International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 10 Issue 8 Series II || August 2021 || PP 19-26

Adding a Remote-Control System to a Manually Operated Electric Golf Cart

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ABSTRACT
This paper focuses on the steps taken, strategies created, technologies used, and a prototype of adding a remote-control system to a Club Car® golf cart. The objective was to add a wireless control system to the golf cart while retaining all the original physical driver controls. Utilizing servo motors, microcontroller, and circuit implementations, this remote-controlled golf cart achieves teleoperated control and is a foundation for further autonomous development.

***KEYWORDS** – Remote-Control, Microcontroller, Embedded System, Engineering, golf cart*

Date of Submission: 16-08-2021 Date of Acceptance: 31-08-2021

I. INTRODUCTION

Globally, in 2020, an average of 3,287 people died in automotive accidents every day, and roughly 95% of these accidents were due to human error [1]. In bids to increase efficiency, safety, and convenience of cars, many interested parties are developing technologies to allow cars to fully drive themselves on existing roads. This goal is generally accepted as the Society of Automotive Engineers (SAE) level 5 autonomous driving [2]. A future with SAE level 5 autonomous vehicles stands not only to significantly reduce auto-accidents, but also to give mobility to groups such as the blind, amputees, or the elderly who can no longer drive safely. This project is to develop a similar mobility platform, but at a lower SAE level. Essentially a self-driving golf cart for use exclusively around a university campus. Adding a remote-control system to the golf cart is the initial step towards automating the golf cart eventually.

II. SYSTEM ARCHITECTURE

The architecture of the remote control system is shown in Fig. 1. The microcontroller receives commands from the Radio Control (RC) receiver and send them to the two servo motors and the digital “Throttle”. The digital “Throttle”

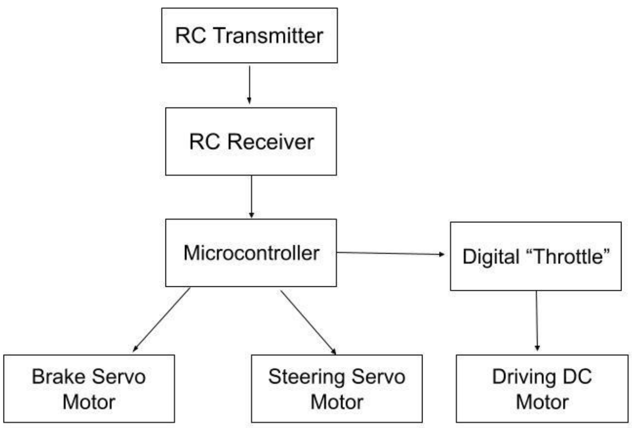


Figure 1: System Architecture of the remote-controlled golf cart.

is to replace the Motor Control Output Regulator (MCOR) of the golf cart, and it controls the acceleration of the DC driving motor. All three motors are powered by the 48V battery bank.

2.1. Hardware

2.1.1 Remote controller

Figure 2: T6A-V2 radio transmitter, receiver, and its connections to a servo for testing.

The 2.4GHz 6 channel radio control system T6A-V2 from Turnigy is used. Fig. 2 shows the wiring of the receiver and a servo motor. Two of the six channels are used: one is assigned to cart steering and another one is for cart braking.

2.1.2 Arduino and Servo Motors

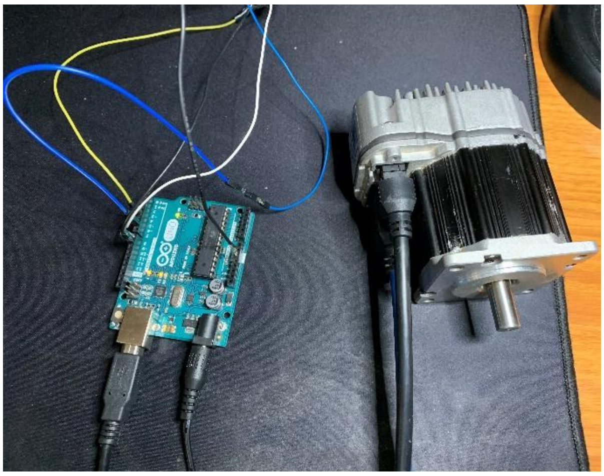


Figure 3: Arduino Uno board and Teknic servo motor.

