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AN-6204

FAN6204 — 反激和正激续流整流的同步整流控制器

简介

本应用指南给出了飞兆半导体次级同步整流 (SR) 控制器 FAN6204 的设计要点, 适用于连续导通模式 (CCM)、断续导通模式 (DCM)、准谐振 (QR) 反激式转换器以及双管正激续流整流 (图 1 和图 2)。

FAN6204 采用了独创的线性预测时序控制技术, 用于决定 SR MOSFET 的开通与关断时序。该控制技术只需检测变压器绕组电压和输出电压, 无需检测 MOSFET 的电流, 因此可以实现抗噪性。另外, 本技术无需来自初级端的通讯信号, 因而减少了外部器件数量, 简化了 PCB 布局。

在异常测试条件下, 由于线性预测时序 (LPT) 控制和因果时序功能有可能无法保证安全运行, 因此应该使用一些保护功能。在负载变化测试条件下, 采用错误因果时序保护、栅极扩展限制保护和 RES 压降保护。当 LPC/RES 电阻损坏时, LPC/RES 引脚开路/短路保护可以防止 SR 控制器的错误操作。另外, 内部过温保护 (OTP) 和 V_{DD} 过电压保护 (VDD OVP) 可使 FAN6204 避免在高温或输出过电压条件下的不可控问题。

为提高空载或轻载效率, 采用了一种绿色模式功能。在绿色模式下, SR 控制器关断所有 SR 开关来降低工作电流, 保证在轻载条件下功率损耗维持在一个较低水平。

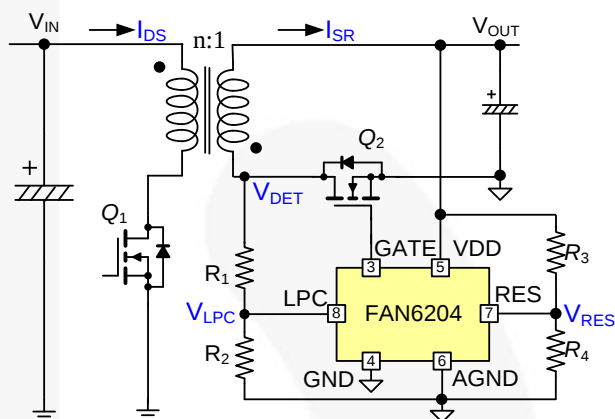


图 1. 反激转换器的典型应用电路

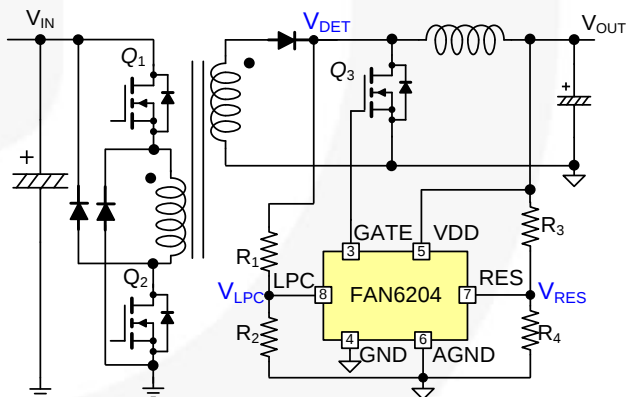


图 2. 双管正激续流整流的典型应用电路

外部组件设计

(a) 反激整流的应用

如图 1 所示, LPC 和 RES 引脚的电阻需要根据 LPT 控制进行适当设计。根据图 3, 当 LPC 端电压在一个消隐时序 (t_{LPC-EN}) 内高于 V_{LPC-EN} 时, SR 的栅极准备输出。当 LPC 端电压跌落到低于 $V_{LPC-TH-HIGH}$ ($0.05 V_{OUT}$) 时, SR MOSFET 开始输出。因此, V_{LPC-EN} 必须高于 $V_{LPC-TH-HIGH}$, 否则 SR MOSFET 不能导通。所以, LPC 端的分压器 R_1 和 R_2 , 应该满足下式:

$$0.83 \cdot \frac{R_2}{R_1 + R_2} \cdot \left(\frac{V_{IN,MIN}}{n} + V_{OUT} \right) > 0.05 V_{OUT} + 0.3 \quad (1)$$

