A6: Mario Kar

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Motivation

- Traditional RC controls are boring.
- Fresh and playful driving experience.

Use Case

- Intuitive, immersive control with real feedback.
- Driver controls a Kar with hand gestures and feels real-time feedback.

MVP

- Glove with gesture sensors, haptics, and Bluetooth.
- Real-time Kar control for steering, acceleration, and braking.

Ethical Considerations

- Uncontrollable Kar driving around.
- Safety inputs and timeouts.

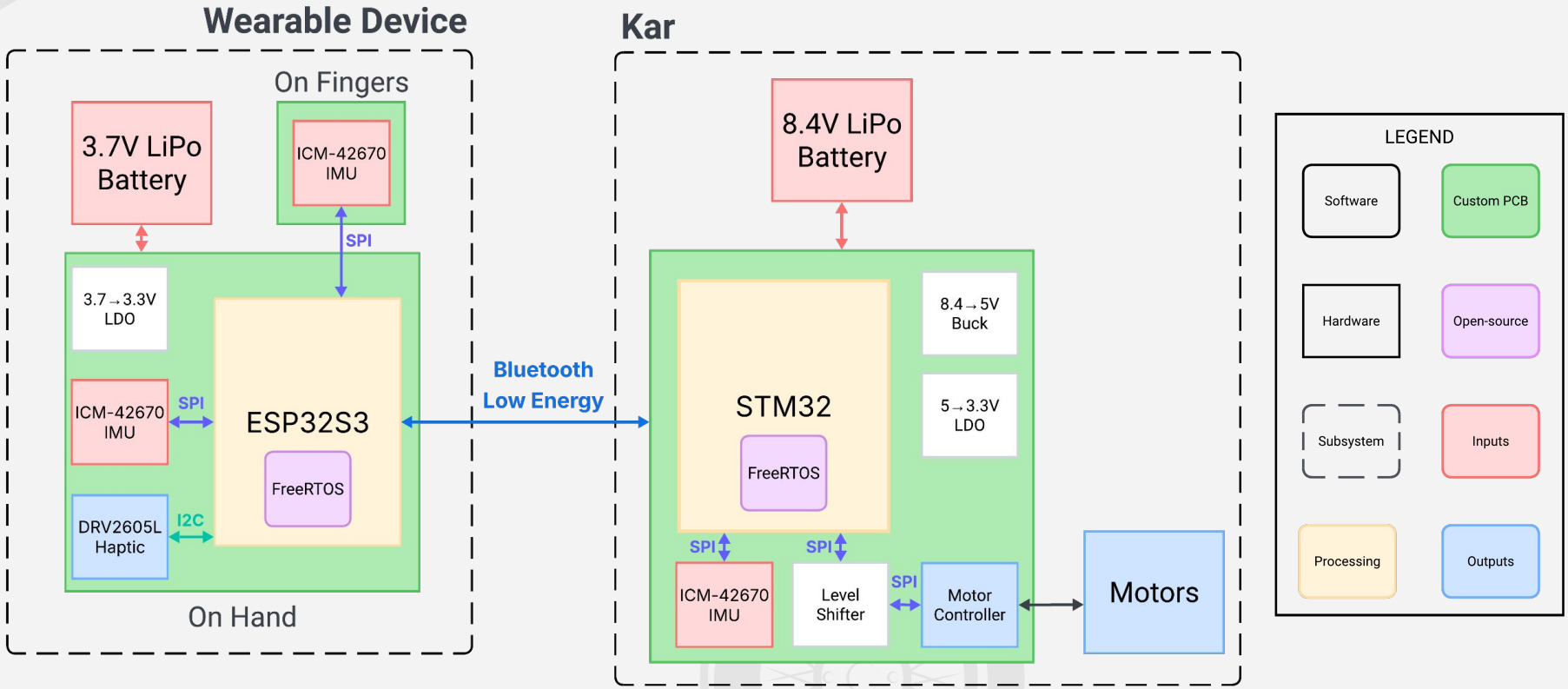
Use-Case & Design Requirements [1]

