# Pulse Sharing: Achieving High Efficiency and Excellent Regulation in Multi-Output Flyback Power Supplies

Xingda Yan | Sr. New Product Definition Engineer, Power Integrations
Toine Werner | Technical Director, New Product Definition, Power Integrations

## Abstract

This paper introduces a pulse sharing control strategy which is a key innovation employed in the InnoMux™-2 IC family of multi-output flyback converters from Power Integrations. InnoMux-2 ICs enable a unique flyback architecture, enabling a multi-output design that can adjust to changes in line and load without affecting the other outputs and eliminate the effects of cross regulation. Pulse sharing eliminates audible noise and reduces fluctuations in power output by distributing energy between outputs in each switching cycle. This article will explore the design challenges associated with this strategy, it will cover how the approach effectively accommodates sudden changes in power demand (load transients) and reduces EMI by adding variations in operating frequency (jitter).

## 1 Introduction of InnoMux-2 IC Family

Traditional multiple output converter designs commonly rely on multiple DC-DC converter stages, such as buck/boost converters following the flyback converter to achieve accurate regulation. The InnoMux-2 IC-based flyback topology, shown in **Figure 1**, offers a highly integrated solution featuring up to three individually regulated outputs. This innovative approach increases the efficiency of multi-output converter design and eliminates cross-regulation issues [1].

By independently regulating and protecting each output, the InnoMux-2 IC family eliminates downstream conversion stages reducing the bill of materials (BOM).

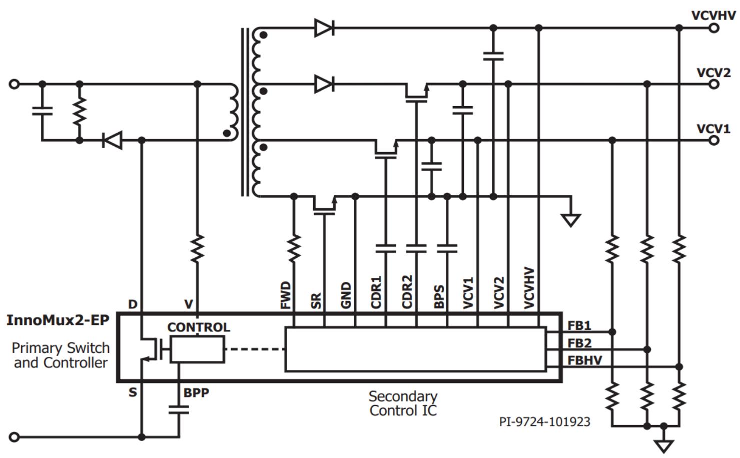


**Figure 1 InnoMux architecture.**

The InnoMux-2 combines a high-voltage power switch, along with primary-side and secondary-side controllers in one device. The InnoMux-2 architecture incorporates a proprietary inductive coupling feedback scheme using the package lead frame and bond wires to provide a safe and reliable means to accurately communicate switching requests from the secondary controller to the primary side. This eliminates the need for optocouplers.

The control mechanism on InnoMux-2 is a quasi-resonant (QR) flyback controller that has the ability to operate in continuous conduction mode (CCM) and discontinuous mode (DCM). The controller uses a variable current control scheme and consists of a receiver circuit magnetically coupled to the secondary controller, a current limit controller, an audible noise reduction engine, a lossless input line sensing circuit, current limit selection circuitry, overvoltage protection, secondary output diode / SR MOSFET short protection circuit, and a 650 V / 725 V silicon or 750 V PowiGaN™ power switch.

The secondary controller consists of a transmitter circuit that is magnetically coupled to the primary receiver, a multi-output controller for regulating up to three outputs independently, synchronous rectifier (SR) MOSFET driver, high-side MOSFET drivers, shunts to prevent individual output current from rising in abnormal loading conditions, single string LED driver, timing functions, and a host of integrated protection features.

## 1.1 An Example: PSU With Two Constant Voltage Outputs

One typical application of InnoMux-2 is a two constant voltage outputs power supply as shown in simplified form in **Figure 2**. The main circuit consists of an InnoMux-2 controller, an isolation transformer with one primary winding, and a single secondary winding, an SR MOSFET on the return side of the output, and a selection MOSFET for the 5 V output plus a diode for 12 V output.

