

ON Semiconductor

Is Now

onsemi™

To learn more about onsemi™, please visit our website at
www.onsemi.com

onsemi and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.



Is Now Part of



ON Semiconductor®

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

ON Semiconductor and the ON Semiconductor logo are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

AN-6204

FAN6204 — Synchronous Rectification Controller for Flyback and Forward Free-wheeling Rectification

Introduction

This application note presents the design considerations for Fairchild secondary-side synchronous rectification (SR) controller, FAN6204, which is suitable for Continuous Conduction Mode (CCM) / Discontinuous Conduction Mode (DCM) / Quasi-Resonant (QR) flyback converters and dual-switch forward free-wheeling rectification (Figure 1 and Figure 2).

FAN6204 utilizes a proprietary innovative linear-predict timing control to determine the turn-on and turn-off timing of SR MOSFET. This control technique detects the voltage of the transformer winding and output voltage instead of MOSFET current, so noise immunity can be accomplished. Furthermore, this technique doesn't need a communication signal from the primary side, so this feature reduces external components and simplifies PCB layout.

In abnormal test conditions, since Linear-Predict Timing control (LPT) and causal function may not guarantee safe operation, some protection functions should be applied. Fault Causal Timing protection, Gate Expand Limit protection, and RES voltage drop protection are used for load-change test condition. LPC and RES pins' open/short protection is to prevent fault operation of SR controller if LPC/RES resistors are damaged. In addition, internal Over-Temperature Protection (OTP) and V_{DD} Over-Voltage Protection (V_{DD} OVP) are also included to avoid a timing sequence where FAN6204 is uncontrollable under high-temperature or output over-voltage condition.

To improve no-load or light-load efficiency, a Green Mode function is utilized. In Green Mode, the SR controller stops all SR switching to reduce the operating current, keeping power consumption at low levels in light-load condition.

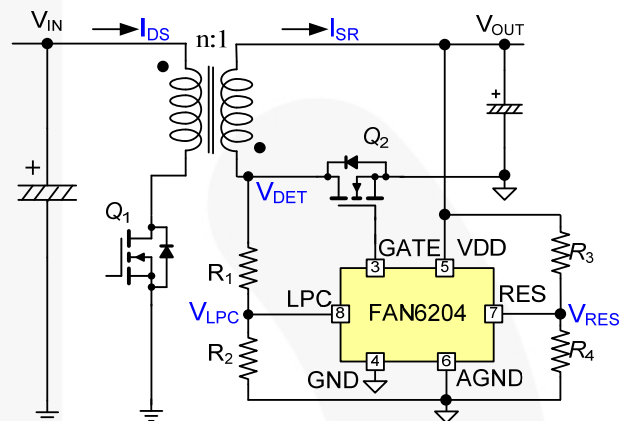


Figure 1. Typical Application Circuit for Flyback Converter

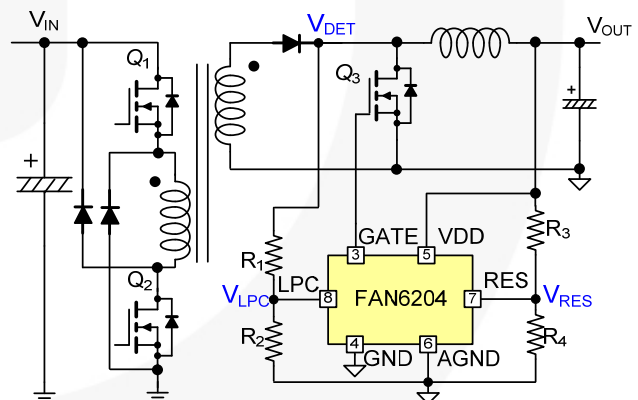


Figure 2. Typical Application Circuit for Dual-Switch Forward Free-wheeling Rectification