USE-CASE REQUIREMENT	DESIGN REQUIREMENT
Kontroller is lightweight: 60-80g	⚐ Power from LiPo batteries (++Power Density) ⚐ Custom PCBs for mass control
Kontroller can support at least 2 hours of use	⚐ At least 600mAh of capacity
Wearable Kontroller for touchless control	⚐ Glove PCB size shall be <3in^2 ⚐ Electronics shall be unobtrusive on glove
Haptic clarity for indicating collisions and acceleration	⚐ Intuitive mapping btwn Kontroller IMU & haptic intensity ⚐ IMU on Kar for collision detection

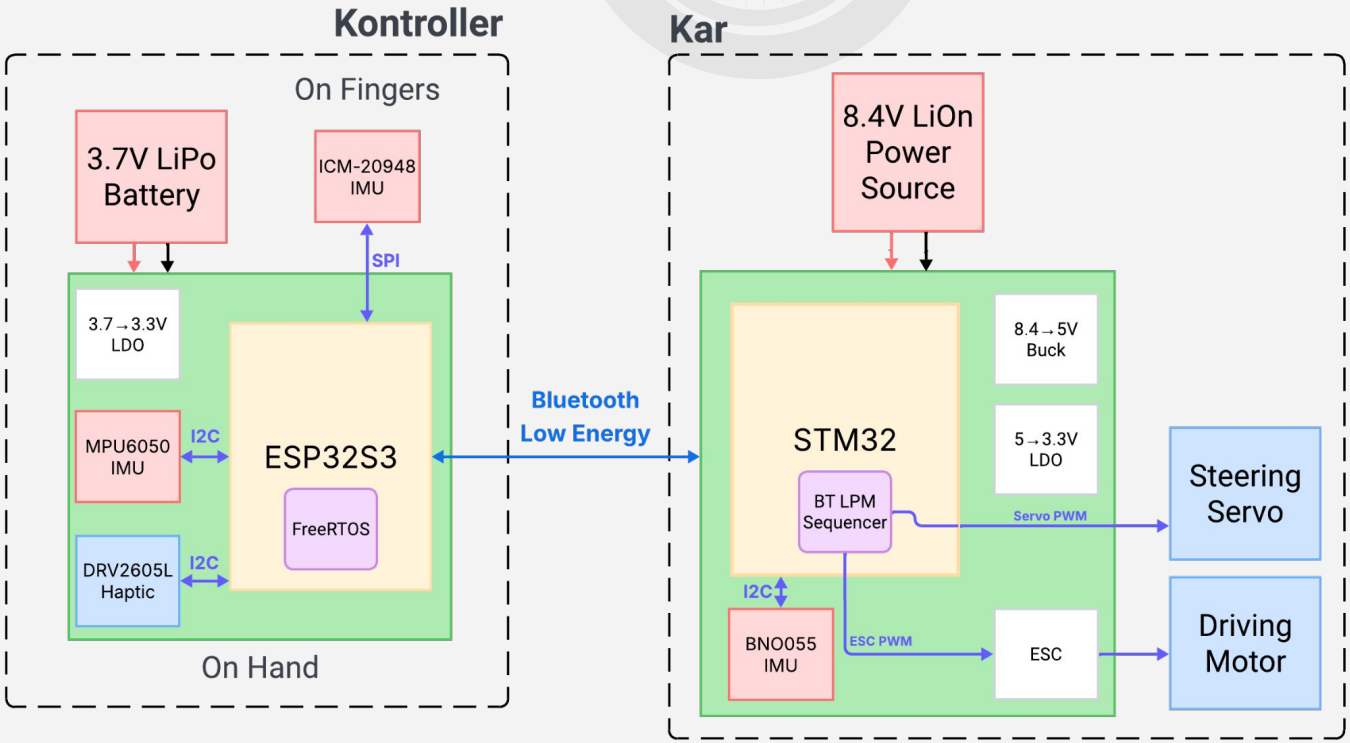
Use-Case & Design Requirements [2]

