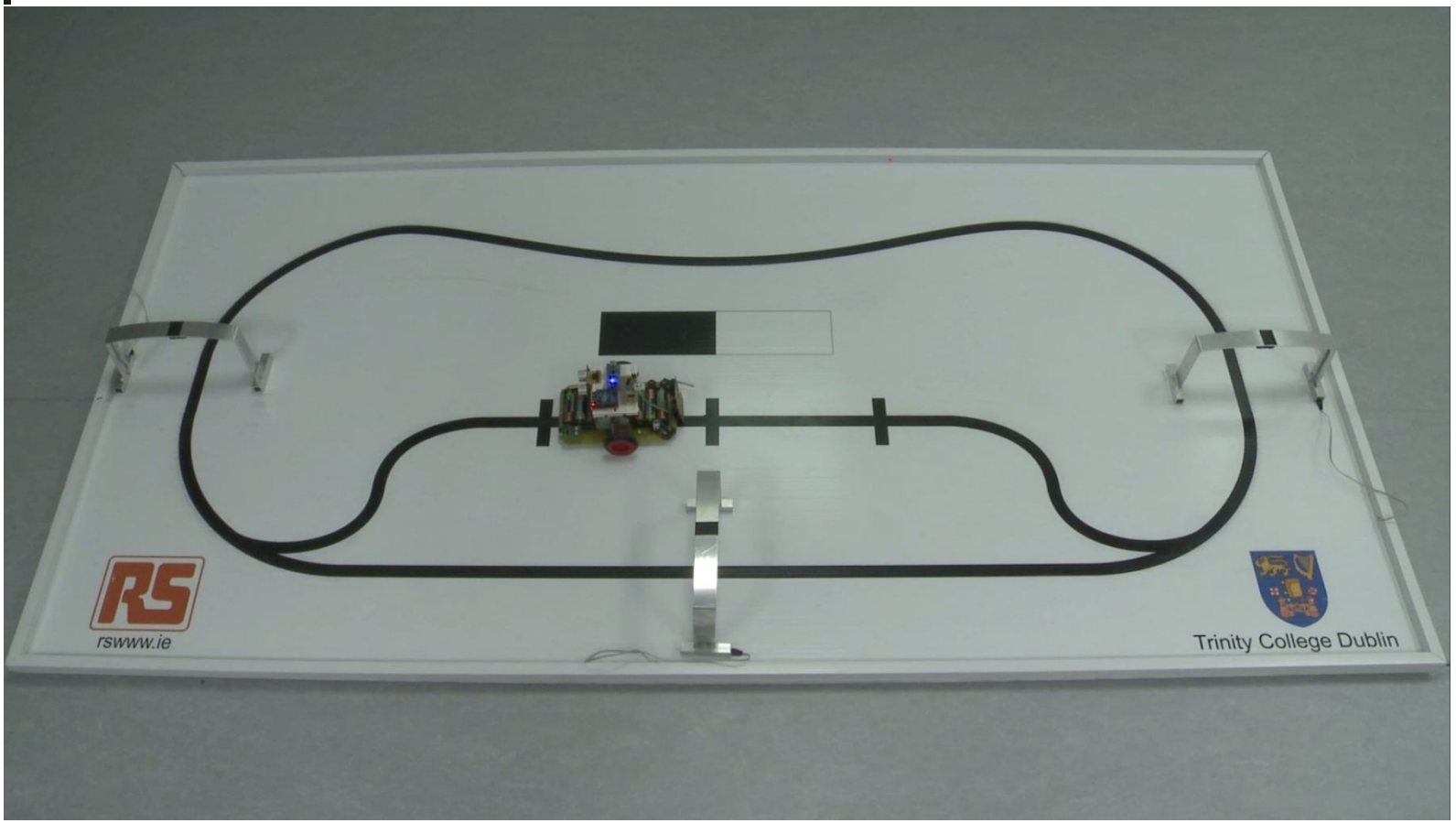
Buggy must be capable of **detecting an obstacle** whilst following the track, coming to a **temporary halt** if it does.

It proceeds **automatically** when the **obstacle is removed**. The buggy must **safely park** in the parking bay after the two loops. **No external** end-user manual control input is **permitted** once the initial start is signalled.

Messages transmitted to control your buggy, and **messages received** from the buggy must be **displayed onscreen** for debug purposes.

You must also **display onscreen** the state of the track and buggy at **each gantry** stop.

Bronze Challenge



Courtesy: Trinity College of Dublin

Silver Challenge

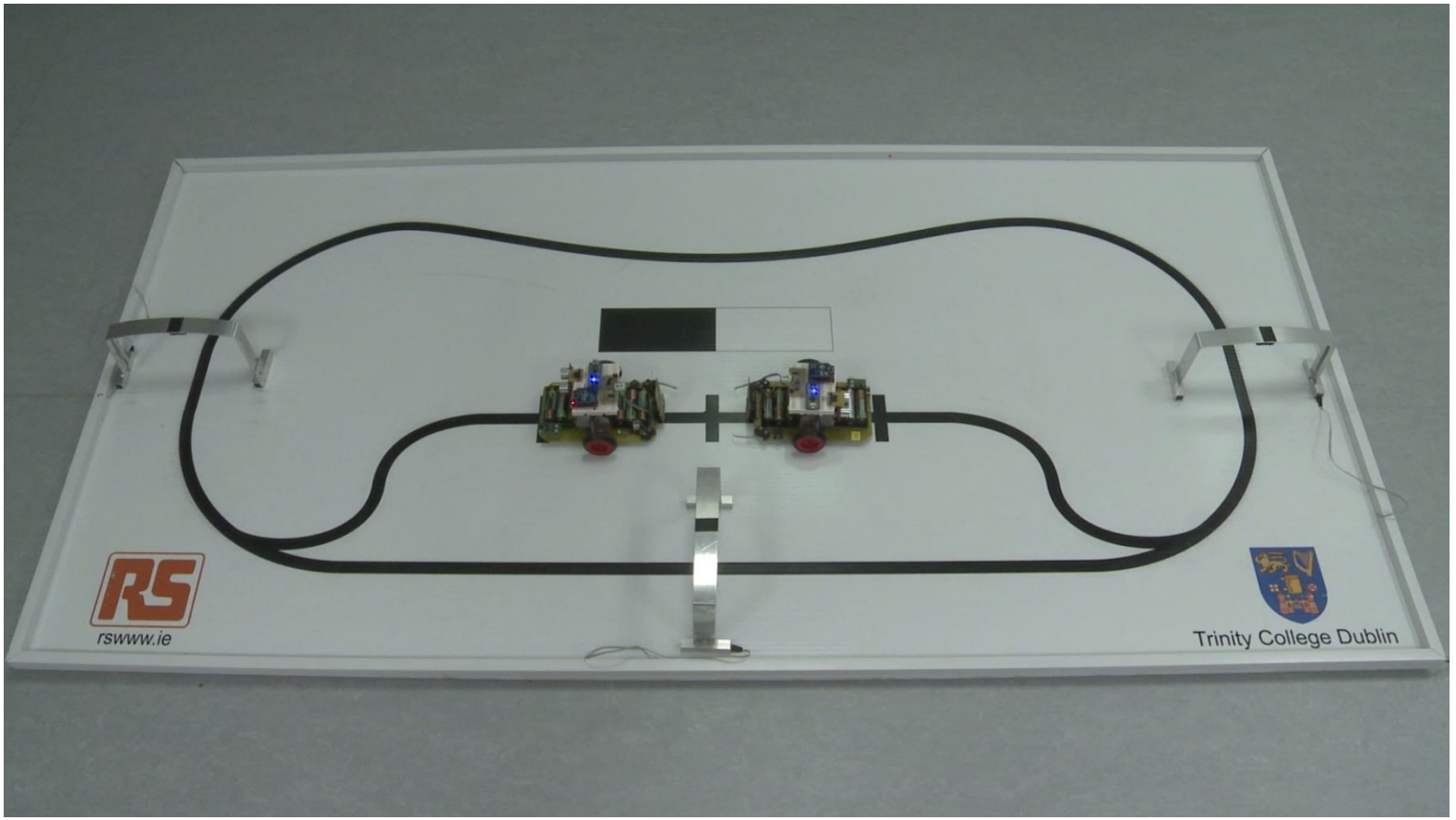
Two buggies on track going in opposite directions and following the **“Rules”** of the track.

The **first buggy** out of the parking lane goes in a **clockwise** direction until it reaches **gantry 3**. The **second buggy** then goes in an **anticlockwise** direction once around **track** and **parks**.

The **first buggy** then **completes** the loop and **parks safely**. Either buggy must be capable of detecting an **obstacle** and **temporarily halting** until the obstacle is removed.

Both buggies must be under **full supervisory** control. **No external** end-user manual control input is permitted once the initial start is signalled. Again, control **messages** and **state of the track** and **buggies** must be displayed on screen.

