Technical Reference Material

Updated

20 November 2018

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 20 November 2018

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. Selected finalist teams will have to present their hardware prototype for the final challenge competition. The team will have to bring only their e-drive hardware prototype for performance testing to the competition. Battery, motor, bicycle, test-gear and mounting details will be provided at the competition.
2. Continuous power rating: 500W
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-ebike-motor-with-freewheel-sprocket/, 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 be 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.
   a. Voltage: 0-60 V fundamental component rms line-line

   b. Current: 0-5 A fundamental component rms per line
   c. Frequency: 0-300 Hz
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 shielded control signal cable (24AWG) 90cm-100 cm long
   c. Connection pins
      i. 1: 5V (red)
      ii. 2: $0_{v\text{-}ref}$ (should be internally connected to battery negative terminal) (black
      iii. 3: Hall sensor blue, open collector pull up to 5V, sync to blue phase voltage
      iv. 4: Hall sensor yellow, open collector pull up to 5V, sync to yellow phase voltage

      v. 5: Hall sensor green, open collector pull up to 5V, sync to green phase voltage

9. Signal connector to the control
   a. 5-terminal Micro Mate-N-Lok Connector (MFR# 1445049-5) to mate with (MFR# 1445022-5)
   b. 5-wire shielded control signal cable (24AWG) 90cm-100 cm long
   c. Connection pin numbers
      i. 1: 5V
      ii. 2: $0_{v\text{-}ref}$
      iii. 3: Throttle signal
         1. accept 0-5V
         2. active 1~4V
         3. Speed, torque, motor current or power regulated
      iv. 4: Enable signal
         1. Low off
         2. High on
         3. Contact not re-bounce protected
      v. 5: 48V sense for 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
    b. Floating, electrical isolation >250V ac, 50V dc
    c. Cables and wiring
    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

h. Target box volume 1500 cm^3

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, 75 rpm output shaft speed

V_b=37V @300Hz, 4500 rpm motor shaft speed, 750 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. Gearbox removed for dynamometer testing

13. Throttle control details

a. 1V: 0A dc

b. 4V: 10A dc

c. Linearly interpolated between 1V and 4V

14. Control modes and indication (RGB LED)

a. E-stop off, Throttle position don't-care: idle mode: green

b. E-stop on, Throttle <1V: ready mode: flashing green @~1Hz

c. E-stop on, Throttle 1~4V: ready mode: steady PWM green @~50Hz

d. Signal cables absent or signals inappropriate: flashing red @~1Hz

e. Protection events under fault; Steady red

f. Fault reset: Throttle back to 0V, E-stop turned off and turned on again

15. Over-current

a. Motor nominal line current 15A rms

b. Motor external fuse: 20A (will be part of the measurement set-up)

c. Battery continuous current 15A

d. DC input external fuse continuous 20A (will be part of the measurement set-up)

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 40ºC hot-spot temperature rise, at 25ºC ambient (respond within x 5s)

18. Over-speed limit: 3000 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 (<48ºC)

21. Cooling: Natural convection.

22. Prototype hardware test conditions

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

b. Back to back motor-generator dynamometer test-stand
    i. DUT kept in a 25ºC temperature chamber
    ii. Generator output rectified to dc bus
    iii. DC electronic load (0, 100, 200, 300, 400, 500W)
c. Cable and connector integrity (pull-test 10N on power cable assembly)
d. Insulation test at 250V, >500kΩ
e. Power up test
    i. All cable assemblies completed, idle state <1mA sustained average current when e-stop is off, motor shaft free to rotate
    ii. Quiescent state <50mA sustained average current when e-stop is on and throttle <1V, motor terminals are short circuited in non-regenerative brake mode
    iii. E-Stop and status indication functionality
f. Free acceleration test
    i. Open circuit electrical load
    ii. Time to reach X rpm TBD
    iii. Enter fault mode
g. Loaded acceleration test
    i. 500W electrical load
    ii. Maximum speed
    iii. Time to reach max rpm TBD
    iv. Enter fault and protection mode(s)
h. Drive cycle and range performance test
    i. 10-minute drive cycle
    ii. 5 output load settings (1 minute at each setting)
    iii. 5 throttle settings
        1. 12 seconds each at 1V, 2.5V, 3V, 3.5V, 4V throttle signal input