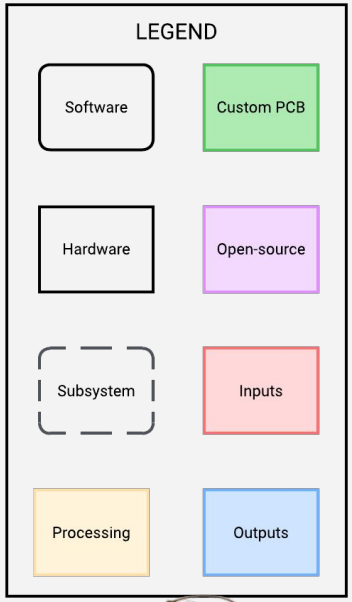
USE-CASE REQUIREMENT	DESIGN REQUIREMENT
30-50ms end-to-end latency	⚐ Processing steps on critical path shall be <5ms each
Intuitive mapping between gestures and Kar motion	⚐ Angle of finger tilt shall correspond to Kar velocity ⚐ Rotation of hand shall correspond to Kar turning angle
Reliable wireless communication up to 10m	⚐ External antenna for stable 2.4GHz
Reset input for entering safe/idle state within 30ms	⚐ Dedicated button on Kontroller and Kar

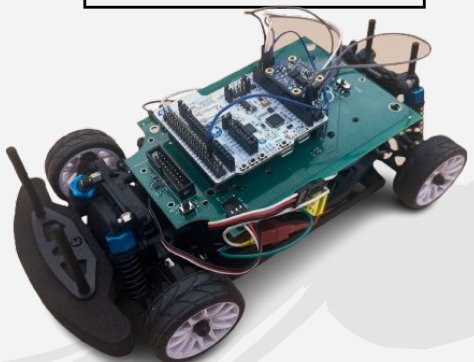
Initial Solution Approach



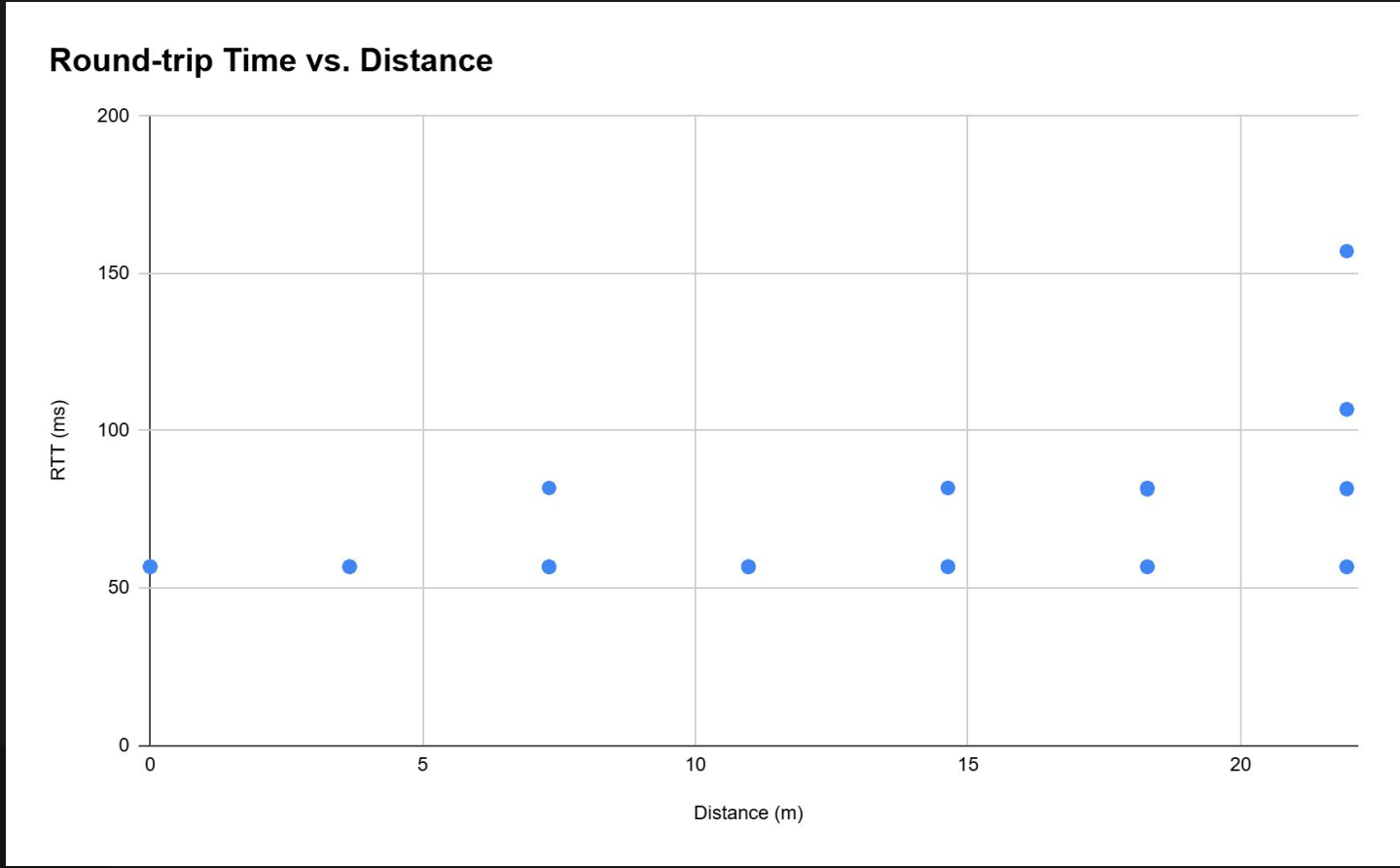
Complete Solution







Verification and Validation – Latency



Verification and Validation – Explicit Tests

Metric	Test Method	Success Output
End-to-end latency	⚐ Delay testing ⚐ User testing (1-5 rating)	< 50ms in delay testing, 4/5 average rating
Control scheme viability	⚐ User testing (Obstacle course + user rating 1-5)	90% success rate in obstacle course, 4.5/5 average rating
Kontroller quality	⚐ User testing (Multiple user ratings 1-5)	3/5 average rating
Haptic feedback clarity	⚐ User testing (1-3 rating)	2.7/3 average rating
PCB functionality	⚐ DRC + Bringup Plan	DRC passes, bringup plan followed successfully

Results

- Buggy behavior leading to some tests having lower preliminary scores

- User testing has not yet concluded (~30% complete)

ID	Metric	Level	Reference	Test	Success Criteria	Pass?
T1	Controller weight 60-80g	1	UC-1	Physically weigh controller	Weight within bounds	78.5g
T2	Perceived controller weight not too heavy	2	T1	Receive feedback in user testing using 1-5 Linkert scale	3/5 average on Linkert scale	Preliminarily yes
T3	Controller wearable	1	UC-2	Inspection	-	Yes
T4	Perceived controller wearability is high	2	T3	Receive feedback in user testing using 1-5 Linkert scale	3/5 average on Linkert scale	Preliminarily yes
T5	Intuitivity of control scheme - Driving ability	1	UC-3	Users test driving ability in obstacle course	90% of drivers pass course with <2 crashes	Broken reverse feature
T6	Intuitivity of control scheme - User perception	2	T6	Receive feedback in user testing using 1-5 Linkert scale	4.5/5 average on Linkert scale	Preliminarily yes
