Autonomous Golf Caddy

Group 43
Thomas Holcomb and William Peterson
ECE 445 Senior Design
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Outline

- Introduction
- Block-Level design and implementation
    - Lessons learned, improvements
- Conclusion

Introduction

- The Golf Caddy is designed to improve the golfing experience
- Allows the user to experience the benefit of walking the course without the strain of carrying their bag or manually pushing a cart
- Golf Caddy is designed to follow the user at a comfortable distance while avoiding obstacles

Objective

The goal of this project was to modify a golf push-cart with a sensor array and an electronic drive system:

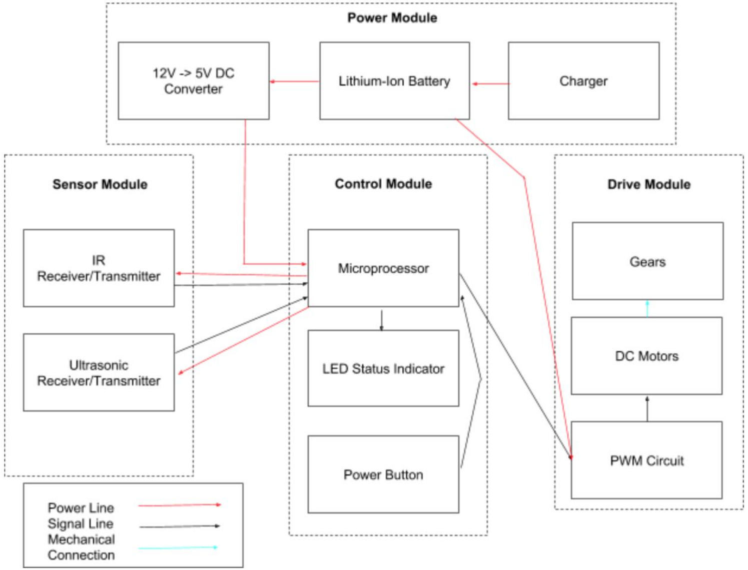
- Follow the user at a comfortable distance (~1m)
- Avoid obstacles present in the environment (i.e. trees)
- Able to maintain its charge for the duration of a round of golf under worst-case conditions

System Overview

- Sensor array gathers information about the environment
  - Position of the user
  - Proximity of environmental hazards

- Microprocessor unit processes sensor information and updates the control variables
  - Adjust speed and heading according to user position
  - Enter object avoidance routine if necessary
  - Handles interrupt events

- Drive system responds to PWM signal generated by the microprocessor unit



Power Module

- Primary power source is 12V 35Ah sealed lead acid battery
  - Rechargeable (8 hour recharge time)
  - Provides direct power source for motors
  - DC converters are used to step down voltage for all other components
  - Typical current draw per motor is 3Ah yielding ~6 hours of continuous operation

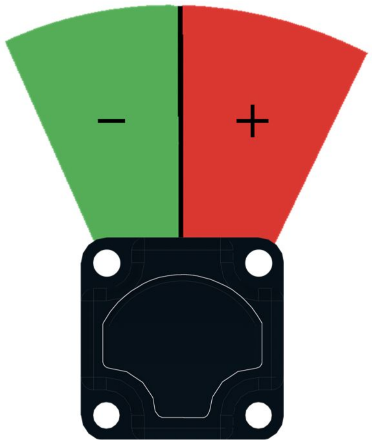
- 12V -> 5V DC converter
  - Provides power to sensor array and gate driver

- 12V -> 3.3V DC converter
  - Provides power to the microprocessor unit

Sensor Array: Infrared Sensor

- Requirement: 150 degree field of view with 3 degree granularity

- IR Seeker V3
  - Tracks the users angular position with respect to the forward facing side of the cart
  - Dual sensor package gives 150 degree field of view
    Tuned to 600Hz infrared wave to filter infrared light from t
  - Communicates over I2C protocol
  - Unreliable, did not meet granularity requirement



Sensor Array: Ultrasonic Sensors

- Requirement: Must track user at a distance of up to 2.5m

- Set of three ultrasonic sensors were used
    - Front facing sensor tracked the user’s distance from the cart
    - Pair of 45 degree offset sensors used to detect potential hazards