另一方面, 需要考虑 LPC 和 RES ($1 \sim 4 V$) 的线性工作范围, 则:

$$\frac{R_2}{R_1 + R_2} \cdot \left(\frac{V_{IN,MAX}}{n} + V_{OUT} \right) < 4 \quad (2)$$

$$1 < \frac{R_4}{R_3 + R_4} \cdot V_{OUT} < 4 \quad (3)$$

由于 RES 和 LPC (K) 之间的分压比是 5, 所以 C_T ($t_{CT,DIS}$) 的放电时间和电感电流的放电时间 ($t_{L,DIS}$) 相等。然而, 考虑到分压电阻和内部电路的公差, 分压比 (K) 应该大于 5, 以确保 $t_{CT,DIS}$ 比 $t_{L,DIS}$ 短。K 的典型值为 $5 \sim 5.5$ 。

$$K \cdot \frac{R_2}{R_1 + R_2} = \frac{R_4}{R_3 + R_4} \quad (4)$$

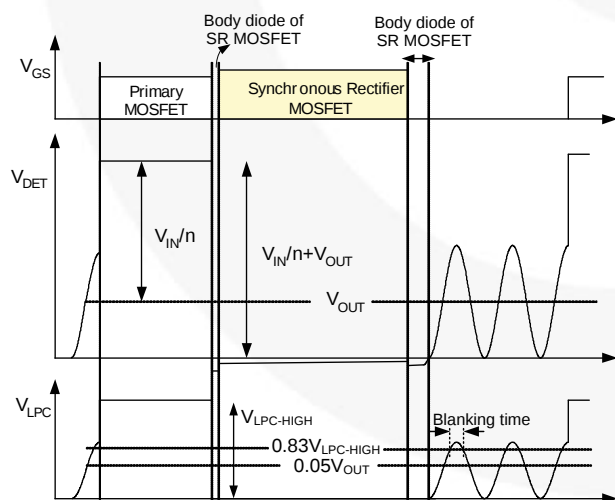


图 3. 采用 FAN6204 时 QR 反激变换器的典型波形

(b) 双管正激式续流整流的应用:

图 2 给出了一种将 FAN6204 应用于正激续流二极管整流的典型应用电路。由于 V_{LPC-EN} 必须大于 $V_{LPC-TH-HIGH}$, 因此 LPC 端分压器 R_1 和 R_2 , 应该满足下式:

$$0.83 \cdot \frac{R_2}{R_1 + R_2} \cdot \frac{V_{IN,MIN}}{n} > 0.05 V_{OUT} + 0.3 \quad (5)$$

应该考虑 LPC 和 RES ($1 \sim 4 V$) 的线性工作范围, 则:

$$\frac{R_2}{R_1 + R_2} \cdot \frac{V_{IN,MAX}}{n} < 4 \quad (6)$$

$$\frac{R_4}{R_3 + R_4} \cdot V_{OUT} < 4 \quad (7)$$

再考虑到分压电阻和内部电路的公差, 分压比 (K) 的取值为 $5 \sim 5.5$ 。

$$K \cdot \frac{R_2}{R_1 + R_2} = \frac{R_4}{R_3 + R_4} \quad (8)$$

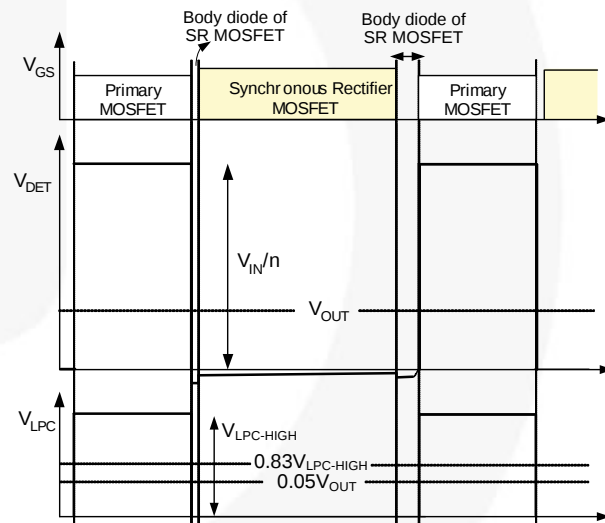


图 4. 采用 FAN6204 时正激续流整流的典型波形

(c) 外部器件取值的考虑

LPC 部件： 为了防止由 V_{LPC} 跌落到低于 $V_{LPC-SOURCE}$ (0.2 V) 而使 LPC 引脚受到负压而损坏，FAN6204 从 LPC 引脚输出电流 $I_{LPC-SOURCE}$ ，将 V_{LPC} 钳位在一个正电平。为实现正常控制，钳位电平必须低于 $V_{LPC-TH-HIGH}$ ，因此 R_2 不能太大。当低钳位电压高于 $V_{LPC-TH-HIGH}$ 时，应当减小 R_2 ，保证 SR 控制器能够正常工作。按照计算所得的 LPC 分压比，一旦 R_2 确定， R_1 也就确定。建议 R_2 的取值低于 15 k Ω 。另外，如果噪声干扰严重，建议在 LPC 引脚并联一个陶瓷电容器（大约 10 pF 至 22 pF）。

