

Selecting the best post-regulation options for isolated power supplies

Introduction

The regulation of the isolated output voltage of an isobuck is ensured by the regulation of the primary output voltage and the transformer.

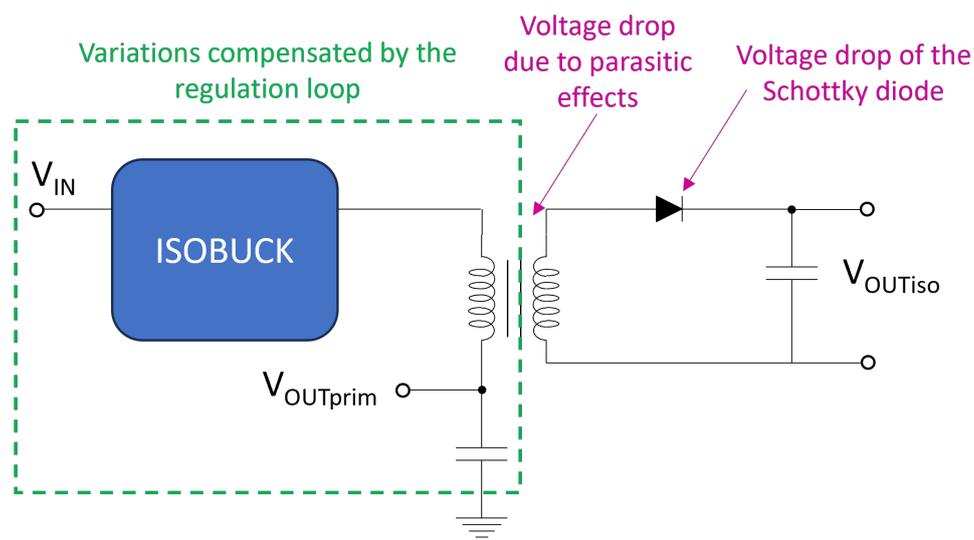
One of the benefits of the isobuck is certainly the excellent regulation of the primary output voltage (as in any standard buck) which rejects any variation of the input voltage.

While the primary output voltage is well regulated, the isolated output voltage shows some variations due to:

- The load applied to the secondary output voltage
- The Transformer turn ratio
- The voltages drop across parasitic components and the Schottky diode

The leakage inductance of the transformer

Figure 1. Contributions to the secondary output voltage regulation



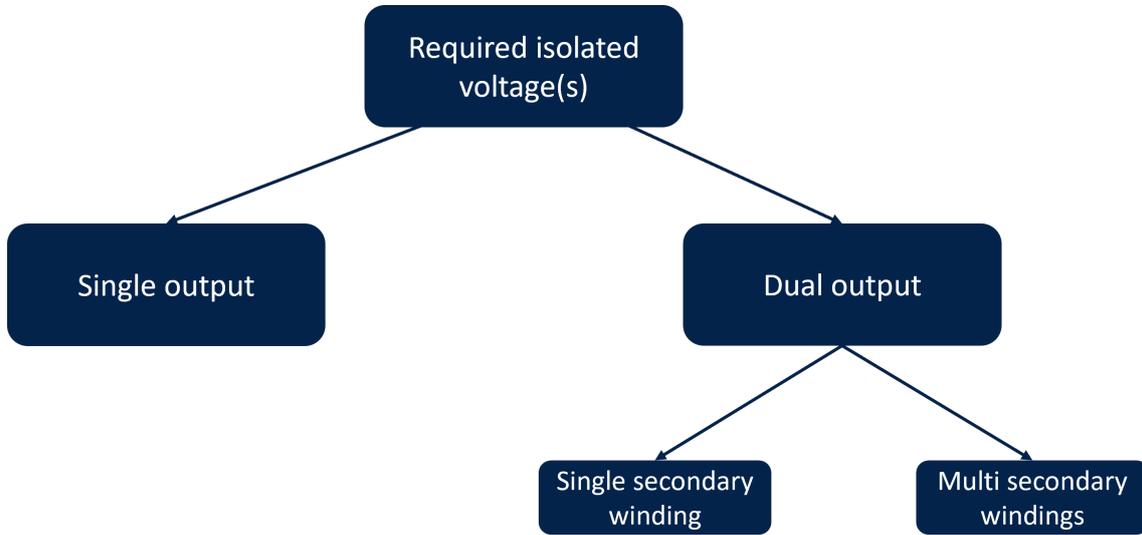
Depending on the application, a post regulation could be required for instance when:

- It is necessary to stabilize the isolated output voltage within a given accuracy range
- The generated isolated voltage should be split into a dual voltage, e.g. positive and negative (e.g. as required by gate driver applications)
- Additional or more effective protection against short circuit on the isolated output is necessary

There are different approaches for the post-regulation circuitries, with pros and cons in terms of cost, complexity, precision, and so on.

This application note describes the most common solutions and highlights for each circuit including advantages and disadvantages. The main cases discussed in this application note are summarized in the [Figure 1](#) below.

