Project 1

EE 394V Power Electronics: Modern Topics and Practice, F19

See Syllabus + Canvas for due dates

Your client needs to educate a variety of employees on power electronics. This is fairly common; not all companies employ power electronics specialists. Your client has the knowledge, but the lacks a suitable system to demonstrate both basic and advanced power electronics concepts. Various evaluation boards can show certain concepts, but your client doesn't want to maintain an array of systems just to demonstrate a complete suite of functions.

Your client has asked you to develop a system to demonstrate as wide of a variety of power electronics concepts as possible in a single system. In particular, your client insists on the following functions:

Required Features:

1. Demonstrate the buck, boost, and buck-boost converter, preferably using a single 4P3T switch to change configuration
2. Sense inductor current(s) and capacitor voltage(s) with ripples
3. Sense at least one gate-source voltage and the switch node voltage
4. Demonstrate the effect of varying inductance(s) and capacitance(s)
5. Demonstrate diode operation and synchronous rectification with noticeable efficiency difference and variable dead time
6. Demonstrate the effect of loop inductance on gate-source and/or switch node voltage waveforms
7. Show switching loss through overlap of switch voltage and current
8. Show diode reverse recovery through diode voltage and current
9. Demonstrate the effect of varying frequency of operation
10. Demonstrate continuous, boundary, and discontinuous conduction modes, including "valley switching"
11. Automatically limit the output voltage in boost and buck-boost modes
12. Demonstrate a substantial load step with transient response, both in opern loop and stable closed-loop for at least some operating point
13. Adjustments should be made future-proof, i.e. physical (buttons, switches, knobs) or "timeless" and open interfaces like RS-232.
14. Excellent protection of "high" voltage nodes from human touch (nothing should be high enough to be dangerous, but extra protection is never bad) without interfering with ability to take measurements

Elective Features: The client would be especially happy to see the following features included, but recognizes that it may be difficult to include all of them:

1. Continuous adjustment of load, inductance, and capacitance (even over limited ranges)
2. Stable closed-loop control over a wide range of operating points
3. Show current-mode control, including sub-harmonic oscillations, variable or on/off ramp slope, and very fast transient response when well-tuned
4. Variable inductance in switching loop; variable inductance/resistance in gate-source loop. Feature must have low enough minimum inductance to demonstrate clean waveforms.
5. On-board efficiency measurements and output with sufficient precision to see the effects of (at least some) circuit variations
6. Methods to easily reach pre-set operating points for given demonstrations
7. If you have creative, useful ideas to enhance the product, the client is willing to consider them

Allowed Equipment: The client is willing to use the following external equipment, and asks that your system not require any more:

1. A single dc power supply (25 V, 1 A rated)
2. A single 2-channel oscilloscope with passive voltage probes and current probe(s)
3. A single TM4C123GXL microcontroller evaluation board
4. A single laptop with USB-A interfaces and no internet connection

Deliverables: Your client asks for the following as the physical output of your work:

1. A written report containing
   (a) Rational for every component selection, including calculations as appropriate
   (b) Documentation of every feature that you have included (photographs, oscilloscope screenshots, etc. as appropriate) with operating point(s) specified for each figure
   (c) A list of things you would/must change to improve the system if given the opportunity
2. Final, well-commented microcontroller code
3. Final, well-commented PCB schematic and layout
4. Final physical prototype (the client may ask for a live demo; you won't have to "turn in" the actual object)

Fee (grade): Your fee (grade) will be based on the following:

A: Successful inclusion of all required features, at least 2 elective features, while only requiring the use of allowed equipment.

B: Successful inclusion of most required features, at least 1 elective feature, while only requiring the use of allowed equipment.

C: Functional product with serious lack of required features or elective features. Requires the use of non-allowed equipment.

D/F: Non-functional product.

"Pluses and minuses" will be based on the clarity, concision, and thoroughness of your written documentation/report and well-commented code and layout files.

Intermediate Targets: The client would like to see your progress and offer feedback at various stages. While your fee (grade) is mainly based on your final product, failing to deliver on intermediate targets will cause you to miss some points (see syllabus). More importantly, you may miss out on valuable feedback and possibly forfeit some opportunity to negotiate your final evaluation. Intermediate targets are labeled P(roject)# and will be assigned throughout the semester and are also listed on the syllabus:

P0: Use of software tools (included in HW0)

P1: Schematic/BOM (nearly) complete check-in

P2: Layout (nearly) complete check-in

P3: PCB Ordering (nearly) complete check-in

P4: Final Report

Updates/Changes: As the semester progresses, changes may need to be made to the project. These will be communicated in advance on Canvas and/or in class. "Change orders" in the middle of a project are authentic parts of the work experience!