RES 部件： 为了减小功耗，应将 R_3 和 R_4 的取值设计得尽可能大（理论上）。事实上，由于高阻抗组件会引起噪声干扰，所以 RES 端的电阻值不能设计得太大。由于以上原因，建议设计值为 10 k Ω 到几百 k Ω 。

（设计范例）假定在反激系统中的输入电压 (V_{IN}) 最大值 ($V_{IN,MAX}$) 为 373 V，最小值 ($V_{IN,MIN}$) 为 127 V；输出电压为 19 V；变压器匝比 (n) 为 4.75。根据式 (1)，可以得到 LPC 的分压比最大值为：

$$\frac{R_1 + R_2}{R_2} < \frac{0.83 \cdot \left(\frac{V_{IN,MIN}}{n} + V_{OUT} \right)}{\frac{2 \cdot V_O}{40} + 0.3} = 30.4$$

根据式 (2)，可以得到 LPC 的分压比最大值为：

$$\frac{R_1 + R_2}{R_2} > \frac{\left(\frac{V_{IN,MAX}}{n} + V_{OUT} \right)}{4} = 24.4$$

因此，LPC 分压比应该在 24.4 和 30.4 之间。考虑到公差，LPC 分压比选为 26.38，LPC 引脚的电阻值 $R_1 = 330$ k Ω ， $R_2 = 13$ k Ω 。

假设 LPC 和 RES 间的分压比 (K) 为 5.32，则 RES 比为：

$$RES \text{ ratio} = \frac{LPC \text{ ratio}}{K} = \frac{26.38}{5.32} = 4.96$$

此外，RES 比 = 4.96 应该满足公式 (3)：

$$1 < \frac{R_4}{R_3 + R_4} \cdot V_{OUT} = \frac{19}{4.96} = 3.8 < 4$$

因此， R_3 和 R_4 分别选为 36 k Ω 和 9.1 k Ω 。

VDD 部分

输出电压 (V_O) 可以用作 FAN6204 的 V_{DD} ，同时 V_O 需控制在 5 V 与 24 V 之间。如果 V_O 未能控制在这个范围，则可以使用变压器的一个额外绕组给 V_{DD} 供能。图 5 给出了简易电路图。为了阻止 V_{DD} 电源电压的变化，可以使用稳压器或电压钳位元件，比如齐纳二极管，将 V_{DD} 电压钳位在适当的范围。

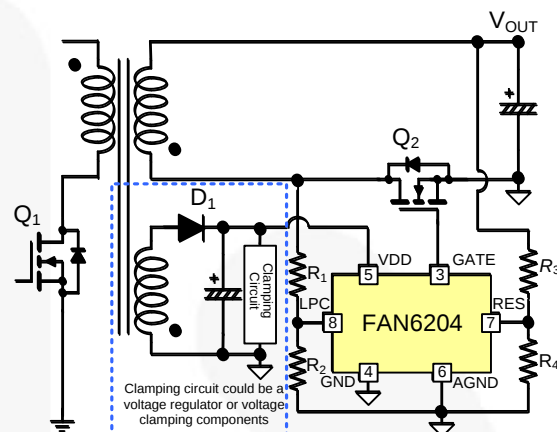


图 5. V_{DD} 电源附加绕组的简易电路

印刷电路板布局

图 6 给出了 FAN6204 在某一转换器中的原理图。良好的 PCB 布局可以提高电源系统效率、最大限度抑制 EMI，并且防止电源在浪涌/静电释放试验中的损坏。

IC 侧:

- LPC 和 RES 引脚的参考地直接连接到 IC 的 AGND。(轨迹 1)
- IC 的 GND 和 AGND 引脚应该通过一条短粗的布线或者较宽区域的布线连在一起。(轨迹 1 和轨迹 2)
- VDD 的参考地应该连接到 IC 的这个接地区域，然后 VDD 的参考地连接到 C_{OUT} 的地。(轨迹 3)
- LPC 和 RES 的布线应该远离磁性元件。

