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AN-8023

使用 FAN8303 降壓穩壓器實現負電壓管理

摘要

FAN8303 是具有內建功率電晶體 (MOSFET) 的 2A、370kHz 單晶片型整合降壓穩壓器。它使用簡單，並且只需要最少的外部元件。此技術應用文件將說明如何使用 FAN8303 來產生負電壓。文中將介紹應用範例，並討論升降壓電路的最佳設計。

簡介

降壓穩壓器廣泛用於高電壓至低電壓的直流 (DC) 轉換。同樣地，FAN8303 原本的設計是爲了需要調整 DC 電壓準位的設備上，例如應用在電腦螢幕和電視的機上

盒的微控制器，以及高效能前級線性穩壓器。在某些情況下，非同步降壓穩壓器也可以用於升降壓電路，藉以產生相對於接地電位的負電壓。這些應用包括音頻擴大器和 LCD 面板的定時控制電路等等。

圖 1 所示爲 LCD 面板的實際應用；LCD 面板需要負電壓進行對比控制。在這個電路方塊中，通常會使用充電泵浦，因爲其設計簡單且成本低廉。但相對於輸入電壓的變化，它會有一定數量的功率耗損及較差的輸出電壓調整。具有負輸出的 FAN8303 將會是克服這些問題的解決方案。

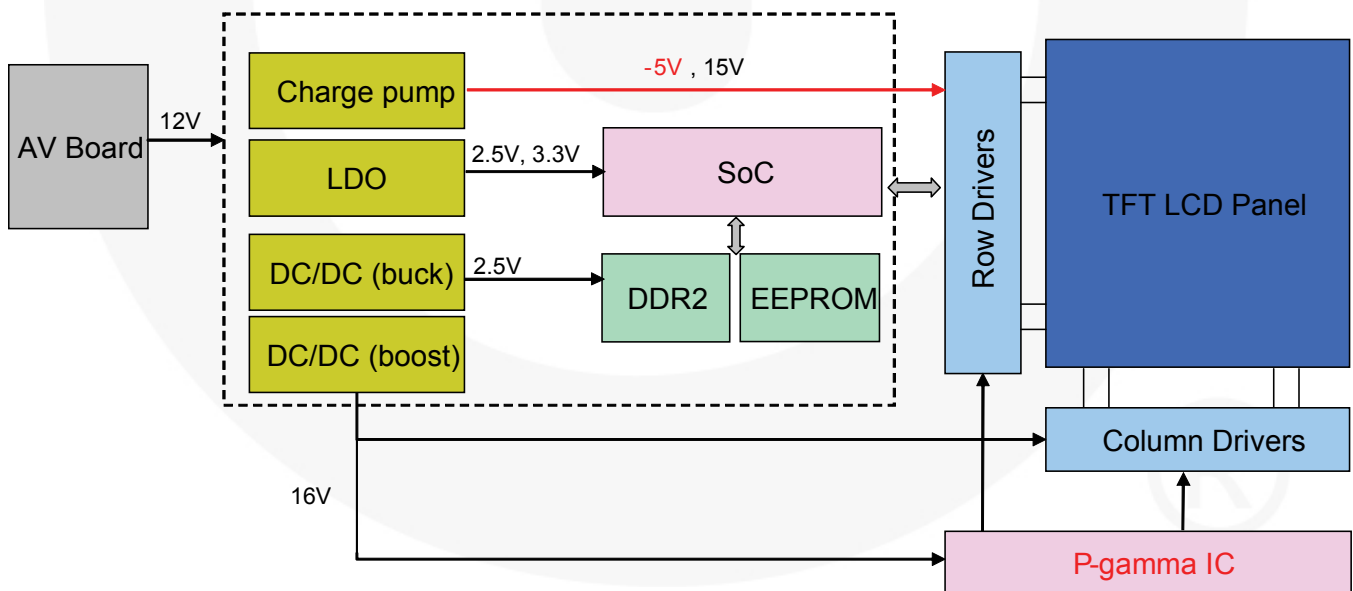


圖 1. 定時控制流程範例

工作原理

為瞭解升降壓拓樸結構，以下將簡單比較降壓拓樸結構。當 MOSFET 開關（圖 3 中的 Q1）開啓時，電感器（ V_L ）兩端的電壓差為 $V_{IN}-V_{OUT}$ 。當 Q1 關閉期間，降壓拓樸結構中的 V_L 等於 $-V_{OUT}$ 。所以電感器電流（ I_L ）會依 $(V_{IN}-V_{OUT})/L$ 斜率上升，並依 V_{OUT}/L 斜率下降。因此，電感器所儲存的能量會被轉換成具有正輸出的電壓。此時，若把電感器和飛輪二極體位置交換，則此降壓拓樸結構會變成升降壓拓樸結構。當 MOSFET 開關