External Components Design

(a) Flyback Rectification Application

As shown in Figure 1, the resistors on the LPC and RES pins need to be designed appropriately for linear predict timing control. Referring to Figure 3, when LPC voltage is higher than V_{LPC-EN} over a blanking time (t_{LPC-EN}), SR gate is ready to output. After LPC voltage drops below $V_{LPC-TH-HIGH}$ ($0.05 V_{OUT}$), SR MOSFET starts to output. Therefore, V_{LPC-EN} must be higher than $V_{LPC-TH-HIGH}$ or the SR MOSFET cannot be turned on. Consequently, the voltage divider of LPC, R_1 and R_2 , should be considered as:

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

On the other hand, the linear operating range of LPC and RES (1~4 V) should also be considered as:

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

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

Since the voltage scale-down ratio between RES and LPC (K) is 5, the discharge time of C_T (t_{CT-DIS}) is same as the inductor current discharge time (t_{L-DIS}). However, considering the tolerance of voltage divider resistors and internal circuit, the scale-down ratio (K) should be larger than 5 to guarantee that t_{CT-DIS} is shorter than t_{L-DIS} . It is typical to set K to 5~5.5.

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

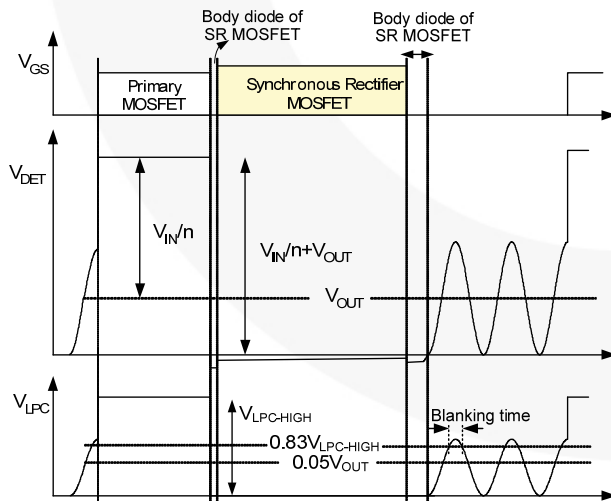


Figure 3. Typical Waveforms of QR Flyback Converter with FAN6204

(b) Dual-Switch Forward Free-Wheeling Rectification Application:

Figure 2 shows a typical application circuit for applying FAN6204 on forward free-wheeling diode rectification. V_{LPC-EN} must be higher than $V_{LPC-TH-HIGH}$ so the voltage divider of LPC, R_1 and R_2 , should be considered as:

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

The linear operating range of LPC and RES (1~4 V) should also be considered as:

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

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

Considering the tolerance of voltage divider resistors and internal circuit, the scale-down ratio (K) is set to 5~5.5.

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

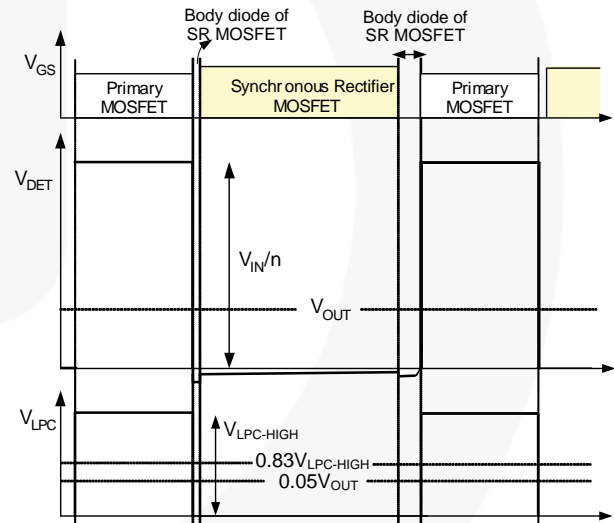


Figure 4. Typical Waveforms of Forward Free-Wheeling Rectification with FAN6204

(c) Consideration of External Component Value

LPC Part: To prevent LPC pin damage by negative voltage while V_{LPC} drops below $V_{LPC-SOURCE}$ (0.2 V), FAN6204 sources a current, $I_{LPC-SOURCE}$, from the LPC pin to clamp V_{LPC} at a positive voltage level. To operate regularly, the clamped voltage level must be lower than $V_{LPC-TH-HIGH}$, so R_2 should not be too large. If the low clamped voltage is higher than $V_{LPC-TH-HIGH}$, R_2 should be decreased to guarantee proper operation of SR controller. Once R_2 is decided, R_1 can also be determined due to calculated LPC ratio. The recommended value of R_2 is under 15 k Ω . In addition, if the noise interference is serious, a ceramic capacitor (around 10 pF to 22 pF) parallel on LPC pin is recommended.