系统侧:

- 由于轨迹 4 是次级侧的功率环路，因此越短越好。
- 在次级端，Y-CAP 应该通过一条粗线连接到 C_{OUT} 的地。(轨迹 5)

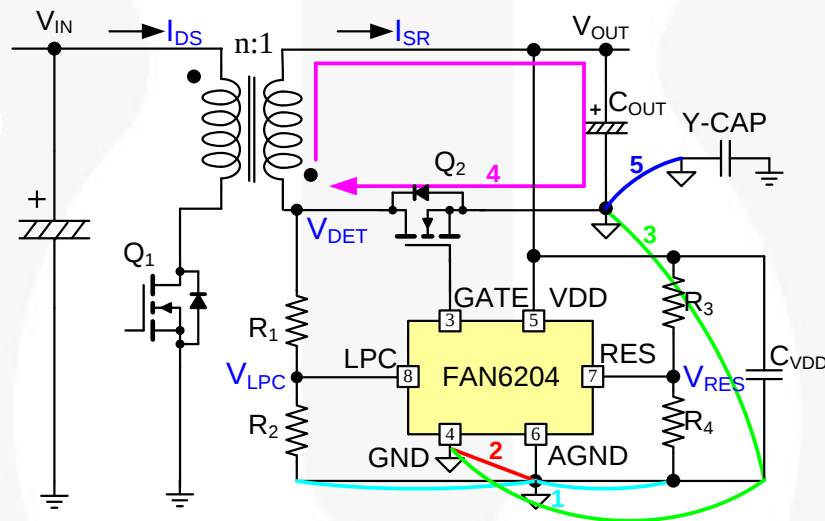


图 6. 布局思路

设计范例

本节给出了采用 FAN6921 时 90 W (19 V/4.74 A) 适配器的设计实例。PFC 输出电压在低输入交流电压时为 250 V，在高输入交流电压时为 400 V。根据技术规格，所有的关键元件都经过了处理，并且给出了最终的测量结果。

表 1. 系统指标

输入	
输入电压范围	90~264 V _{AC}
电源频率范围	47~63 Hz
输出	
输出电压 (V_o)	19 V
输出功率 (P_o)	90 W

表 2中总结了关键参数。

表 2. 关键系统参数

PFC电路	
PFC 输出电压电平 1 ($PFCV_{o1}$)	250 V
PFC 输出电压电平 2 ($PFCV_{o2}$)	400 V
PFC 电感 (L_b)	385 μ H
PFC 电感匝数 (N_b)	60 T
辅助绕组匝数 (N_{aux})	8 T
最小开关频率 ($f_{s,min,PFC}$)	55 kHz
PWM电路	
PWM 变压器初级电感匝数 (N_p)	41 T
PWM 变压器辅助绕组匝数 (N_{aux})	6 T
PWM 变压器的匝比 (n)	6.8
初级电感 (L_p)	700 μ H
最小开关频率 ($f_{s,min,PWM}$)	52 kHz