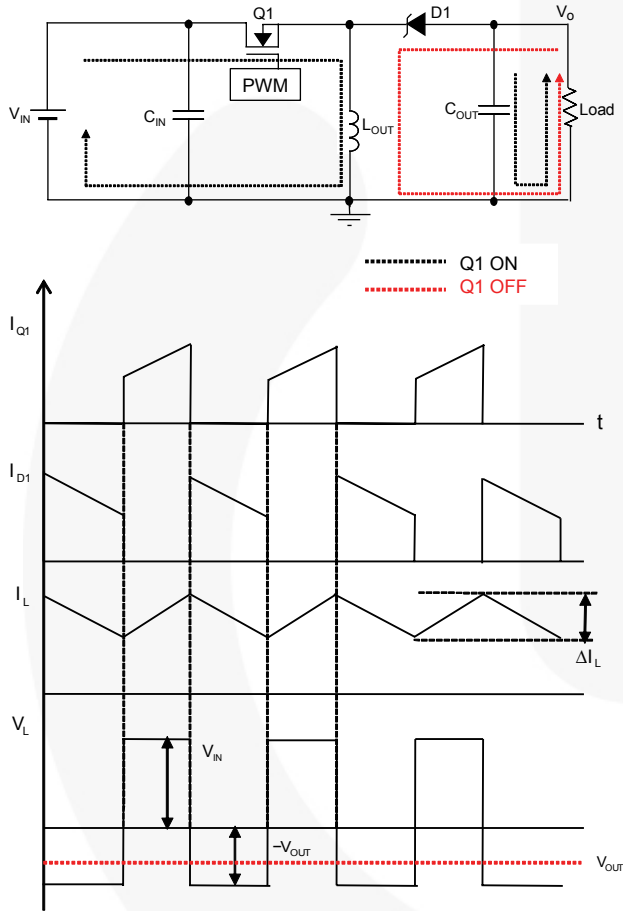


圖 2. 升降壓拓樸結構

Q1（圖 2）開啓時， V_L 與 V_{IN} 相同，因此 I_L 會依 V_{IN}/L 斜率上升。在 Q1 關閉期間， V_L 具相反極性，以維持連續電感器電流。因此，它可以產生負輸出電壓 $-V_{OUT}$ 。

在設計具降壓穩壓器的升降壓電路時，有幾點需要考量。表 1 概略比較降壓與升降壓電路之間的设计參數。

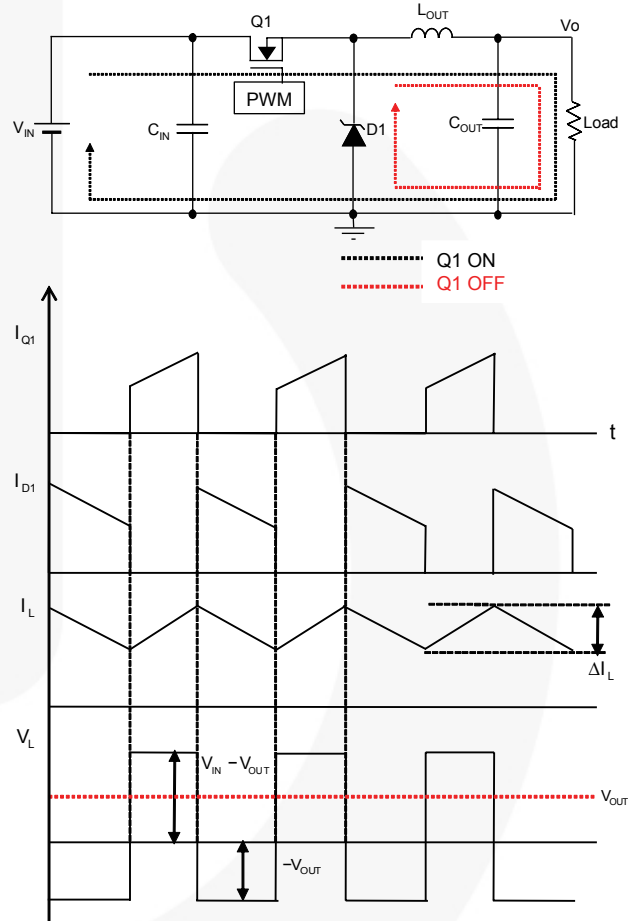


圖 3. 降壓拓樸結構

表 1. 降壓與升降壓設計參數

| 拓樸結構 | I_L (平均值) | 最大 V_{SW} | 工作週期 |
|------|-----------------------|----------------------|--|
| 升降壓 | $\frac{I_{OUT}}{1-D}$ | $V_{IN} + V_{OUT} $ | $\frac{ V_{OUT} }{V_{IN} + V_{OUT} }$ |
| 降壓 | I_{OUT} | V_{IN} | $\frac{V_{OUT}}{V_{IN}}$ |

