Technical Reference Material

Updated

17 July 2019

Details in this document supersede other details provided in Call for Proposals and Request For Proposal, and previous updates of this document.

Green highlighted information is new in this document

See: Items 12. Motor and 8.2. Hall sensor information

The 2019 International Future Energy Challenge (IFEC'19)

A student competition sponsored by the

The Institute of Electrical and Electronics Engineers (IEEE)

Competition Topic: E-Drive for a Bicycle

Updated 17 July 2019

This document is intended to provide an overview of the technical requirements for the design, realization and testing of the prototype e-drive for an electric bicycle. The document is intended to be a reference guide to provide a frame of reference for the competing teams to stay within a set of common guidelines and use their creative and innovative skills to meet the challenge.

It is a live and working document that may be updated when new questions arise and we develop additional guidelines. All updates will be posted on the website for the competition.

When a particular question is not addressed in the guideline, you are free to make suitable assumptions. You are of course welcome to pose your question to the technical team who can provide clarifications.

1. Each team will have to submit a design proposal outlined under item 23 in this document.
    a. First round finalists are required to submit a progress report and make a presentation at the IFEC 2019 workshop to be held at APEC 2019 in Anaheim, CA on the 17th of March 2019. After this presentation second round finalists will be announced.
    b. Selected second round finalist teams will have to present their hardware prototype for the final challenge competition to be held in Madison, WI.
    c. The team will have to bring only their e-drive hardware prototype for performance testing to the competition. Test conditions for the competition are outlined in this document and will be continuously updated.
2. Nominal power rating: 500W. Actual test conditions are provided further in the document, will be dictated by speed and torque, as determined by the current.
3. Battery model number: SLA 48V 9AH battery, Product code: BAT489.
    - Available at: https://www.ebikekit.com/collections/batteries/products/sla-48v-9ah?variant=27965742534, with Anderson power pole connector and charger.
4. Motor model:

- Available at: https://lunacycle.com/cyclone-mid-drive-3000w-planetary-kit/ , standard 171.5mm long version and NOT the 205mm long. version.

5. Motor nominal ratings: Notice that these are *nominal* ratings. Motor operating conditions may exceed these ratings during transient and dynamic conditions. Extended continuous and sustained operation outside these ratings will lead to increased temperature rise and should be avoided. We will not be testing against these ratings. Test conditions for the hardware are specified further in this document.
    a. Voltage: 0-34 V fundamental component rms line-line
    b. Frequency: 0-200 Hz
    c. 15Arms Phase Current
6. Power connector to battery
    a. Anderson power pole connector (contact: MFR# 262G2)
    b. Red (MFR# 1327), Black (MFR# 1327 G6), color terminals to be stacked in the same order
    c. Red corresponds to + terminal of battery
    d. Black corresponds to – terminal of the battery
    e. Battery power cable (10AWG) 30cm-35cm long
7. Power connector to the motor
    a. 3-terminals: Anderson Connector Contacts MFR# 262G2
    b. Housing: Blue (MFR# 1327 G8), Yellow (MFR# 1327 G16), and Green (MFR# 1327 G5), color terminals to be stacked in the same order
    c. Terminals should connect to corresponding motor terminal wires of the same color.
    d. Motor power cable (12 AWG) 30cm-35cm long
8. Signal connector to the motor
    a. 5-terminal Micro Mate-N-Lok Connector (MFR# 1445049-5) to mate with (MFR# 1445022-5)
    b. 5-wire control signal cable (24AWG) 90cm-100 cm long

c. Connection pins

Pin	Description	I/O	Notes
1	Power	5 V output	Hall sensor power
2	Com	0 V	Must be internally connected to battery negative terminal
3	Hall Sensor Blue	Open collector	Synced to blue phase voltage. Must include pull up resistor.
4	Hall Sensor Yellow	Open collector	Synced to yellow phase voltage. Must include pull up resistor.
5	Hall Sensor Green	Open collector	Synced to green phase voltage. Must include pull up resistor.

9. Signal connector to the control

   a. 5-terminal Micro Mate-N-Lok Connector (MFR# 1445022-5) to mate with (MFR# 1445049-5) Gender opposite from motor hall sensors!

   b. 5-wire control signal cable (24AWG) 90cm-100 cm long

   c. Connection pin numbers

Pin	Description	I/O	Notes
1	Power	5 V output	Power for throttle potentiometer
2	Com	0 V	Power and signal reference
3	Throttle Command	0 to 5 V, input	1~4V linear command region
4	E-Stop Input	5V – Drive Enabled 0V – Drive Disabled	Contact not debounce protected. Must include pull down resistor.
5	Battery Sense	0 to 60V output	Output used to display the battery voltage on an external display.