The Arduino Uno microcontroller board and a Teknic CPM-SDHP-2310S-ELN DC servo motor are shown in Fig. 3. The Teknic servo motors used in the golf cart are Step and Direction servos.

The wiring setup of the Arduino Uno and the logic used for controlling the Teknic motors is shown in Figure 4. The radio control receiver gets 5 V from the microcontroller and send the output signals to Arduino Uno's digital pin 3 and 9, respectively. Since this output is a 5V PWM, the terminal must have a "~" sign which denotes the terminal is capable of properly analyzing PWM. Digital ~9 in this case, is responsible for receiving the position of 1 channel from the remote control.

Arduino wiring is organized into 2 sets, one for each motor with 4 Input/Output (I/O) wires, and a bundle of 4 wires going to ground (GND) for each motor. In Fig. 4, starting at the top right-most GND pin of the Arduino Uno, a tan wire represents 4 bundled wires going to ground. At digital pin 12, a black cable outputs 5V or 0V to the Teknic motor which determines whether the motor will turn counterclockwise or clockwise. At digital pin 11, a white cable provides steps to the Teknic motors. A step consists of a 0V initial state, a period at 5V, and a return to 0V. The step cable will ping the Teknic motor a proportional number of times to control overall movement. The Teknic motors are configured to turn 1 full revolution per 200 and 400 pings for the steering and braking motors, respectively. Digital pin 10 carries the motor enable output. This cable simply delivers 5V whenever the motor is given permission to move according to step and direction instructions, or 0V otherwise. To implement a duty-cycle-control for the forward-control motor, pin ~5 was needed to output a 980Hz square waveform to realize different DC voltage levels for different motor speed. Terminal ~5's output simulates an accelerator pedal position to control golf cart speed. Pin 7 output an enable signal when a forward speed signal is received from the RC receiver.

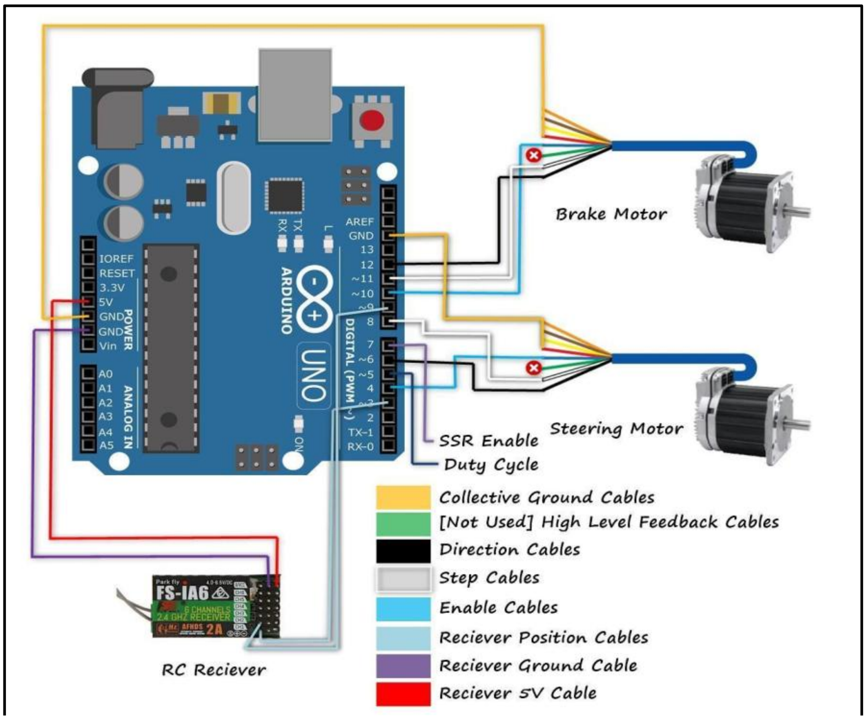
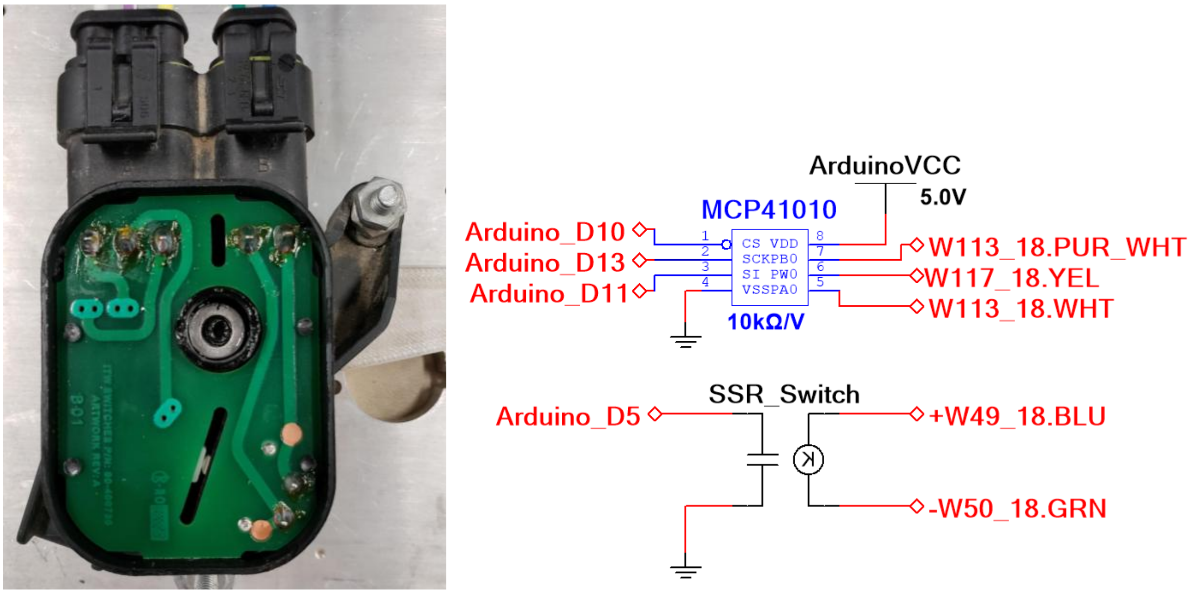