- Ultrasonic sensors had a reliable range of roughly 120cm
    - Did not meet the requirements in our design specifications
    - Reliable range of up to 3 meters when tracking flat objects with large surface area
    - Higher quality sensors would be needed for practical application

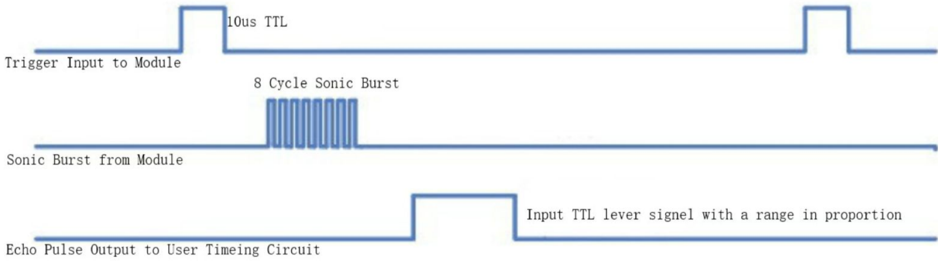
Lessons Learned: Sensor Arrays

- Device is expected to behave reliably over long periods of time in unknown terrain
- The quality of our sensors were not to the standard of any commercial product
- Upgraded sensors will be important for future iterations of the Golf Caddy

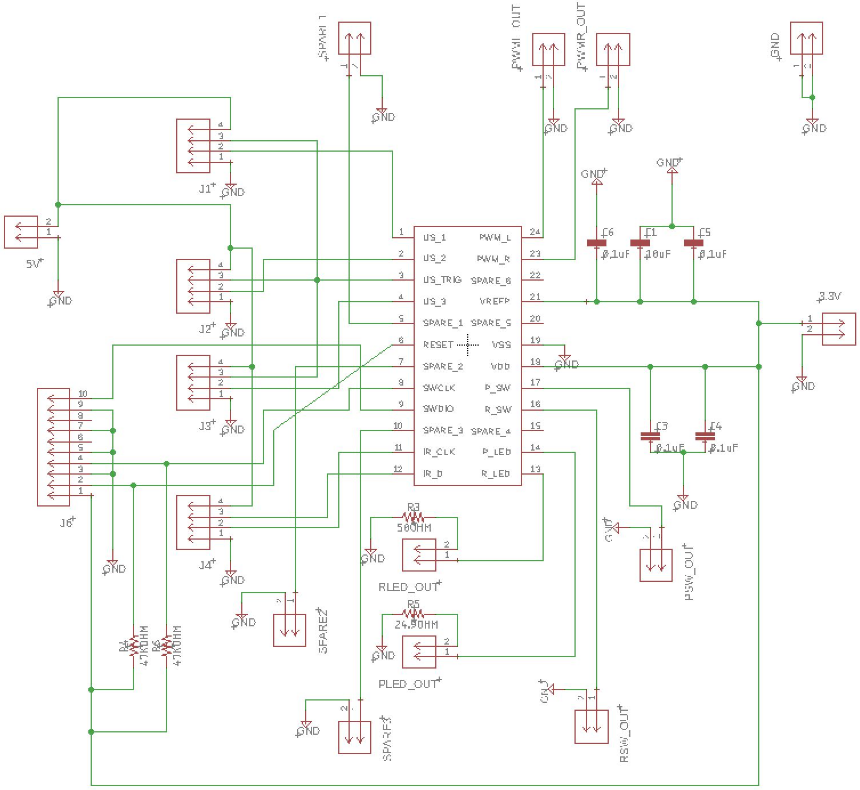
Control Module

- Microprocessor Unit: LPC804 ARM Cortex M0+ (Low Power MCU)
    - I2C capable, 16 GPIO, high-current outputs, PWM outputs, Analog-to-Digital Converter

- Fixed rate polling to acquire sensor data
    - IR data transferred via I2C
    - Ultrasonic response received via interrupt



