# Application Note AN-122 Power Limit Design Guidelines for InnoMux-2

Design Guide

## Introduction

IntroductionThe InnoMux-2 IC regulates multiple outputs in a flyback topology and includes built-in over-power protection. The output power is primarily constrained by the maximum switching frequency, beyond which the output voltages start to drop below regulation. If any output remains below its regulation voltage for an extended period, the IC shuts down all outputs as a protective measure. This serves as an overall power limit, providing gross overload protection for short circuits or extreme overload conditions. To provide more precise overload protection for each output, an individual power limit feature is introduced.

This document provides design guidelines for configuring power limits in InnoMux-2 applications, covering the relationship between switching frequency, load conditions, and individual power limit settings.

## Power Limit Protection Mechanism

In discontinuous conduction mode (DCM), the total power is determined by the following equation:

$$P_{TOTAL} = \frac{1}{2} L_P I_P^2 \times F_{SW}$$

Where $L_p$ is the transformer primary magnetizing inductance; I_P is the primary current, and $F_{SW}$ is the switching frequency. Since $\frac{1}{2} L_P I_P^2$ is fixed for a given design, the maximum output power is largely dictated by the switching frequency.

The InnoMux-2 does not directly sense output power; instead, the output power is estimated based on the switching frequency. Thus, individual power limit protection is implemented in InnoMux-2 by restricting the maximum equivalent switching frequency of each output. InnoMux-2 considers the energy distribution between outputs in each discharge cycle in pulse-sharing mode.

## Equivalent and Effect Switching Frequency in Pulse-Sharing Mode

### Effective and Equivalent Switching Frequency for Each Output

As shown in Figure 1, in pulse-sharing mode, the switching frequency is the same for both the primary switch and the secondary outputs. As a result, the individual power limit cannot be set directly based on this frequency.

To set power limits correctly, the power distribution ratio between all outputs should be correctly determined. During shared pulses, the power received by an output is proportional to the fraction of the discharge pulse delivered to that output, as shown in Figure 1. This fraction can be represented by the equivalent switching frequency ($F_{EQ}$) of the output when there's no pulse-sharing, as shown in Figure 2.

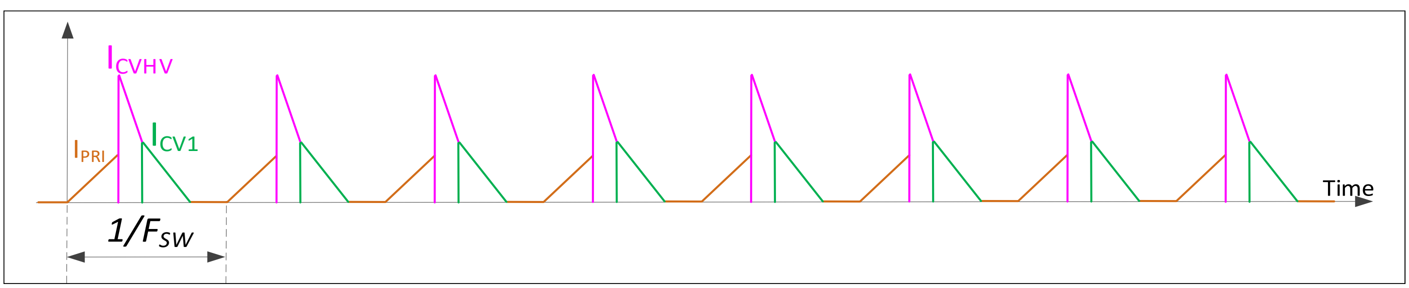


Figure 1. Switching Frequency for a 2CV Application in Pulse-Sharing Mode.