Figure 4: Arduino Uno with wiring for 2 Teknic motors and receiver as seen by software logic.
Source: [4].

2.1.3 Digital "Throttle"

The Motor Control Output Regulator (MCOR4) from the Club Car Golf Cart are connected by a parallel circuit, which includes a 10 kΩ digital potentiometer and a Solid-State Relay (SSR). This circuit is called digital "Throttle", which is designed to mimic the specific functions of the primary MCOR4. As shown in Figure 5 below, the digital "throttle" could allow the Arduino to control the speed of the golf cart. The purpose of this design is to maintain the original accelerator pedal behavior, but to also be able to control the golf cart's speed by digital means; have the original, physical pedal working, and a digital circuit that can work alongside the original.



(a) (b)

Figure 5: (a) MCOR4 device used on golf cart chassis for operator throttle control; (b) MCP41010 digital potentiometer and SSR switch circuits.

A terminal block was implemented into our design to be able to control the MCOR4 by Pulse Width Modulation (PWM). A PWM signal is proportionally emulate a voltage signal by the duty ratio. Figure 6 shows the terminal block wiring diagram of the MCOR4's two components. In this implementation, certain MCOR4 inputs are duplicated through the terminal block. Particularly, the yellow (signal) and purple-white (GND) inputs are split to output to the MCOR4 and the Arduino. The same methodology is used for the green (GND) and blue (+48V) MCOR4 switch inputs, which output to the MCOR4 and SSR switch. The MCOR4 with the MCP41010 digital potentiometer and SSR switch circuits used in the control system is shown in Figure 7.

