Lab 5: Power Supply

In this lab, you will build a buck converter that regulates its output voltage as the input voltage changes. You will first characterize the hardware, design a controller, and then build the power supply using the lab hardware.

The design goals for this power supply are:

1. Input voltage range: 7-20V.

2. Output voltage: 5V ±1%, including ripple.

3. Maximum transient output voltage: 5.25V.

4. Output current: 0-1A.

While you will be testing this power supply with a large resistor load, these specifications would be suitable for running digital logic which may be sensitive to power supply variations. The output transient voltage specification allows the output to rise temporarily to a higher voltage due to input or load steps, but when the input voltage and output current are stable the typical output voltage specification should be met.

The output current does not need to be actively limited by the power supply. The output current specification only describes what the supply should be capable of.

Assigned: October 23, 2017

Due: Week of October 30, 2017

Part 1

Electronics

For this lab, build a synchronous buck converter with the half-bridge module, two large filter capacitors, and the inductor on the component board. For characterization, the PWM signal for the half-bridge will come from a function generator.

Noise

Since the controller must measure voltages (and possibly currents) which change on a nearly cycle-by-cycle basis, reducing noise is important. Keep the high current paths as short as possible. You may want to add a small capacitor across R_L for filtering, but be aware that it will cause a phase shift that may need to be considered in your controller design.
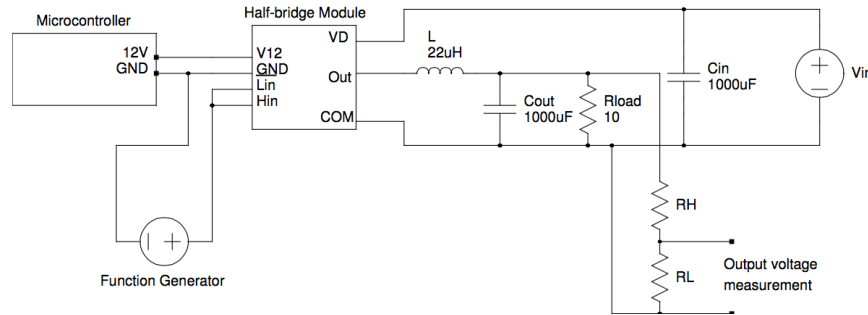
Figure 1: Test setup.

Part 2

Characterization

Drive the half-bridge with a function generator. Set the function generator to produce a 195kHz square wave with a minimum voltage of 0V and a maximum voltage of 3V. This simulates the signal that the microcontroller will produce. Make sure that the function generator output termination is set to High-Z so that the output voltage is correct. It's a good idea to check its output with the oscilloscope before connecting it to the half-bridge.

Adjust the duty cycle to achieve an output voltage of about 5V. Measure the output voltage at the output of the divider with the load present and with it disconnected. Check at a few duty cycles. Repeat this measurement for a few input voltages from 10V to 20V.

Inaccuracy

To achieve the target output voltage tolerance, you will need to account for parasitic resistance in the power supply, half-bridge, and inductor, and the tolerances of the voltage divider resistors.

The output voltage will be measured by a 12-bit ADC which has a 1.5V reference. The accuracy of this reference and the ADC may require some gain correction in your controller and calibration, but that can be handled when you implement it in real hardware.

Modeling

Build a mathematical model of the circuit which predicts the output voltage based on the input voltage, load current, and duty cycle. Try to determine where parasitic resistances are located and how they affect output voltage at different operating points - the apparent resistance may change with duty cycle.

Design a controller which will keep the output voltage at nearly 5V as the input changes quickly from 10V to 20V. The output voltage should quickly settle at around 5V and should never exceed 5.25V. Note that

the controller can't measure the output voltage directly — it must measure the divided (and filtered, if you choose) voltage from the voltage divider. The voltage divider's actual ratio and any phase shift produced by filtering components should be considered.

The controller should ultimately take as input the measured output voltage and produce a duty cycle to drive the half-bridge. It may be helpful to design the controller initially using MATLAB, but you will need to implement it in the microcontroller later.

Part 3

Hardware

The hardware for the final power supply is the same as the test setup, except the microcontroller now generates the PWM control signal. The voltage reading is fed back to an ADC on the microcontroller to close the control loop.

You may find that doing a differential measurement may help reduce noise in addition to adding a filter to the voltage divider. If you add filters to the voltage reading, you may find that the phase shift added by the filter can effect the behavior of your controller.

Use the LCD to display the desired voltage setpoint and the current voltage.

Make sure that your power supply meets all of the above specs and explain any difference between your model and the actual power supply.

Signoffs

1. Build power supply circuitry and demonstrate operation with a function generator.

2. Explain mathematical model of circuit and show which parasitics were accounted for.

3. (Optional but recommended) Simulation of system and controller in MATLAB. Demonstrate it operating with a dynamic load.

4. Implemented power supply meets all specifications.