# Line Operated Variable Voltage Power Supply

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1. Introduction:
    a. Problem: Many low-cost bench power supplies are noisy with bad accuracy and are sometimes unsafe. Even the top positive reviews of Amazon's best-selling bench power supply (Kungber 30V 10A) [1] have serious complaints about its performance, such as drift, inaccurate display readings, excessive voltage error, and outright failure. Low-cost bench supplies with poor power factors inject harmonics into the power lines, and their switching noise and other distortions can disrupt precision circuits. Additionally, basic protections are sometimes lacking, leading to unsafe conditions that could damage the supply, the circuit, or you.
    b. Solution: We intend to build a line operated variable voltage power supply that is relatively low cost. To provide for low cost, isolation, and high efficiency, isolated switched mode conversion will be used in order to correct the power factor, as well as to ultimately transform the voltage from line levels down to the selected voltages while providing for the output error specifications. Its subsystems will include the input rectification & power factor correction, isolated switched mode conversion, feedback & control, and thermal & overcurrent protection. Its output should be adjustable from 5V to 25V at 50W, at less than 1% total deviation under a static full load.
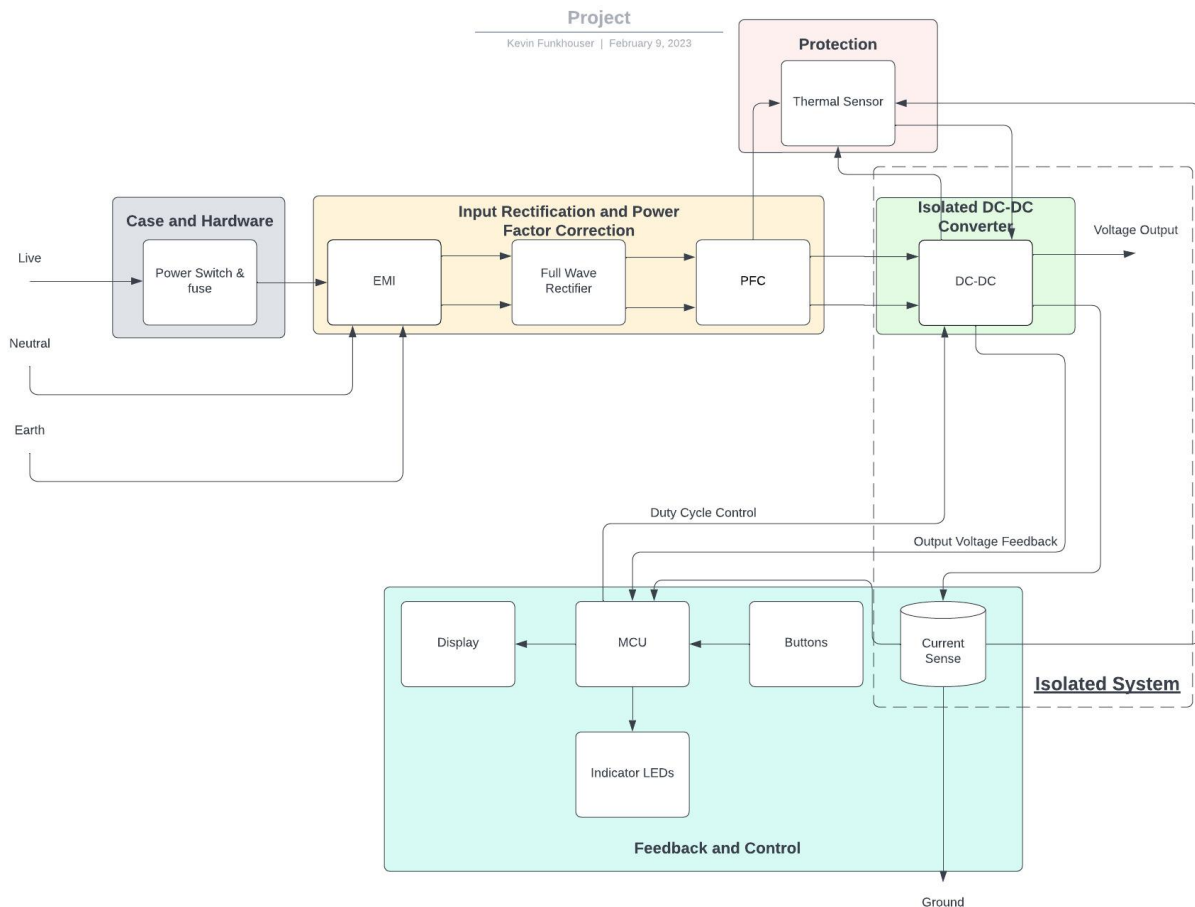    c. Visual Aid:



    d. High Level Requirement:
        i. The power factor for the device will be greater than 0.9.

      ii.     The device will meet or exceed IEC 61000-3-2 standards for harmonic current.

      iii.    The device will deliver 5V - 25V at 50W with 1% accuracy to a static load across the whole voltage range.