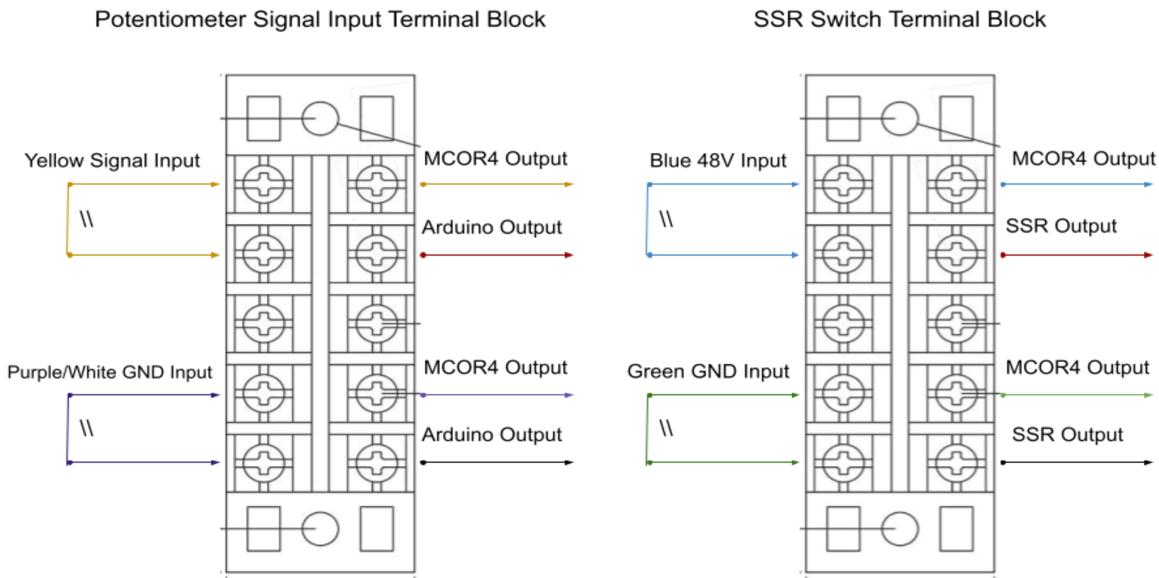


Figure 6: Terminal block wiring diagram of the MCOR4 potentiometer (a) and switch (b) inputs. Source: [5].

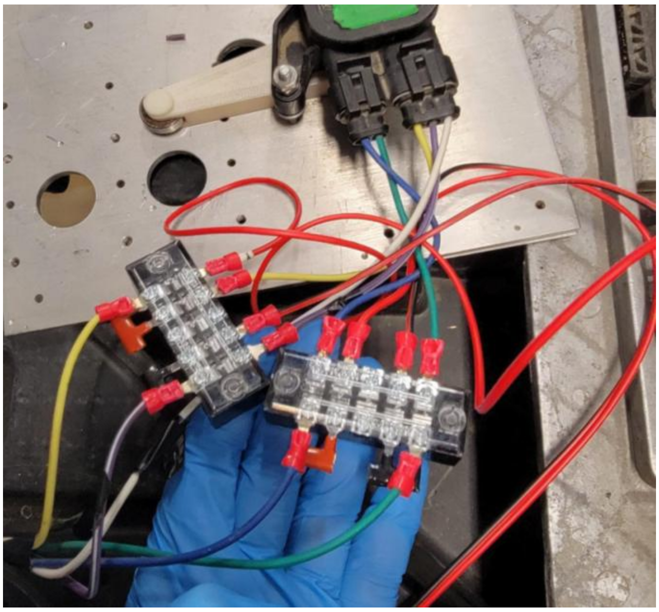


Figure 7: Image of MCOR4 input/output emulation circuit.

2.2 Control Algorithm

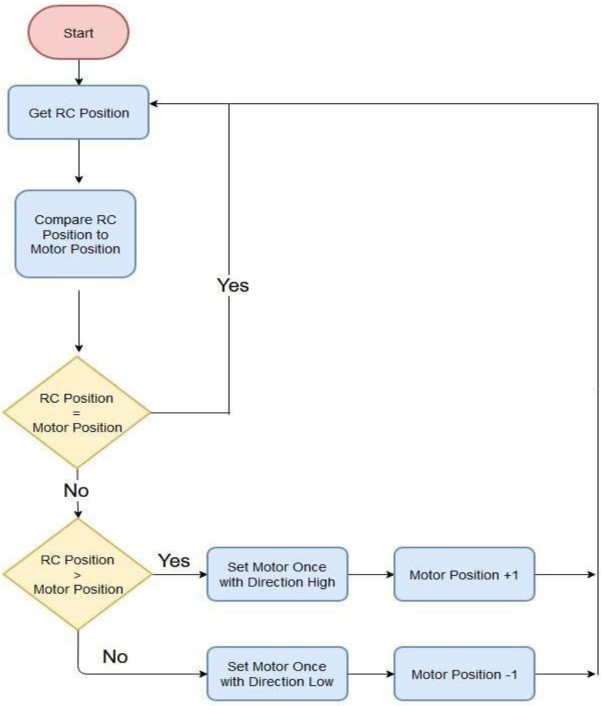


Figure 8: Flow chart of logic used to control the steering and braking Teknic motors.

