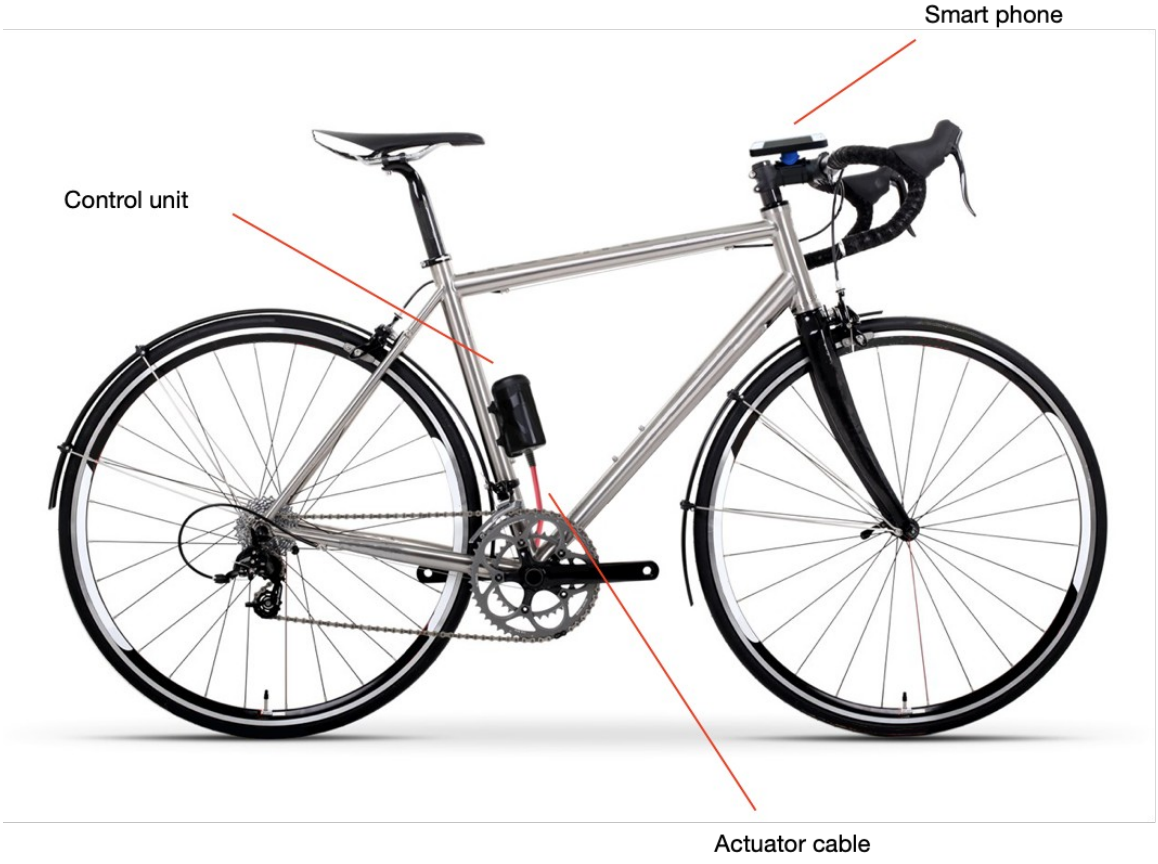
**Bicycle Automatic Gear Changer**

A prototype of a “low cost” system for automatically changing the gears on a bicycle.

The product is designed to be retrofitted to any bicycle with cable operated gears, replacing the manual controls.




**Product Features**

- Gears may be changed manually or automatically using the Auto-Changer phone app.
- Normal or sport modes.
- Energy efficient, to obtain maximum range.
- Suitable for bicycles with derailleur or hub gears that are cable controlled.
- Control unit mounted on the seat tube, the unit pulls cables attached to the front and rear derailleurs (or hub), replacing the manual controls.
- Self-contained with rechargeable batteries - no external wiring.
- Wireless connection from control unit to handlebar-mounted smart phone.
- Unit may be installed at home with simple tools, or entrusted to a bike shop.
- No major modifications to the bike are necessary.
- Set-up using Auto-Changer app, may be re-calibrated as parts wear.
- Weight kept to a minimum.

**Key Components**

- Control unit (GCCU), similar in size and shape to a water bottle, contains the control systems and actuators that pull the cables.
- Cables, which connect the actuators to the derailleurs (or hub).
- Handlebar-mounted iOS or Android smart phone with app.

**Research**

The research focused on the following key areas:

- Energy requirements
- Actuators
- Power supply
- User controls
- Control systems

**Energy Requirements**

- Target time between recharges: one week*
- Intelligent use of battery by control systems

**Bicycle used for a "typical" commute to work of 8km each way.*

The energy needed to pull the gear change cables and power the control unit were estimated from manufacturers data and actual testing.