10. Inverter semiconductor case hot-spot sense

    a. Thermocouple (Mini thermocouple male plug Omega SMPW-K-M or similar)

    b. Type K thermocouple wire 90-100 cm

11. Mechanical and mounting details

a. Waterproof enclosure [will not be tested]

b. Floating, electrical isolation >250V ac, 50V dc, between case at the electrical connections. This will be tested using a hipot tester between the case and all the power terminals short circuited.

c. Cables and wiring: 'feed-through' from the box using water-proof grommets, terminated as specified in Items 6-10 above.

d. Mounting face with a nominally flat surface about 15 cm x 4 cm

e. 4 mounting holes on a (170 mm x 35 mm) rectangle center-center

f. Accept M3 10 mm machine screw

g. Target weight: 1.5 kg. This is a target. There are no specifications.

h. Target box volume 1500 cm^3. This is a target. There are no specifications.

12. Motor details

a. Average phase resistance (line to neutral) (40 mΩ)

b. Average phase inductance (line to neutral) (0.11 mH)

Measured using Agilent LCR meter at 1V excitation voltage at 100Hz

c. Line to neutral back-emf trapezoidal waveform

0^o to 60^o: linear increase from 0 to V_b

60^o to 120^o: constant V_b

120^o to 180^o: linear decrease from V_b to 0

180^o to 240^o: linear decrease from 0 to $-V_b$

240^o to 300^o: constant $-V_b$

300^o to 360^o: linear increase from 0 to V_b

V_b=3.7V @30Hz, 450 rpm motor shaft speed, 73 rpm output shaft speed

V_b=21V @167Hz, 2500 rpm motor shaft speed, 410 rpm output shaft speed

d. Motor number of poles: 8

e. Shaft integrated planetary gear speed reduction ratio: 1:6

f. Motor frictional and viscous losses: 5W @ 1krpm

g. Rotor inertia of motor: 0.44 gm^2

h. Motor shaft equipped with ratcheted freewheel to prevent wheel or pedal driving the motor

i. Planetary gearbox 6.1:1 reduction (11t sun, 3 x 22t plants, 56t ring). The gearbox is removed for dynamometer testing

13. Throttle Command

Throttle Command	Phase Current	Error Limits
1V	0 A_{rms}	0.1 A_{rms}
2V	5 A_{rms}	0.5 A_{rms}
3V	10 A_{rms}	1 A_{rms}
4V	15 A_{rms}	1.5 A_{rms}
4.5V	Unspecified[1]	N/A

14. Control modes and indication (RGB LED)

~~a. E-stop ON (open), Throttle position don't care: idle mode: green~~

b. E-stop OFF (closed), ready mode: flashing green @~1Hz

c. E-stop OFF (closed), Throttle 1~4V: ready mode: steady PWM green @~50Hz (Not evaluated)

d. E-stop OFF (closed), Hall sensor cable disconnected: flashing red @~1Hz

e. E-stop OFF (closed), Faulted, Steady red

f. Fault reset: Throttle back to 0V, E-stop ON (open) and turned OFF (closed) again

15. Over-current

a. Motor

i. Motor output external fuse: 20A fuse (will be part of the measurement set-up) Littelfuse Inc. / 0997020.WXN

[1] 4.5V Wide Open Throttle (WOT) command is only current limited by the hardware fuse in series with the motor terminals, and the battery. Teams may pick the actual operating condition for full throttle and implement a current limit and/or speed limit as they wish to ensure safe operation of the drive and bicycle.

b. Battery

i. Maximum Battery continuous current 12Arms (0.1 second average)

ii. DC input external fuse continuous 20A fuse (will be part of the measurement set-up) Littelfuse Inc. / 0997020.WXN

16. Voltage

a. Overvoltage withstand up to 60V (for 50ms)

b. Undervoltage cut-out at 44V (respond within 50 ms)

17. Temperature

a. Thermal cut-out 40^{o}C hot-spot temperature rise, at 25^{o}C ambient (respond within x 5s) (not evaluated)

18. Over-speed limit: 2500 rpm

19. Safety:

a. No live electrical elements are to be exposed when the unit is fully configured. The system is intended for safe, routine use by non-technical customers.

20. Thermal consideration: Case should be touch-safe for prolonged operation (<48^{o}C)

21. Cooling: Natural convection

22. Brake Disable

a. The motor output must be disabled (open circuit) when brake feedback switch is closed (brake ON). <100ms response time recommended

b. 2-terminal Micro Mate-N-Lok Connector (MFR# 1445049-2) to mate with (MFR# 1445022-2)

c. 2-wire control signal cable (24AWG) 90cm-100 cm long

Pin	Description	I/O	Notes
1	Power	5 V output	Power for break enable sense
2	Brake Input	5V – Brake ON 0V – Brake OFF	Contact not debounce protected. Must include pull down resistor.