2. 5-minute ramp-up and 5-minute ramp-down

iv. Input electrical power, output electrical power and mechanical output power measured on dynamometer test-stand

v. Input energy consumed and output distance traveled (calculated from speed measurement)

i. Field test on actual bicycle TBD

23. Design proposal (PDF file submission upload details TBD)

a. Not more than 25 pages and 11-point Times New Roman Font, including all the figures, charts, references, charts, etc.

b. Information page (On-line entry details TBD)

c. Letter of support (On-line upload details TBD)

d. Narrative document:

i. Introduction

ii. Overall block diagram

iii. Circuit topology

iv. Controller

1. Block diagram

2. Hardware realization

3. Software flow-chart

v. Design/Analysis

1. Power circuit components (including gate drives)

2. Losses, efficiency and thermal analysis

3. Sensing, control, interface hardware

vi. Time-domain simulation results, including ideal switch model for the inverter, block-diagram level controller for the system, electromechanical model for the motor showing steady state waveforms at 250W motor output power, over two electrical cycles of the output waveforms illustrating

1. Battery current
2. Motor currents
3. Motor voltages
4. Motor electrical speed
5. Motor electrical torque

vii. Cost: Bill of materials cost information for production of 1000 units, using the price information on http://www.digikey.com/.

viii. Mechanical design details

2019 INTERNATIONAL FUTURE ENERGY CHALLENGE

PRELIMINARY TEAM INFORMATION FORM

LETTER OF INTENT INFORMATION
TO BE ENTERED ONLINE THROUGH
TEAM REGISTRATION

WEB LINK

ATTACHMENT II

LETTER OF SUPPORT

To be uploaded with Proposal

[The letter below is a typical sample and should not simply be copied. Please send a letter with similar content on your university letterhead.]

To:

Giri Venkataramanan
Professor
Department of Electrical and Computer Engineering
University of Wisconsin-Madison
Madison, WI, 53711, USA
Ph: 608-262-4479
Fx: 608-62-5559
E-mail: giri@engr.wisc.edu

Dear International Future Energy Challenge Coordinator,

Our university has organized a student team to participate in the 2019 International Future Energy Challenge. Our proposal is enclosed. A Preliminary Team Participation Form is attached, listing our contact person, the faculty advisor(s), and some of the students who plan to be involved. The team will keep an eye on the Energy Challenge web site for detailed rules and other information. We understand that we will be notified whether we have been accepted to participate by December 21, 2018. If we are accepted, we agree to have our student team perform the design tasks and prepare the reports and hardware prototypes required for the competition. Our school is prepared to support the team with the following resources:

- A final year project course, ***XXX***, has been authorized to provide engineering students across several disciplines with the opportunity to include this project in their curricula. Laboratory space has been arranged for this course.
- A faculty advisor, Prof. ***XXX***, has been identified, and has been formally assigned to teach the project course and to advise the student team as a portion of his/her regular duties.

- A graduate advisor has been identified to help manage the student team and to supervise direct laboratory activity. This student is supported with a Teaching Assistantship, which represents a funding commitment of our university of approximately ***$X.***
- The student team will be provided with an appropriate level of technician and machine shop support to assist them with package preparation and assembly. This assistance represents a funding commitment of approximately ***$X***, and we consider this as a matching commitment for any in-kind support received from external sponsors.
- In addition, we will provide limited funds to help secure special parts and equipment, with a total commitment of up to ***$X.***
- The student team will be encouraged to secure outside sponsorship. Our university strongly supports all these efforts, and will match any outside cash support 1:1 up to an additional total of ***$X***.

In the event that our school receives prizes from the competition, we are committed to using approximately X% of this money for scholarships for the student team members. The remainder of the funds will be added to our Team Design Program fund, which supports this and similar projects through sponsorship matching, travel funds for participation in competition events, and other direct costs of large team design projects. In the event that our team creates new inventions in the topic area, our university also provides the possibility of assisting with organization of a start-up company.

We understand the importance of student team projects in the engineering curriculum and look forward to our participation in the 2018 International Future Energy Challenge.

Sincerely,

(Head of Department, Dean of Engineering or similar school official)