The result was increased to allow for variations due to different gear change mechanisms and their condition.

By matching candidate power supplies with the overall energy requirement, it was possible to calculate approximately how long the gear changer could operate.

**Actuators**

The mechanical engineering aspect of the project.

Requirements:

- Average gear change of 1 second or less
- No power required when not changing gear
- Precise control of position
- Minimum cost
- Acceptable lifetime
- High power to weight ratio
- Easily sourced components
- Straightforward fabrication

Each actuator consists of four components:

1. Power controller
2. Motor
3. Gearbox
4. Final drive

**Power Controller**

The power controller's function is to take digital inputs and convert them into an output voltage to power the d.c. motor. There are several low cost alternatives for low power/voltage motor drivers.

**Motor**

The options for the motor included stepper motors, brushless d.c. motors and brushed d.c. motors. Each had their own advantages and were part of the feasibility study.

**Gearbox**

The gearbox was a necessary requirement to convert the low torque of the motor into the much higher torque required to pull the gear change cable. The options included a motor and gear box combination, a separate gearbox or a combination of pulley drive and gear box.

**Final Drive**

The final drive's function was pulling the gear cable smoothly and accurately and to maintain the gear cable's position when stationary.

**Power Supply**

The power supply consists of rechargeable batteries and the associated charging electronics.

Key requirements:

- High energy density
- Low cost
- Low weight
- High number of charge/discharge cycles
- Safe

Due to their high energy density and availability, Lithium ion batteries were chosen.

**User Controls**

The user controls include the terminal that configures and operates the automatic gear changer as well as any buttons or switches on the GCCU itself.

Key requirements:

- Simple to use
- Terminal uses existing device e.g. Smartphone
- Same user interface regardless of device used as terminal
- Low power requirements for both terminal and GCCU
- GCCU has "soft" buttons to turn it on/off

To satisfy the above goals, iOS and Android devices were added to the technical options list as well as Bluetooth low energy.

### Control Systems

The control systems include the software and hardware used to control the gear change actuators, calculate when to change gear and communicate with external sensors and the user’s terminal.
The software should “compensate” for lower quality mechanical parts.

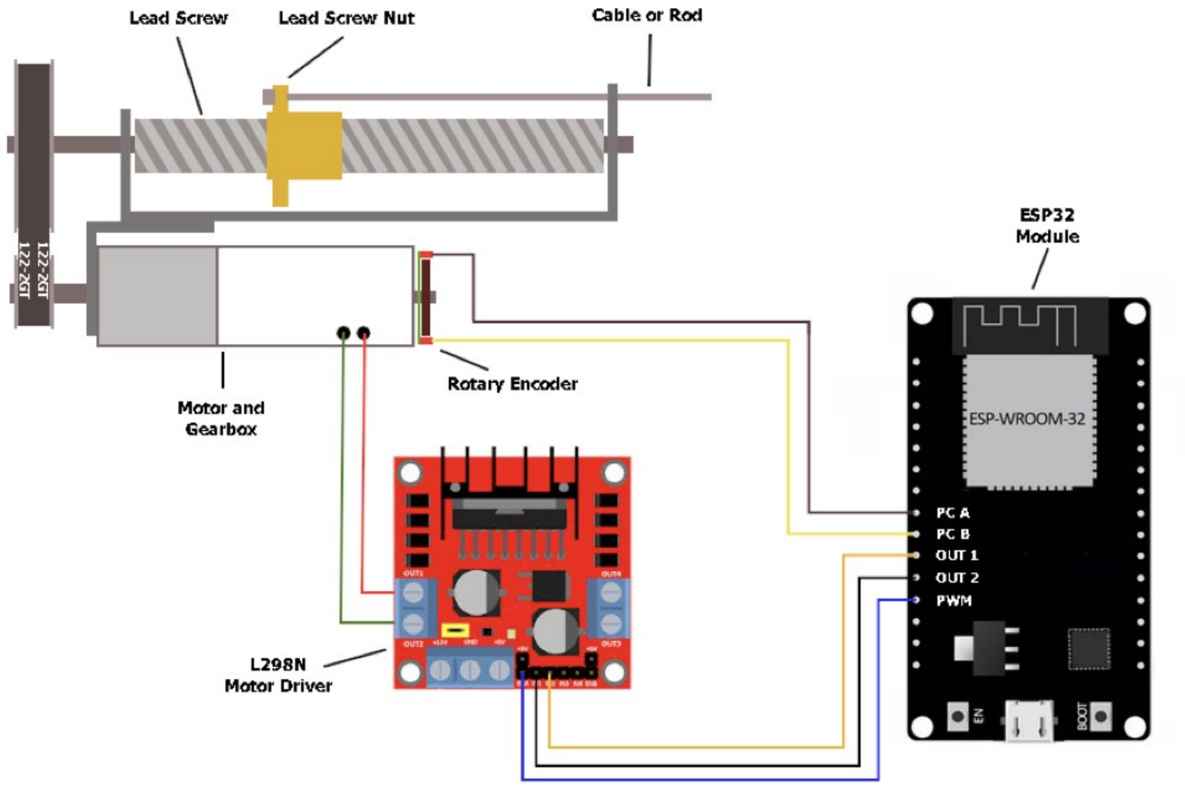
Key requirements:

