

# Technical Reference Material

Updated

September 18th 2023

Details in this document supersede other details provided in Call for Proposals and Request For Proposal, and previous updates of this document. As new information is added to this document, it will be highlighted in green.

## The 2024 International Future Energy Challenge (IFEC 2024)

A student competition sponsored by the

The Institute of Electrical and Electronics Engineers (IEEE)



## Competition Topic: Switch-mode Audio Power Amplifier

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Updated August 2023

### ***Vision Statement and Intent of the Competition:***

*It is important for students to understand the intent of the committee and what they are looking for from competing teams. We state here that the committee is particularly interested in seeing innovations in the amplifier power stage electronics, its modulation, and particular attention will be given to metrics that quantify high-quality audio performance. Any team that creates a design with an off-the-shelf power stage and/or other components that bypass the key engineering effort to create a high performance power stage and its closed-loop modulator will receive lower scores. It is particularly important to note that the committee decided to provide an external 48 V supply so that students can squarely focus on the power stage, modulation, and output filtering. Moreover, designs that use excessively bulky filtering components to achieve high quality waveforms can expect to receive lower scores with regards to metrics that quantify weight and volume. An ideal design would have an innovative power stage, high-bandwidth closed-loop performance, a modest-sized output filter, and sound exceptional to an audio professional.*

This remainder of this document is intended to provide an overview of the technical requirements for the design, realization and testing of the prototype switch-mode audio power amplifier. The document is a guide to provide a frame of reference for the competing teams to stay within a set of common guidelines and use their creative skills to meet the challenge.

It is a live and working document that may be updated as 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 17 in this document.
  - a. First round finalists are required to submit a progress report and make a

presentation at the IFEC 2024 workshop to be held at APEC 2024 in Long Beach, CA on Sunday the 25<sup>th</sup> of February 2024. 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 Austin, TX.
  - c. The team will have to bring only their amplifier 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 output maximum power rating: 135 W per output channel. The output will have 3 channels for left, right, and subwoofer signals. This implies a total power rating of approximately 400 W. Note that actual tests may be conducted at lower power levels as described in the remainder of this document. The continuous power rating is the maximum power level that your converter should be expected to work at. It should also be emphasized that this power rating pertains to the converter output.
3. Left/right stereo speakers model: DALI - Oberon 3 Bookshelf Speakers.
  - Available at: [Dali - Oberon 3 Bookshelf Speakers \(Pair\) - Music Direct](#)
4. Subwoofer model: Dayton MKSX4 Passive Subwoofer
  - Available at: [Dayton - MKSX4 Four 4" Driver Low Profile Passive Subwoofer](#)
5. Nominal input and output 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. Input voltage: A fixed 48 V dc voltage will be provided by a power supply. For the final competition in Austin, each team will be provided the dc supply specified below and must use this supply during the competition. Teams are encouraged to use the same power supply during their hardware development.
    - i. Dc power supply model: Keysight E36155A
  - b. Input audio format: WAV format digital audio files will be standardized across the

team. Files and/or download links will be posted on the IFEC website. The data will be formatted in 24-bit and will have a sample rate between 44.1 kHz and 96 kHz. Under item 10 below, we describe the three audio formats teams will need to be able to receive these signals at their amplifier input.

- c. Load characteristics: For listening tests, the teams may refer to the speaker and subwoofer models described above. To facilitate high sound quality, teams are expected to understand and implement crossover filters that shape the sound which goes to the main left/right speakers and the subwoofer. In particular low frequencies should go to the subwoofer and frequencies above that will go to the main left/right speakers. Teams may design the crossover filter however they see fit and they may need to consider the nonlinear properties of their speakers to get a desired response. Electrical characterization tests will be conducted using wirewound 6 Ohm ceramic resistive loads.
  - d. Output frequency range: Output audio tests will be conducted across the 20 Hz - 20 kHz range.
6. Power connector to dc supply
- a. Anderson power pole connector (contact: MFR# 261G3)
  - b. Red (MFR# 1327), Black (MFR# 1327 G6), color terminals to be stacked in the same order
  - c. Red corresponds to + terminal of power supply
  - d. Black corresponds to – terminal of the supply
  - e. Dc power cable (12 AWG) 30cm-35cm long
7. Audio output connectors to speakers and resistive loads
- a. The converter enclosure must have 3 pairs of panel-mounted jacks for the three speaker connections (see below for panel-mount plate model). Each set of speaker terminals will have one black and red Anderson connector. Speaker cable must be at least 20 feet to facilitate speaker placement, and the cables must be outfitted with load-side connections that are compatible with the speaker models described above.

- i. Anderson Panel Mount Plate: Manufacturer # 1462G1
- 8. Mechanical and mounting details
  - a. An electrically touch-safe enclosure with a grounded chassis is required.
  - b. A grading scheme will be formulated that penalizes designs in proportion to their weight and volume above certain thresholds.
  - c. Target box volume 1500 cm<sup>3</sup>. This is a target. There are no specifications.
- 9. Operational and volume controls
  - a. A power-indicator LED with a label is required.
  - b. A rotary or linear control mechanism must be used to control volume between 0% and 100% power.
- 10. Audio input ports:
  - a. In accordance with standardized for professional audio applications, the hardware unit must accept differential-balanced stereo analog signals via XLR plugs.
- 11. Over-voltage protection
  - a. The teams should anticipate that the power supply may provide a voltage above the nominal 48 V value if not adjusted properly. If this occurs, the converter should protect itself for the full peak voltage of 60 V that the Keysight E36155A can provide.
- 12. 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.
- 13. Thermal consideration: Case should be touch-safe for prolonged operation (<48°C)
- 14. Cooling: Natural convection or fans are allowed. If fans are used, they must be quiet to avoid a scoring penalty.
- 15. Prototype hardware test:
  - a. The final tests will be carried out at the University of Texas at Austin, USA.
  - b. The EMI generated by the audio amplifier will be measured and it must adhere to typical FCC requirements that limit emissions.

- c. A sequence of tests will be prescribed using a Audio Precision analyzer unit as shown here: <https://www.ap.com/audio-analyzers/>
  - d. Efficiency tests:
    - i. Efficiency will be measured with a noise input signal at output power levels of 25%, 50%, 75%, and 100% into a fixed 6 Ohm resistive loads across each channel.
  - e. Subjective listening test:
    - i. A studio space will be secured on or near the UT campus where music will be played through your amp and assessed in a subjective listening test.
16. Design proposal (PDF file submission upload details will be posted online soon)
- 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. Modulation method
    - v. Controller
      - 1. Block diagram
      - 2. Hardware realization
    - vi. Design/Analysis
      - 1. Power circuit components (including gate drives)
      - 2. Losses, efficiency and thermal analysis
      - 3. Sensing, control, interface hardware
    - vii. Time-domain simulation results, including ideal switch model for the

inverter, block-diagram level controller for the system, model showing steady state waveforms with the provided audio test signals.

1. Input current
2. Output voltage and current at load
3. Switch-level waveforms

viii. Cost: Bill of materials cost information for production of 1000 units, using the price information from online distributors.

17. Progress Report: Submission details will be updated soon. 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.

18. Workshop presentation: Submission details will be updated soon.

- 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