Controlling the steering and braking motors in a flexible manner has been the priority when coding the Arduino. In practice, this means the software must be responsive, allowing new instructions to begin executing as quickly as possible while minimizing the time software is executing obsolete instructions. By experimentation, an iterative approach was found to complete step instructions quickly enough, while being greatly more responsive than an algorithm which would fully move the motor to a position before considering another move instruction. The layout of the current iterative algorithm for steering and braking is captured below in Figure 8 and the rear wheel drive (RWD) motor logic in Figure 9.

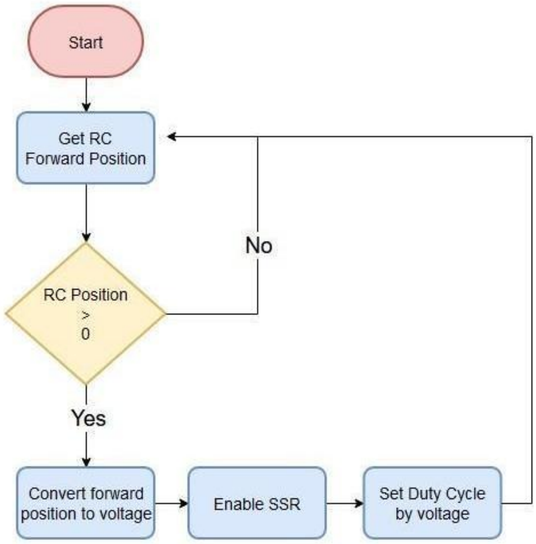


Figure 9: Flow chart of logic used to control the rear-wheel-drive motor.