RES Part: For power saving, the values of R_3 and R_4 are designed as large as possible (theoretically). Actually, since high-impedance components can cause noise interference, the values of RES resistors should not be designed too large. For the reason, the recommended value is 10 k Ω to several hundred k Ω .

(Design Example) Assume the input voltage (V_{IN}) is 373 V for high line ($V_{IN,MAX}$) and 127 V for low line ($V_{IN,MIN}$) in a flyback system; the output voltage is 19 V; and transformer turn-ratio (n) is 4.75. The maximum value of LPC ratio can be obtained from Equation (1):

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

The maximum value of LPC ratio can be obtained from Equation (2):

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

Consequently, the LPC ratio should be between 24.4 and 30.4. After considering tolerance, LPC ratio is chosen to 26.38 and resistor value of LPC pin is $R_1=330$ k Ω and $R_2=13$ k Ω .

Assuming the scale-down ratio between LPC and RES (K) is 5.32, the RES ratio should be:

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

In addition, RES ratio=4.96 should also be checked by Equation (3):

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

Thus, R_3 and R_4 are chosen to 36 k Ω and 9.1 k Ω , respectively.

V_{DD} Section

Output voltage (V_O) can be applied as V_{DD} of FAN6204, while V_O is regulated between 5 V and 24 V. If V_O is not regulated in that range, an additional winding of transformer can be utilized to provide energy to V_{DD} . The simplified circuit is shown as Figure 5. To prevent the variation of the V_{DD} supply voltage, use a voltage regulator or voltage clamping components, such as a Zener diode, to clamp V_{DD} voltage in a proper range.

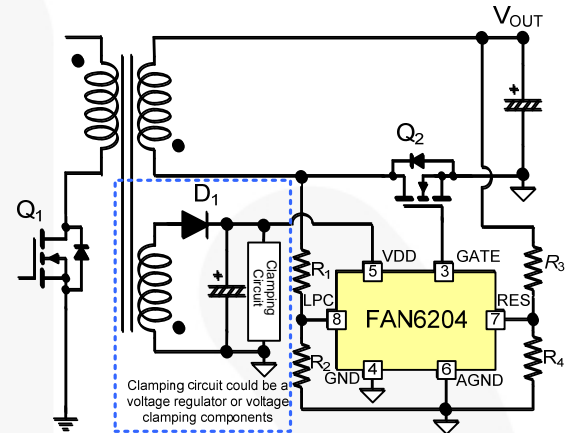


Figure 5. Simplified Circuit of Additional Winding for V_{DD} Supply

Printed Circuit Board Layout

Figure 6 shows the schematic for FAN6204 in a converter. Good PCB layout improves power system efficiency, minimizes excessive EMI, and prevents the power supply from being disrupted during surge/ESD tests.

IC Side:

- Reference ground of LPC and RES pins are connected to IC's AGND directly. (trace 1)
- IC's GND and AGND pins should be connected together with a **short, wide trace** or a **wide area**. (trace 1 and trace 2)
- Reference ground of VDD should connect to this **ground area of IC**, then the reference ground of VDD connects to C_{OUT} 's ground. (trace 3)
- The trace line of LPC and RES should be **far away** from magnetic components.