T7	Haptic feedback system is clear to user	1	UC-4	Receive feedback in user testing using 1-3 Linkert scale	2.7/3 average on Linkert scale	Preliminarily no
T8	End-to-end latency 30-50ms	1	UC-5	Perform RTT testing at standardized distances 0-20m, and LED delay test at 10m	<50ms up to target range of 10m	28.3ms at 10m
T9	Perceived latency is not too high	2	T8	Receive feedback in user testing using 1-5 Linkert scale	4/5 average on Linkert scale	Preliminarily yes
T10	Wireless communication is reliable up to 10m	1	UC-6	Perform packet loss test from standardized ranges of 0-10m	<1% packet loss at and below 10m	Yes
T11	Kar reset input implemented	1	UC-7	Observation	-	Yes
T12	Kar reset input latency <30ms	1	UC-7	Test operation of reset input, perform delay test using oscilliscope	Kar stops within 30ms of reset input	5ms
T13	Kontroller reset input implemented	1	UC-7	Inspection	-	Yes
T14	Kontroller reset input latency <50ms	1	UC-7	Test operation of reset input, latency verified by T8	Kar stops within 50ms of reset input	29.1ms at 10m
T15	Kontroller power supplied by LiPo battery	1	DR-1	Inspection	-	Yes
T16	Kontroller electronics will be implemented on custom PCB	1	DR-1	Inspection	-	Yes
T17	Kontroller PCB size <3in^2	1	DR-2	Measurement	Area within bound	2.56in^2
T18	Angle of finger tilt corresponds to Kar velocity	1	DR-3	Demonstration	Tilting finger should clearly cause Kar to accelerate	Yes
T19	Rotation of hands corresponds to Kar turn	1	DR-3	Demonstration	Rotating hand should clearly cause Kar to turn	Yes
T20	Two-way communication implented between Kar and Kontroller	1	DR-4	Demonstration	-	Yes
T21	IMU integrated into Kar	1	DR-4	Inspection	-	Yes
T22	Magnetometer integrated into Kar	1	DR-4	Inspection	-	Yes
T23	Processing steps on critical path <5ms each	1	DR-5	Each major processing step will be timed using on-MCU timers	Processing steps meet timing requirement	Yes
T24	PCB shall be manufacturable	2	T16	PCB shall be verified using design rule check tuned to JLCPCB's specifications	DRC pass	Yes
T25	Manufacured PCB shall meet project specifications	2	T16	Finished PCB will be tested for continuity, functionality, and be assembled according to bringup plan	PCB functional for project use	Some reworking required