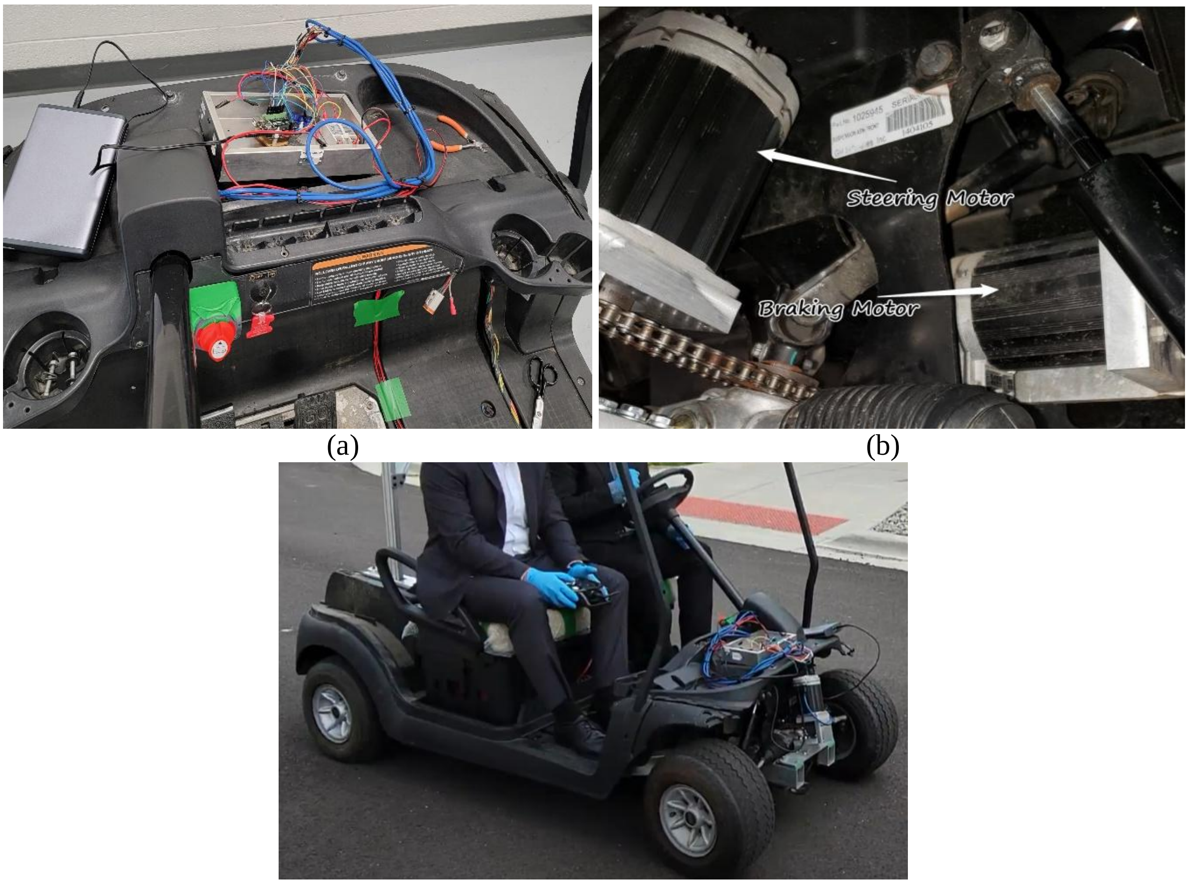
III. Results and Discussion

A prototype of the remote-controlled golf cart is successfully built and test on Eastern Michigan University's campus. Figure 10(a) shows the control circuit including a microcontroller, a potentiometer and a SSR. The two Teknic servo motors installed in the golf cart functioning as the steering and braking motors are shown in Figure 10 (b). Adding these motors will impact how much power is taken from the 48 V, 112 Ah battery bank. Peak draw conditions are dependent on the 148W steering and 196W braking motors [3]. Given the 48V input, this equates to 3.08A and 4.08A for steering and braking sustained usage. For safety, inline fuses are required, but to ensure a fuse does not blow needlessly, 10A fuses have been installed in series with the motor's power lines. Table 1 is a power usage parameter chart of the main systems. This shows the battery bank working with a theoretical electrical current

Table 1: RC Golf Cart Power Distribution

RCGC Power Distribution				
	Max Power (W)	Voltage (V)	Current (A)	Capacity (Ah)
48V Battery Source	2688	48	56	112
3.3hp Motor (Throttle)	-2461	48	51	-103
Teknic Motor (Steering)	-148	48	3.1	-6
Teknic Motor (Braking)	-196	48	4.1	-8

value of 56A. This would only allow the battery to work for 117 minutes, or approximately 2 hours. Notice how it is not enough to power all the systems if each component is working at max power. This means that the battery will have a charge time of two hours before being recharged. This is the worst-case scenario. Most likely the devices will not be using power the entire time, such as the servo motors for steering and braking systems. Thus, the golf car will be able to reach the goal between 2-5 hours of operation. The test run of the drive-by-wire golf cart can be found in Figure 10(c). It can run at 15 mph at most [6].



(a) (b)

(c)

Figure 10 (a) Control circuit added to the golf cart; (b) Undercarriage view of the golf cart with the steering and braking motors visible; (c) Drive-by-wire golf cart with the RC control system.

IV. CONCLUSION

In this paper, a remote-control system is designed, developed, and implemented in parallel with the Club Car Golf cart's original steering, braking and driving system. The RC control system uses RC transmitter, receiver, Arduino, two Teknic Servo motors, a digital potentiometer and a Solid-State Relay.

Future milestones include improvements on the preexisting RC implementations. Optimization of power delivery, closed-loop control, and peripheral sensor feedback would enable a higher-level control of the chassis. Improvements like voltage regulation on the servo motors, regenerative energy remedies through shunt circuit additions, more powerful microcontrollers to reduce latency, and smoother proportionality control, would accomplish a reliable RC transportation system. Through testing and perfection of the design, the addition of sensors could yield a rudimentary autonomous system.

ACKNOWLEDGEMENT

We would like to acknowledge John Earl, Scott Becker, Qiheng Zheng, Jonah Nelson, Dr. Johnathon Lin and the Autonomous Golf Cart (AGC) project group at EMU for their gracious support and work. We are grateful for their time and dedication during the difficult times of COVID-19. In addition, we would like to acknowledge the EMU Game Above College of Engineering and Technology's financial support of this senior capstone project.

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Andrei Adam, et. al. "Adding a Remote-Control System to a Manually Operated Electric Golf Cart." *International Journal of Engineering Science Invention (IJESI)*, Vol. 10(08), 2021, PP 19-26. Journal DOI- 10.35629/6734