Figure 2. Post regulation options



1 Isolated output voltage variation

1.1 Variation with the load

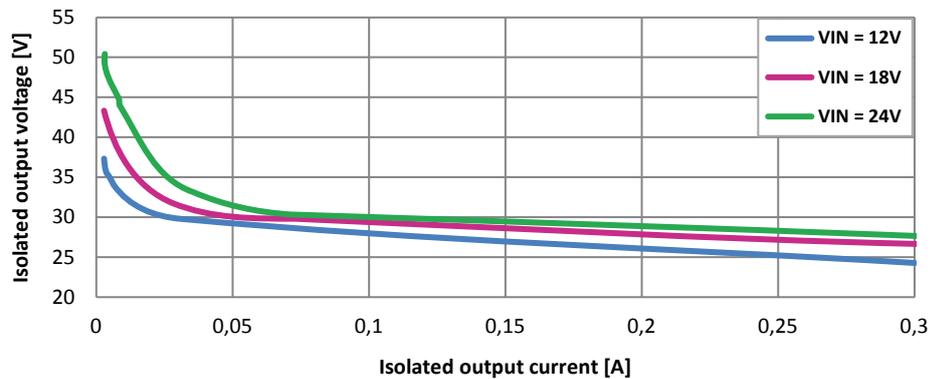
The Figure 2 shows the variation of the isolated output voltage with the load variation at different input voltages. It can be observed that:

- At low output currents, the effect of the leakage is dominant. The leakage generates an extra-voltage, which quickly dissipates once a load, even light, is applied.
- At higher output currents, other effects are more significant. (drops due to the winding resistances, Schottky diode, other parasitic effects, etc.)

The curves show a slight influence of the input voltage on the isolated output voltage. Increasing the input voltage, the duty cycle changes, and this alters the period during which the energy is transferred to the secondary side.

That affects power losses as well and also determines a small variation of the isolated output voltage.

Figure 3. Variation of the isolated output voltage with the load (test performed on the L6983I)



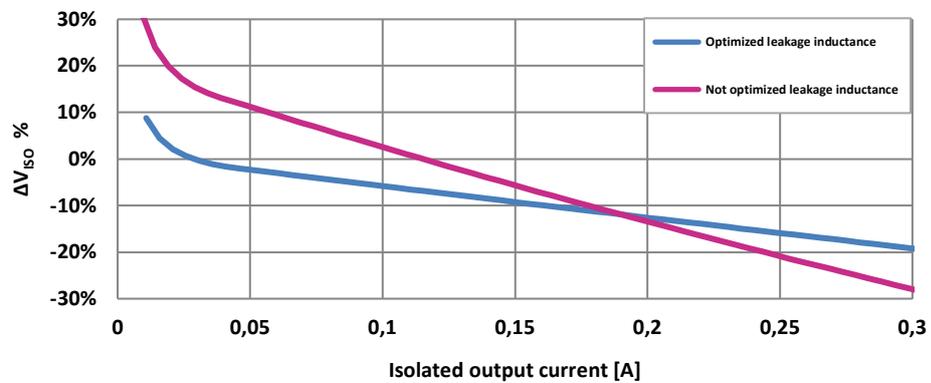
1.2 Variation with the leakage inductance

It is normally recommended to select a transformer with a leakage inductance not higher than 1% of the magnetizing inductance. The reason is clearly illustrated in the [Figure 3](#). The optimized leakage curve corresponds to a leakage inductance of around 1% of the magnetizing inductance whereas the not optimized leakage curve shows a case with a leakage above 2%.

The selection or construction of a transformer with a very low leakage inductance is desirable and not always achievable due to:

- Unavailability among the off the shelf transformers
- Impossibility to achieve the desired value when other constraints are also present (size, resistance, etc.)
- Impact of a low leakage inductance on other relevant parameters (e.g. interwinding capacitance)

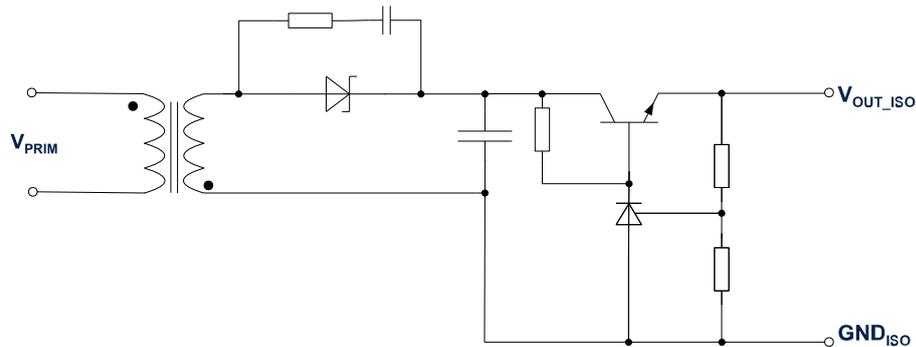
Figure 4. Impact of the leakage inductance on the load regulation



2 Post-regulation solutions for single isolated voltage

2.1 BJT and shunt voltage reference

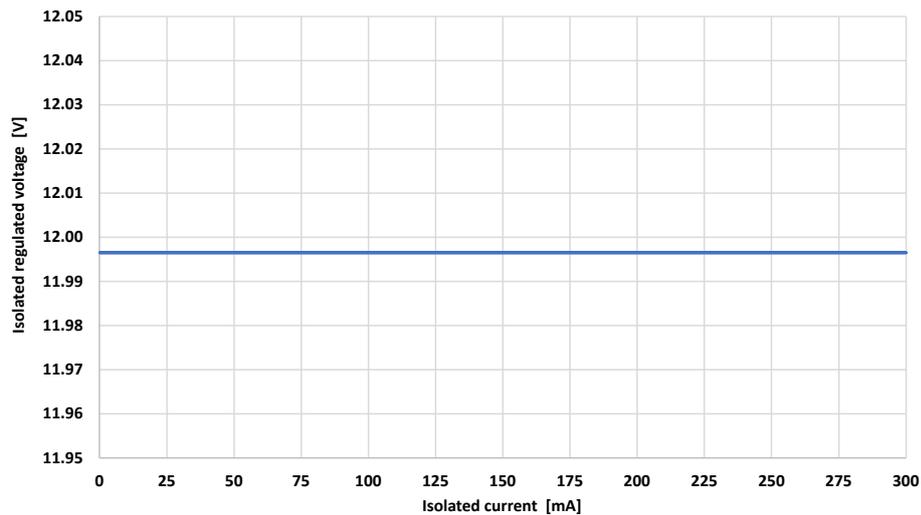
Figure 5. Post regulation circuit for single isolated voltage with BJT and shunt voltage reference



The implementation of a BJT together with a shunt voltage reference is almost equivalent to a linear regulator. The simplicity and easy adjustability of the output voltage (by changing the resistor divider) are definitely the strength of this solution. On the other hand, compared to a solution with a linear regulator, the number of components used affects the occupation of PCB area. Moreover, there is no protection against a short circuit event at the output.

