PROJECT PRESENTATION

MON - 21

P-31 : Simulator for firefly flashing synchronization studies

INTRODUCTION

Nature presents us with fascinating examples of spontaneous synchronization like the rhythmic flashing of fireflies and the synchronized firing of neurons in our brains. In 1993, Renato Mirollo and Steven Strogatz introduced their electronic implementation of firefly synchronization, demonstrating how simple electronic oscillators could mimic this natural phenomenon.
Our project reimagines this classic experiment using modern embedded systems, specifically the STM32G030X microcontroller.

PROBLEM STATEMENT

- Synchronization is a key phenomenon in complex systems. So to study it we need a programmable synchronization system with adjustable parameters to study real-time effects.
- Classical electronic fireflies (1993 design) lacked programmability and flexibility. Now, Modern advancements in microcontrollers enable digital control & experimentation.

PROPOSED SOLUTION

GOAL 01

- Modular electronic units mimicking firefly behavior
- Real-time visualization through LEDs
- Programmable synchronization parameters
- Ambient light immunity

VALUE PROPOSITION:

- Modern approach to classical synchronization studies
- Highly configurable platform for experiments
- Bridge between theory and practical implementation
- Educational tool for complex systems understanding

METHODOLOGY & APPROACH

After discussions with our professor, we have planned a three-step hardware development process:

- Initial Prototype: We will first design a basic STM32 board with just the microcontroller. This will help us gain hands-on experience with PCB design using the STM32G030X.
- Second Iteration: We will integrate IR LEDs, photodiodes, and other components onto the board and fabricate 2-3 units. These will be tested for functionality, synchronization accuracy, and any necessary design refinements.
- Final Prototype: After validating the second iteration, we will manufacture 9 boards (to form a 3×3 matrix) for full-scale testing. Any design improvements identified in the previous step will be incorporated into this version.

METHODOLOGY & APPROACH

Throughout this process, software development and implementation will run in parallel, ensuring efficient debugging and integration.

The choice of STM32G030X was recommended by our professor due to its suitability for the application. The IR LED and receiver pair was selected for its strong resistance to ambient light interference, ensuring reliable synchronization.

PRINCIPLE OF OPERATION

- Each unit flashes its LED at a programmable frequency.
- Nearby units detect flashes via IR sensors and dynamically adjust their timing.
- The system models coupled oscillators to achieve synchronization.

BLOCK DIAGRAM

Core Processing Unit:

- STM32G030X MCU
- Programming interface (ST-Link)

Communication System

- IR Emitters (SFH 4550)
- IR Receivers (SFH 309FA)
- Signal conditioning circuits