SYSTEM Side:

- Since trace 4 is the power loop on secondary side, it is as **short** as possible.
- Y-CAP should be connected to C_{OUT} 's ground with a **wide trace** on secondary side. (trace 5)

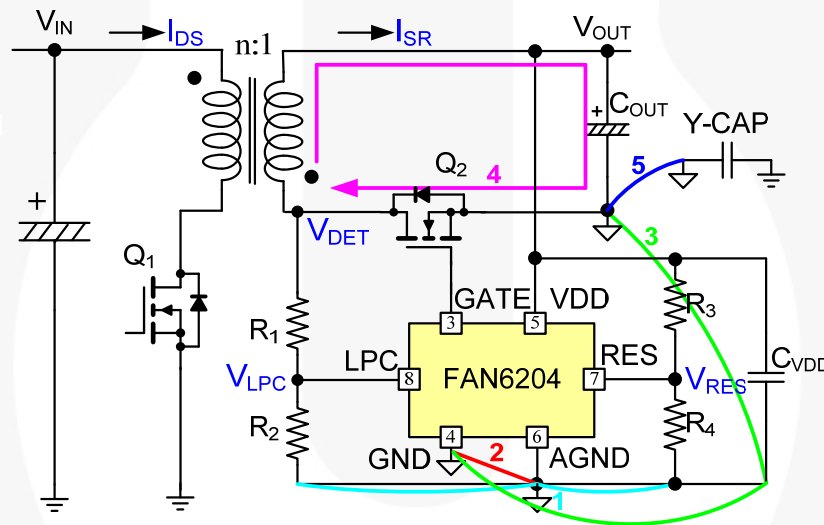


Figure 6. Layout Considerations

Design Example

This section shows a design example of 90 W (19 V/4.74 A) adaptor using FAN6921. The PFC output voltage is 250 V at low AC input voltage, 400 V at high AC input voltage. From the specification, all critical components are treated and final measurement results are given.

Table 1. System Specification

Input	
Input Voltage Range	90~264 V _{AC}
Line Frequency Range	47~63 Hz
Output	
Output Voltage (V _o)	19 V
Output Power (P _o)	90 W

The critical parameters are summarized, shown in Table 2.

Table 2. Critical System Parameters

PFC Stage	
PFC Output Voltage Level 1 (PFCV _{o1})	250 V
PFC Output Voltage Level 2 (PFCV _{o2})	400 V
PFC Inductor (L_b)	385 μH
Turns of PFC Inductor (N_b)	60 T
Turns of Auxiliary Winding (N _{AUX})	8 T
Minimum Switching Frequency (f _{s,min,PFC})	55 kHz
PWM Stage	
Turns of Primary Inductor of PWM Transformer (N _P)	41 T
Turns of Auxiliary Winding of PWM Transformer (N _{AUX})	6 T
Turns Ratio of PWM Transformer (n)	6.8
Primary Inductor (L _P)	700 μH
Minimum Switching Frequency (f _{s,min,PWM})	52 kHz