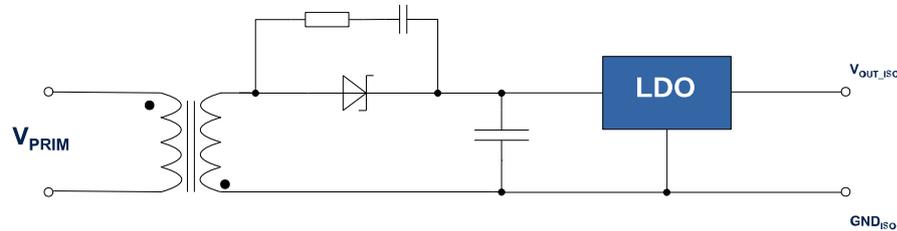
The simulated load regulation performance is shown in the [Figure 5](#).

Figure 6. L6983I, $V_{IN} = 12\text{ V}$, $V_{OUT_{prim}} = 6\text{ V}$, $f_{SW} = 200\text{ kHz}$, $N = 2.5$, target isolated voltage = 12 V



2.2 Linear regulator

Figure 7. Post regulation circuit for single isolated voltage with LDO



Although the solution described in the Section 2.1 can be assimilated to a linear regulator, the post-regulation that implements a LDO (shown in Figure 6) is definitely advantageous due to less components, higher precision, lower power losses and protection against short circuit events, provided that the selected LDO offers this feature.

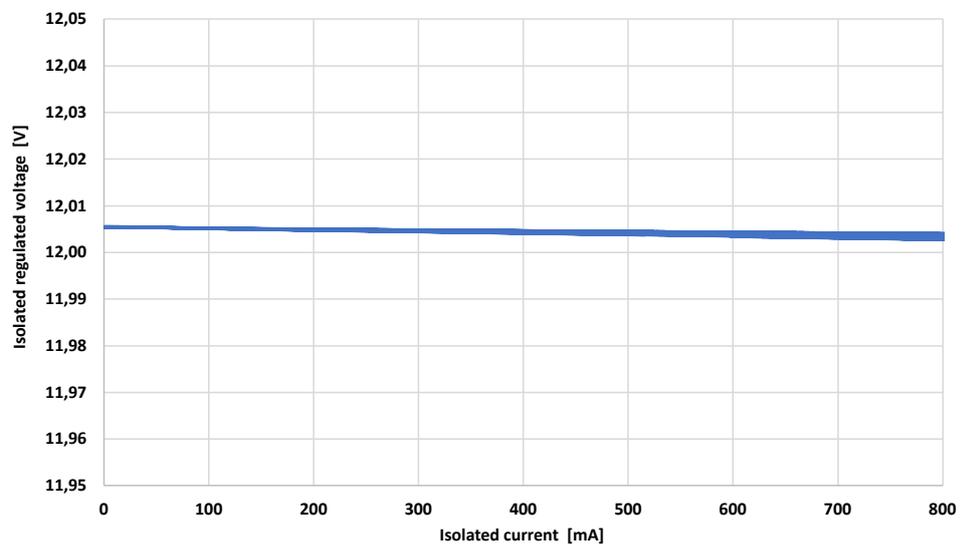
Whether or not this option is also convenient in terms of cost compared to the one in Figure 4 should be carefully assessed.

A possible disadvantage can derive from the limited output voltage regulation offered by the selected LDO.

Nevertheless, the selection of a LDO like the LDH40 would comply with the most common requirements in terms of regulation of the isolated voltage (it can regulate the output voltage up to 22 V).

The simulated load regulation performance is shown in the Figure 7

Figure 8. L6983I, $V_{IN} = 12\text{ V}$, $V_{OUTprim} = 6\text{ V}$, $f_{SW} = 200\text{ kHz}$, $N = 2.5$, target isolated voltage = 12 V



2.3 Comparison of the two solutions

Table 1. Comparison between the solutions for single isolated voltage

solution	PCB area	Accuracy	Power losses	Protections
BJT and shunt voltage reference	large	good	Mainly due to the BJT	Not available
LDO	small	higher	lower	Available if embedded in the LDO

3 Post-regulation solutions for dual isolated voltage

The generation of a dual voltage is a common request especially for gate drivers applications. Splitting the isolated voltage generated by the isobuck into two voltages (typically one positive and one negative) does not necessarily demand the use of a post-regulation circuit downstream of the secondary winding. The same goal can be achieved by using a transformer with two secondary windings. The two approaches, together with their pros and cons are summarized in the picture below.

Figure 9. Solutions for dual voltage regulation



The use of a two-secondary windings transformer allows the presence of different load conditions at the positive and the negative outputs (in [Figure 8](#) that is indicated as “unbalanced loads”). This benefit compensates the drawbacks in terms of size (the transformer can be bigger), availability (more difficult to find it among the solutions off-the-shelf), and cost (the two winding transformer can be more expensive).