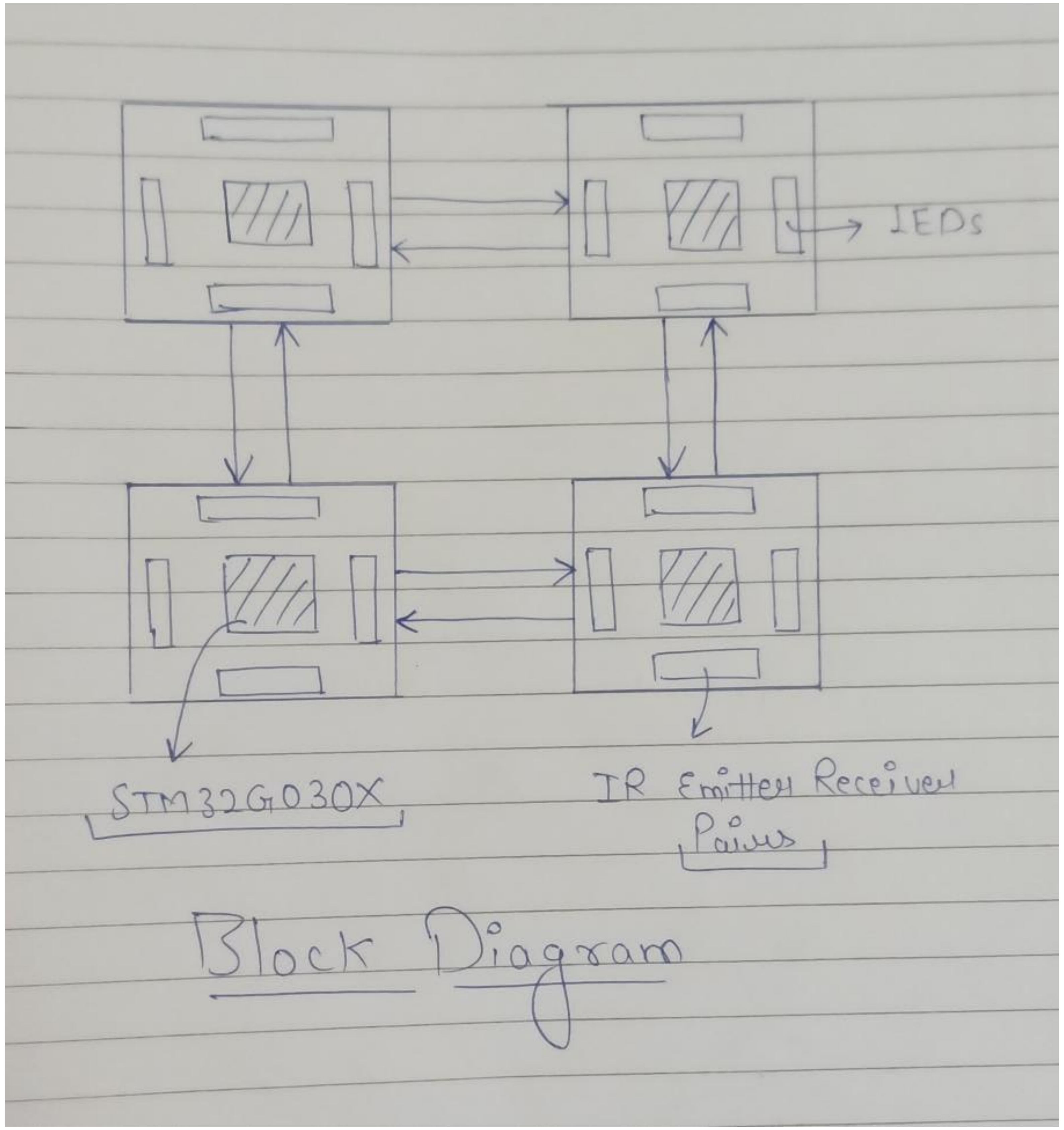
Visual Feedback

- Status LEDs

Power Management

- Voltage regulation
- Power distribution

BLOCK DIAG.



COMPONENT SELECTION JUSTIFICATION

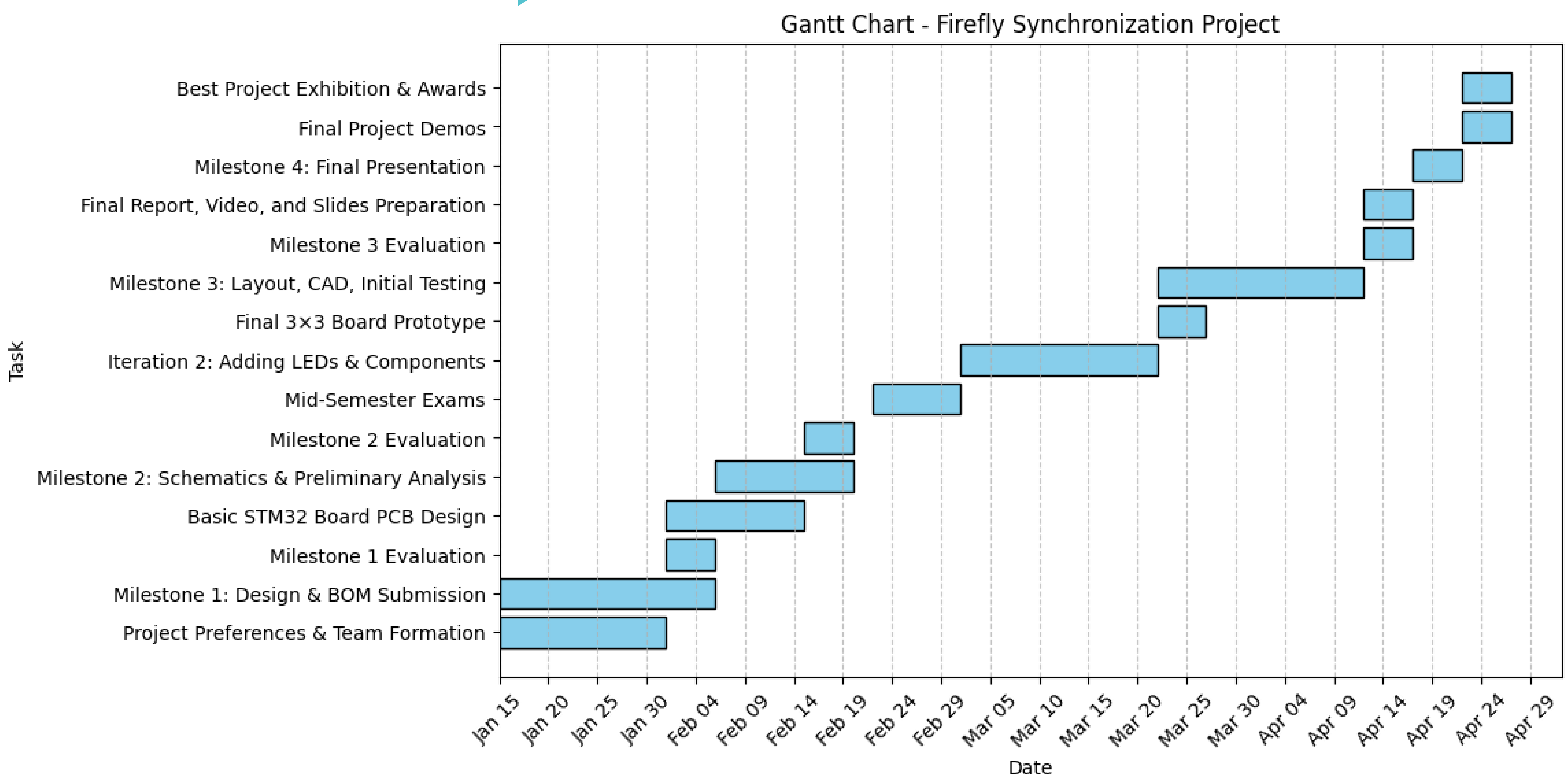
MICROCONTROLLER (STM32G030X)