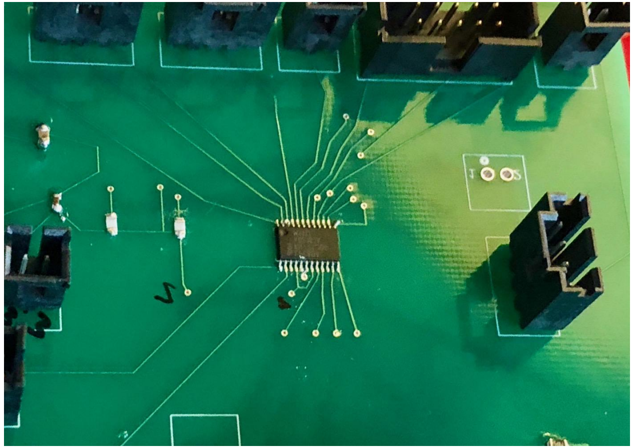
Control Module Schematic



Microprocessor Unit

- High-level purpose is translation of sensor data into PWM signal to drive motor (software)
- Handles user interaction (button press) and operation mode display (LEDs)
- Four States:

1. Off
2. Normal Operation
3. Collision avoidance routine
4. Safe-state

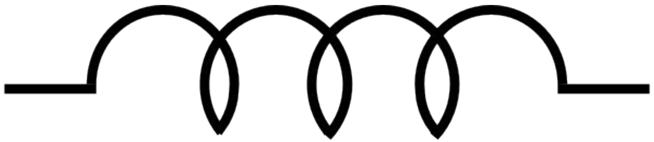


Lessons Learned: Microprocessor Unit

- Microprocessor was installed on a PCB with lack of circuit protection about the input/output ports

- Disturbances on the PWM output pins produced by the motors caused damage to the microprocessor

- Must be addressed by smoothing capacitors and output line protection

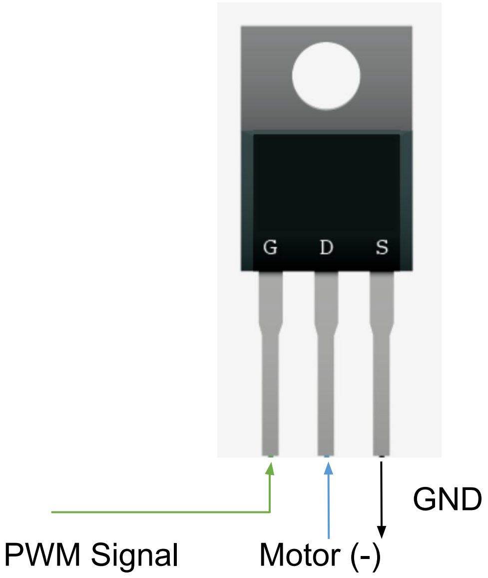


Speed Controller Overview

- High power MOSFET used to control PWM direct to motors

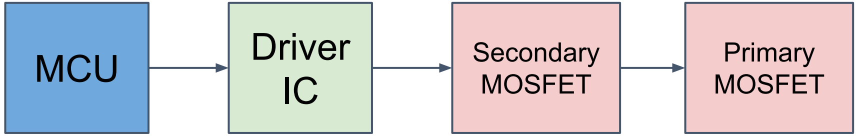
- MCU voltage was too low to gate the MOSFET
  - Gate driver was constructed to elevate the voltage to a level which could open the channel

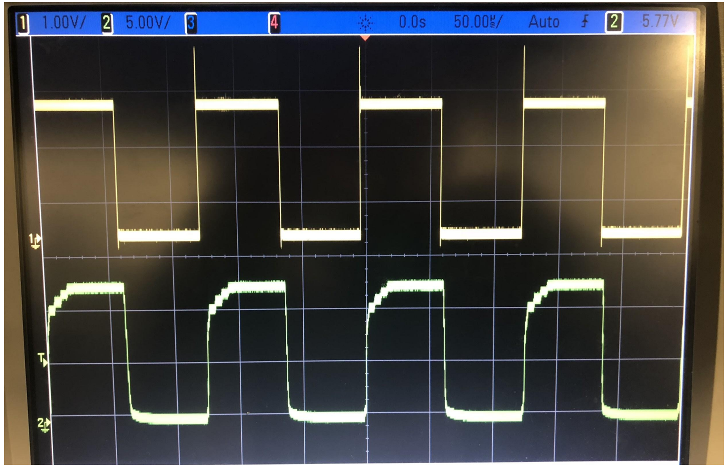
- With gate driver we were able to deliver power to the motors
  - Unreliable
  - Very little control
  - Once open, channel occasionally would not close