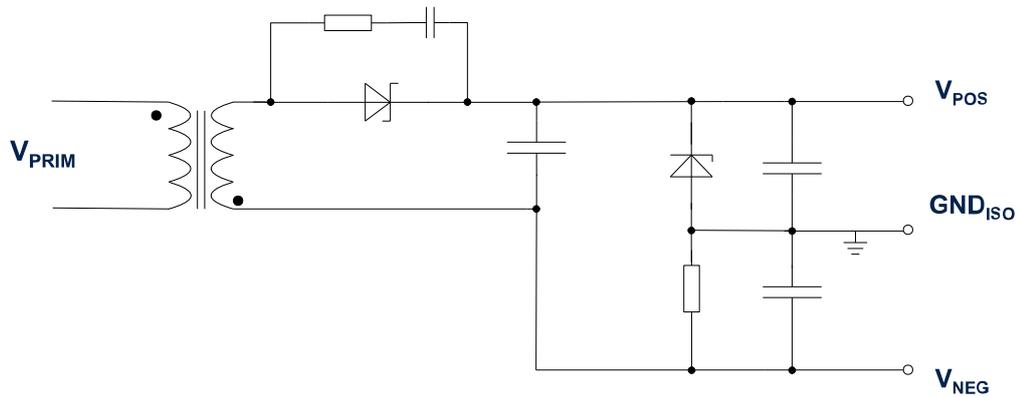
In the next sections, different solutions for both approaches are presented.

3.1 Single secondary winding

3.1.1 Zener diode and resistor

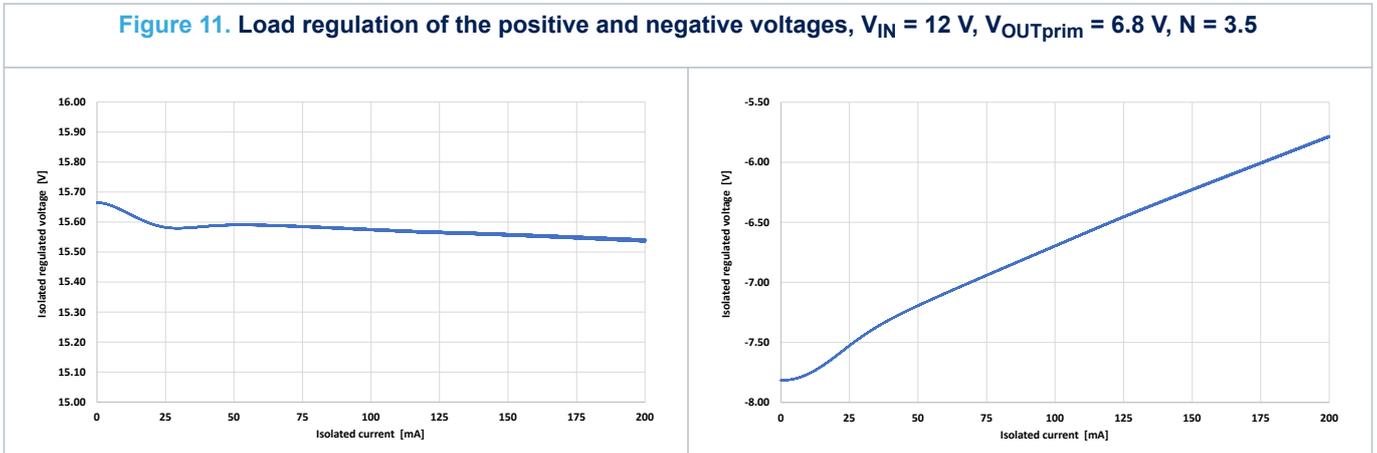
This is by far the simplest solution to split the isolated voltage generated at the secondary winding of the isobuck into a positive and a negative voltage. The positive voltage is determined by the Zener diode, and the negative voltage is basically defined by the remaining voltage. Despite the variations of the Zener voltage, the positive voltage generated by the Zener diode shows a good regulation. The same consideration is not valid for the negative one however. Since it simply derives from the difference between the voltage at the secondary winding and the Zener diode, it is completely affected by the variations of the former.

Figure 10. Post regulation circuit for dual isolated voltage with Zener diode and resistor



The trends of the two regulated voltages (in this example +15 V/-8 V) are shown below:

Figure 11. Load regulation of the positive and negative voltages, $V_{IN} = 12\text{ V}$, $V_{OUTprim} = 6.8\text{ V}$, $N = 3.5$



To achieve a better accuracy of the negative output voltage, the Zener and resistor can be swapped.

3.1.2 Shunt voltage reference and resistor

This solution is a slight improvement of the circuit described in Section 3.1.1 sharing the same simplicity. The improvement refers to the positive voltage. The typical variation observed with a Zener diode is overcome here by implementing the shunt voltage reference (TL431). Therefore, this solution is characterized by an accurate positive voltage and a poor precision of the negative voltage (just like in the circuit described in the previous section).