- Low cost, high performance
- Sufficient I/O for multiple IR pairs
- Built-in timers for precise timing
- Good development ecosystem

IR COMMUNICATION

- SFH 4550 & SFH 309FA pair
- Narrow beam angle for directed communication
- Good ambient light rejection
- Suitable range for tabletop experiments

GANTT CHART



Gantt Chart - Firefly Synchronization Project
Best Project Exhibition & Awards
Final Project Demos
Milestone 4: Final Presentation
Final Report, Video, and Slides Preparation
Milestone 3 Evaluation
Milestone 3: Layout, CAD, Initial Testing
Final 3×3 Board Prototype
Iteration 2: Adding LEDs & Components
Mid-Semester Exams
Milestone 2 Evaluation
Milestone 2: Schematics & Preliminary Analysis
Basic STM32 Board PCB Design
Milestone 1 Evaluation
Milestone 1: Design & BOM Submission
Project Preferences & Team Formation
Task
Jan 15
Jan 20
Jan 25
Jan 30
Feb 04
Feb 09
Feb 14
Feb 19
Feb 24
Feb 29
Mar 05
Mar 10
Mar 15
Mar 20
Mar 25
Mar 30
Apr 04
Apr 09
Apr 14
Apr 19
Apr 24
Apr 29
Date

Area	Responsibilites	Member Name
1. Embedded Systems & Firmware Development	- Programming the STM32G030X microcontroller - Implementing firefly synchronization algorithms - Configuring PWM for LED intensity control - Implementing IR-based communication protocols	Shivam
2. IR Communication & Signal Processing	- Selecting appropriate **IR emitters & receivers** - Implementing **ambient light rejection techniques** - Testing and optimizing **IR-based synchronization** - Debugging **signal inconsistencies and interference**	Sumanth
3. Hardware Design (PCB & Power Management)	- Designing and optimizing the **custom PCB** - Managing **power distribution & efficiency** - Handling **circuit integration & miniaturization** - Ensuring compatibility with **STLink debugger**	Sami
4. System Testing & Debugging	- Testing hardware and software integration - Evaluating synchronization under different conditions - Performing real-world validation of distance-based LED intensity control - Debugging any hardware/software failures	Yashwanth and Lokesh

BOM

1. STM32 Microcontroller
2. 3.3V Voltage Regulator
3. IR LED
4. Photodiode
5. LED
6. NPN Transistor
7. Crystal Oscillator
8. USB-C Female
9. ESD Protection Diode
10. STlink V2
11. Other Passive components (Resitor,capacitors etc.)

KEY RISKS & MITIGATION STRATEGIES

Risk	Mitigation Strategy
Power management issues	Will try to optimize LED driving & low-power modes
Ambient light interference	Proper selection of IR emiiter and recievers. Also reducing the firing angle of LEDs.
Synchronization delays	Optimize signal processing algorithms
Hardware debugging	Iterative PCB design & prototyping
Programming complexity	Will use proven STM32 libraries & debugging tools

THANK YOU