Trade-offs

Performance Vs. Quality

- Glove “quality” metrics pass at 3/5 rating
- Based on use-case, experience trumps wearability + weight

Skillset Vs. Design

- Our strengths are custom electronics, and embedded firmware
- Mechanical design offloaded, to detriment of control, cost

Cost Vs. Everything

- Third PCB cut
- No spare parts
- IMUs scrounged + switched out
- No PCB assembly from fab
- PCB complexity reduced

GANTT CHART - MARIO KAR

PROJECT TITLE	Mario Kar	COMPANY NAME	Mario Kar
PROJECT MANAGER	Scrum Master Enrique	DATE	

Schedule

WBS NUMBER	TASK TITLE	TASK OWNER	PCT OF TASK COMPLETE	September					October				November				December
				08/31-09/06	09/07-09/13	09/14-09/20	09/21-09/27	09/28-10/04	10/05-10/11	10/12-10/18	10/19-10/25	10/26-11/01	11/02-11/08	11/09-11/15	11/16-11/22	11/23-11/29	11/30-12/06
1	**Logistics and Setup**																
	Website Setup	Everyone	100%														
	Slack	Everyone	100%														
	Proposal Presentation	Everyone	100%														
	Design Presentation	Everyone	100%														
	Interim Demo	Everyone	100%														
	Final Presentation	Everyone	100%														
	Final Report	Everyone	20%														
	Final Video	Everyone	15%														
2	**Project Planning**																
	Abstract	Everyone	100%														
	Order Materials	Everyone	100%														
	Finalize Design	Everyone	100%														
3	**Project Definition**																
	Custom PCB Schematic	Nick	100%														
	Custom PCB Layout	Nick	100%														
	Breadboarding Components	Nick	100%														
	FreeRTOS Setup Research	Caitlyn & Enrique	100%														
	FreeRTOS Setup for ESP32/STM32	Caitlyn & Enrique	100%														
	IMU raw-value interpretation	Caitlyn	100%														
	IMU FIR experimentation	Caitlyn	100%														
	IMU Kalman filter experimentation	Caitlyn	100%														
	Bluetooth research and prototyping	Enrique	100%														
	Bluetooth communication implementation	Enrique	100%														
	Haptic controller	Caitlyn	100%														
	PCB Bringup	Nick	100%														
	PCB Design Fixes	Nick	100%														
	PID system for motor control	Caitlyn & Enrique	100%														
	Final PCB Bringup	Nick	100%														
	Final Software Fixes	Enrique	90%														
	Construct Track (Slack)	Caitlyn & Nick	0%														
	Integrated Camera (Slack)	Enrique	0%														
4	**Project Testing / Monitoring**																
	Prototype hardware verification	Nick	100%														
	Coverage Tests	Enrique	100%														
	Safety Tests	Everyone	30%														
	User Testing	Everyone	30%														

Division of Labor

Nick
Hardware

Enrique
Software/Firmware

Caitlyn
Firmware

Next Steps

Testimonials

"This is awesome!"

- Spencer Li

"It's intuitive, but not functional."

- Liam Carden

(The battery died)