Figure 12. Post regulation circuit for dual isolated voltage with shunt voltage reference and resistor

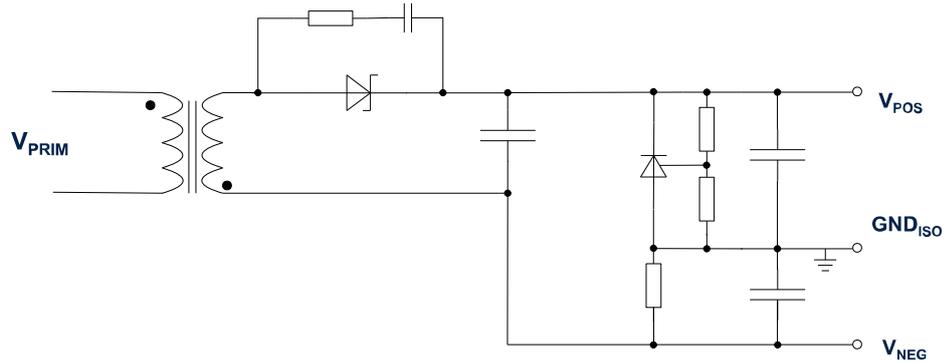
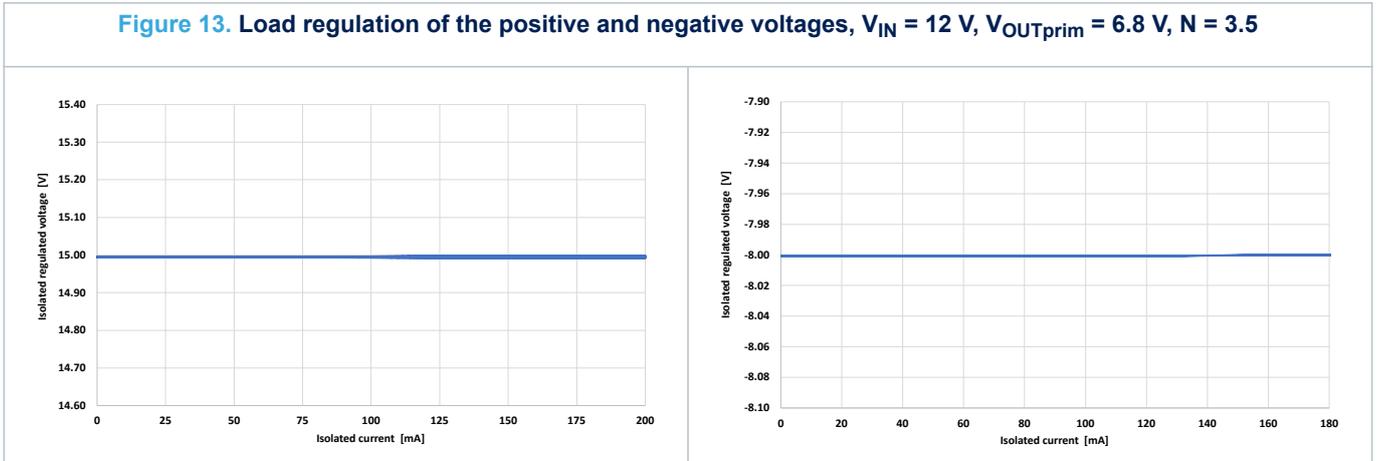


Figure 13. Load regulation of the positive and negative voltages, $V_{IN} = 12\text{ V}$, $V_{OUT_{prim}} = 6.8\text{ V}$, $N = 3.5$

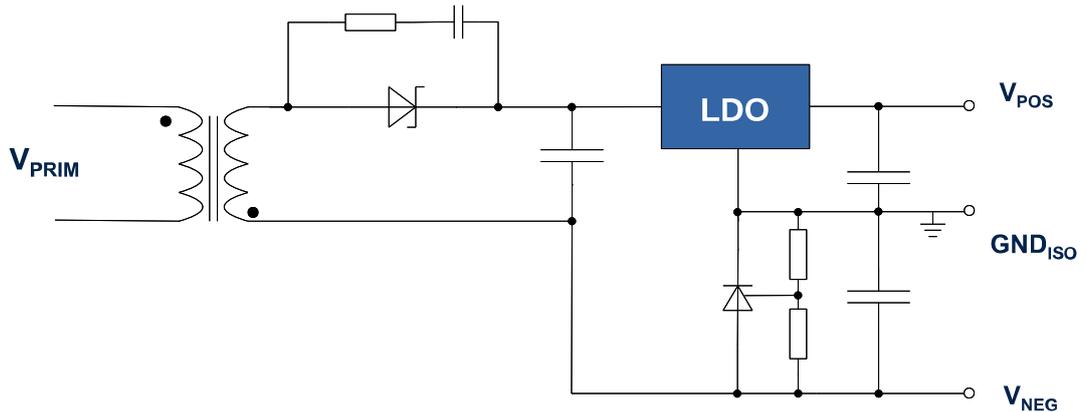


To achieve a better accuracy of the negative output voltage, the shunt voltage reference and resistor can be swapped.