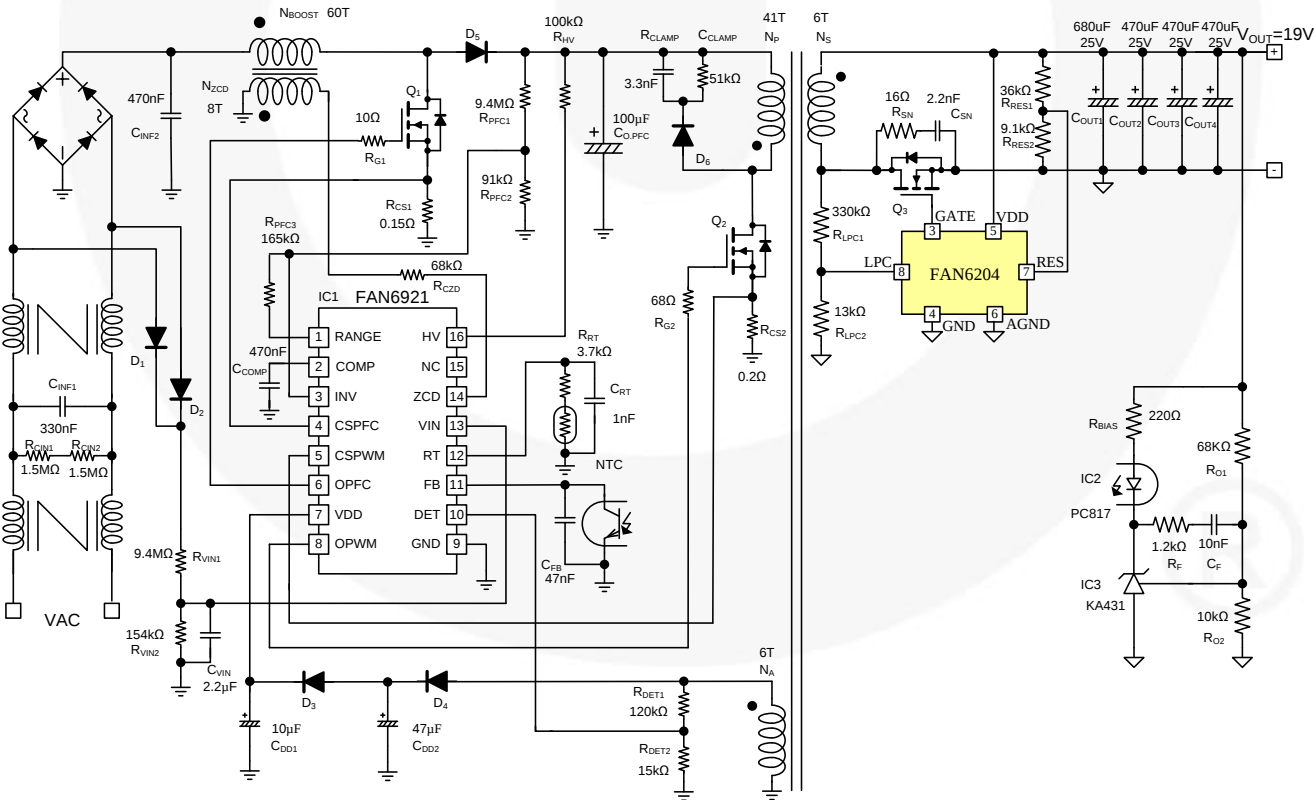


图 7. 完整电路图

表 3. 材料单

部件	数值	备注	部件	数值	备注
电阻			C_{RT}	1 nF	
R_{PFC1}	9.4 M Ω	1/4 W	C_{FB}	47 F	
R_{PFC2}	91 k Ω	1/8 W	C_{CLAMP}	3.3 nF	
R_{PFC3}	165 k Ω	1/8 W	$C_{O,PFC}$	100 μ F	450 V
R_{VIN1}	9.4 M Ω	1/4 W	C_{SN}	2.2 nF	
R_{VIN2}	154 k Ω	1/8 W	C_F	10 nF	
R_{ZCD}	68 k Ω	1/4 W	C_{OUT1}	680 μ F	25 V
R_{HV}	100 k Ω	1/2 W	C_{OUT2}	470 μ F	25 V
R_{CLAMP}	51 k Ω	1/4 W	C_{OUT3}	470 μ F	25 V
R_{RT}	3.7 k Ω	1/8 W	C_{OUT4}	470 μ F	25 V
R_{CS1}	0.15 Ω	1 W	二极管		
R_{CS2}	0.2 Ω	2 W	D_1	S1J	
R_{G1}	10 Ω	1/4 W	D_2	S1J	
R_{G2}	68 Ω	1/4 W	D_3	1N4148	
R_{DET1}	120 k Ω	1/4 W	D_4	1N4935	
R_{DET2}	15 k Ω	1/8 W	D_5	EGP30J	
R_{CIN1}	1.5 M Ω	1/4 W	D_6	RGP10M	
R_{CIN2}	1.5 M Ω	1/4 W	MOSFET		
R_{LPC1}	330 k Ω	1/8 W	Q_1	FCPF11N60	
R_{LPC2}	13 k Ω	1/8 W	Q_2	FDPF15N65	
R_{RES1}	36 k Ω	1/8 W	Q_3	FDP090N10	
R_{RES2}	9.1 k Ω	1/8 W	IC		
R_{SN}	16 Ω	1/2 W	IC_1	FAN6921MR	
R_{O1}	68 k Ω	1/8 W	IC_2	FOD817A	
R_{O2}	10 k Ω	1/8 W	IC_3	KA431	
R_{BIAS}	200 Ω	1/4 W	IC_4	FAN6204	
R_F	1.2 k Ω	1/8 W			
电容					
C_{INF1}	330 nF	XCAP			
C_{INF2}	470 nF				
C_{VIN}	2.2 μ F				
C_{COMP}	470 nF				
C_{DD1}	10 μ F	50 V			
C_{DD2}	47 μ F	50 V			