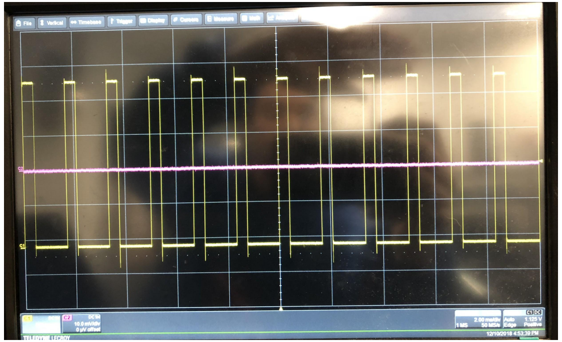
Speed Controller: Gate Driver

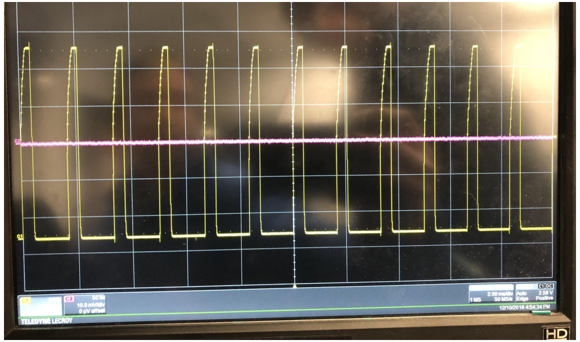
- Gate driver IC takes direct input from microprocessor unit PWM output
- Drives a secondary voltage level MOSFETs
- Source of each MOSFET is used to gate the primary MOSFET directly controls the motor

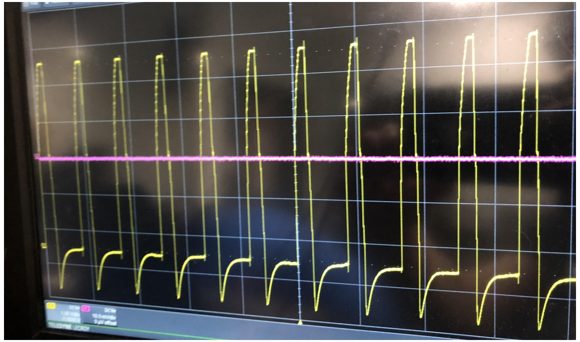




Speed Controller: Disturbances

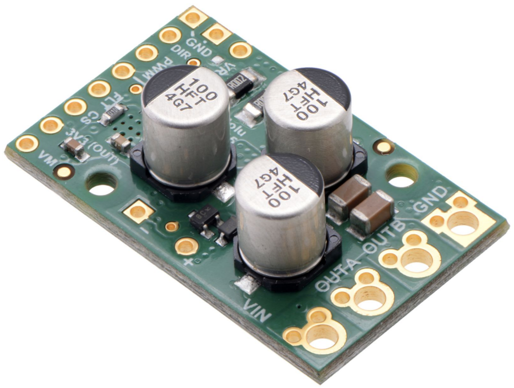






Lessons Learned: Speed Controller

- A single production MOSFET was not an acceptable design choice for high-power motor control (150W max)
- High frequency switching required to produce desired PWM signal lead to MOSFET damage
- More robust high-power motor driver is better suited for such a purpose

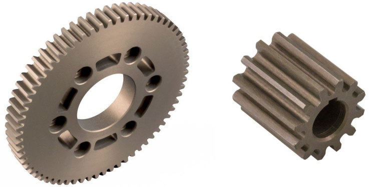


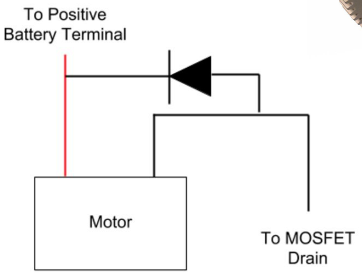
Drive Module (excluding PWM) Overview

- Mini CIM DC Motor
  - 12v, 215w maximum output
  - 5840 RPM free speed

- 72:11 gears
  - 72 tooth gear attached to each wheel driven by an 11 tooth gear attached to each motor

- Diode bypass
  - Diodes placed in parallel with motor to prevent back EMF from harming CPU