Silver Challenge



Courtesy: Trinity College of Dublin

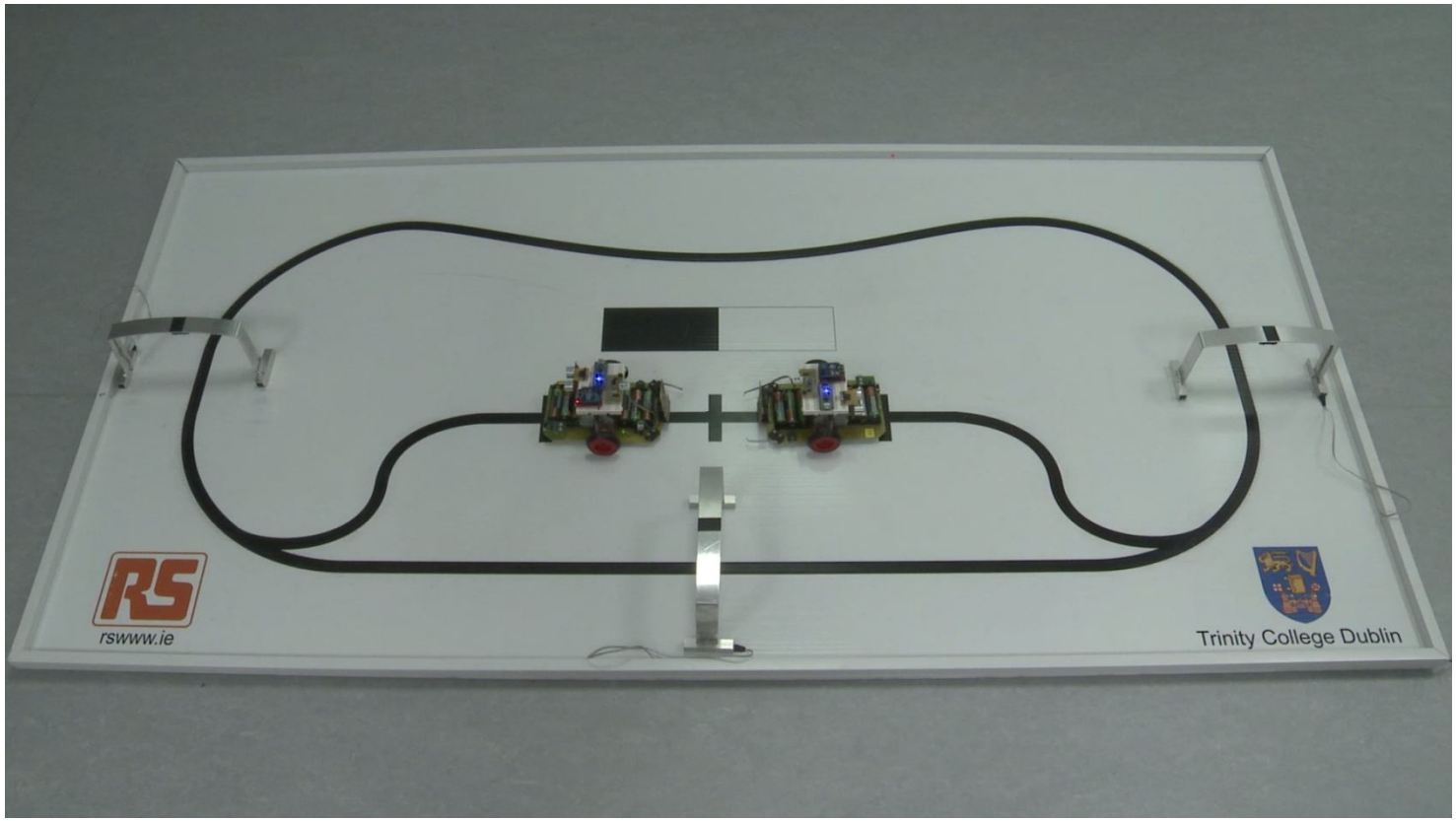
Gold Challenge

The **Gold challenge** is the **same as** the **Silver Challenge** but at the start the Supervisor **PC must ask** the end-user **how many loops** of the track the two buggies should perform before parking safely.

Therefore your **code** must be **generalised.** The buggies will perform the required **number of loops** in **opposite** directions and park safely. Either buggy must be **capable** of **detecting** an **obstacle** and temporarily **halting** until the obstacle is removed.

Both buggies under full supervisory control. **No external** end-user manual control input is permitted once the initial start is signalled. Again, **control messages** and **state of the track** and buggies must be **displayed** on screen.

Gold Challenge



Courtesy: Trinity College of Dublin

Requirements of Project

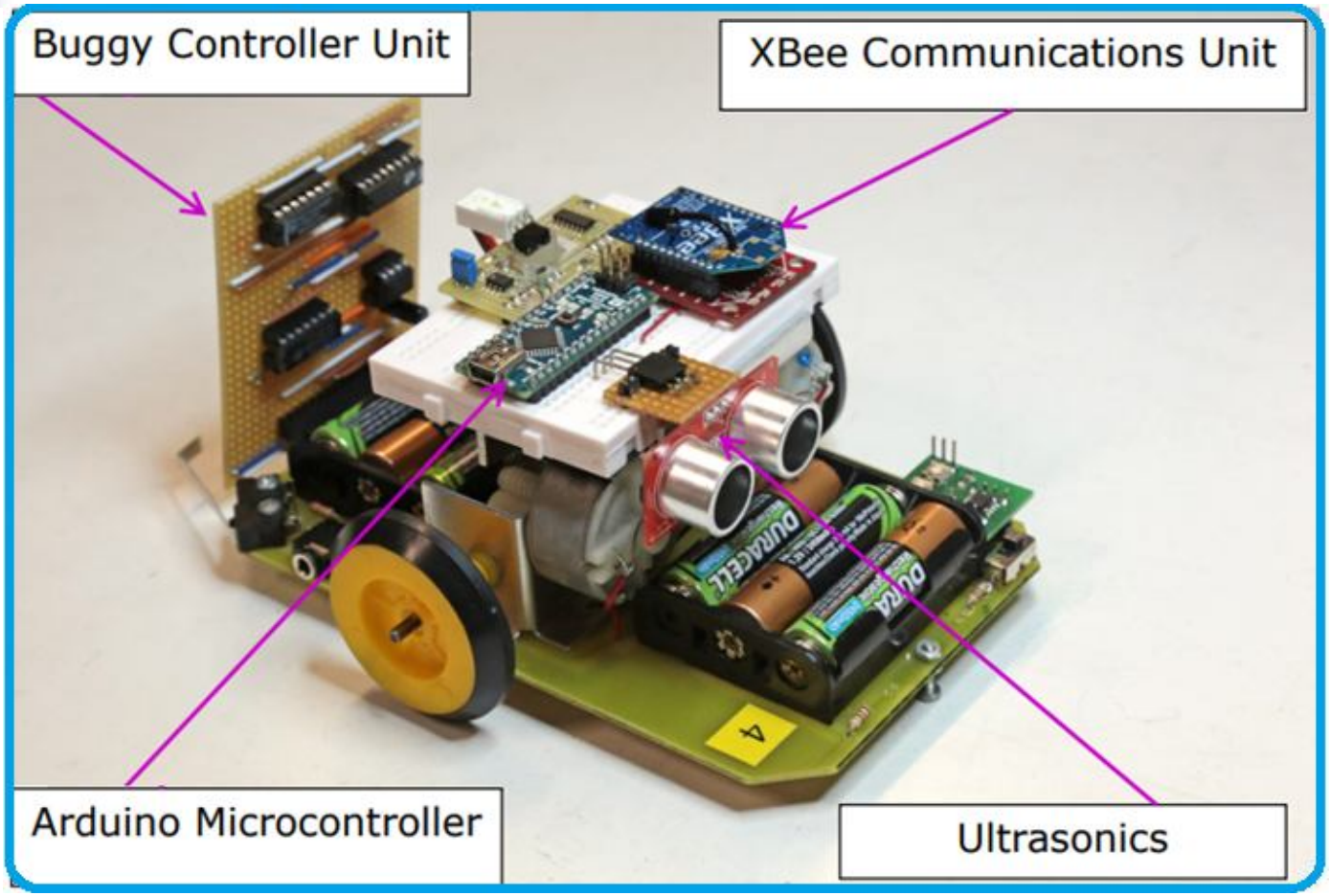
Electronics Lab:

- **Buggy equipped with**
  - **Microcontroller (Arduino Uno)**
  - **IR sensors (To detect path to be followed)**
  - **Ultrasonic sensor (To detect any obstacle on the track)**
  - **Receiver circuit (To receive signals from each gantry whenever passes through it)**
  - **Wireless Serial communication devices (X-Bee module) (To send/receive signals between computer system and Buggy**

- **Track with three gantries equipped with**
  - **IR sensors (To send a unique pulse signal to the buggy receiver)**
  - **Transmitter circuit (To transmit three unique waveforms of different pulse width to corresponding gantries)**

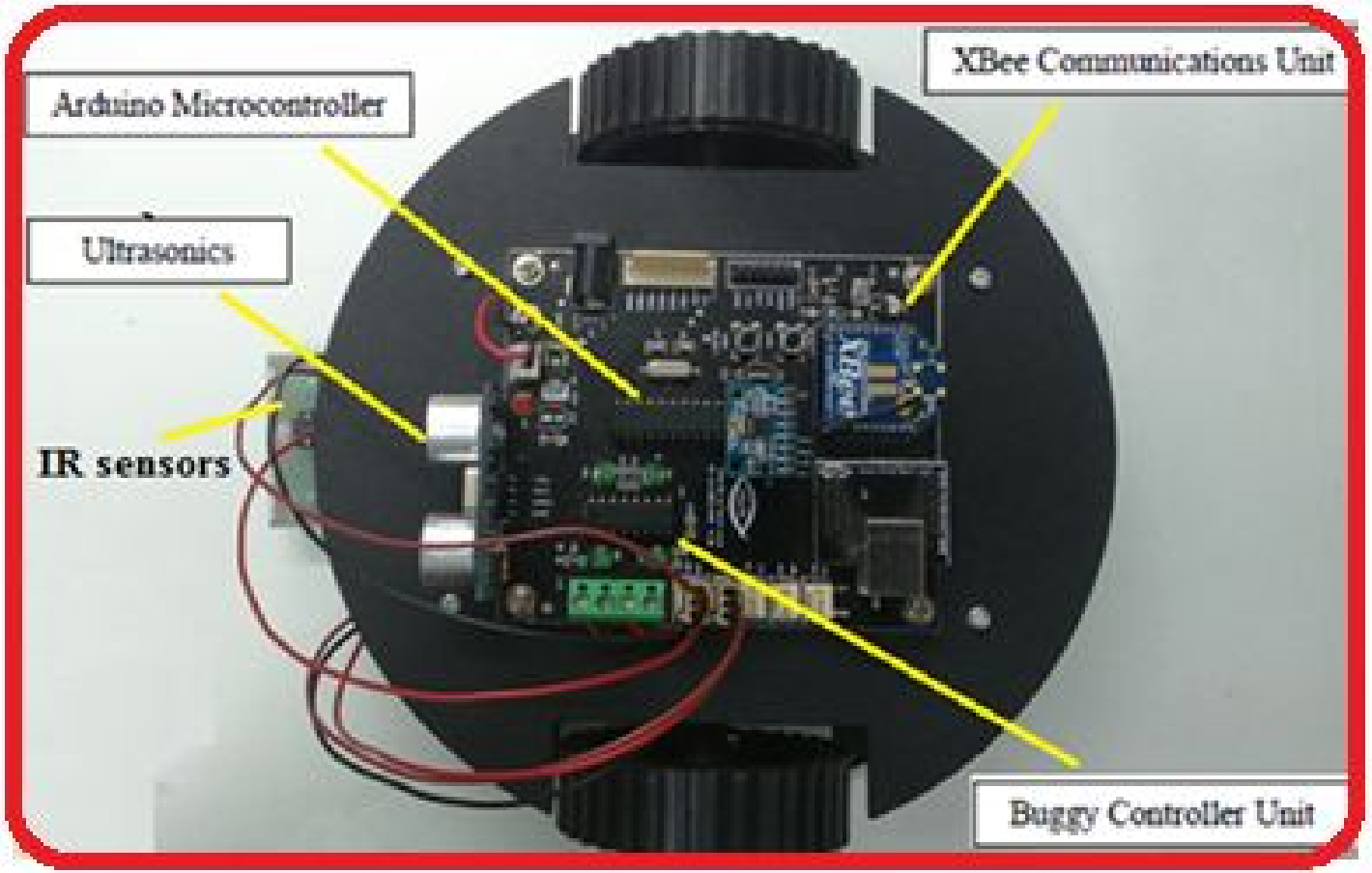
- **Computer system (To simulate C# program for supervisory control)**