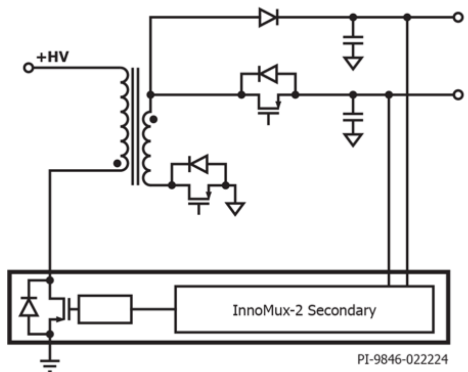


**Figure 2 Power supply with 2 CV outputs.**

When a switching cycle is required, the secondary side requests the primary controller to energize the primary winding. This occurs whenever an output voltage dips below its set reference level. Once the inductor is charged to a pre-determined level (controlled by the rate that switching requests are received), the primary switch is turned off, and the flow of energy to the secondary side begins. The direction of this energy to the appropriate output stage is achieved by the state of the

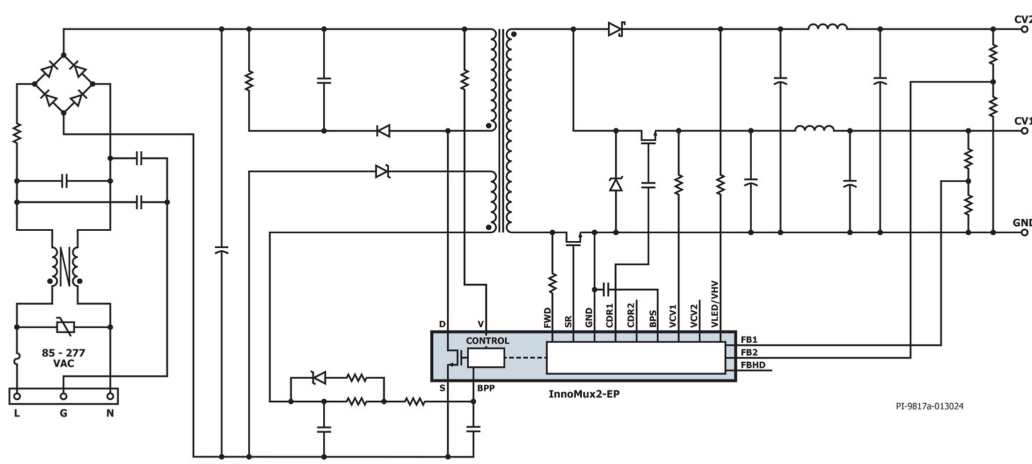


**Figure 3 Reference design showing dual output design (+5 V and +12 V outputs).**

Selection FET. When the Selection FET is on, energy is directed solely to the 5 V output capacitor. If the Selection FET is off, the energy is directed to the capacitor across the 12 V output. The SR (Synchronous Rectification) FET and a diode in the circuit for the 12 V output work together to block any backward flow of current. A specialized control strategy for the SR FET within the secondary control system is implemented to regulate the SR FET's operation, optimizing efficiency during the flyback discharge phase. The control of the Selection FET ensures that each output receives the correct amount of energy, maintaining stable voltage levels and high efficiency.

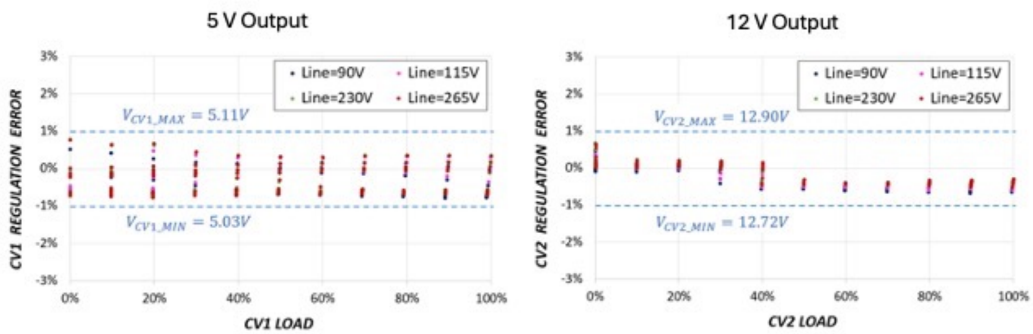


**Figure 4** **Effect of line voltage, output load and loading on other outputs on output accuracy for each output of a dual output power supply with +5 V and +12 V outputs.**

A primary switching cycle request is only triggered when one of the outputs drops below an output voltage threshold. By steering the energy provided between outputs, it is possible to ensure extremely accurate regulation for each output. **Figure 4** illustrates output accuracy across line-, load-, and cross-regulation in a typical reference design (**Figure 3**). Because output voltage is measured directly, transformer tolerances and other variability in power train performance between units is eliminated, ensuring that excellent load regulation will be retained across production.