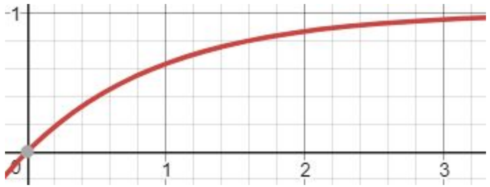




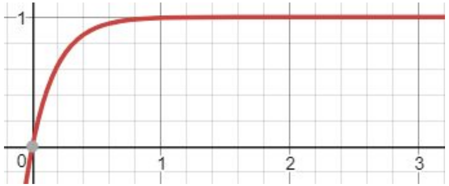
Lessons Learned: Drive Module

- Gearing ratio too low
  - 50:1 was calculated to be ideal, we had 6.54:1
  - Rise time of voltage across motor very long (slow acceleration)
  - A higher gear ratio would have given us better control over each motor due to reaching steady-state speed faster for a given duty cycle
  - A higher gearing ratio would have also given us a better range of speeds for a 12v PWM signal

- Motor torque, speed not ideal
  - Using higher torque, lower speed would have helped alleviate issues outlined above



Rise time with low ratio



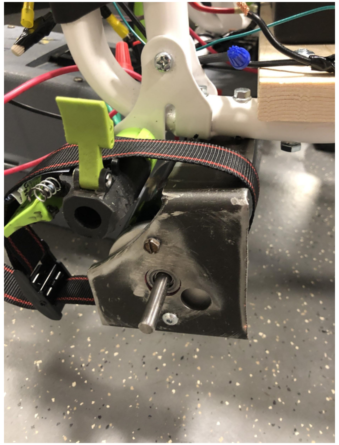
Expected rise time with higher ratio

Cart Assembly: Cart Base

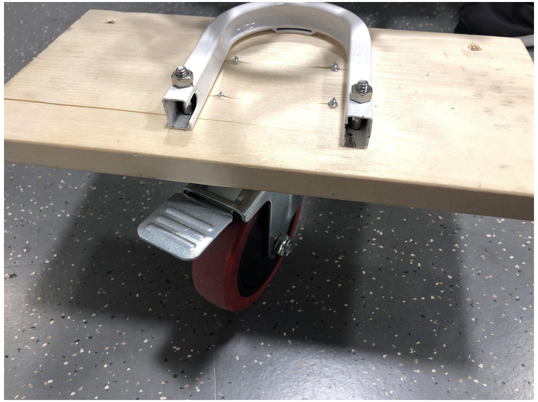
- Caddymatic Continental 3
- Metal tube frame allowed for easy modification and mounting
- Independent axles allowed us to drive each wheel at a different speed and control the cart

Cart Assembly: Motor Mounts

- Aluminum drawer repurposed as two motor mounts
  - Existing 90 degree bends in metal allowed for single-part design
  - Holes drilled for motor screws and output shaft
  - Spacers added to allow output shafts to align with wheel gears
  - Straps later added to keep motor shaft in proper position and to allow adjustment of mounts



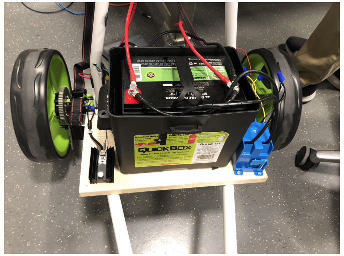
Cart Assembly: Wheels



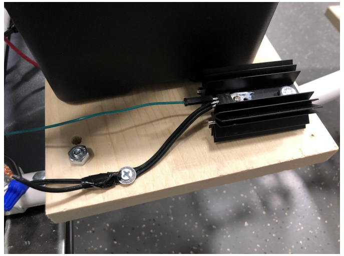
- Cart front wheel did not pivot to allow precise turning, was replaced with a caster wheel
  - Wheel and axle removed from front of cart
  - Wooden plank was bolted to axle mounts to allow mounting of caster wheel

- Gears were screwed directly into rear wheels to allow them to be driven by each motor

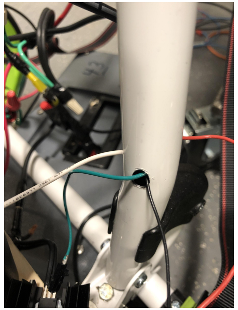
Cart Assembly (contd.)