Buggy Module-TCD

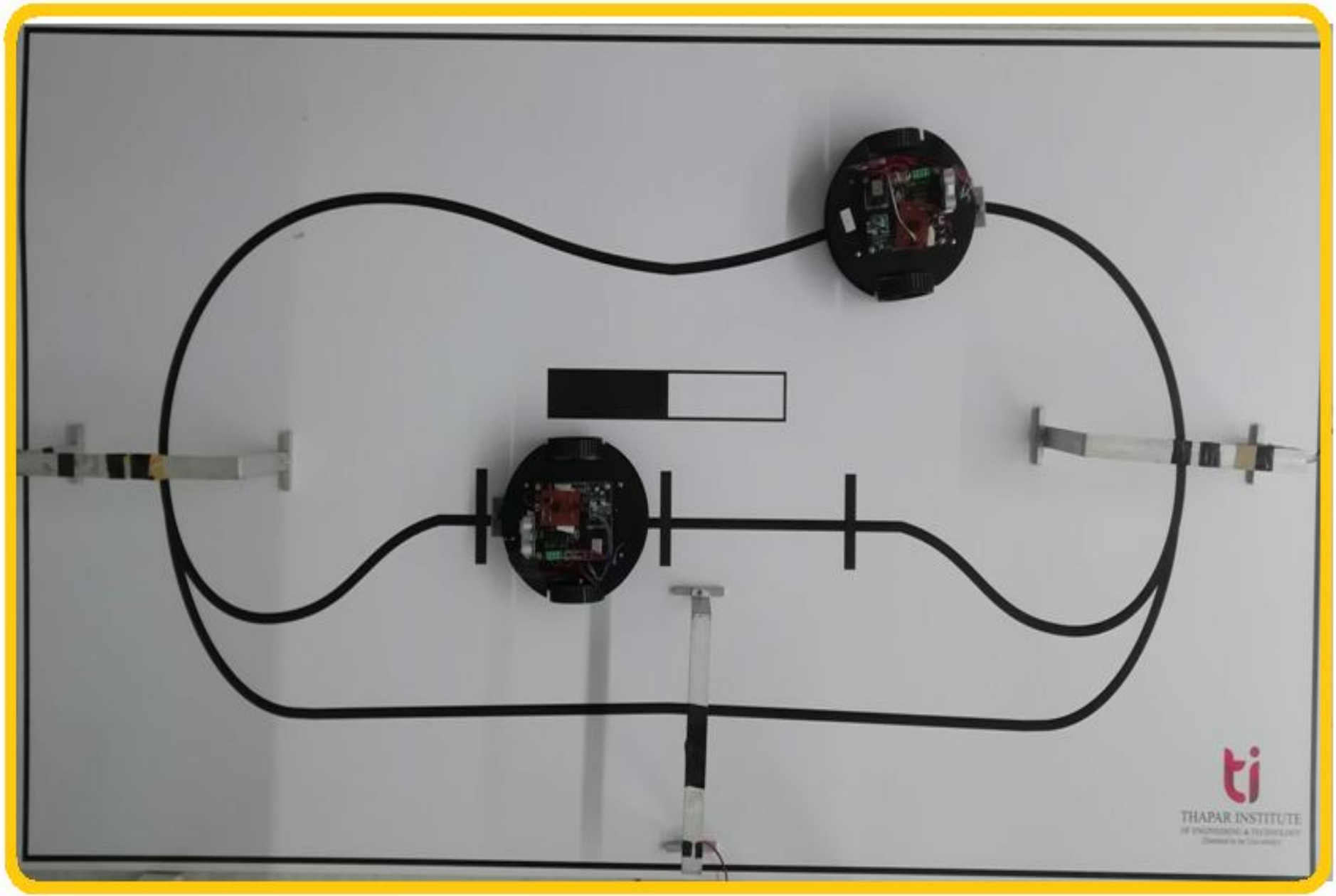


Courtesy: Trinity College of Dublin

Buggy Module-TIET



Buggy Module with track-TIET



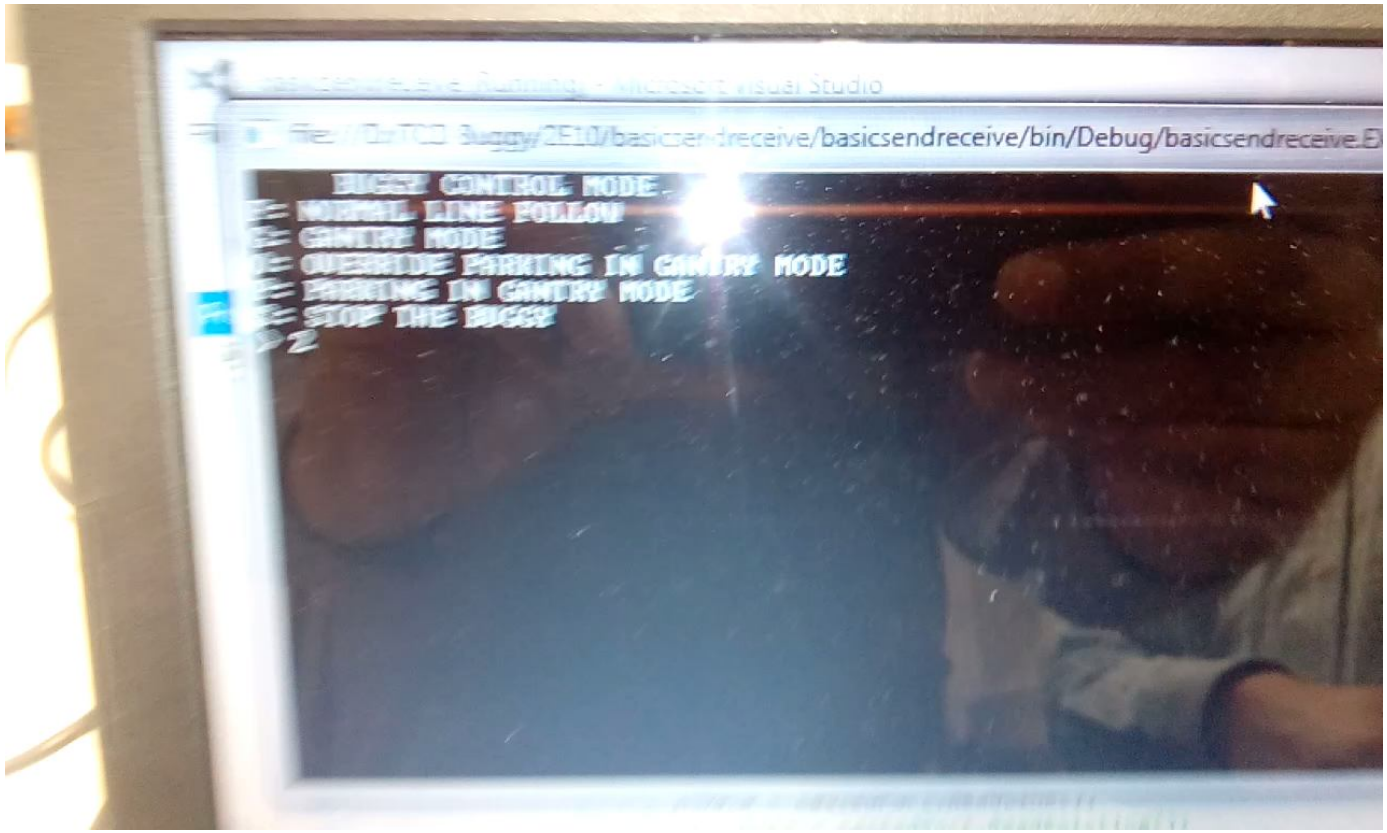
Communication Protocol
(Machine to Machine (M2M) communication)

Zigbee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. The Zigbee standard operates on the **IEEE 802.15.4** physical radio specification and operates in unlicensed bands including **2.4 GHz, 900 MHz and 868 MHz**.