- Low power
- Low cost
- Widely available microcontroller (MCU) preferably with inbuilt Bluetooth
- MCU must have sufficient memory and I/O
- Open source/free libraries for low-level MCU functions
- Development environment that supports C/C++
- Straightforward to program using USB link

### Prototype

The prototype consisted of the GCCU and iPhone app.
GCCU power was provided by two rechargeable Li-Ion 18650 batteries.

### Control Unit Design




The control unit design was split into three sections: mechanical, electronics and embedded software.

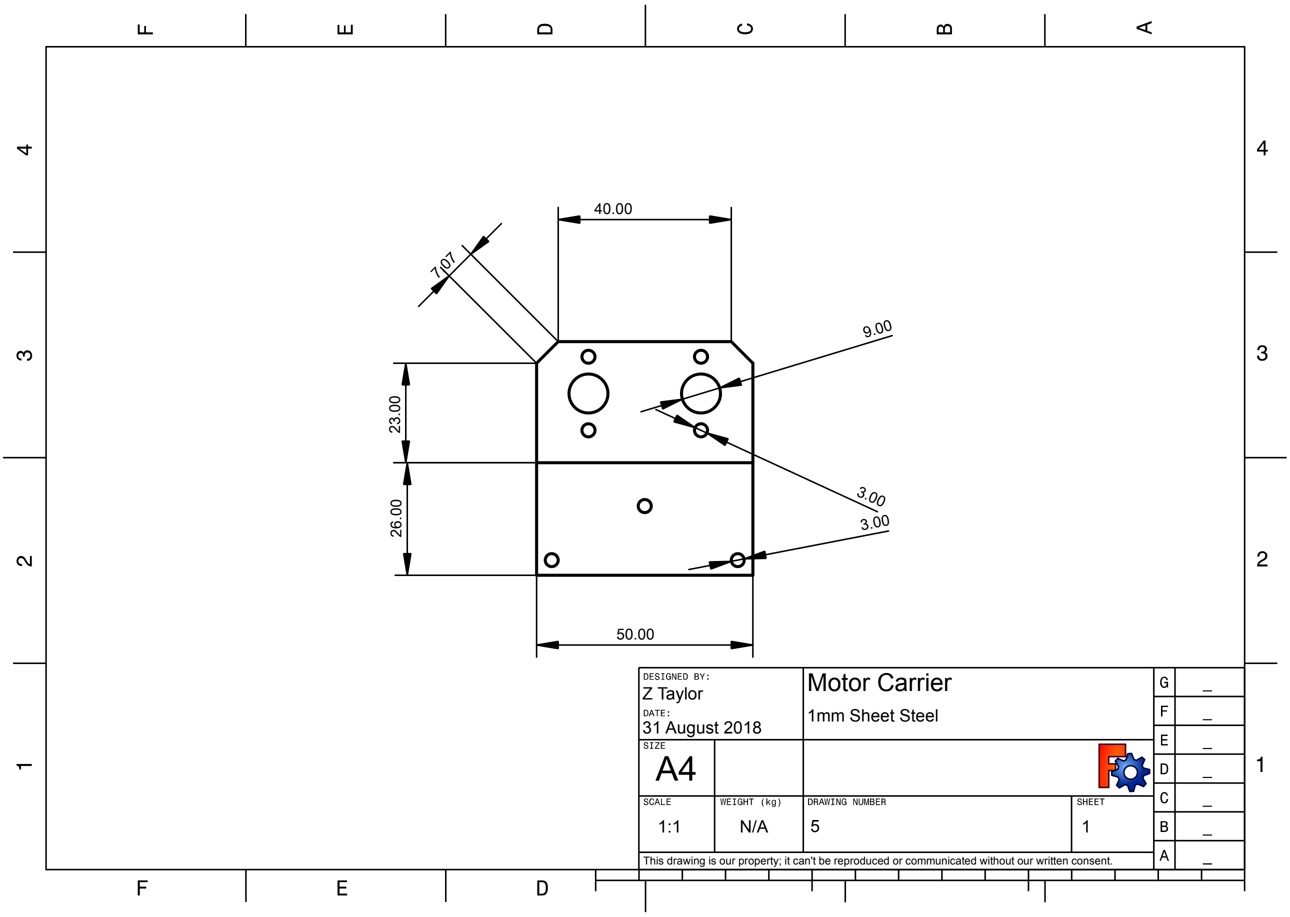
## Mechanical

A brushed DC motor with gearbox was chosen for low weight and cost. The motor included a rotary encoder (with two digital outputs). Using a gearbox to reduce the motor's output speed, increased the torque available and allowed for more precise control.