3.1.3 LDO and shunt voltage reference

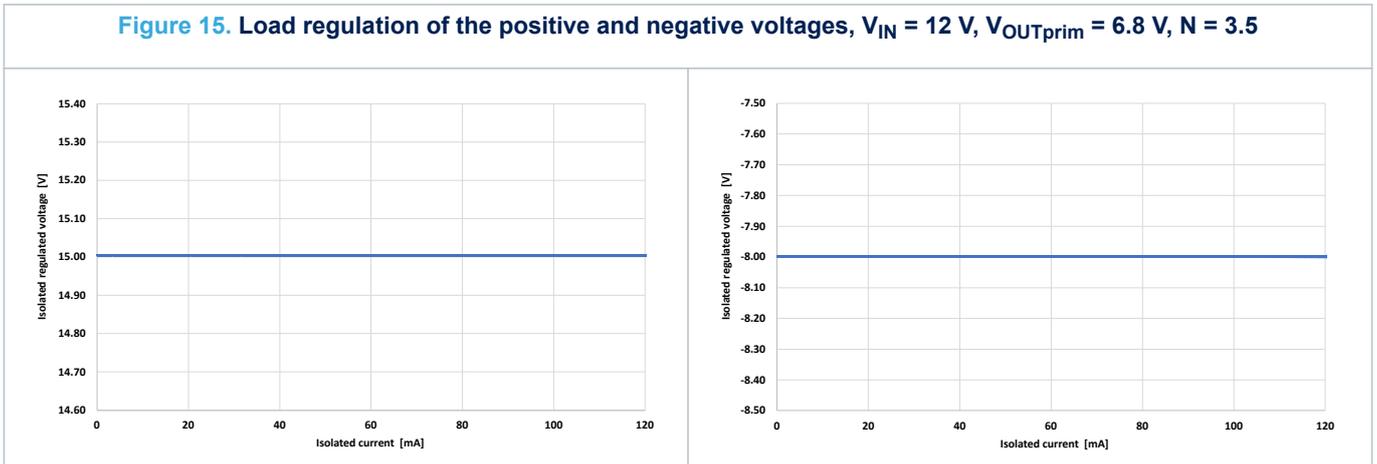
This solution uses the shunt voltage reference by assigning it to generate the negative voltage, which benefits from its precision. The positive voltage is regulated by an LDO. The presence of the LDO implies an over-regulation of the isolated voltage on the secondary winding to consider the minimum drop required by the LDO for a proper operation.

Figure 14. Post regulation circuit for dual isolated voltage with LDO and shunt voltage reference



Among the possible solutions with a single secondary winding, this one provides excellent load regulation performances (see Figure 14) for both the positive and the negative voltages. If the LDO implements a protection against short circuit, this will prevent the solution from being damaged in case of a short circuit event between V_{POS} and V_{NEG} .

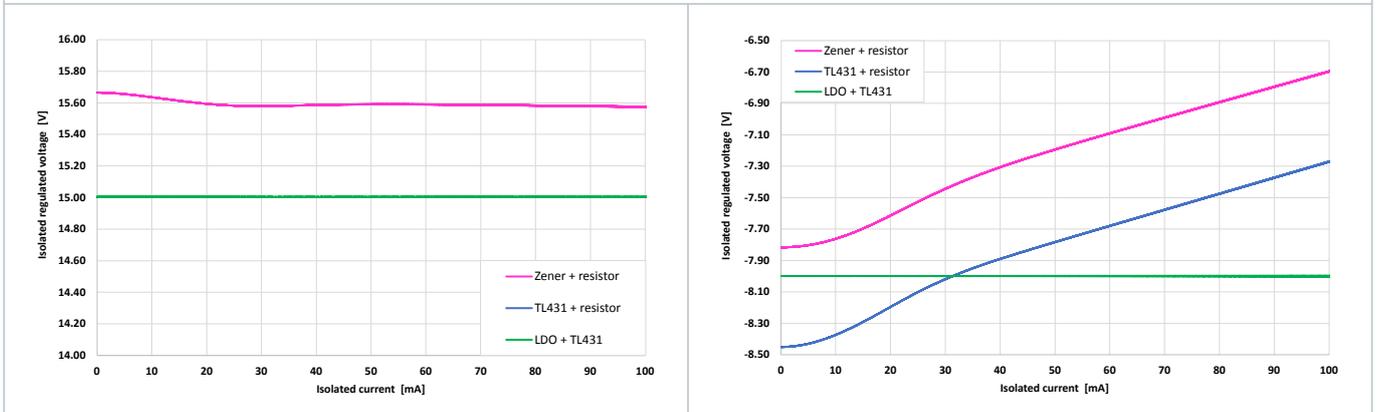
Figure 15. Load regulation of the positive and negative voltages, $V_{IN} = 12\text{ V}$, $V_{OUT_{prim}} = 6.8\text{ V}$, $N = 3.5$



3.1.4 Comparison among the solutions

The graphs below compare the trends of the positive and negative voltages for the solutions described in the previous sections.

Figure 16. Comparison of the load regulations among the different solutions



The table below summarizes the pros and cons of the different solutions.

Table 2. Comparison of the main performances among the different solutions

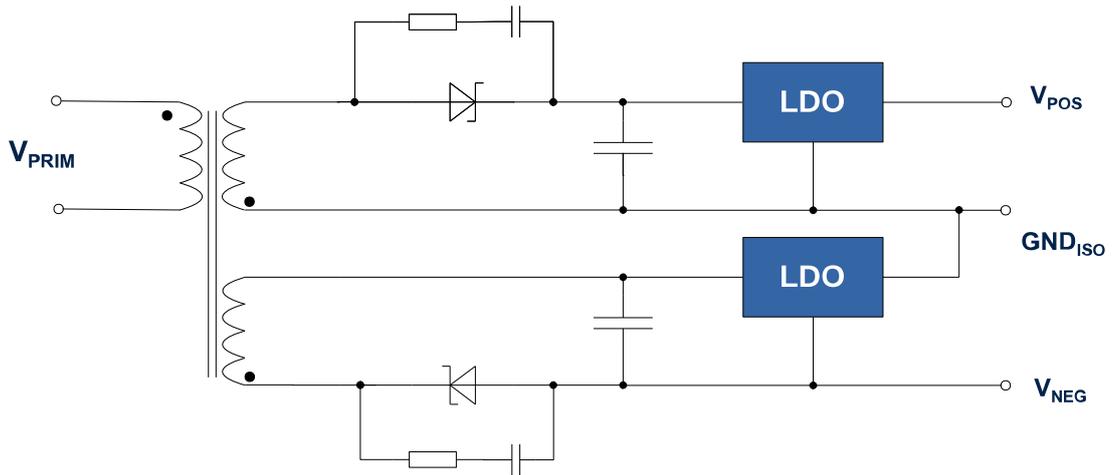
Solution	Positive voltage accuracy	Negative voltage accuracy	Protections	Over regulation of the secondary winding voltage
Zener diode and resistor	acceptable	poor	nothing	Not necessary
Shunt voltage reference and resistor	Excellent	poor	nothing	Not necessary
LDO and shunt voltage reference	Excellent	Excellent	Yes, if provided by the LDO	Necessary, depends on the selected LDO

3.2 Two secondary windings

The selection of a two secondary windings transformer allows to regulate the positive and negative voltages separately, avoiding any interaction with each other. The current drawn from the positive output can differ from the current drawn from the negative one, without impacting on the regulation of the voltages.