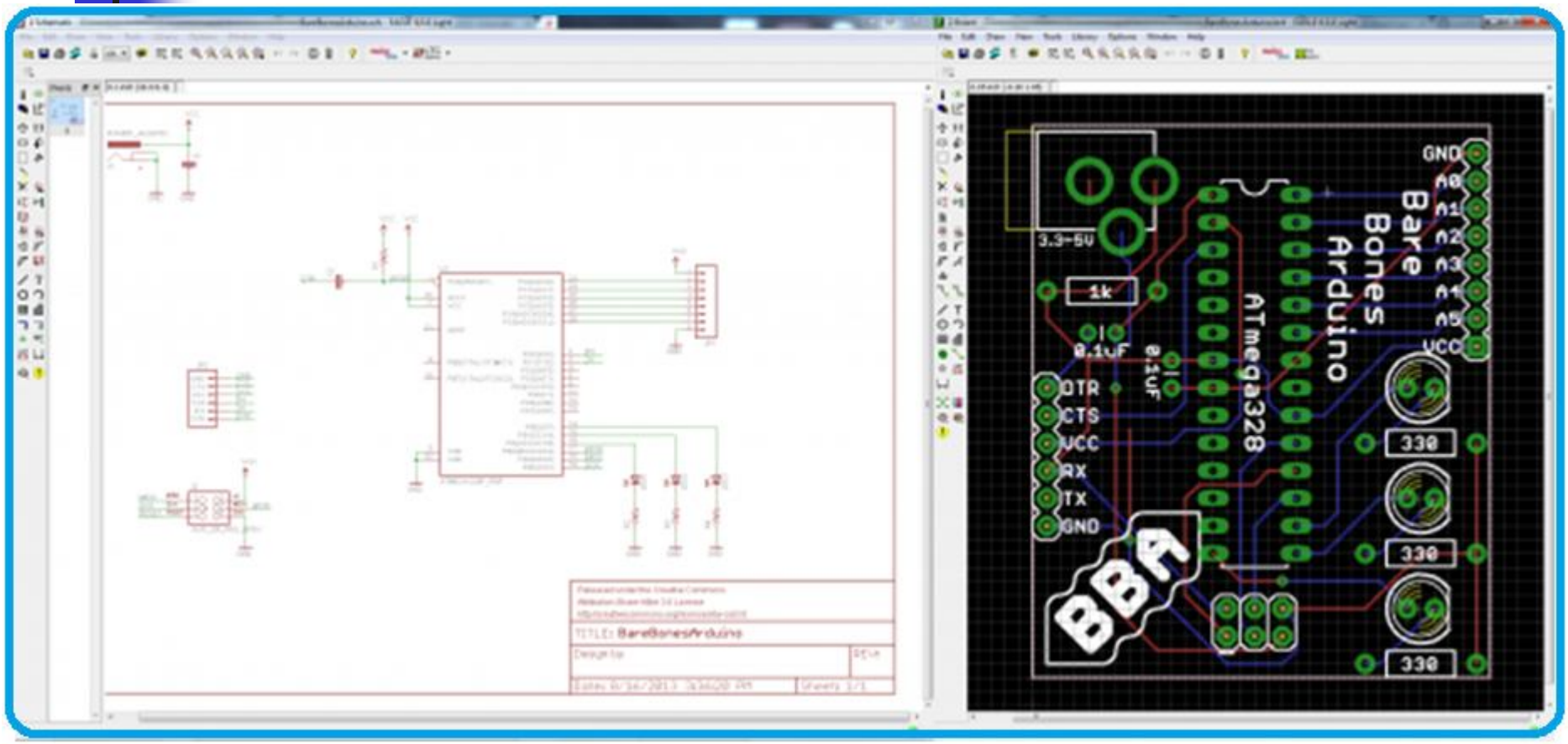
Xbee S2 module

Image Source: Google

Silver Challenge with TIET &TCD buggy



Schematic diagram and PCB layout design using Autodesk Eagle software



Source: sparkfun.com

Learning Outcomes of Electronics Lab (UTA 014)

Students should be able to:

- **Design and test an IR sensor module which helps buggy to move on the given track as path follower.**

- **Design and test a transmitter circuit on PCB to generate waveforms of different pulse width for three Gantries placed on the track.**

- **Design and test a receiver circuit on PCB for sensing Gantries placed on the track at various locations.**

Electronics Lab (UTA 014)

List of Experiment

Experiment-1

a. To design a schematic circuit diagram of **PWM Transmitter** for Gantry using Eagle software tool.

b.To design a Printed Circuit Board layout of PWM Transmitter for Gantry using Eagle software tool.

Experiment-2

•To design a schematic circuit diagram of **Receiver** for Gantry using Eagle software tool.

•To design a Printed Circuit Board layout of PWM Receiver for Gantry using Eagle software tool.

Experiment-3

•To draw a schematic diagram of **IR sensor module** circuit (which helps Buggy robot to move on a predefined path as a line follower) using CAD tool (Eagle).

•To design a printed circuit board layout of IR sensor module circuit (which helps Buggy robot to move on a predefined path as a line follower) using CAD tool (Eagle).

Continued…

Project Activity-1

Design and testing of IR transmitter circuit which generates rectangular pulses of specific pulse width for corresponding Gantry.

•To solder IR transmitter circuit on a general purpose PCB.

•To write a Program and upload it on the ATtiny based microcontroller through Arduino boot-loader circuit.

•To test the output pulses on CRO generated through IR transmitter circuit.

Project Activity-2

Design and testing of IR receiver circuit which can sense the signal of a specific pulse width and able to recognize the corresponding Gantry.

•To solder IR receiver circuit on a general purpose PCB.

•To test the combined module of IR transmitter and receiver circuits on Buggy Track with Gantry provision through supervisory control mode for Bronze and silver level.

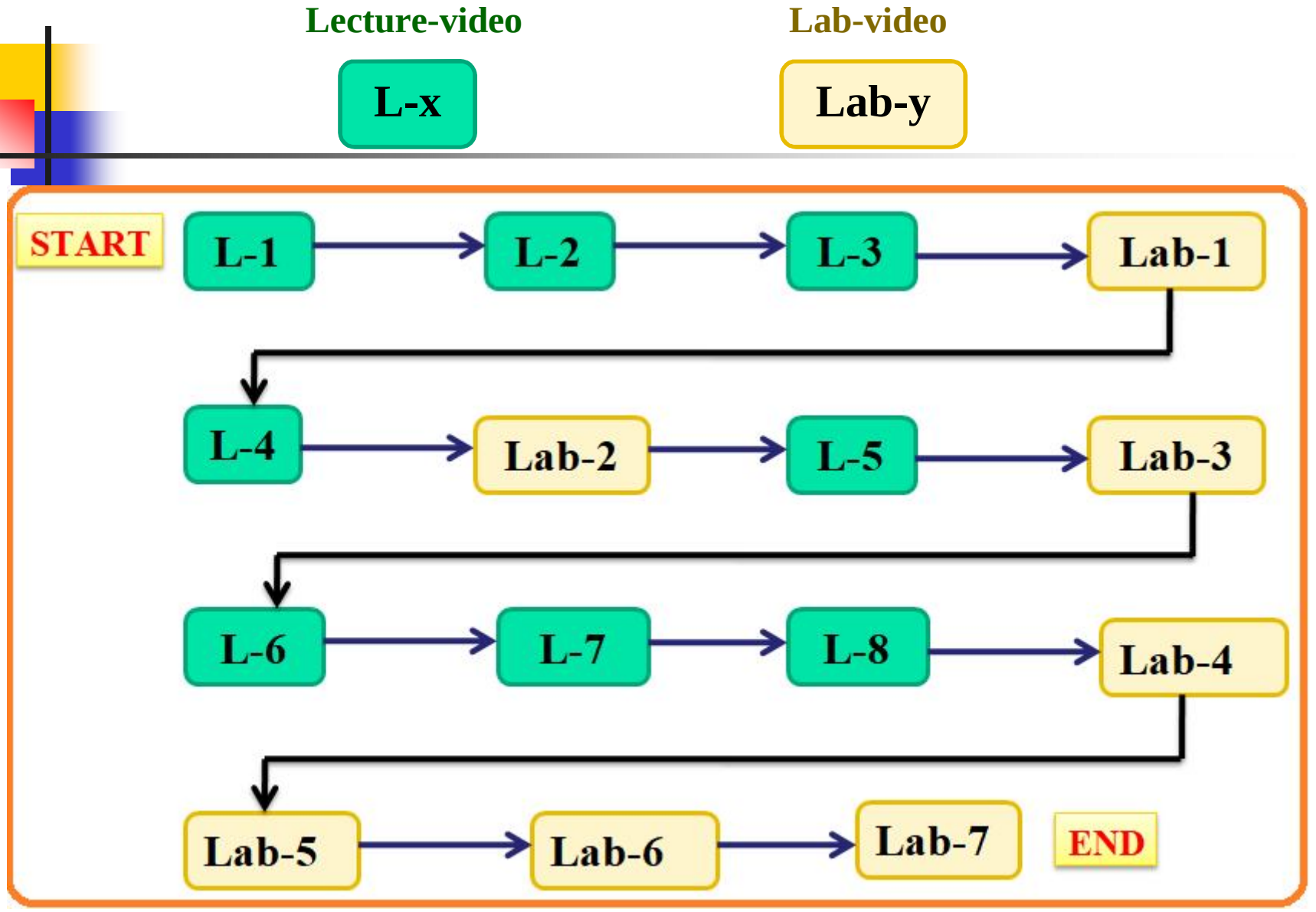
Continued…

Project Activity-3

Design and testing of IR sensor module circuit which helps Buggy robot to move on a predefined path as a line follower.

- To solder IR sensor module circuit on a general purpose PCB.
- To test the output pulses of IR sensor module on predefined track as path follower.