首先，電感器電流受限於 $(1-D)$ ；所以請注意，降壓穩壓器的最大輸出電流，一定低於升降壓電路的最大電流。其次，開關節點 V_{SW} 為升降壓電路中，輸入電壓與輸出電壓的總和。它亦必須受到降壓穩壓器的最大開關

節點電壓的限制。由於與降壓電路比較起來，升降壓的輸入和輸出有許多雜訊，因此它需要高品質的 MLCC 作為輸入和輸出濾波器。

設計考量

選擇電感器

在選擇電感器時，主要需考量到電感值、RMS 額定電流和 DCR。所採用的電感值通常高於最小電感，以便在「連續電流模式」Continuous Current Mode (CCM) 中作業。RMS 電流應高於電感器電流，以防止沒有磁損的電感器飽和。當功率系統需要高效能時，通常會採用低 DCR 的電感器。

若要在連續電流模式中作業，請依下列方程式算出臨界最小電感量：

$$L = \frac{V_{IN} \times D}{f_{SW} \times \Delta I_L} \quad (1)$$

其中：

$$D = \frac{|V_{OUT}|}{|V_{OUT}| + V_{IN}} = \text{工作週期；}$$

$$f_{SW} = \text{切換頻率；而}$$

$$\Delta I_L = \text{維持連續電流模式的漣波電流（一般為 } I_L \text{ 的 } 20\% \sim 30\% \text{）。}$$

輸出電容器

為滿足輸出電壓的漣波需求，並在動態負載的情況下維持恆定的輸出電壓，需要使用輸出電容器。漣波電壓會隨 ESR、輸出電容量和 ESL 改變。若要獲得所需的輸出漣波，下列方程式非常有用，可用來計算所需的最小電容量：

$$C_{MIN} = \frac{I_{OUTMAX} \times D_{MAX}}{f_{SW} \times \Delta V_{OUT}} \quad (2)$$

其中：

$$D_{MAX} = \text{最大工作週期；}$$

$$I_{OUTMAX} = \text{最大輸出電流；而}$$

$$\Delta V_{OUT} = \text{所需的輸出漣波電壓。}$$

計算所需 ESR 的方程式為：

$$ESR = \frac{\Delta V_{OUT}}{I_{LMAX}} \quad (3)$$

輸入電容器

輸入電容器應該要能處理最大輸入 RMS 電流，因此請使用下列方程式進行計算。以基層陶瓷電容 (MLCC) 為例，合理的估計值為每安培 (amp) 10 μ F 或 22 μ F。

最大 RMS 輸入電流：

$$I_{RMS_MAX} = I_{OUTMAX} \times \sqrt{D \times (1-D)} \quad (4)$$

所需的最小電容量：

$$C_{MIN} = (I_{RMS} \times D) / (f_{SW} \times \Delta V_{IN}) \quad (5)$$

其中 ΔV_{IN} 是所需的輸入漣波電壓。

飛輪二極體

飛輪二極體的作用，是在開關關閉時，作為電感器電流放電的路徑。要求低功率耗損時，需考慮崩潰電壓、較低的順向壓降和最大額定電流。此處最好使用蕭基 (Schottky) 二極體，因其擁有低順向壓降。

所需的二極體額定電流：

$$> I_{LMAX} \quad (6)$$

此處的 I_{LMAX} 是最大電感器電流。

所需的崩潰電壓：

$$> V_{IN} + |V_{OUT}| \quad (7)$$

設計範例

以下所示為設計範例，其測試條件為： $V_{IN} = 12V$ 、 $V_{OUT} = -5V$ 、 $I_{OUT} = 1A$ 和 $f_{SW} = 370\text{ kHz}$ （固定）。第一個步驟是設定臨界設計參數，例如電感器漣波電流（ ΔI_L ）和所需的輸出漣波電壓（ ΔV_{OUT} ）。第二個步驟是計算工作週期。為得出正確的值，需將二極體的順向壓降和 MOSFET 導通時的壓降納入考慮。Fairchild FAN8303 是非同步的降壓穩壓器，它整合了 0.22Ω 的 N 通道

