Technical Reference Material

Updated

1 February 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 1 February 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. Continuous power rating: 500W. Notice that this is the nominal power rating. We will not be testing the continuous power rating of the drive at the nominal power level. 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-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 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: 0-60 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. This is a measurement signal that is used to display the battery voltage on a voltmeter, on the test set-up or on the handlebar of the bicycle.

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, between case at the electrical connections. This will be testing 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, 75 rpm output shaft speed

V_b=37V @300Hz, 4500 rpm motor shaft speed, 750 rpm output shaft speed

These are provided for specifications. We will not be running the motor above 2500 rpm during test conditions.

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 40°C hot-spot temperature rise, at 25°C ambient (respond within x 5s)
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°C)
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 25°C temperature chamber
        ii. Generator output rectified to dc bus (varies as the motor operates at different speeds, about 40V at 3000 rpm)
        iii. Constant current DC electronic load (0, 2.5, 5, 7.5, 10A)
    c. Cable and connector integrity (pull-test 10N on power cable assembly)
    d. Insulation test between case and power connectors 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 2500 rpm

iii. Enter fault mode at 2500 rpm

g. Loaded acceleration test

i. 10A electrical load

ii. Maximum speed

iii. Time to reach 2500 rpm, or the highest speed whichever is lower

iv. Enter fault and protection mode(s) at 2500 rpm

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 (12 seconds each at each 5 throttle signal level [total 1minute] for each of the 5 output load settings at 1 minute [total 5 minutes] each) and 5-minute ramp-down (12 seconds each at each 5 throttle signal level [total 1minute] for each of the 5 output load settings at 1 minute [total 5 minutes] each)

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 completed)

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

24. Progress Report: must be sent to Progres.vla6opljq60wonie@u.box.com in PDF format by March 7th 2019. The progress report must include following contents:
    a. Names and email address of all team members including faculty advisor, graduate student assistants, and undergraduate students
    b. Technical Approach
    c. Design Methodology and Procedure
    d. Simulation Results
    e. Preliminary Experimental Results
    f. Future Work Plan
    g. The progress report must conform to the following requirements:
        i. The progress report must be written in English.
        ii. The progress report must not exceed 25 pages in length including cover page, figures, tables and references.
        iii. The page size must be 8.5" x 11" or A4 with margins not less than 25 mm on every side.
        iv. Double space all text and use Times New Roman typeface, and a font size of 12 point or larger.
25. Workshop presentation must be sent to Worksho.mqosd3fiuwl9cqcm@u.box.com in PPT format by March 15rd, 2019
    a. The workshop presentation only can be presented by undergraduate students.
    b. Each team will have 15 minutes for presentation and 5 minutes for Q&A. There is no slide limit for presentation. However, it is highly recommended to prepare a presentation with less than 20 slides.
    c. The workshop presentation must include following contents:
        i. Technical Approach
        ii. Design Methodology and Procedure

iii. Preliminary Experimental Results

iv. Future Work Plan