Sequence of lecture and Lab videos to learn the course material

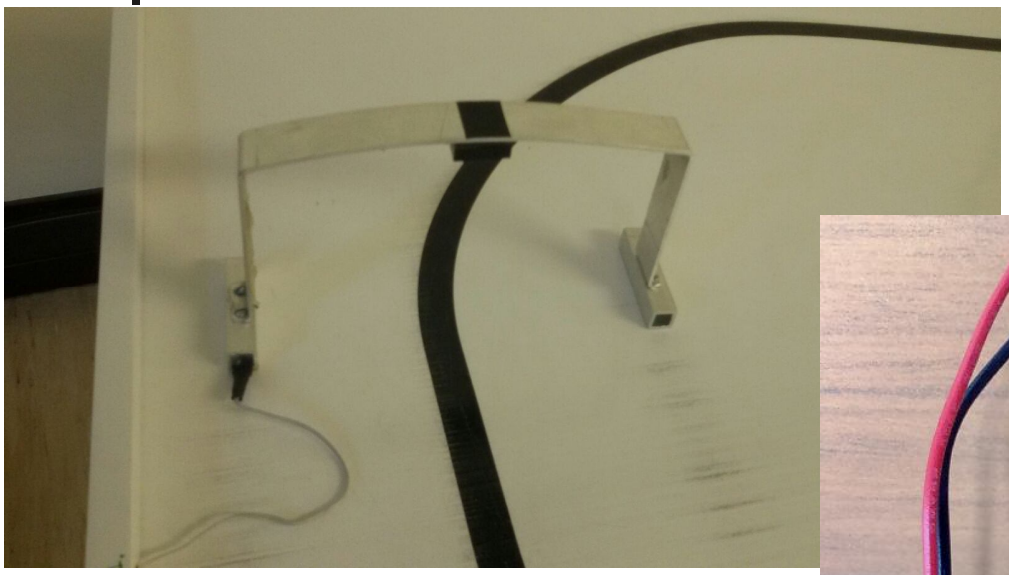


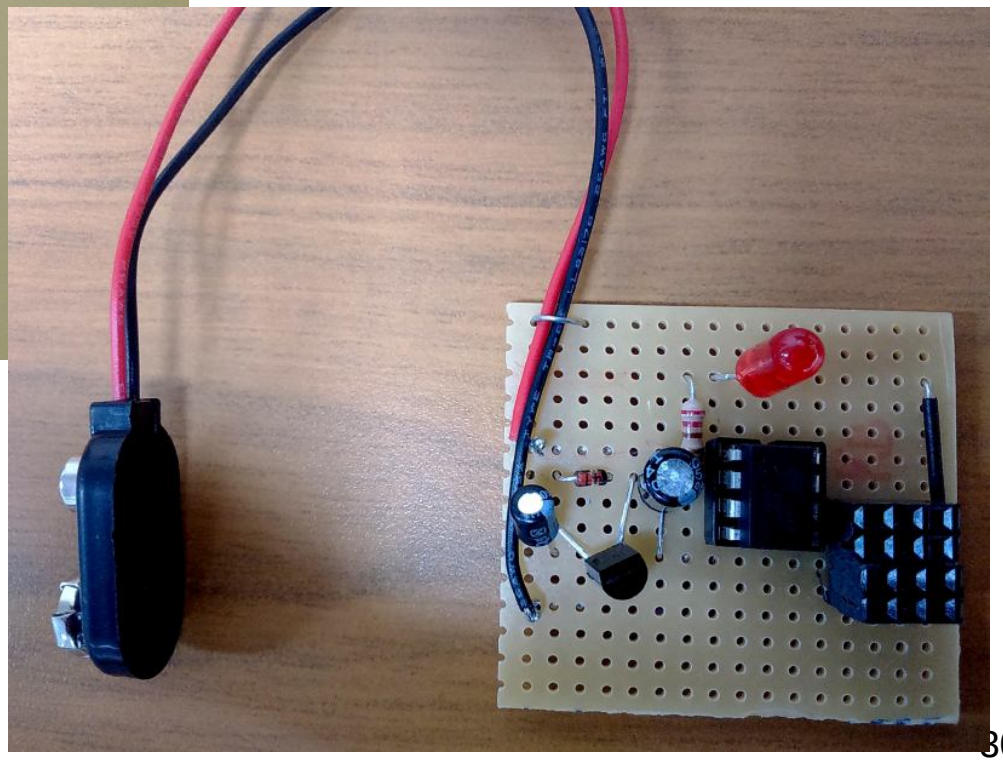
References

- https://www.digi.com/solutions/by-technology/zigbee-wireless-standard
- https://www.elprocus.com/what-is-zigbee-technology-architecture-and-its-applications/
- http://www.cadsoftusa.com/
- https://www.youtube.com/watch?v=1AXwjZoyNno
- https://www.youtube.com/watch?v=CCTs0mNXY24
- https://www.youtube.com/watch?v=D8pHKHV7xqc

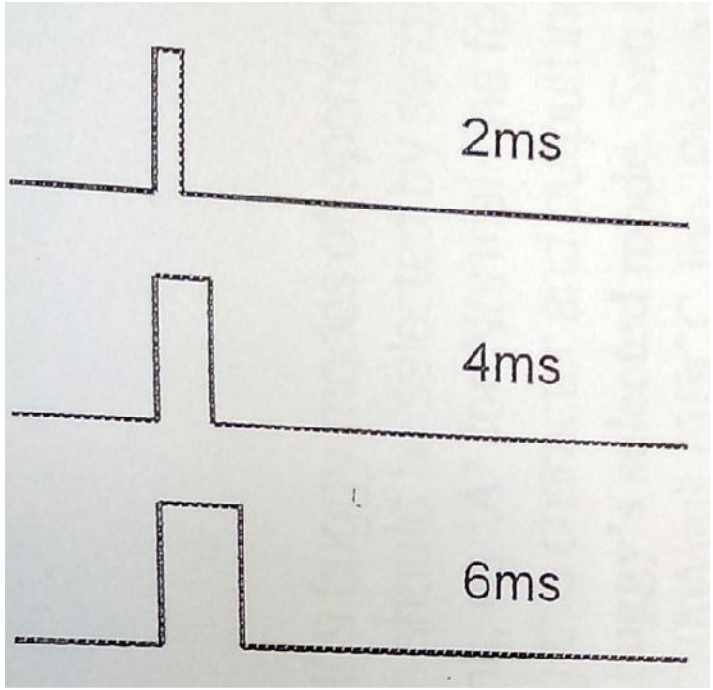
Thanks !

