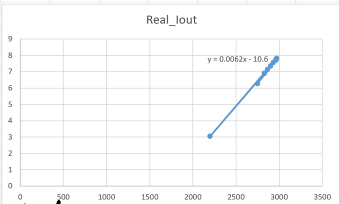
Lab Results

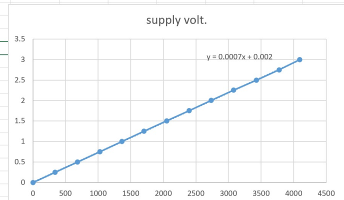
1. Provide a snippet of your code showing the calculation of the voltage at the input of the ADC pin. Provide a screenshot of the CCS debugger showing the calculated voltage.
2. Provide a screenshot of your MPPT algorithm implemented in code.
3. Provide the maximum power point identified by your control for both full and half I_{SC}. For each point, provide the duty cycle, input voltage, and output power as measured by your microcontroller.

(1). screenshot of Vout and iout (True value and calculated values)

ADC_raw_iout	Real_Iout
1690	0
2830	6.916
2865	7.136
2900	7.359
2930	7.573
2960	7.746
2970	7.82
2200	3.05
2960	7.7
2747	6.276
2830	6.9158



ADCRESULT0	supply volt.
0	0
340	0.25
685	0.5
1025	0.75
1365	1
1701	1.25
2050	1.5
2395	1.75
2735	2
3080	2.25
3430	2.5
3775	2.75
4095	3



Actual Vout= 12.51V

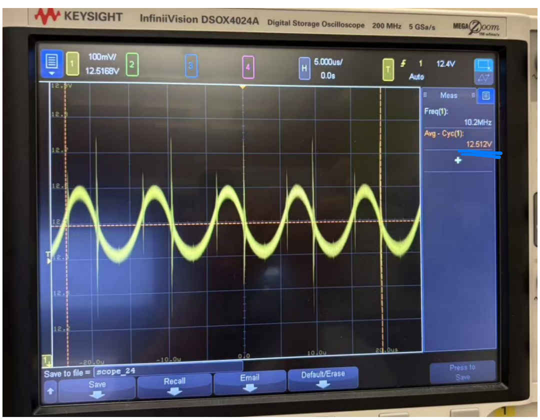
estimated Vout=12.36V

within 5% ✓

MPPT_duty ≈ 61.5%

duty_cmp	unsigned int	295	0x0000A9
duty	float	0.615000069	0x0000A9
adc_raw_vout	unsigned int	1537	0x0000A9
adc_vout	float	12.3860807	0x0000A9
adc_raw_iout	unsigned int	3006	0x0000A9
adc_iout	float	7.9041338	0x0000A9
MPP_Duty	float	0.615000069	0x0000A9
MPP_power	float	97.3910446	0x0000A9
pout	float	97.8375397	0x0000A9
flag_sweep	int	1	0x0000A9

(3). Full Isc = 5.21 A.

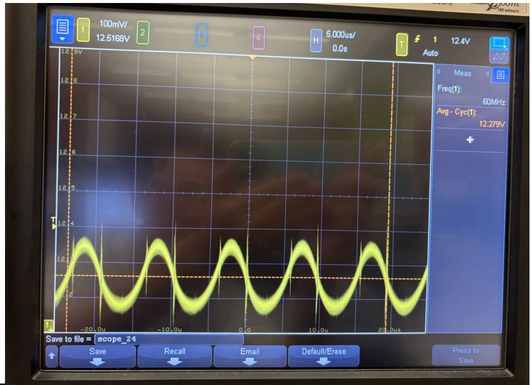


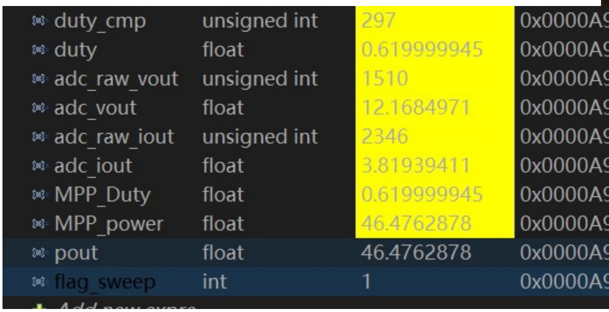
Estimated power: 97.83W

Actual power: 7.9674 × 12.512 ≈ 99.6W

& 95.61 W

between 99.6 & 95.61W





duty_cmp	unsigned int	297	0x0000A9
duty	float	0.619999945	0x0000A9
adc_raw_vout	unsigned int	1510	0x0000A9
adc_vout	float	12.1684971	0x0000A9
adc_raw_iout	unsigned int	2346	0x0000A9
adc_iout	float	3.81939411	0x0000A9
MPP_Duty	float	0.619999945	0x0000A9
MPP_power	float	46.4762878	0x0000A9
pout	float	46.4762878	0x0000A9
flag_sweep	int	1	0x0000A9

when $I_{sc} \approx 2.60A$, $V_{out} \approx 12.28V$, $I_{out} \approx 3.95A$.