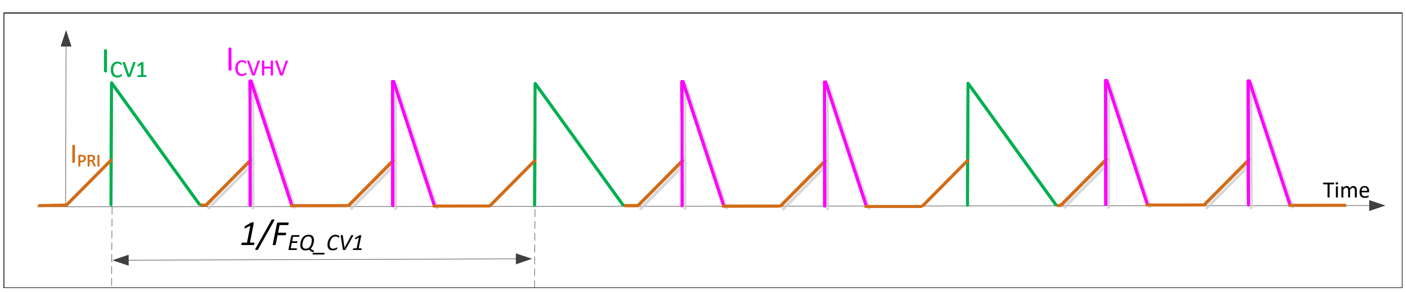


Figure 2. Equivalent Switching Frequency ($F_{EQ}$) for a 2CV Application with No Pulse-Sharing.

Equivalent Switching frequency ($F_{EQ}$): the switching frequency for each output, if there had been no pulse-sharing, with all outputs loaded to their maximum rated power.

Since $F_{EQ}$ cannot be directly measured in a power supply operating in pulse-sharing mode, the effective switching frequency ($F_{EFF}$) is used instead, as shown in Figure 3(a) and (b).

Effective switching frequency ($F_{EFF}$): the switching frequency when only one output is loaded to its rated power while keeping all other outputs at no load.

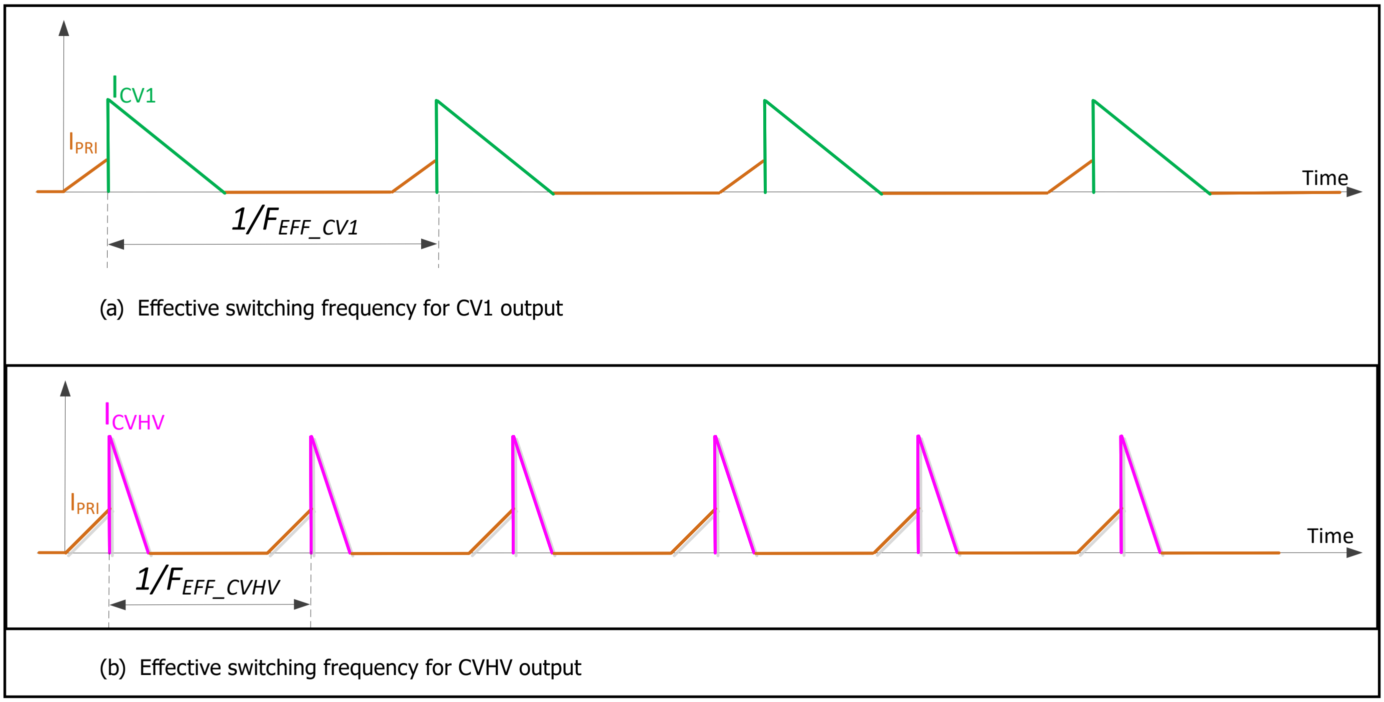


Figure 3. Effective Switching Frequency for a 2CV Application.

## Relationship Between Effective and Equivalent Frequency

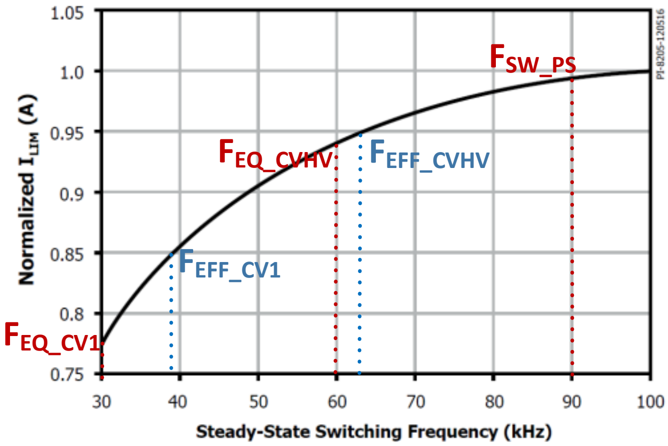


Figure 4. Normalized Primary Current vs. Switching Frequency.

It is important to note that $F_{EQ}$ is not exactly equal to $F_{EFF}$ as the peak current changes with switching frequency, as shown in Figure 4. For a 2CV application with pulse-sharing, the relationship between $F_{EQ}$ and $F_{EFF}$ is:

$$F_{SW\_PS} = F_{EQ\_CV1} + F_{BQ\_CVHV}$$

$$F_{EQ\_CV1} < F_{EFF\_CV1}$$

$$F_{EQ\_CVHV} < F_{EFF\_CVHV}$$

Where $F_{SW\_PS}$ is the switching frequency of the primary switch in pulse-sharing mode; $F_{EQ\_CV1}$ and $F_{EQ\_CVHV}$ represent the equivalent frequencies for CV1 and CVHV without pulse-sharing; $F_{EFF\_CV1}$ and $F_{EFF\_CVHV}$ are the effective switching frequency measured by loading a single output to full load while keeping the other output at no load.

When the PSU is fully loaded without pulse-sharing, as shown in Figure 2, the primary switching frequency remains high, as does the current limit ($I_{LIM}$). However, as frequency decreases, $I_{LIM}$ also decreases. Consequently, as shown in Figure 3 and Figure 4 when determining $F_{EFF}$ by loading only one output, the unit operates at a lower $I_{LIM}$, which results in a higher $F_{EFF}$ to achieve the same output power. This higher $F_{EFF}$ inherently provides a margin when setting the power limit threshold.

## Power Allocation in Pulse-Sharing Mode

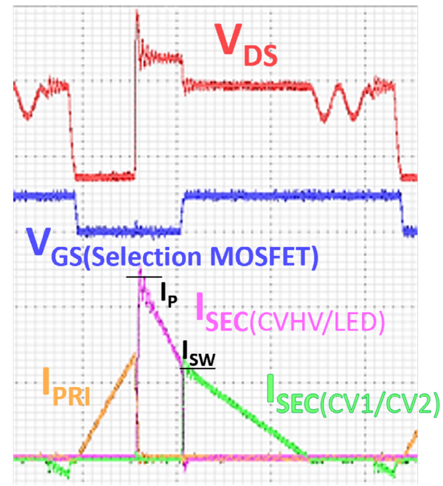


Figure 5. InnoMux-2 DCM Current Waveforms of a 2CV Application.

For a 2CV or LED application with two outputs, in pulse-sharing mode, the secondary current is always discharged to CVHV/LED first and then to the CV1 output. Similarly, for a 3CV application, energy is first shared with CVHV, and then CV1 or CV2 in any switching cycle. The secondary current can be converted back to the primary side using the turns ratio of the respective output, as shown in Figure 5:

$$I_P = I_{SEC\_CVHV/LED\_PK} \times \frac{N_{CVHV/LED}}{N_P}$$

$$I_{SW} = I_{SEC\_CV1/CV2\_PK} \times \frac{N_{CVI/CV2}}{N_P}$$

Where I_P is the peak primary current and I_SW is the switch-over current when current transitions from CVHV/LED output to CV1 or CV2 output; $I_{SEC\_CVHV/LED\_PK}$ is the peak discharge current of CHVV/LED output; $I_{SEC\_CV1/CV2\_PK}$ is the peak discharge current of the CV1 or CV2 output when switch-over occurs; $N_P$, $N_{CVHV/LED}$ and $N_{CV1/CV2}$ are the primary and secondary turns ratios.

The power allocation for each output is:

$$\begin{cases} P_{CV1/CV2} = \frac{1}{2} L_P I_{SW}^2 \times F_{SW} \\ P_{CVHV/LED} = \frac{1}{2} L_P (I_P^2 - I_{SW}^2) \times F_{SW} \end{cases}$$

Where $F_{SW}$ is the primary switching frequency; The output power can be rewritten as:

$$\begin{cases} P_{CV1/CV2} = \frac{1}{2} L_P I_P^2 \times F_{EFF\_CV1/CV2} \\ P_{CVHV/LED} = \frac{1}{2} L_P I_P^2 \times F_{EFF\_CVHV/LED} \end{cases}$$

The equivalent switching frequencies can be derived as:

$$\begin{cases} F_{EQ\_CV1/CV2} = \frac{I_{SW}^2}{I_P^2} \times F_{SW} \\ F_{EQ\_CVHV/LED} = \frac{I_P^2 - I_{SW}^2}{I_P^2} \times F_{SW} \end{cases}$$

## Setting the Power Limit Threshold

Power limit setting is calculated and recommended in PIXLs, but to ensure accuracy taking into account all the parameter tolerances of the circuit, it is recommended to measure the actual $F_{EFF}$ on the PSU.

### Steps to Determine the Correct Power Limit Threshold

- Measure maximum effective switching frequency at maximum/peak load condition and minimum input voltage. Take ILIM and primary inductance tolerance into account.
- In case the power supply is expected to operate in deep-CCM ($K_P < 0.8$) at minimum input mains and full load, the effective switching frequency should be increased. With $K_P = 0.5$, the effective switching frequency should be increased by 25%.
- Select a power limit threshold about 15 – 20% higher than the maximum effective switching frequency from Table 1.
- Power Limit Options for each output are shown in Table 1.

| Power Limit Options |
| --- |
| 30 kHz |
| 38 kHz |
| 47 kHz |
| 59 kHz |
| 73 kHz |
| 92 kHz |
| 115 kHz |
| Individual Power Limit Disabled for this Output |

Table 1. Power Limit Maximum Frequency Options.

## Recommended Testing with Samples

To ensure correct setting for power limit, the following testing is advised:

- **Protection threshold verification:** determine/verify the protection threshold under various load conditions across the full input voltage range:
  - Increase loading on protected output while maintaining full load on other output(s).
  - Increase loading on protected output with partial or no load on other output(s).
- **Dynamic and transient conditions:** verify correct operation under dynamic conditions and load transient steps up to the rated load on all outputs.
- **Start-up performance:** Evaluate startup performance to ensure proper operation.

Note that the actual protection point may vary from the set value due to circuit tolerances. If peak power is required, the power limit should be assessed to ensure the system can meet the peak power demand before triggering protection.

## Default Power Limit Configuration in InnoMux-2

By default, InnoMux-2 standard parts shown in the data sheet implement only overall power limit to accommodate various load combinations. If the individual power limit is not enabled, the overall power limit remains active in the IC.

Customers requiring individual power limit protection for each output should contact the PI sales team to enable this feature.

| Revision | Notes | Date |
|---|---|---|
| A | Introduction release. | 07/25 |