Gantry and its transmitter circuit using Attiny-45 IC

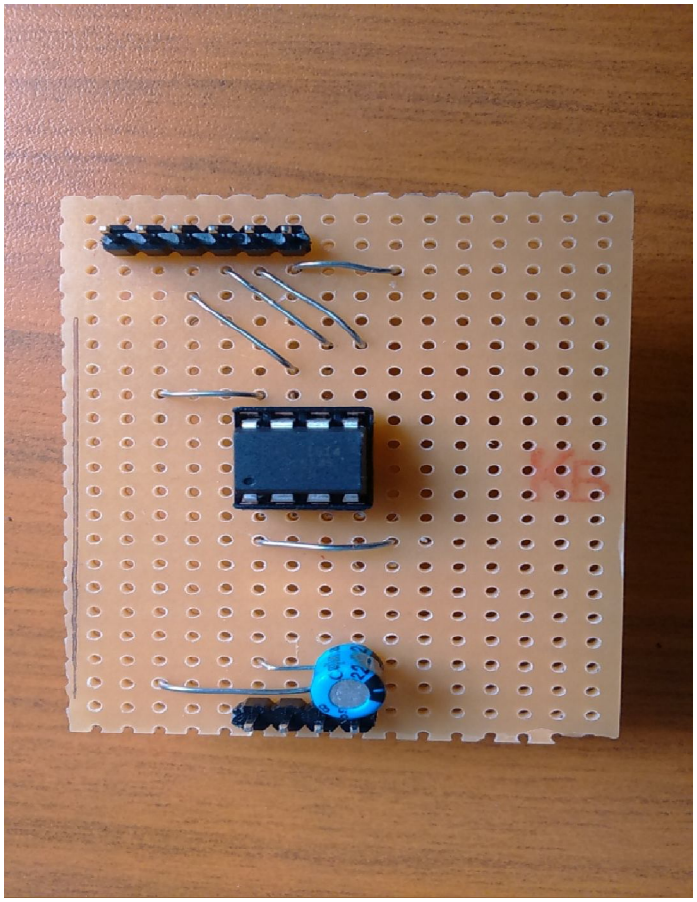


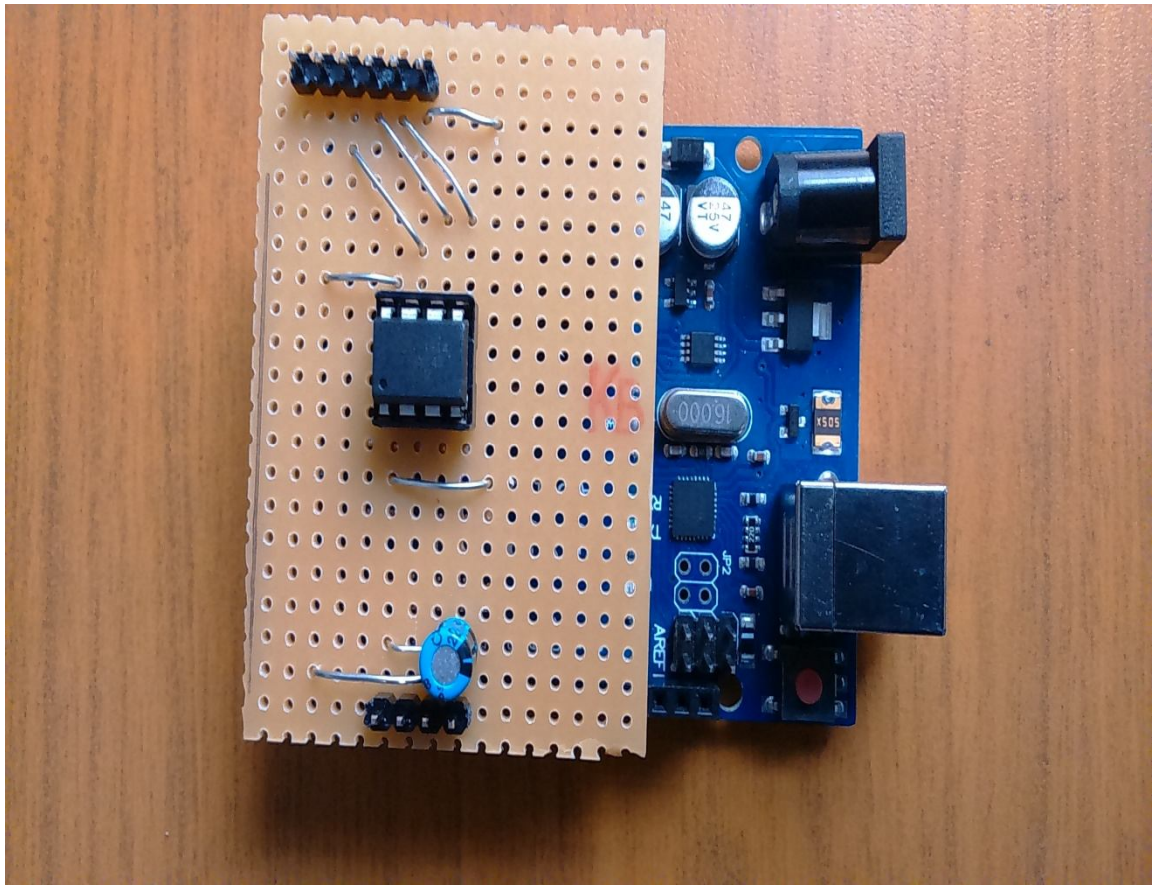


Pulses generated by transmitter circuit to recognize Gantries



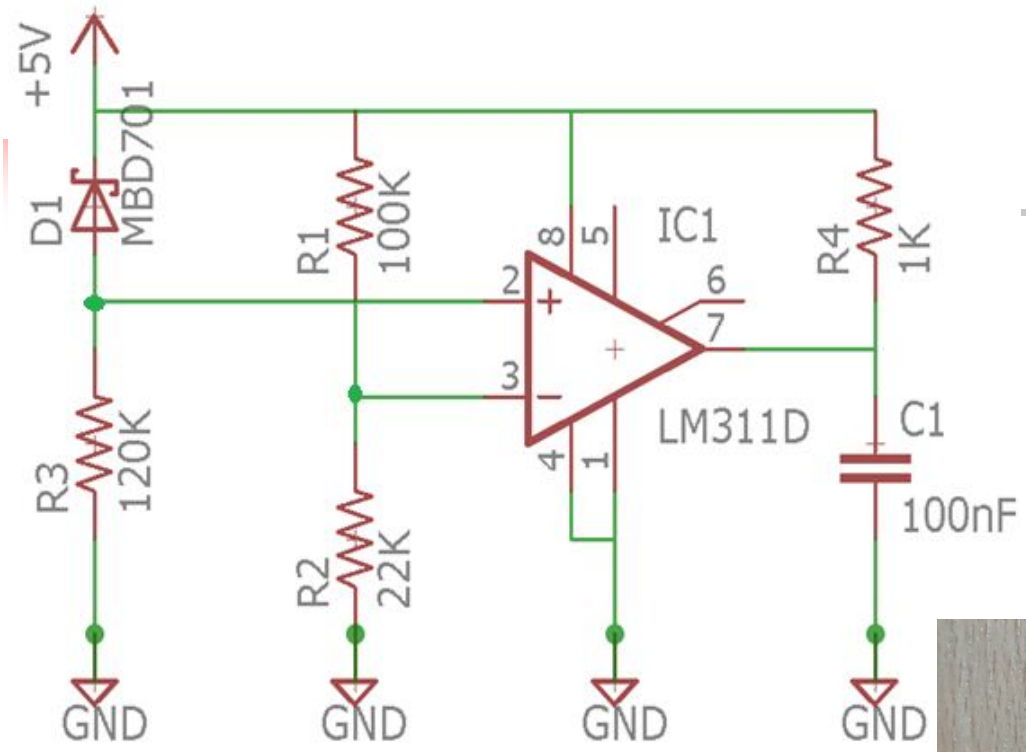
Design of Boot loader to program ATtiny IC in transmitter circuit of gantry