- Wooden plank bolted to frame near rear wheels to allow battery, MOSFETs and converters to be mounted
  - Plastic battery box screwed into plank to allow battery to be secured without mounts connecting directly to it



- Holes drilled in vertical tubing to allow certain wires to be routed cleanly through frame



Lessons Learned: Cart Assembly

- Cart was not intended to be modified, leading to various integration issues
  - Gears were not easily centered on wheels, leading to imperfect rotation
  - Wheels tilted in when cart was set down, causing gears to not mate properly

Golf Caddy Software

- Follows setpoint control protocol
  - 1m following distance setpoint
  - Zero degree offset setpoint

- Reacts to the computed error between setpoint and measured values

- Implemented as a PID controller

Golf Caddy Software: PID Control

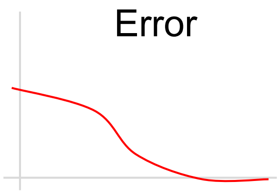
Proportional Control

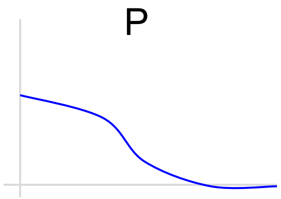
- Provides feedback based on the raw error between measured value and setpoints
- Intuitive basis for control

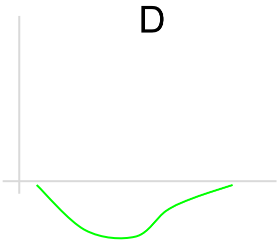
Golf Caddy Software: PID Control

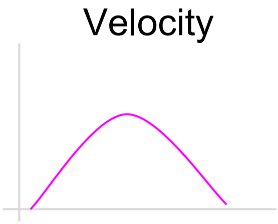
Derivative Control

- Provides feedback based on the rate at which the error is changing
    - Necessary to react quickly to sudden changes
    - Needed to counteract proportional control when setpoint is to bring the cart to rest





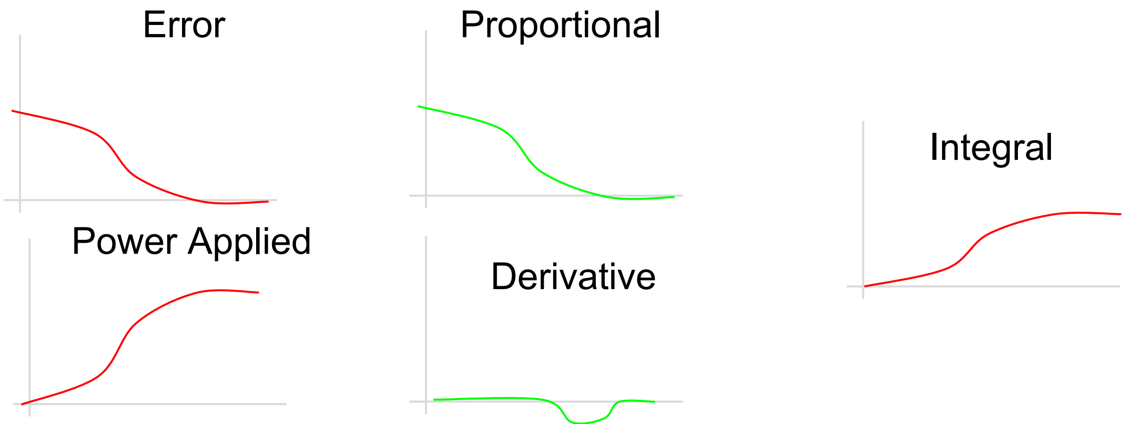




Golf Caddy Software: PID Control

Integral Control

- Feedback grows steadily over time
- Counteracts additional error brought about by change in load (i.e. golf bags with different weight)
- Necessary when the setpoint requires a constant non-zero speed to be met



Golf Caddy Software: PID Control

- Slow sampling rate due to high variance in sensor reading
- High derivative control compensates for sampling speed
- Gains needed to be calculated separately for each motor due to differences in response to PWM input

Golf Caddy Software: User Interface

- Run/Pause switch is handled via interrupt service routine
- LEDs are driven by general purpose input/output

Closing Remarks

- All modules functioned in a canned environment
- Modules failed during system integration
- Underestimated the difficulty involved in system integration
  - This was ultimately the root of our problems
- Future work on this project

Acknowledgements

Thanks to:

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