**Figure 4** shows the effect of line voltage, output load and loading on other outputs on accuracy for each output of a dual output power supply with +5 V and +12 V outputs. Note that regulation performance is achieved down to zero load without the need for dummy-load resistors on the output.

## 1.2 Audible Noise and Sub-Harmonics

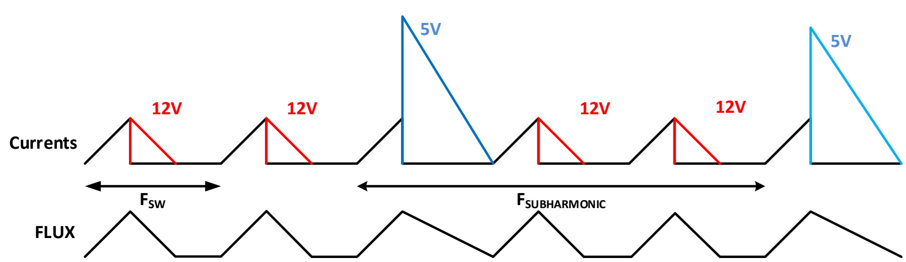


**Figure 5** **Multi-output control switching pattern (2CV example).**

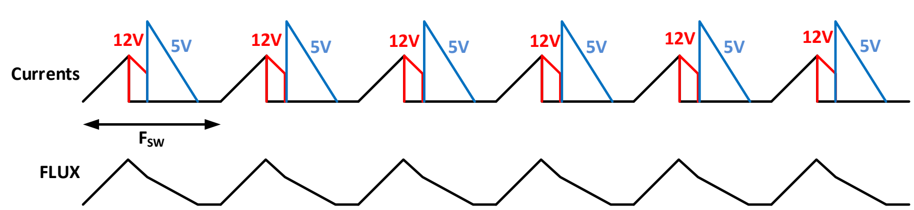


**Figure 6** **InnoMux-2 switching pattern (2CV example) showing pulse sharing.**

A typical switching pattern is shown in **Figure 5**. The 5 V and 12 V outputs receive different numbers of energy packets. The main control scheme effectively eliminates cross-regulation effects, where loading on one output would influence the other output(s). However, a notable downside of this approach is the creation of audible noise. With each cycle, a pulse of energy is sent to one of the outputs, and since each output has a different reflected voltage, the speed at which magnetic energy changes in the transformer's core also changes based on which output is receiving the energy. This change in magnetic energy will induce a subharmonic transformer excitation frequency, which is lower than the main switching frequency. The nature of this subharmonic frequency depends on the load distribution between the two outputs. If this subharmonic frequency falls within the audible range, between approximately 1 kHz and 25 kHz, it's likely to produce a sound that can be heard. The magnetostriction effect will be amplified by the resonant frequency of the transformer mass which will typically also be in this region. This audible noise is a byproduct of the way the switching pattern operates under certain conditions.

## 2 Pulse Sharing

A new control strategy — pulse sharing — solves this problem. The purpose of pulse sharing is to mitigate audible noise by distributing energy to multiple outputs during each cycle. Instead of delivering a complete pulse to a single output, each pulse is divided and shared between the two outputs (PWM divided for each to match output requirements). This approach ensures that every cycle is more uniform, eliminating the presence of subharmonics on the primary side. This also supports the system's capability to quickly adapt to changes in load without causing a disruption to the output voltage levels, ensuring reliable operation during dynamic load conditions.

### 2.1 Steady-State Operation

**Figure 6** provides a visual representation of the pulse sharing technique for the same two CV applications (5 V and 12 V). The process of pulse sharing involves sending the discharge pulse to the top-side 12 V output initially and then later in the discharge phase activating the selection MOSFET to enable the second part of the discharge to be directed to the 5 V output. By adjusting the duty cycle, regulation is maintained.