The solution proposed in Figure 17 implements a LDO for each output.

Figure 17. Post regulation circuit for dual isolated voltage with two secondary windings transformer

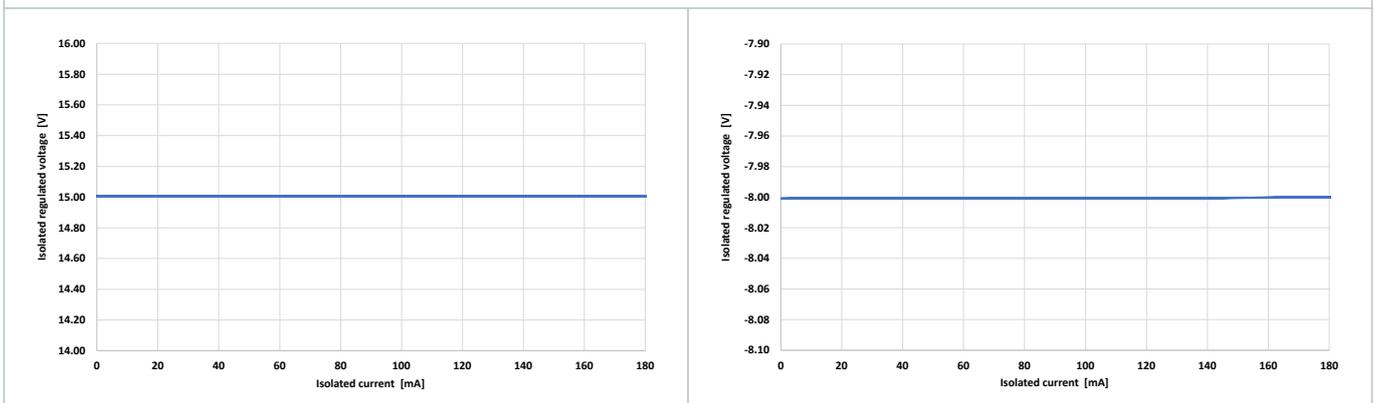


Implementing two LDOs implies an excellent regulation of the voltages and ensures the protection against a short circuit event for both outputs, provided that the selected LDOs offer this protection (e.g LDH40 offers this protection).

This solution represents the best one in terms of performance when a dual voltage is required.

The search for the suitable transformer (more challenging than looking for a single secondary winding), or the construction of a customized one, along with embedding two LDOs, may result in an expensive solution. As usual, a compromise between performances, costs, areas, and so on, should be found.

Figure 18. Load regulation of the positive and negative voltages, $V_{IN} = 12\text{ V}$, $V_{OUT_{prim}} = 6.8\text{ V}$, $N_1 = 2.6$, $N_2 = 1.6$