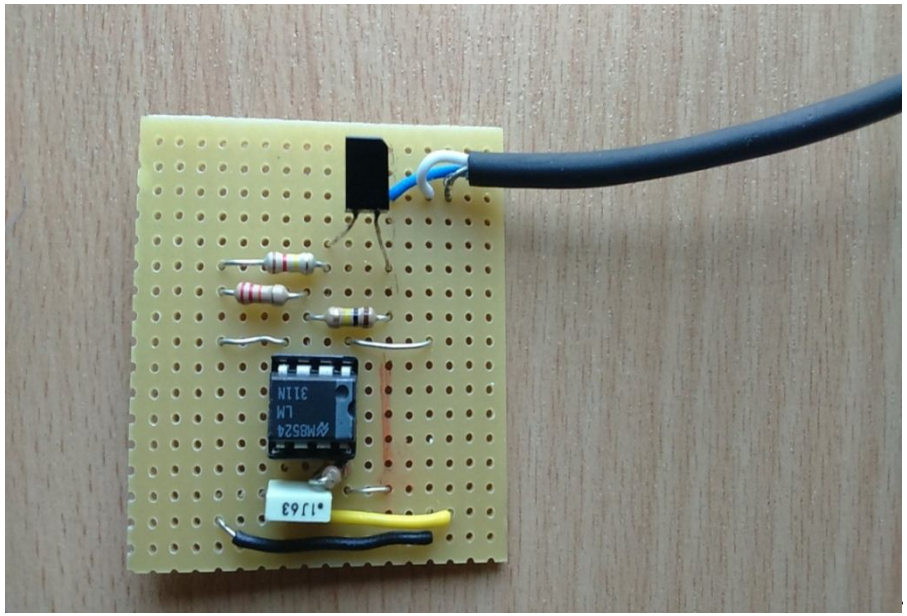




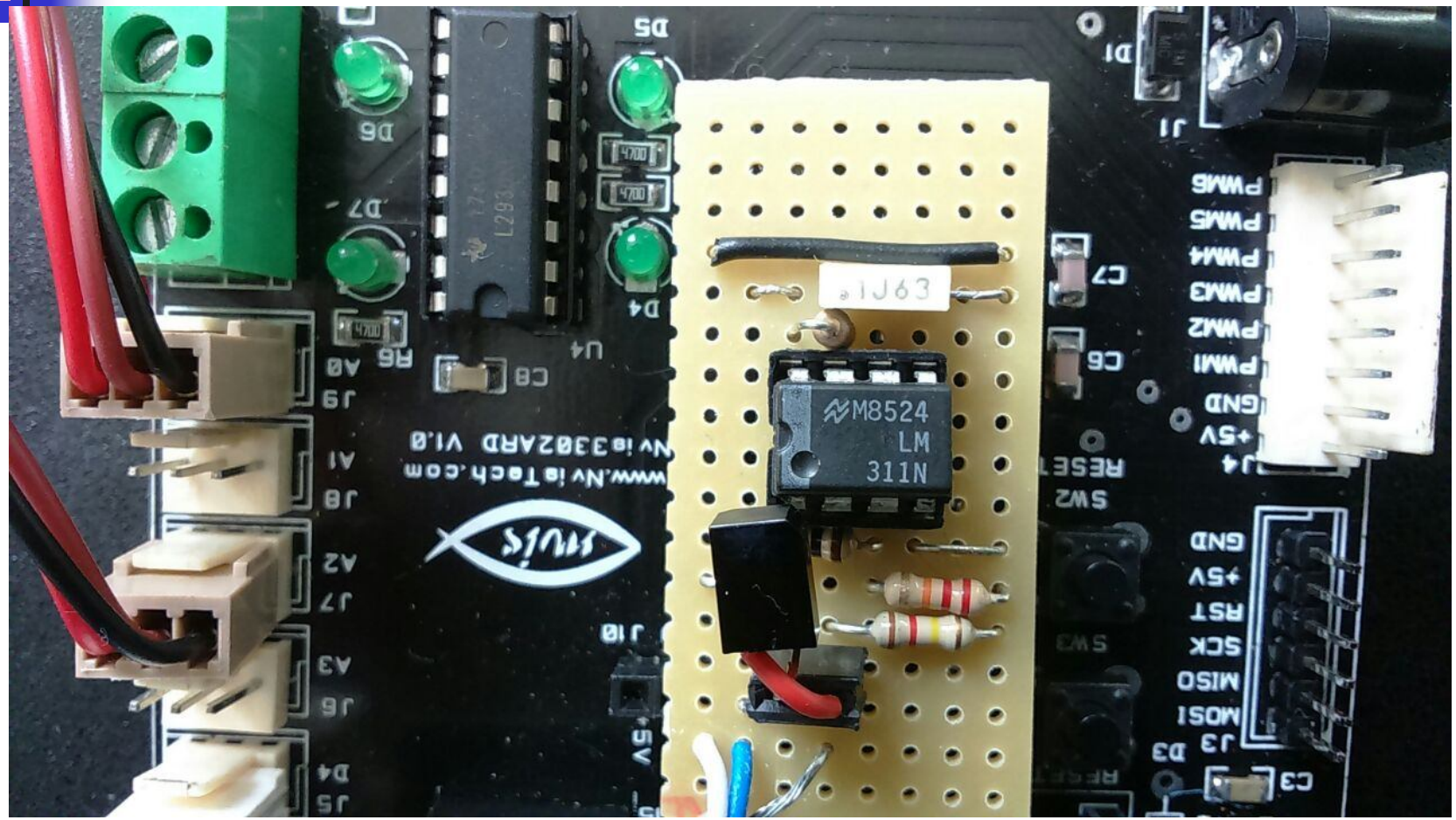
Gantry Receiver circuit

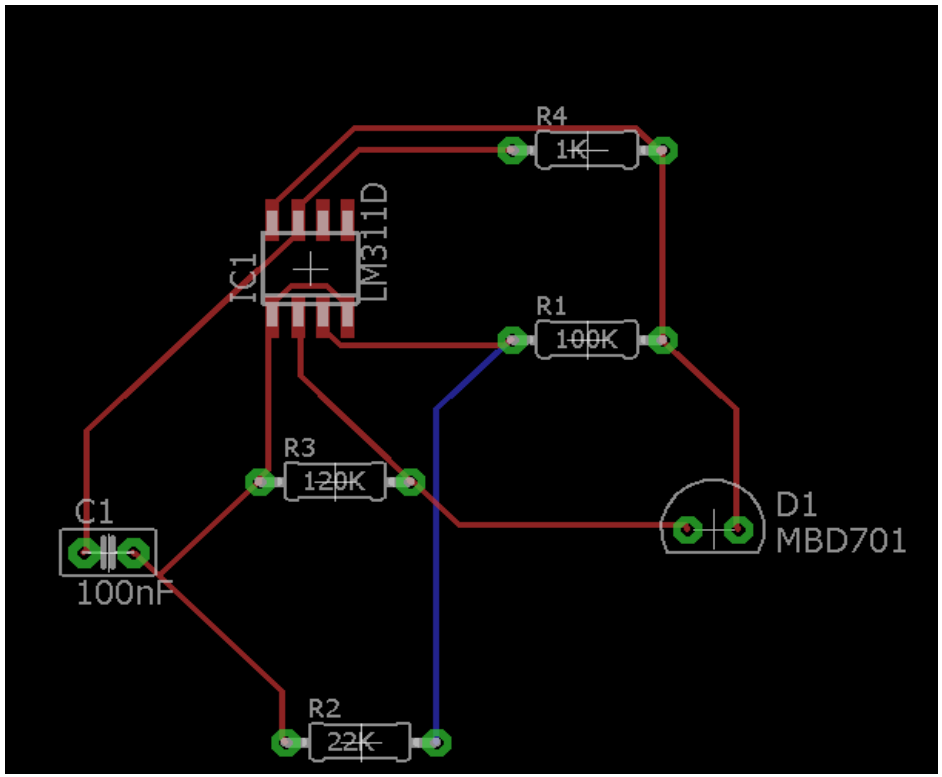
Gantry Receiver circuit diagram



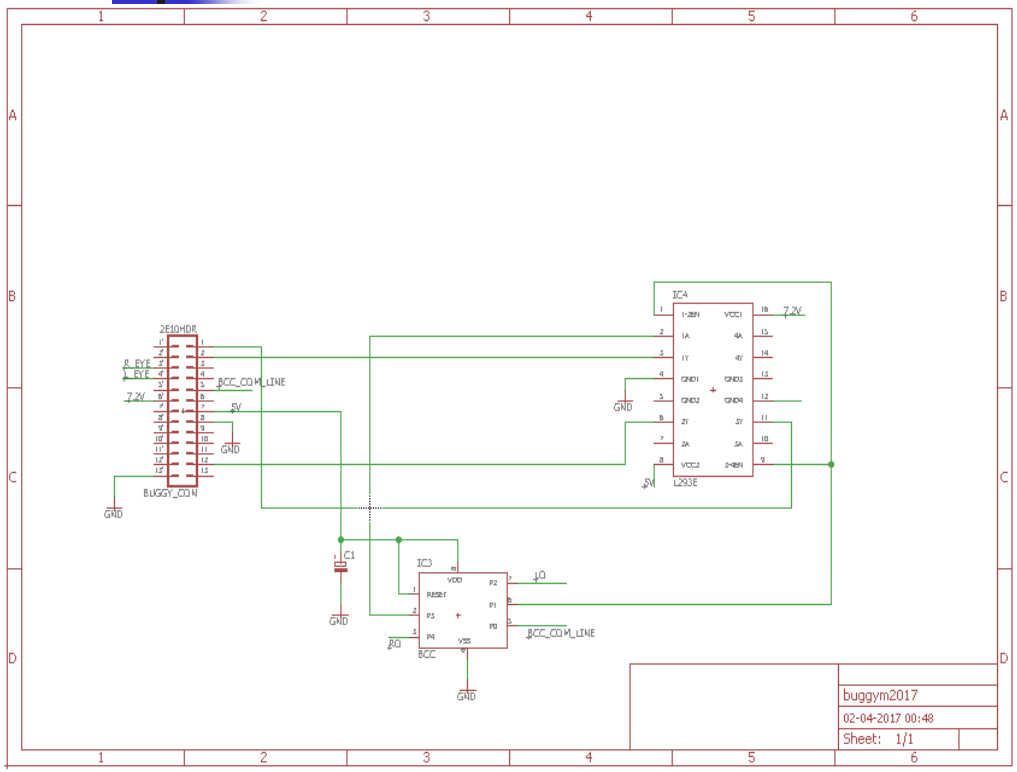


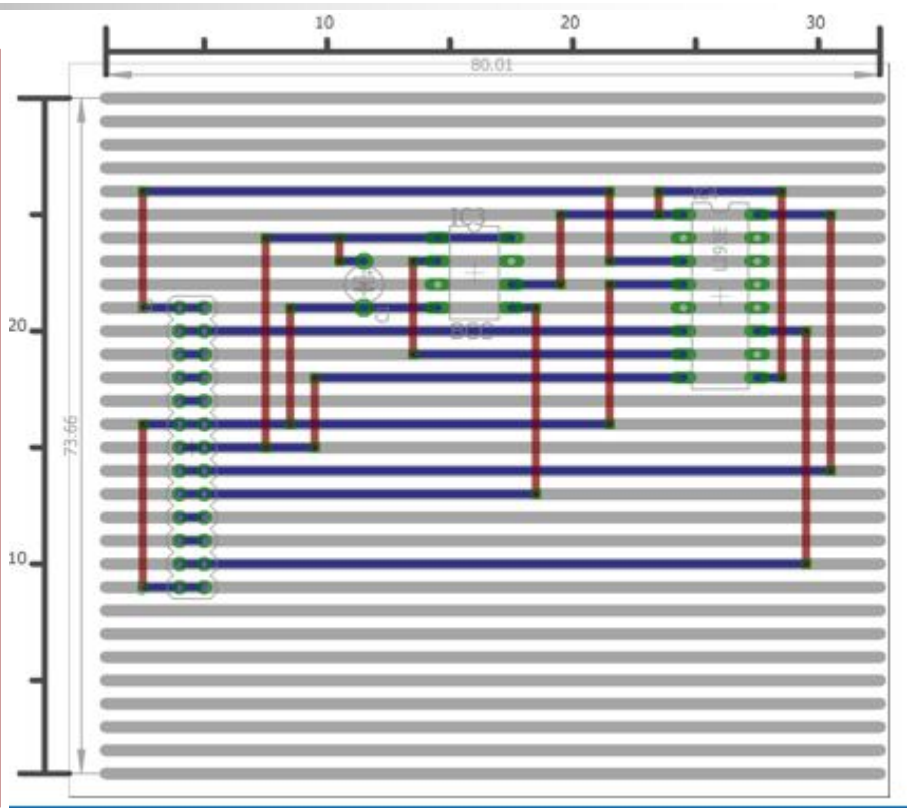
Gantry receiver circuit




R4
1K
IC1
LM311D
R1
100K
R3
120K
C1
100nF
D1
MBD701
R2
22K

Custom controller PCB layout design through software tool ‘Eagle’