MOSFET，因此壓降約為 $0.4V$ 。蕭基（Schottky）二極體的順向電壓（ $40V_{RRM} / 2A I_{OUT}$ ）為 $0.45V$ 。而關於電感器的部分，建議您使用高於計算值的電感值，並且最好使用低 DCR 電感器：

表 2. 設計範例計算

| | | |
|----------|---|---|
| 工作週期： | $= (V_{OUT} + V_F) / (V_{IN} + V_{OUT} + V_F - V_{Q1})$ | 0.33 |
| 電感量： | $= (V_{IN} \times D) / (f_{SW} \times \Delta I_L)$ | 35.6 μ H（所需的 $\Delta I_L = 20\%$ ） |
| 輸出電容量： | $= (I_{OUT} \times D) / (f_{SW} \times \Delta V_{OUT})$ | 86.8 μ F（所需的 $\Delta V_{OUT} = 10\text{mV}$ ） |
| 輸入電容量： | $I_{RMS} = I_{OUT} \times \sqrt{D \times (1-D)}$ | 0.47A |
| | $C_{IN} = I_{RMS} \times D / (\Delta V_{IN} \times f_{SW})$ | 4.05 μ F |
| 二極體額定電流： | $I_{DIODE_MAX} = I_{AVG} + \Delta I_L / 2$ 此處 I_{AVG} = 平均電感器電流 | 1.77A |