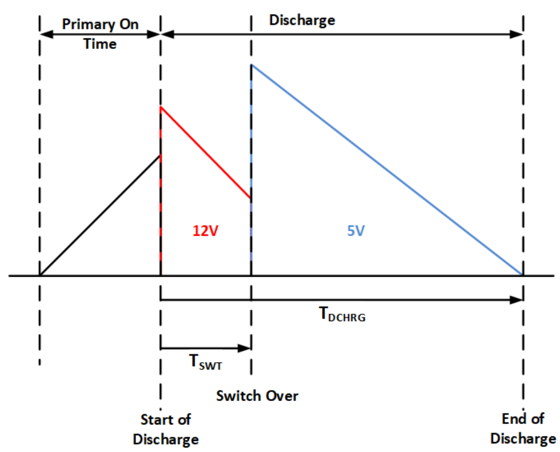


**Figure 7 Pulse sharing during each cycle.**

As shown in **Figure 7**, the discharge period starts with the 12 V output. The amount of time discharged to the top-side output is defined as T_SWT. The secondary controller will regulate this value to match the operating conditions.

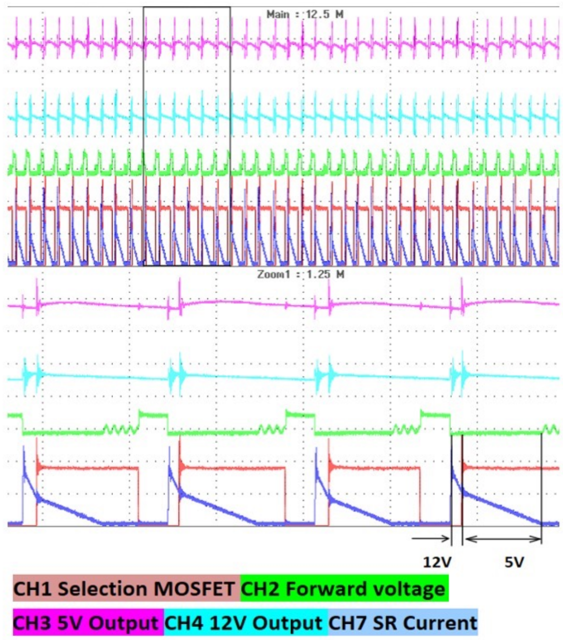


**Figure 8  Steady-state operation.**

**Figure 8** displays a screenshot from an oscilloscope when the two constant voltage (CV) application is functioning under nominal load conditions. Here, the switching frequency appears to be consistent, as shown by the very similar waveforms of inductor current from one cycle to the next. This indicates well-balanced operation.

## 2.2 Load Transients

Operation must be maintained during disturbances caused by changes in the load on any of the outputs.