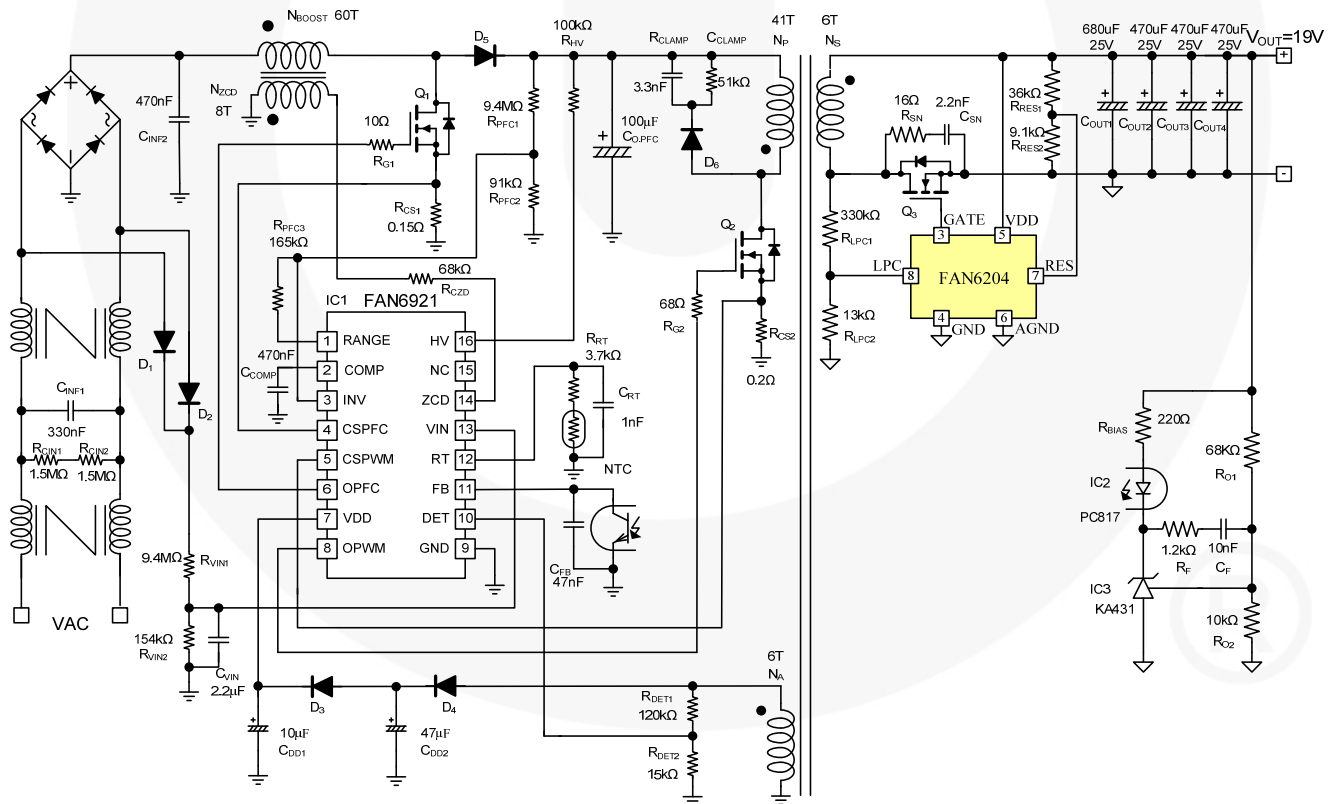


Figure 7. Complete Circuit Diagram

Table 3. Bill of Materials

Part	Value	Note	Part	Value	Note
Resistor			C _{RT}	1 nF	
R _{PFC1}	9.4 MΩ	1/4 W	C _{FB}	47 F	
R _{PFC2}	91 kΩ	1/8 W	C _{CLAMP}	3.3 nF	
R _{PFC3}	165 kΩ	1/8 W	C _{O.PFC}	100 μF	450 V
R _{VIN1}	9.4 MΩ	1/4 W	C _{SN}	2.2 nF	
R _{VIN2}	154 kΩ	1/8 W	C _F	10 nF	
R _{ZCD}	68 kΩ	1/4 W	C _{OUT1}	680 μF	25 V
R _{HV}	100 kΩ	1/2 W	C _{OUT2}	470 μF	25 V
R _{CLAMP}	51 kΩ	1/4 W	C _{OUT3}	470 μF	25 V
R _{RT}	3.7 kΩ	1/8 W	C _{OUT4}	470 μF	25 V
R _{CS1}	0.15 Ω	1 W	Diode		
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 kΩ	1/4 W	D ₄	1N4935	
R _{DET2}	15 kΩ	1/8 W	D ₅	EGP30J	
R _{CIN1}	1.5 MΩ	1/4 W	D ₆	RGP10M	
R _{CIN2}	1.5 MΩ	1/4 W	MOSFET		
R _{LPC1}	330 kΩ	1/8 W	Q ₁	FCPF11N60	
R _{LPC2}	13 kΩ	1/8 W	Q ₂	FDPF15N65	
R _{RES1}	36 kΩ	1/8 W	Q ₃	FDP090N10	
R _{RES2}	9.1 kΩ	1/8 W	IC		
R _{SN}	16 Ω	1/2 W	IC ₁	FAN6921MR	
R _{O1}	68 kΩ	1/8 W	IC ₂	FOD817A	
R _{O2}	10 kΩ	1/8 W	IC ₃	KA431	
R _{BIAS}	200 Ω	1/4 W	IC ₄	FAN6204	
R _F	1.2 kΩ	1/8 W			
Capacitor					
C _{INF1}	330 nF	XCAP			
C _{INF2}	470 nF				
C _{VIN}	2.2 μF				
C _{COMP}	470 nF				
C _{DD1}	10 μF	50 V			
C _{DD2}	47 μF	50 V			

Figure 8 shows the test waveforms of 100% loading (4.74 A) on 19 V/90 W demonstration board. The SR gate can be turned off by linear-predict timing control and can keep a dead time between the primary-side and secondary-side MOSFET.