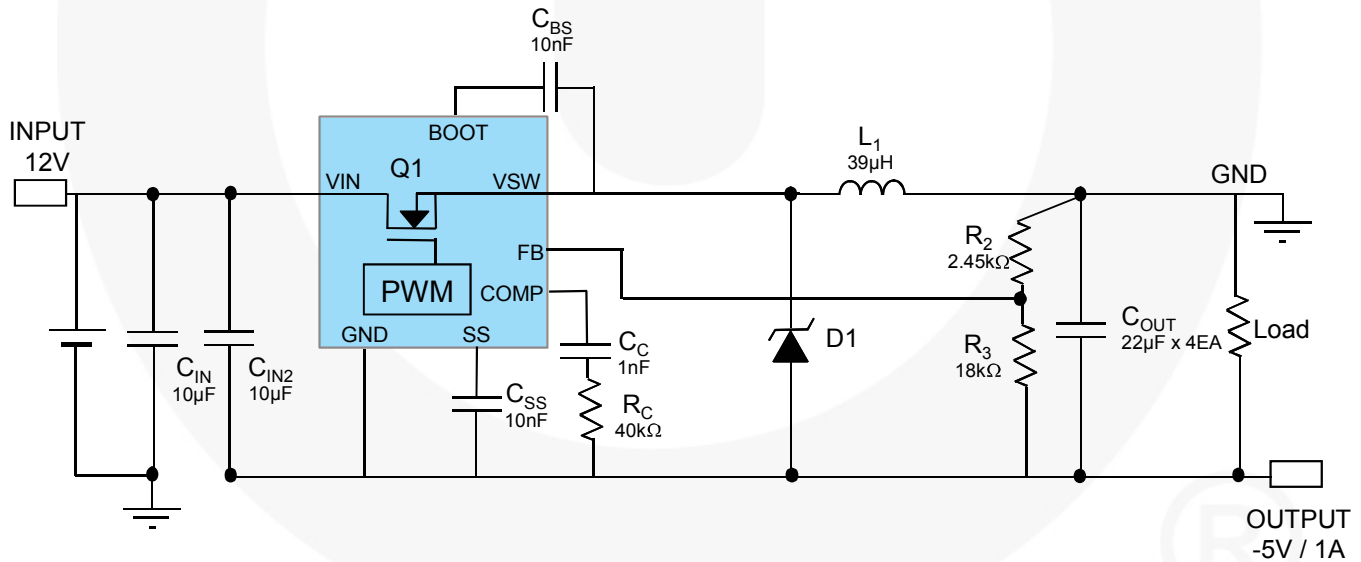


圖 4. 使用 FAN8303 的升降壓電路圖

一般波形和圖表

圖 5 和 圖 6 所示為 FAN8303 輸出漣波電壓的一般波形。為達到低漣波電壓，需使用低於 10mΩ 的 MLCC。

圖 7 所示為 FAN8303 效率與功耗圖。圖中表示，當負載條件為 400mA、功耗為 0.31W 的情況下，最高效率為 87%。

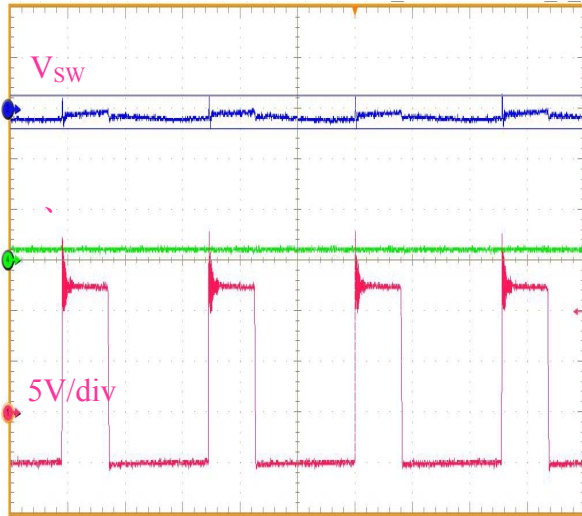


圖 5. 33mV 在 100mA 時的 V_{OUT} 漣波 (1 μ s/div)

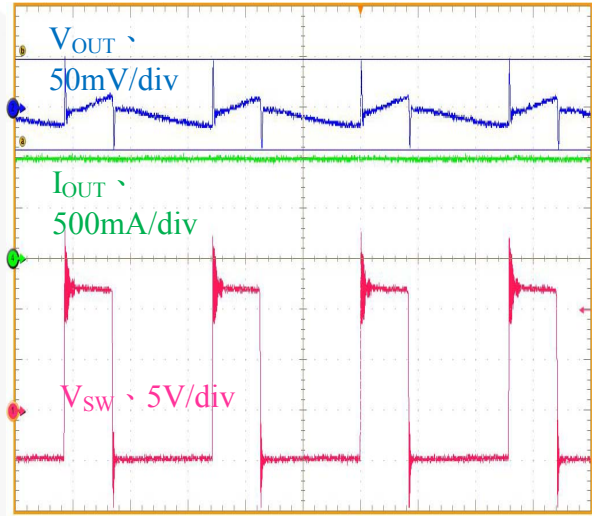


圖 6. 89mV 在 1A 時的 V_{OUT} 漣波 (1 μ s/div)

附註：

1. 測試條件： $V_{IN}=12V$ 、 $V_{OUT}=-5V$ 、 f_{SW} = 固定 370 kHz 和 $I_{OUT}=0\sim 1A$ 。

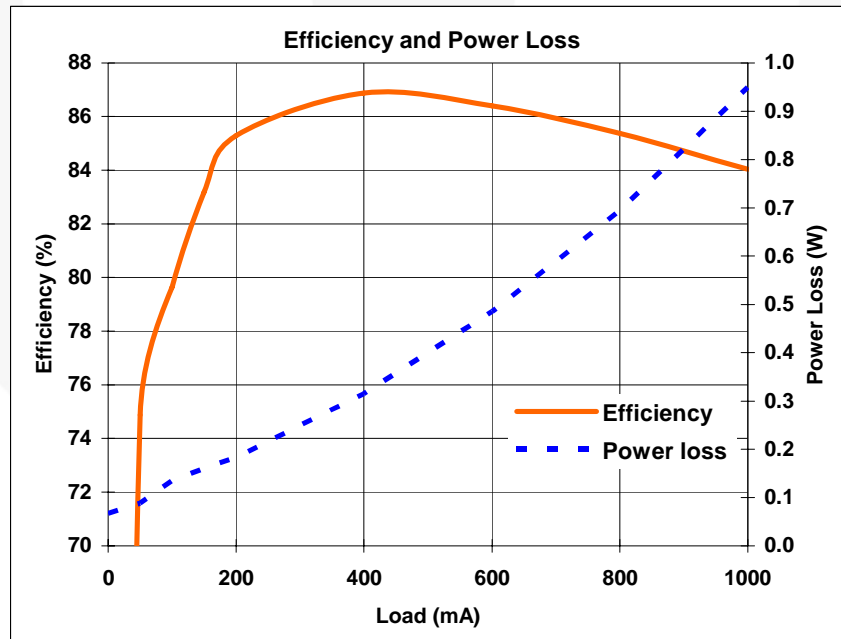


圖 7. 效率與功耗

結論

Fairchild 2A 單晶片型，非同步降壓穩壓器 FAN8303 的輸入範圍廣 (~23V)，並且有絕佳的負載和線性調整率。儘管是降壓穩壓器拓樸架構，但只要變更被動元

件，便可以在升降壓電路中使用 FAN8303 來產生負輸出電壓。

相關資料表

[FAN8303 — 2A 23V 非同步降壓式 DC/DC 穩壓器](#)

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