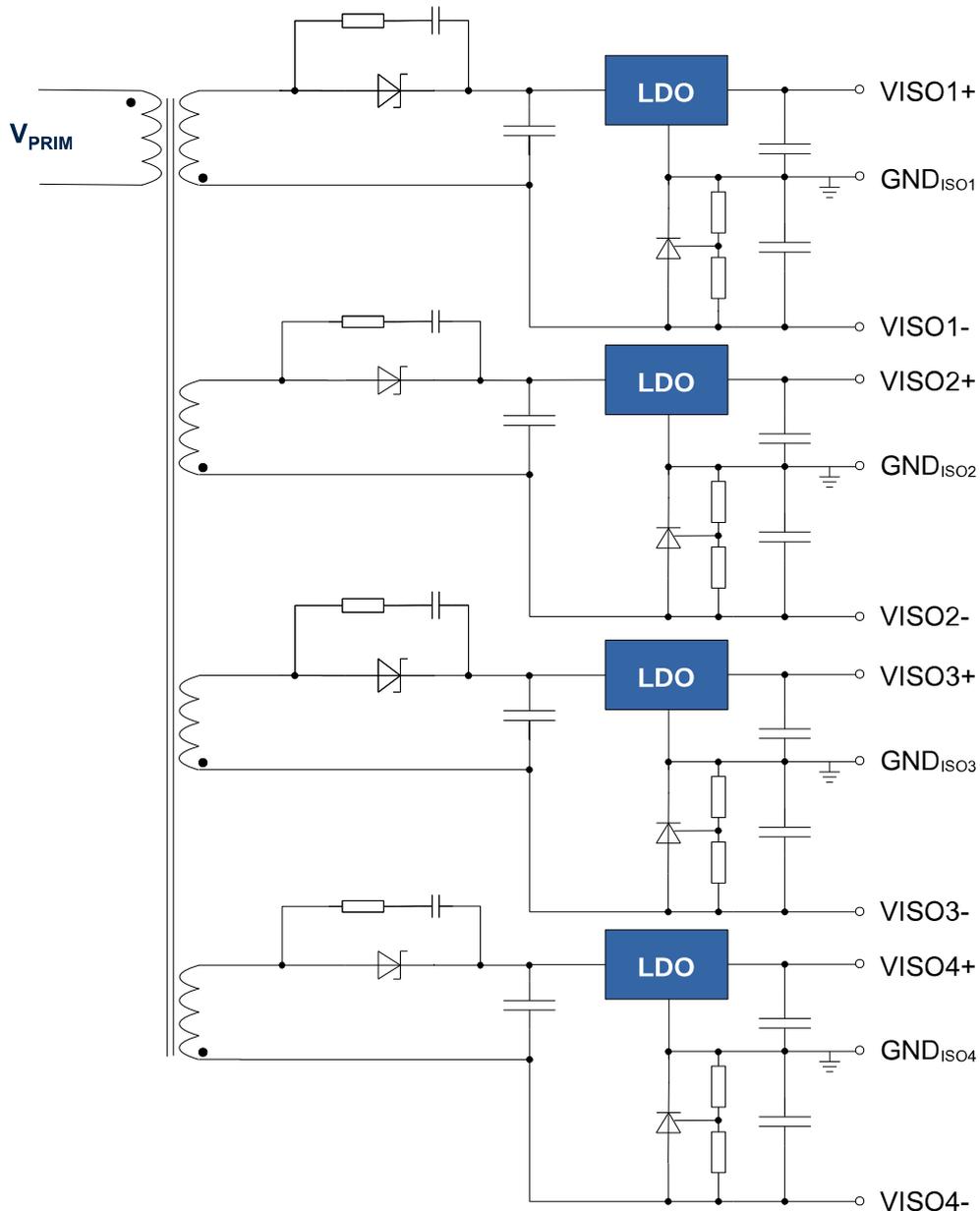


3.3 Extending and combining the solutions

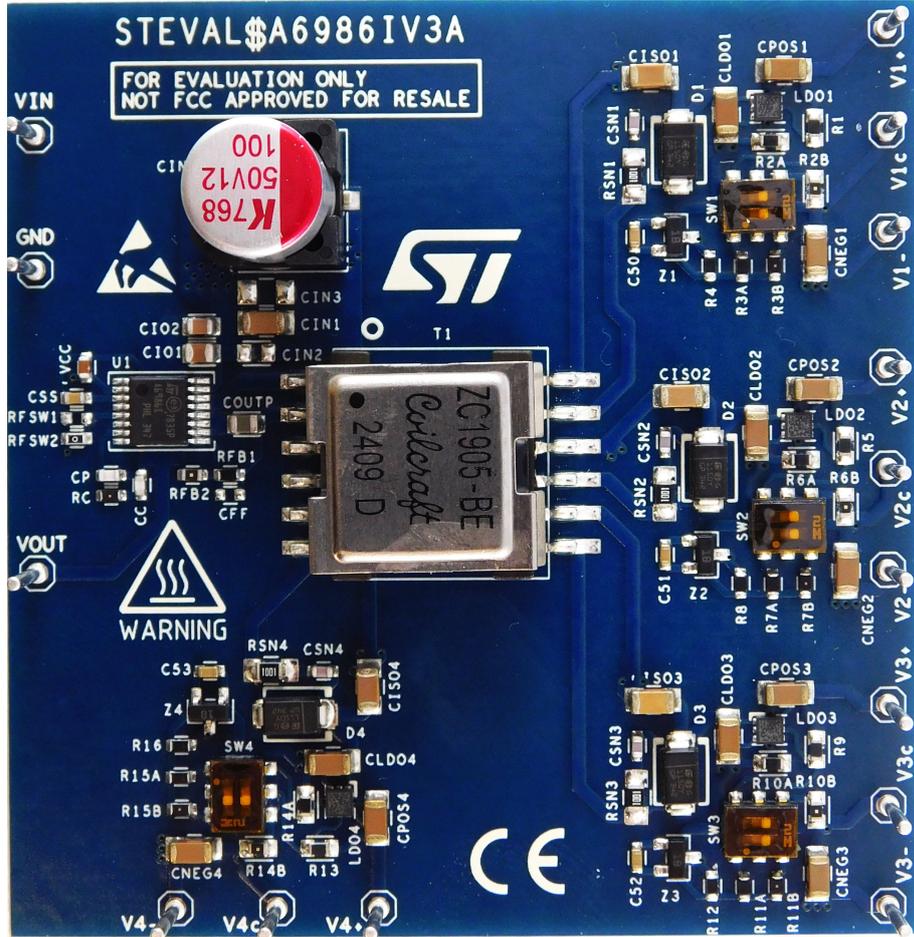
The post regulation circuits described in the previous sections can be combined to generate other solutions.

For instance, the solution in Section 3.1.3 can be implemented in a multi secondary winding application to achieve several dual voltages, which can be useful for instance, in a three-phase system. A possible solution is described in the Figure 19. The first three voltage pairs can be used for driving the three high sides, whereas the fourth dual voltage can be used for driving together the low sides.

Figure 19. Solution for gate drivers in a three phase system



An example of implementation is the STEVAL-A6986IV3, shown in Figure 20.

Figure 20. Board implementing the solution for gate drivers in a three phase system


4 Conclusions

The isobuck isolated output voltage is inherently unregulated. For certain applications and for limited load variation, this can be acceptable. Otherwise, a post-regulation circuit should be foreseen. This application note presents different possible solutions suitable for various approaches and requirements. As usual, a compromise among different and sometimes conflicting constraints should be found:

- Single or dual voltage required
- Expected accuracy of the regulated voltages
- Complexity
- availability of suitable transformers and/or other components (e.g. LDO)
- robustness of the solution
- PCB area
- cost

Revision history

Table 3. Document revision history

Date	Version	Changes
12-May-2025	1	Initial release.

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