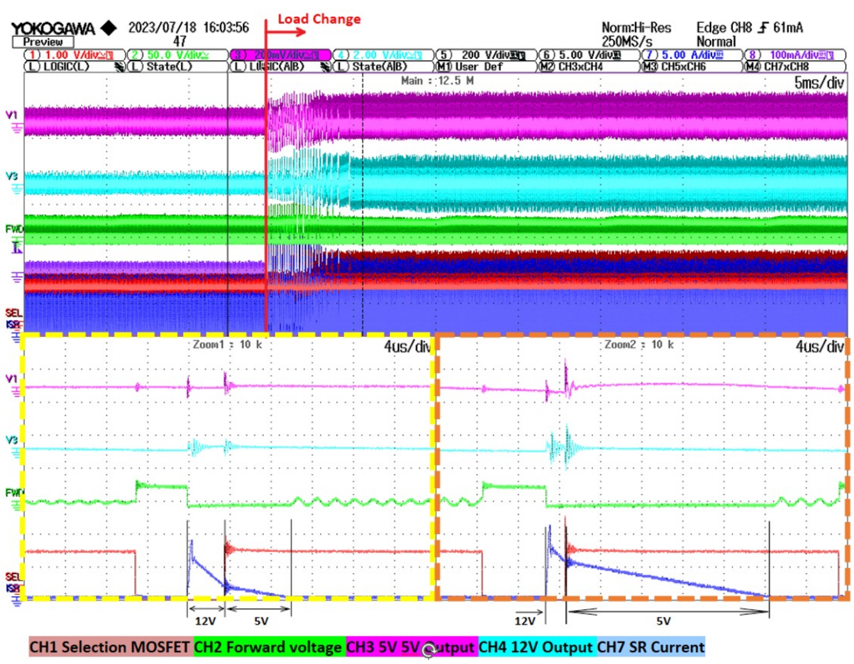


**Figure 9  Load change of bottom output from half-load to full-load with zoom.**

A change in the load on either output leads to a change in the distribution of required energy between the outputs. This necessitates an adjustment in T_SWT, the period designated for top-side discharge. In **Figure 9**, the effect of a change in load is shown. A step change in the 5 V load is introduced. This causes a transient response from the system, during which the outputs experience a minor fluctuation (within the regulation limits). The fast response of the controller prevents significant overshoot or undershoot on any output. Within ~ 5 milliseconds, the system adjusts to a new balance point. At this new state, the period allocated for top-side discharge, T_SWT, is shorter, but there is an increase in the maximum current from the primary side. This illustrates the system's capability to quickly adapt to changes in load without causing disruption to the output voltage levels, ensuring reliable operation during dynamic load conditions.

### 2.3 Benefits of Pulse Sharing

The immediate benefit of pulse sharing is the reduction in audible noise. The acoustic performance of this two CV application (5 V, 12 V) is shown in **Figure 10**. The graph on the left is the measurement without pulse sharing, whereas the plot on the right shows the audible-noise measurement with the pulse sharing feature enabled. This clearly demonstrates the dramatic reduction of the audible noise – by 13 dBA in this example. Pulse sharing allows the topology to work efficiently in CCM, which was previously limited by the high diode recovery losses for the top output if operated in DCM only.

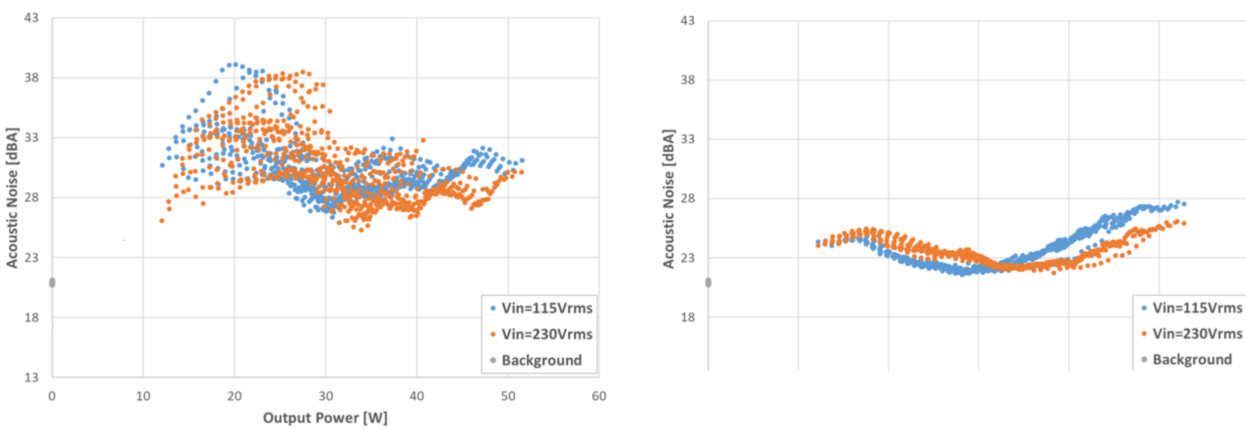


**Figure 10 Audible noise measurement (left: without pulse sharing; right: with pulse sharing)**

Pulse sharing provides additional advantages, one of which is the reduction in the RMS current in the secondary winding, leading to a decrease in conduction losses. Moreover, this technique contributes to an increase in the operating frequency for each output, thereby reducing output ripple when using the same output filter capacitor.

## Conclusion

This paper introduces an innovative control mechanism — pulse sharing — to improve the operation of multi-output power delivery and addresses the challenge of audible noise associated with varying discharge rates of the transductor in multi-output flyback converters. By distributing energy across multiple outputs in each cycle, the pulse sharing technique not only mitigates the issue of audible noise but also enhances the overall robustness of the system while increasing efficiency and improving transient response.

## References


[1] Motte-Michellon D, Cogitore B, Lembeye Y and Ramdane B. A Study on the Influence of the Transformer on Cross-Regulation in DCM Multi-Output Flybacks. PCIM Europe 2022: Intelligent Motion, Renewable Energy and Energy Management: 1-8. VDE.

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