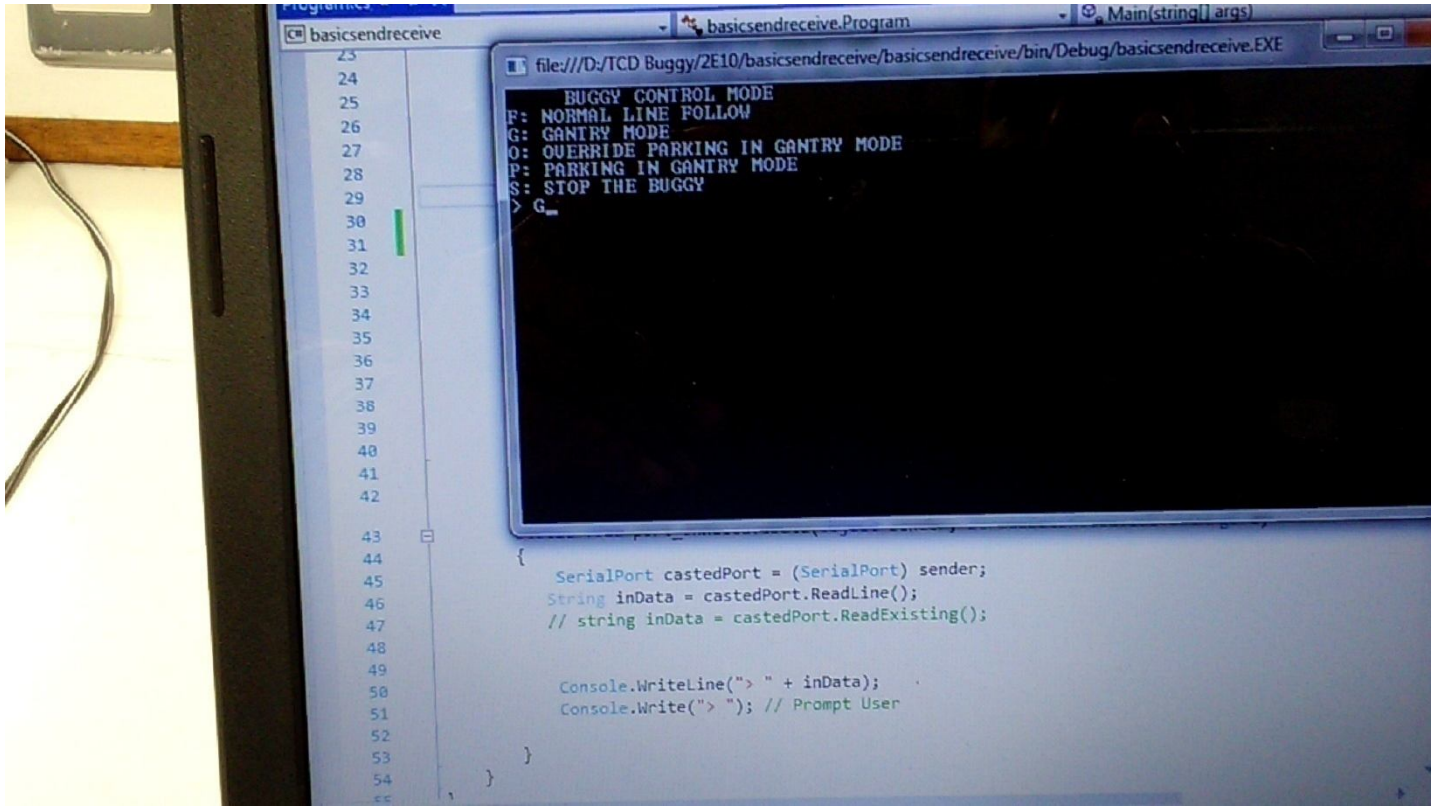
‘Eagle’ Software

Learning Outcomes of CSE Lab

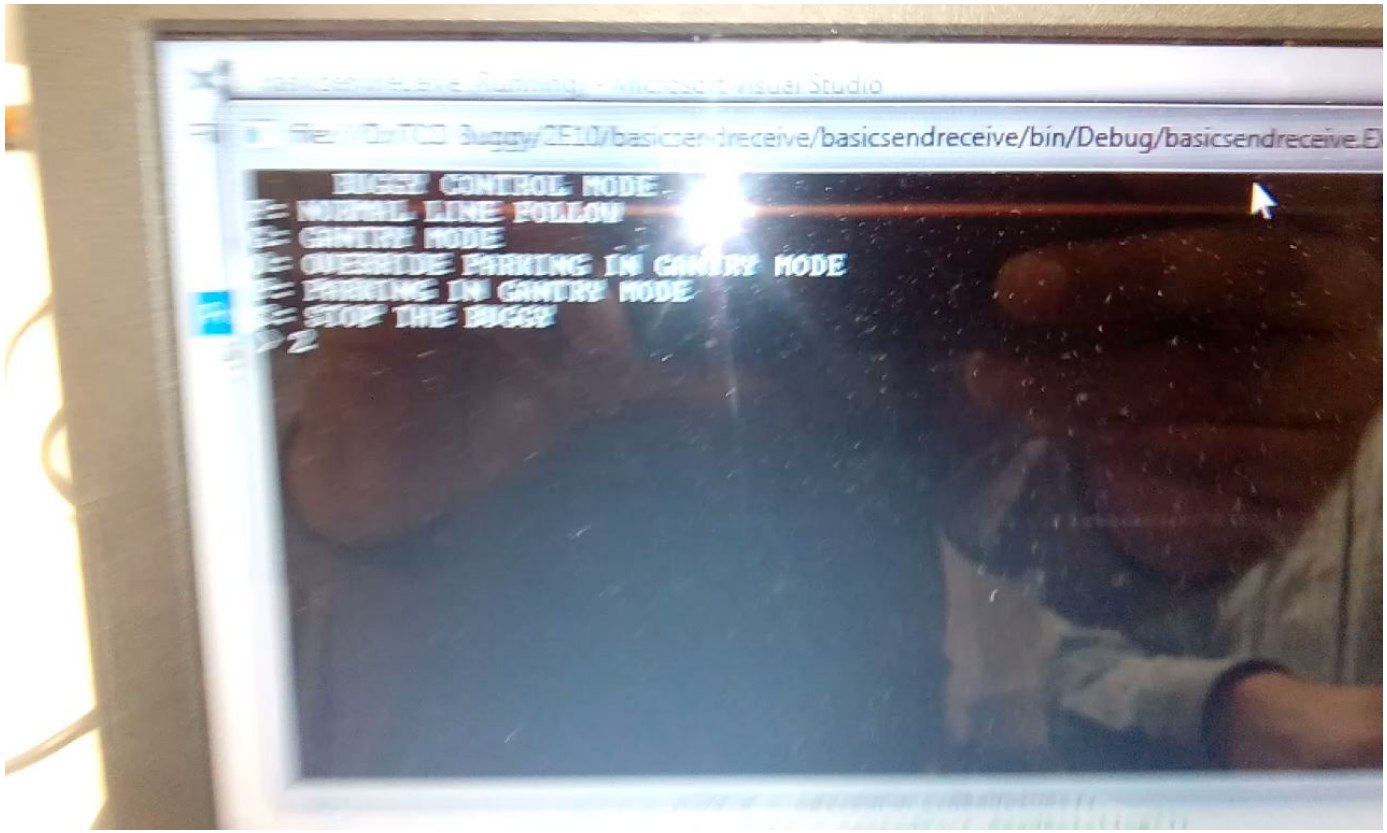
Computer Science Lab:

Write codes (C# and Arduino) according to new add-on PCB circuits on TU buggy for Bronze, silver and Gold challenges in supervisory mode.

Testing of Gantry transmitter-receiver circuit and parking provision through C# and Arduino programming



Silver Challenge with TU &TCD buggy



Lecture session and Lab activities

Each Group will have **two 2** X **2-hour** supervised laboratory sessions **(for ECE & CSE each)** and **1 hour** lecture/tutorial sessions per week.

All students are expected to spend approximately **6 to 8** ADDITIONAL hours per week working on the Project.

This will include personal study to understand the technology and the challenges that must be addressed to deliver a successful outcome.

Lecture session (ECE): (12 Lectures)

•Introduction to Arduino Board: Technical specifications, accessories and applications. (**2 lectures**)

•Procedure to simulate **Eagle** (PCB layout tool) software. (**1 lecture**)

•Concepts of sensors, their technical specifications, selection criterion, working principle and applications such as IR sensors, ultrasonic sensors. (**3 lectures**)

• Familiarization with hardware components, input and output devices, their technical specifications, selection criterion, working principle and applications such as-

- •Active and passive components: Transistor (MOSFET), diode (LED), LCD, potentiometer, capacitors, DC motor, Breadboard, general PCB etc.
- •Instruments: CRO, multimeter, Logic probe, solder iron, desolder iron
- •Serial communication: Concept of RS232 communication , Xbee (**4 lectures**)

•Introduction of **ATtiny** microcontroller based PWM circuit programming. (**2 lecture**)

Lab Exercise (ECE): 14 Weeks +2 week for Evaluations (Bronze, Silver and Gold challenges)

•Design a schematic circuit and PCB layout of Receiver for Gantry using Eagle software tool. (**2 week**)

•Design and testing of IR receiver circuit which can sense the signal of a specific pulse width and able to recognize the corresponding Gantry. (**3 week**)

•Design a schematic circuit and PCB layout of PWM Transmitter for Gantry using Eagle software tool. (**2 week**)

•Design and testing of IR transmitter circuit which generates rectangular pulses of specific pulse width for corresponding Gantry. (**3 week**)

•Write a Program and upload it on the ATtiny based microcontroller (essential component of IR transmitter circuit) through Arduino. (**2 week**)

•Write a Program and upload it on the ATtiny based microcontroller (essential component of IR transmitter circuit) through Arduino. (**2 week**)

Evaluation: Group/Individual performance

Evaluation Buggy Lab (UTA 014)
Electronics Lab

	Parameters / Marks	**5**	**4**	**3**	**2**	**1**	**0**
Eagle Software Module (Group)	Schematic Diagram (Transmitter circuit)						
	PCB lay out (Transmitter circuit)						
	Schematic Diagram (Receiver circuit)						
	PCB lay out (Receiver circuit)						

	Parameters / Marks (Working, Partially working, Not working)	**10**	**5**	**0**
Hardware Module (Group)	PCB Design (Transmitter circuit)			
	PCB Design (Receiver circuit)			

Viva (Individual)	Knowledge of Hardware Design, Arduino, Buggy control, Ultrasonics, IR sensors, X-Bee, Receiver & Transmitter circuits etc.	**10**

Total: 50

Lecture session (CSE): (12 Lectures)

Programming of Arduino:

• Introduction to Arduino: Setting up the programming environment and basic introduction to the Arduino micro-controller.

• Programming Concepts: Understanding and Using Variables, If-Else Statement, Comparison Operators and Conditions, For Loop Iteration, Arrays, Switch Case Statement and Using a Keyboard for Data Collection, While Statement, Using Buttons, Reading Analog and Digital Pins, Serial Port Communication, Introduction programming of different type of sensors and communication modules, DC Motors controlling. **(8 lectures)**

Basics of C#:

• MS.NET Framework Introduction, Visual Studio Overview and Installation

• Programming Basics: Console programming, Variables and Expressions, Arithmetic Operators, Relational Operators, Logical Operators, Bitwise Operators, Assignment Operators, Expressions, Control Structures, Characters, Strings, String Input, serial port communication: Read and write data using serial port.

Software Quality: Code optimization **(4 lectures)**

Lab Exercise (CSE): 12 Weeks +3 week for Evaluations (Bronze, Silver and Gold challenges)

Arduino Controller

- To Blink an LED **(1 week)**
- To Control LED Using PUSH button **(1 week)**
- To Control Buggy DC Motor movements: Forward, backward, left, right turn and anti rotation. **(2 week)**
- To Read IR Sensor using analog and digital read command **(1 week)**
- Buggy normal line follower **(1 week)**
- Buggy normal line follower using obstacle avoidance. **(1 week)**

C#

- Read and write on console **(1 week)**
- Read IR sensors value from buggy using serial port communication **(1 week)**
- Recognize and read Gantry number using serial port communication **(2 week)**
- Control movements of Buggy into supervisory mode using serial communication **(1 week)**

•**Bronze Challenge**: Single buggy around track twice in clockwise direction, under full supervisory control. Can detect an obstacle. Parks safely. Prints state of the track and buggy at each gantry stop. (**1 week**)

•**Silver Challenge**: Beyond bronze - Two buggies, both one loop around, track in opposite directions under full supervisory, control. Can detect obstacles. Both park safely. Prints state of the track and buggies at each gantry stop. (**1 week**)

•**Gold Challenge**: Beyond silver – Same as silver but user enters the number of loops around the track. So your code must be generalized. (**1 week**)

Thanks !