$\Rightarrow$ Estimated power $\simeq$ 46.47W

Actual power = 47.47W.

basically because at low current, the value is not so correct.

Lab Takeaway

1. In your own words, describe how voltage sensing can be designed and implemented to provide feedback to a controller.

The voltage sensing part uses a resistive division like 100k ohms and 10k ohms to measure the voltage dropped from the 10k ohms. We have to use a comparatively large resistive value for not affecting the current in the buck converter.

2. In your own words, describe how current sensing can be designed and implemented to provide feedback to a controller.

Current sensing part uses an extremely small resistor to measure the voltage dropped down from the resistor. We normally use the resistive value like 2.5m ohms. By measuring the voltage between the current-sense resistor, and use the current operational amplifier (times 50) to get the iout_sense, which can be read by the ADC GPIO from the microcontroller C2000.

3. Describe how the various supply voltage needs of gate drive and sensing circuits can be met with minimal external supplies.

Instead of the PV+ power supply and 12V gate driver power supply, we need to use 5V to drive the current amplifier, so we need the LDO to get a 5V output voltage supply. And for the current sensing circuit, to ensure the iout_sense is always above 0 (or just in case there's a huge negative current flowing through the resistor), we need to have a 1.25V voltage supply which is connected to the VREF of current amplifier.

4. In your own words, describe how to calibrate an ADC and why it is necessary

Because we read the register value from ADC, which should be converted to real ADC sensing voltage. Also because of the voltage bias of the circuit like the bias from the 12V gate driver power supply and the load, we have to calibrate the ADC value.

5. In your own words, describe how closed-loop control may be implemented using a microcontroller.

When we get the open-loop Vout of the buck converter, we can add a perturbation on the duty cycle and compare whether the power it gets is higher than the MPPT duty cycle we've set. If it's larger, then set the duty cycle to the new value with the perturbation. If not, keep the original value.

Build Intuition

1. Compare voltage sensing and current sensing in terms of cost, complexity, and loss. If you could only implement one in a converter design, which would you choose and why?

Voltage sensing is generally more cost-effective, simpler, and has negligible power loss compared to current sensing, which requires additional components like a shunt resistor and a current sense amplifier, leading to higher cost and complexity. While voltage sensing only requires a resistive divider and an op-amp buffer, current sensing involves differential measurements and introduces some power loss due to the voltage drop across the sense resistor. If only one could be implemented in a converter design, voltage sensing would be the preferred choice as it enables essential feedback for output voltage regulation with minimal impact on efficiency. However, current sensing is necessary for applications requiring current-mode control, overcurrent protection, or power calculations.

2. Describe how certain types of sources and loads may be emulated in a laboratory setting with power supplies and electronic loads. Provide two examples of sources that you would emulate in different ways, and how you would emulate them. Provide two examples of loads that you would emulate in different ways, and how you would emulate them.

The first emulation is a 12V load as batteries. The second emulation is 5.21A current source as solar panel PV+ emulation.
In a laboratory setting, a 12V battery load can be emulated using an electronic load set to constant voltage (CV) mode, ensuring that the voltage remains at 12V while allowing the current to vary based on the circuit demand, similar to how a real battery behaves under load. This is useful for testing battery chargers or DC-DC converters designed to charge or discharge batteries.
For solar panel emulation, a 5.21A current source can be replicated using a programmable DC power supply with current-limited mode, where the supply is configured to output a maximum of 5.21A while allowing voltage to fluctuate based on the power converter’s operation. This mimics the behavior of a PV panel, where the current is dictated by irradiance levels, and the voltage is determined by the connected load. Using such controlled emulations ensures accurate and repeatable testing conditions for power electronics applications.

3. Describe how your MPPT algorithm would behave if your electronic load was configured to emulated a constant-resistance load. Would it still work? If so, what would be different?

It would not work. Because when we set a constant-resistance load, theoretically, Pout = Vout^2/R. We don’t’ change the resistance of load by duty cycle because it’s fixed. Rload = R/D^2, such that we can change resistance by changing D, to see the crosspoint of PV module and Rload and detect the actual working point of the PV panel.

Feedback: 1.5 hours post-lab