图 8给出了 19 V/90 W 演示板上 100% 负载 (4.74 A) 下的测试波形。通过线性预测时序控制可以关断 SR 栅极, 而且 SR 栅极可以在初级端与次级端 MOSFET 之间设置的一个死区时间。

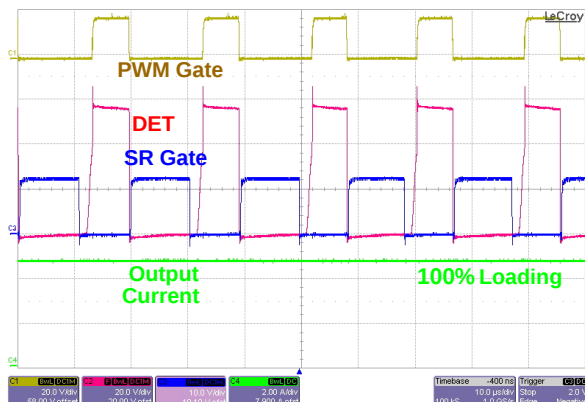


图 8. 100% 负载下的测试波形

图 9 给出了在 19 V/90 W 演示板上 25% 负载下的测试波形。线性预测时序控制可用来关断 SR MOSFET，防止其与 PWM MOSFET 的重叠。

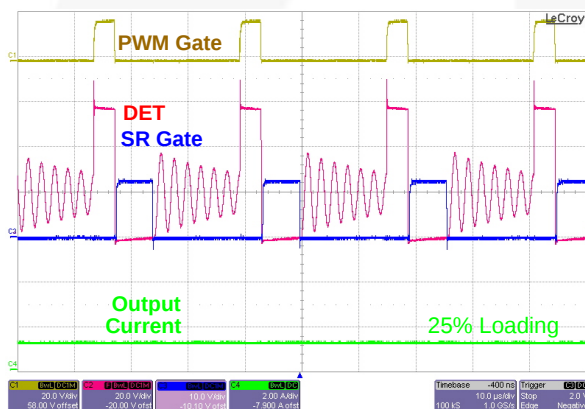


图 9. 25% 负载下的测试波形

图 10和图 11分别给出了负载由轻载到重载、由重载到轻载下的测试波形。初级端与次级端的 MOSFET 之间没有出现重叠。

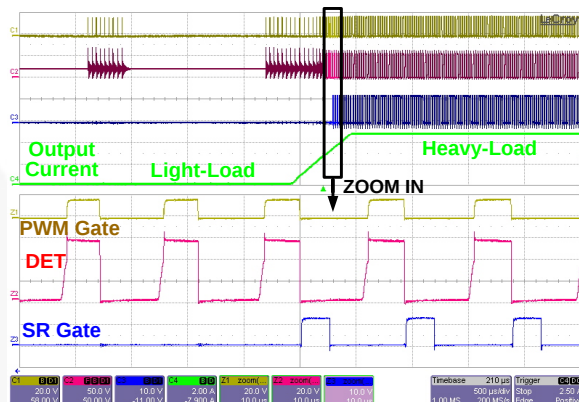


图 10. 负载变化的测试波形
(从轻载到重载)

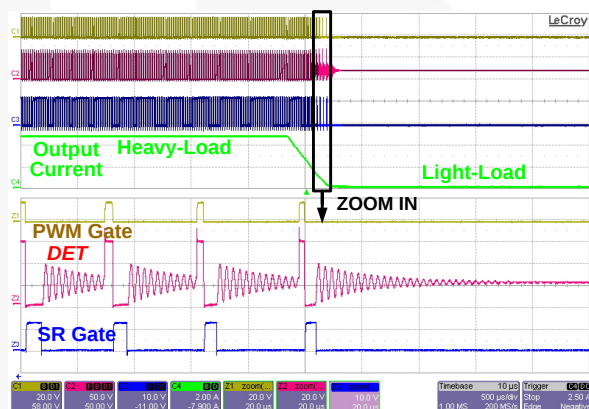


图 11. 负载变化的测试波形
(从重载到轻载)

相关数据表

[FAN6921MR — 高集成准谐振电流模式 PWM 控制器](#)

[FAN6921ML — 高集成准谐振电流模式 PWM 控制器](#)

[SG6742MR/ML — 高度集成的绿色模式 PWM 控制器](#)

[FAN6754A — 高度集成的绿色模式 PWM 控制器](#)

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