2. Design:
   a. Block Diagram



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   b. Subsystem Overview:
      i.     INPUT RECTIFICATION & POWER FACTOR CORRECTION: The current proposed system entails an EMI filter followed by a full bridge rectifier. The rectified output is then boosted to a 250VDC intermediate bus, which is later switched down to output levels. There are a variety of chips that can control a boost converter for PFC use, such as the UCC28180. The EMI filter will likely consist of simple protection TVS or zener diodes and a ferrite. It is of note that there will be a fuse and a power switch "upstream" of this subsystem. This circuit should meet IEC 61000-3-2 standards for line harmonic current.

      ii.    ISOLATED DC-DC CONVERTER:

This regulated converter will transform from 250VDC down to the desired voltage. This converter must be galvanically isolated, i.e. uses a transformer or coupled inductors. The topology could possibly be a bridge, forward, or flyback converter. A possible control chip for this application is the NCP1252. A fortified output filter, with possible topologies of a capacitance multiplier or a noise clipper circuit, will provide thorough output regulation and good transient response.

iii.    FEEDBACK & CONTROL:

The switching signals for the converters must be generated using feedback from both the 250V bus and the output. Some of these signals must be isolated, likely by means of optocouplers. Control signal generation can be MCU or analog control chip based, though for the PFC and DC-DC modules we plan to choose analog (or digital controllers that act like analog) as they are both good and common these days. For display processing and input control, we plan to use an MCU to encode the sensed current and voltage for display on a simple screen such as the seven-segment. The MCU we will select depends on whether we decide to originate the voltage reference through digital means (e.g. a digital potentiometer dividing a precision reference) or analog means, as this may or may not require an ADC onboard. Though we currently do not plan to use any digital control schemes for switching logic, protection, or feedback, this is a very powerful tool we could integrate, if necessary, at a later time using a hybrid digital logic/analog control scheme.

iv.    PROTECTION:

There must be a method to measure, determine, and protect against thermal overload conditions via a thermal sensor directly coupled to the limiting semiconductors. There also must be a current sense and response to overcurrent conditions, both transient and steady state. Current and heat sensing and managing are well detailed issues with many possible solutions. We believe the selection of particular topologies and devices should come after more deliberation on the exact converter topologies so that the failsafes respect the failure modes of the system. Additionally, it must be said that the first line of defense against overcurrent and overheating conditions is solid thermal management, proper device selection, and judicious board and circuit design.

v.    CASE & HARDWARE:

This instrument will need to be operable. It will need to have a case with adequate venting and heatsink capabilities, a three prong plug with strain relief and perhaps a ferrite bead, a fused input, and a power switch. Shielding will be investigated. It will also need to have simple displays to

tell real time voltage and current conditions. There must be a dial or buttons to select voltage, and banana plugs or other connectors for power, ground, and earth. Other indicators must include a power good LED as well as a power bad LED.

- c. Subsystem Requirements:
    - i. Input Rectification & PFC
        1. PF>0.9
            - a. PF meter, Oscilloscope & Spectrum Analyzer
        2. Exceed IEC 61000-3-2 standards for harmonic current
            - a. Spectrum Analyzer
        3. Output voltage 200-300VDC at 50W
            - a. Oscilloscope
    - ii. Isolated DC-DC Converter
        1. Galvanic Isolation
            - a. Continuity Tester, possibly Signal Generator & Oscilloscope
        2. Converts to the specified output voltage within 1% static error at 50W
            - a. Oscilloscope
        3. Must be BIBO stable
            - a. Signal generator, Electronic load, Oscilloscope
    - iii. Feedback & Control
        1. Processes and displays the output voltage to 7-segment within 1%
            - a. DMM
        2. Processes and displays the output current to 7-segment within 10%
            - a. DMM
        3. Processes button inputs to a counter then outputs a voltage reference within 0.1%
            - a. DMM, Logic Analyzer
        4. Recognizes and displays indicators
            - a. Oscilloscope and visual observations
    - iv. Protection
        1. Disconnects the output in case of overheating or output overcurrent - these conditions are hardware specific and yet to be determined.
            - a. IR thermometer, Ammeter, Shunt, Continuity Tester, Oscilloscope
    - v. Case & Hardware
        1. Case with space for all necessary hardware
        2. Power Switch
        3. Fuse

     4. Three Prong Plug
     5. 7-segment Displays for Current and Voltage
     6. Buttons
       a. Visible verification for this subsystem
  d. Tolerance Analysis:

  The only requirement that has strict tolerance that may provide difficulty is the 1% output tolerance. Active PFC modules generally achieve PF>0.9 with relative ease, whereas SMPS controller ICs generally guarantee a few percent static error, which is unacceptable.

    i. The ADP1071 isolated flyback controller chip [2] offers static output error less than 1% average from the reference voltage. There are other options of control chips with acceptable guaranteed error, though they are often either expensive or would require us to commit to a specific topology.

    ii. Precision PWM generator systems such as the TIPD108 [3] (<0.11% offset, <0.02% gain errors) are available more readily than precision controller ICs. A discrete error amplifier (as good as the op-amp and sampling resistor tolerance), isolation amplifier (though generally poorer, <0.5% is common and the $25 ISO124 achieves[4] <0.010%) and PWM generator system combination may be used to achieve better accuracy as compared to a controller IC. This option could afford us greater precision at the cost of higher expense and greater complexity.

3. Ethics and Safety: We will be working with high voltage in this project so it is important that every member in our group take the high voltage safety training assessment. In addition, we will enforce that at least two group members be in the lab at all times to ensure someone will always be there to check up on one another. We will also address the heat dissipation and have a thermal sensor that can protect against thermal overload conditions, so the user is protected from catastrophic failure. The output display must also be accurate, so that the user can accurately assess emergency situations. The specifications of the device must also be properly measured, characterized, and accurately reported so that the user can operate within a safe and predictable region To protect building infrastructure in the case of uncontrollable overcurrent, the inputs will be fused. Additionally, to respect and credit the work which helped us build our project, we will cite our sources. Citing our sources as well as accurately reporting specifications falls under IEEE Code of Ethics I.5 [5].

References:

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