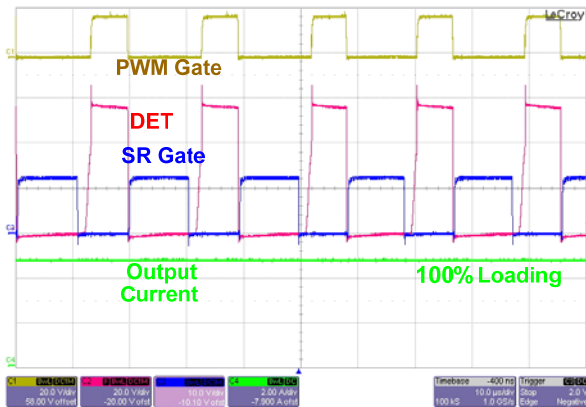


Figure 8. Test Waveforms of 100% Loading

Figure 9 shows the test waveforms of 25% loading on 19 V/90 W demonstration board. Linear-predict timing control can also be activated to turn off SR MOSFET to prevent overlap with PWM MOSFET.

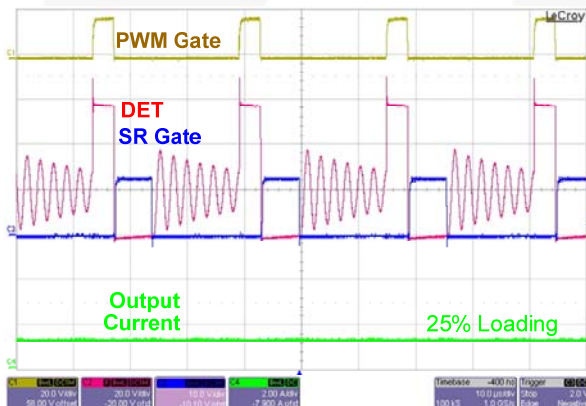


Figure 9. Test Waveforms of 25% Loading

Figure 10 and Figure 11 show the test waveforms for load changing from light load to heavy load and from heavy load to light load. There is no overlap between the primary- and secondary-side MOSFET.



Figure 10. Test Waveforms for Load Change (Light Load to Heavy Load)

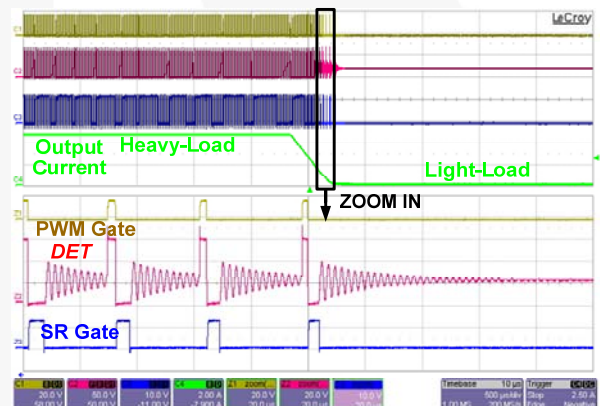


Figure 11. Test Waveforms for Load Change (Heavy Load to Light Load)

Related Datasheets

[FAN6921MR — Highly Integrated Quasi-Resonant Current PWM Controller](#)

[FAN6921ML — Highly Integrated Quasi-Resonant Current PWM Controller](#)

[SG6742MR/ML — Highly Integrated Green-Mode PWM Controller](#)

[FAN6754A — Highly Integrated Green-Mode PWM Controller](#)

[FAN6204 — Synchronous Rectification Controller for Flyback and Forward Freewheeling Rectification](#)

DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION, OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free
USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81-3-5817-1050

ON Semiconductor Website: www.onsemi.com
Order Literature: <http://www.onsemi.com/orderlit>
For additional information, please contact your local
Sales Representative