User Guide for

FEBFAN6224M_CP01 Evaluation Board

Green-Mode Synchronous Rectification Controller for Flyback Converters

Featured Fairchild Product: FAN6224

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

[Fairchild Semiconductor.com]

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This user guide supports the evaluation kit for the FAN6224. It should be used in conjunction with the FAN6224 datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

This document is the evaluation board user manual for the synchronous rectification controller, FAN6224. This device is designed for secondary-side rectification of flyback converters. It is suitable for Continuous Conduction Mode (CCM), Discontinuous Conduction Mode (DCM), and Quasi-Resonant (QR) operation. With proper design, it can be applied for flyback high-side and low-side rectification, as the typical application circuits show in Figure 1 and Figure 2. In addition, it is capable of forward free-wheeling rectification. The maximum operating frequency is up to 140 kHz.

Green Mode improves no-load and light-load efficiency by stopping switching to reduce the operating current and switching losses. To increase the flexibility of design, the loading level to trigger Green Mode is adjustable by the external resistor on the RP pin. The user guide focuses on the flyback application and includes design introductions, design examples, and fabrication of the daughter card. The daughter card includes the SR controller (FAN6224), a SR MOSFET (100 V/8.5 mΩ), and detection circuits.

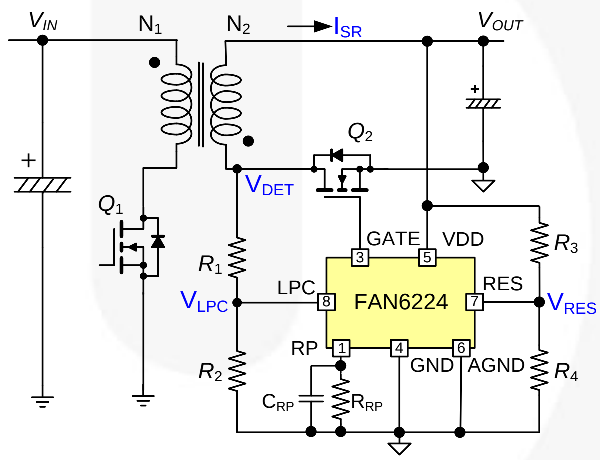

Figure 1. Typical Application Circuit for Low-Side Flyback Converter

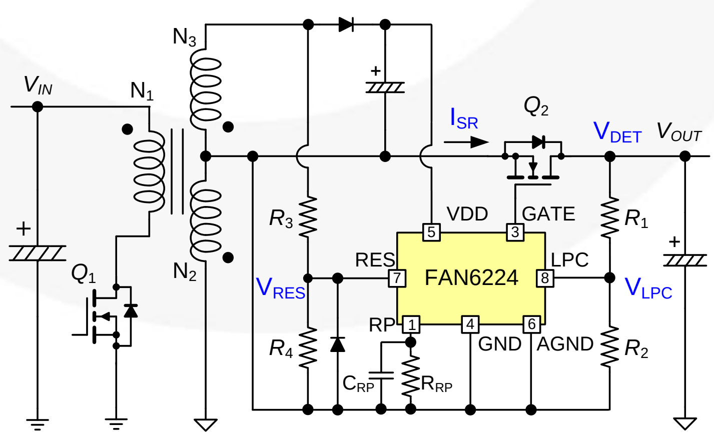

Figure 2. Typical Application Circuit for High-Side Flyback Converter

1.1. Introduction of Linear Predict Timing Control

The SR MOSFET turn-off timing is determined by linear-predict timing control. The operation principle is based on the volt-second balance theorem, which states: the inductor average voltage is zero during a switching period in steady state, so the charge voltage and charge time product is equal to the discharge voltage and discharge time product. In flyback converters, the charge voltage on the magnetizing inductor is input voltage (V_{IN}), while the discharge voltage is the reflected output voltage (nV_{OUT}). The following equation can be drawn:

$$V_{IN} \cdot t_{PM.ON} = n \cdot V_{OUT} \cdot t_{L.DIS} \tag{1}$$

where $t_{PM,ON}$ is the inductor charge time; $t_{L,DIS}$ is the inductor discharge time; and n is the turn ratio of primary windings (N_1) to secondary windings (N_2).

FAN6224 senses the DET voltage (V_{DET}) and output voltage (V_{OUT}) with LPC and RES pins, respectively. Therefore, V_{IN}/n, $t_{PM.ON}$, and V_{OUT} can be obtained. As a result, $t_{L,DIS}$, which is the on-time of SR MOSFET, can be predicted by Equation (1). As shown in Figure 3, the SR MOSFET is turned on when the SR MOSFET body diode starts conducting and DET voltage drops to zero. The SR MOSFET is turned off by linear-predict timing control.

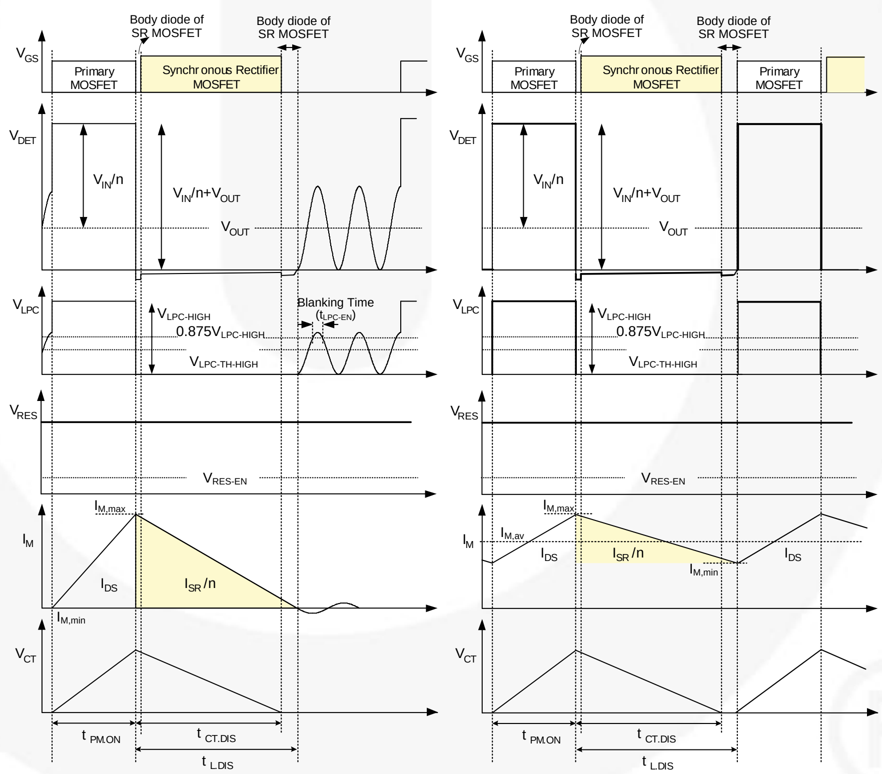

Figure 3. Waveforms of Linear-Predict Timing Controller in CCM, DCM, QR Flyback

1.2. Features of mWSaver™ Technology

- