PRIMARY SIDE DETECTION AND PEAK CURRENT MODE CONTROL IN FLYBACK CONVERTER\(^1\)

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Abstract A new cycle-by-cycle control flyback converter with primary side detection and peak current mode control is proposed and its dynamic characteristics are analyzed. The flyback converter is verified by the OrCAD simulator. The main advantages of this converter over the conventional one are simplicity, small size, rapid regulating and no sensing control signals over the isolation barrier. The circuit is suitable for digital control implementations.

Key words Flyback converter; Peak current mode; Primary side detection

I. Introduction

A conventional switch-mode power supply with galvanic isolation is provided by an optocoupler, signal transformer or capacitor for the feedback voltage path. Signal transformer or capacitor isolation schemes complicate the circuit, and opto-coupler is hardly operated at high temperature and radiate environment\(^1\).

However, the output voltage also exists across the primary side switch when it is in off state and all the necessary information for control is available from the primary switch voltage. Previous attempts at implementing primary side control were impeded by the performance and bandwidth of the components available\(^2\text{,}^3\). The other attempts were that the output voltage was extracted within on switching cycle and a flyback converter with a cycle-by-cycle control was developed\(^4\text{,}^5\). Because the on-time is not the linear function of input voltage in this control circuit, it needs a complicated fast analog multiplier for calculation and three sawtooth waveform generators. In this paper, a new flyback converter with primary side detection and peak current mode control is proposed, and it is suitable for cycle-by-cycle control.

II. Circuit and Operation Principle

The flyback converter circuit is shown in Fig.1. The desired information is available from the primary switch voltage, \(V_{sw}\), during the off-time in Continuous Conduction Mode (CCM),

\[
V_{sw} = V_{in} + (V_o + V_F) \frac{N_p}{N_s}
\]

where \(V_{in}\) is the input voltage, \(V_o\) is the output voltage, \(V_F\) is the forward voltage drop of the output diode, \(N_p/N_s\) is the flyback transformer turn ratio. The relationship between \(V_o\) and the peak of \(V_{sw}\) for Discontinuous Conduction Mode (DCM) is also given in Eq.(1). So a peak detector is used in circuit to calculate \(V_o\) at the beginning of off-time when \(V_{sw}\)

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reaches its the highest point. However the initial spike on $V_{sw}$ will be neglected when $V_{sw}$ is being detected.

The value of $V_{sw}$ must be hold within the complete off-time and a regulation error signal $V_E$ is calculated from output voltage $V_o$ and the reference voltage $V_{ref}$. $V_E$ is zero in the ideal case, where the on-time will be calculated according to the offset voltage, $V_{offset}$. The reference voltage for current control, $V_c$ is given by:

$$V_c = (V_{ref} + V_{offset}) - \left( (V_{sw} + V_{in}) \frac{N_s}{N_p} - V_F \right)$$

On the constant voltage control mode, $V_{offset}$ is the nonlinear function of $V_{in}$, so the control circuit operated and the constant voltage control mode need a fast analog multiplier for solving this problem. But when control circuit operates under peak current control mode, $V_c$ is independent of $V_{in}$. When $V_c$ is constant, the limiting current is constant. From the viewpoint of energy, the winding energy storage in on-time of one cycle is constant, even if $V_{in}$ is varying\[6\]. Solution for output voltage detected from $V_{sw}$ waveform for CCM and DCM, is shown in Fig.2.

The inductor current can be detected from the current sense resistor ($R_s$) during on-time. The waveforms of the inductor current in the peak current control mode for CCM and DCM conditions are shown in Fig.3, where $m_1$ and $m_2$ are the rising and falling slopes (with units of volts per second) of the inductor sensed current waveform scaled by $R_s$. Both the CCM and DCM have the same $m_1$

$$m_1 = \frac{V_{in}}{L} R_s$$

The output of the peak current detector $V_I$ by the gain of $K_s$ is fed to a comparator, where it is compared with $V_c$. The result of the comparison is the next cycle on-time, and it is shown in Fig.4. In the peak current mode control, duty cycle expressions in CCM and