Further speed reduction/torque increase was obtained by using toothed pinions and a miniature toothed belt turning a lead screw.
A lead screw nut connected to the gear change cable moved linearly.
The lead screw enabled the motor power to be turned off following the gear change, saving power.

The frame was constructed of sheet steel, drilled and bent to shape.

The above components have multiple sources/alternatives and are low cost. The frame is constructed using basic tools.




Motor Carrier Technical Drawing

## Electronics

The actuators were driven by an L298N motor driver, capable of driving two motors.
The digital input was supplied by the ESP32 system on a chip (SOC) which combined a microcontroller with the required Bluetooth low energy transmitter/receiver.

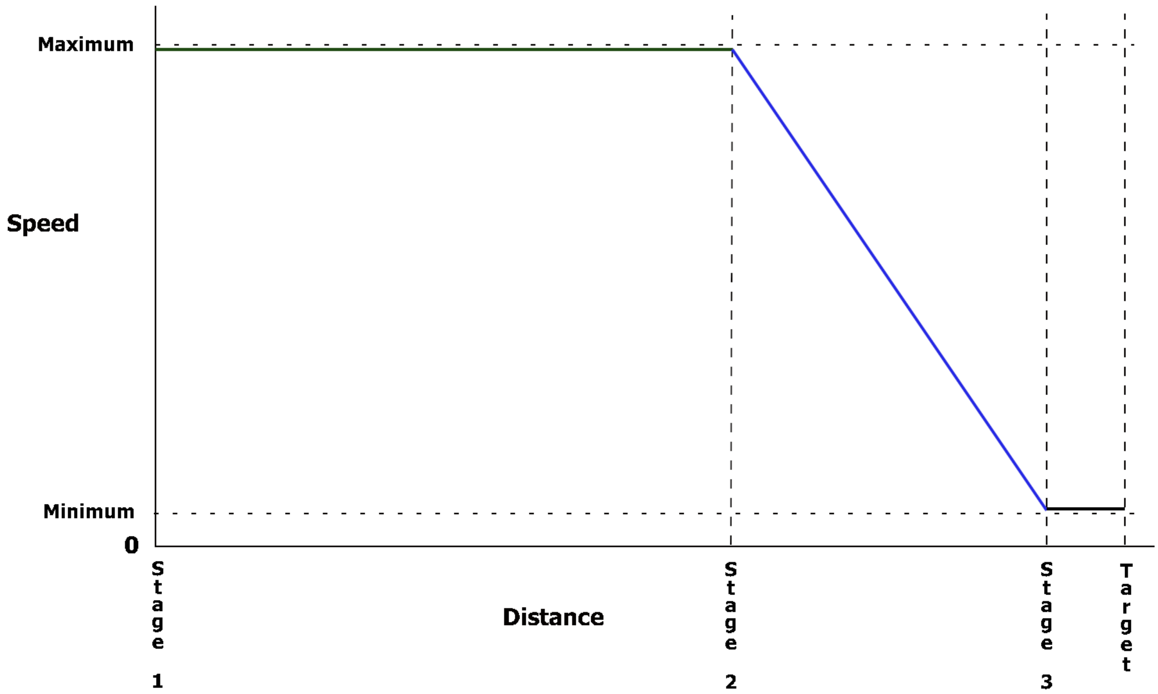
## Embedded software

The control systems software consists of the following modules:

- Communications with terminal (smart phone)
- Actuator setup
- Changing gears, combined gear changer
- Actuator motor controller

Changing gears used a single control to combine front and rear gear sets. Each combined gear represents a ratio of the front a rear teeth counts.

The actuator motor controller was designed for accuracy and power saving. The use of a pulse width modulator as the input to the motor driver allowed for a wide variation in motor torque and speed. Both the frequency and duty cycle are altered in an attempt to set the motor’s speed.




Actuator Speed vs Distance by Stage

The graph above shows the ideal motor speed as a gear is changed. To change a gear, the cable must move a preset distance (0 .. Target).
By dividing the distance into three stages, both power economy and avoidance of overshoot are obtained.

The program running on the ESP32 makes use of speed control algorithms and user set gear cable distance tables.

Refer to the demonstration video *AC_Demo.m4v* to see how the actuators respond when the user changes gear.