23. Prototype hardware test conditions

The final test will be carried out at the University of Wisconsin-Madison, USA.

Back to back motor-generator dynamometer test-stand

- DUT kept in a 25ºC temperature chamber
- Dynamometer generator output rectified to DC (varies as the motor operates at different speeds, about 48V rectified at 3000 rpm)
- DC output connected to constant voltage (CV) electronic load (12V, 24V, 36V, 48V set points)

a. Cable and connector integrity (pull-test 10N on power cable assembly)

b. Insulation test between case and power connectors at 250V, >500kΩ.

c. Basic Operation Test

   i. *Disabled State* <1mA sustained average battery current and motor shaft free to rotate when e-stop is pressed (open contacts).

   ii. *Idle State* <50mA sustained average battery current and motor terminals are open circuited (non-regenerative braking) when e-stop is not pressed (closed contacts), 0V throttle command.

   iii. *Brake State* - the motor terminals must be open circuited when e-stop is not pressed (closed contacts), 2V throttle command, and brake is ON (closed contact).

   iv. E-Stop and status indication functionality

d. Free Acceleration Test

   i. Pass/Fail functional test to simulate a broken chain event

   ii. Open circuit electrical load (48V CV dynamometer load will limit speed to 3000rpm)

   iii. Must reach 2400 rpm within 2 seconds

   iv. Enter fault mode if speed exceeds 2500 rpm

e. Efficiency Map

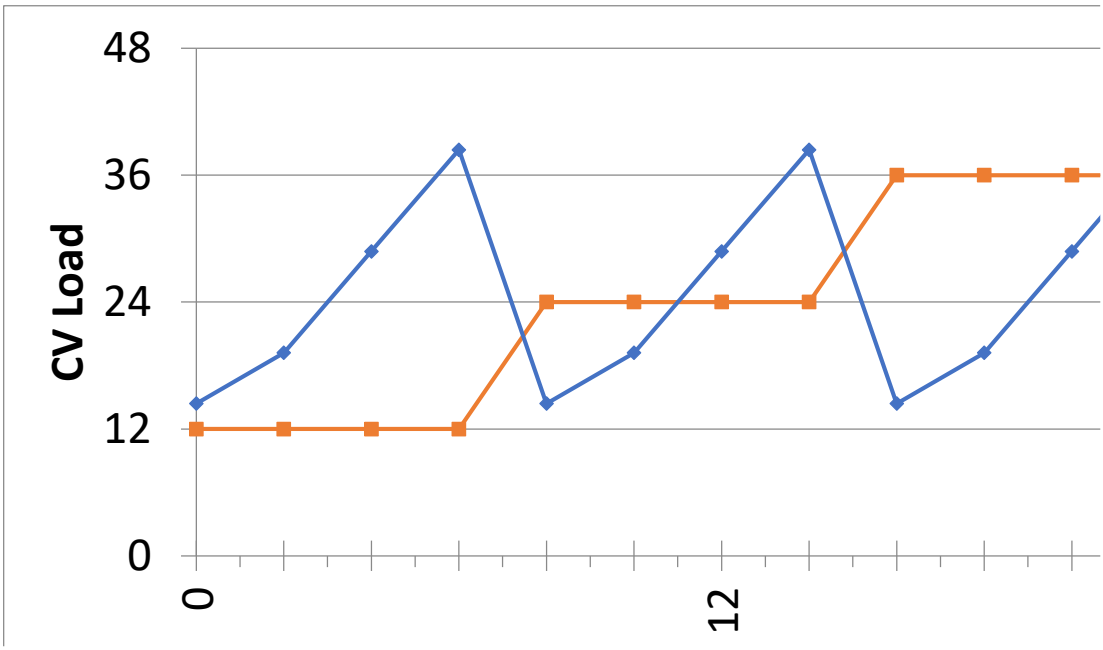
i. Each set point must be held for 2 seconds

ii. Three CV dynamometer load set points: 12V, 24V, 36V at the rectified output of the dynamometer load machine.

iii. Four throttle command set points: 1.5V, 2V, 3V, 4V. 2min rest allowed between each throttle command set.

iv. Input DC electrical power, output DC electrical power and mechanical power will be measured.

v. Performance will be evaluated based on efficiency at each operating point.



f. Simulated Hill Climb

i. 0.1 Ohm load setting at the rectified output of the dynamometer load machine

ii. 4.5V Throttle Command - Wide Open Throttle (WOT) for 30 seconds

iii. Highest average speed over the 30 sec

g. Field Test on actual bicycle

i. 4 Person relay race on concrete surface

ii. 400m per lap

iii. 1600m total race length

iv. Performance will be evaluated based on elapsed time.

Figure 1 - Field test course.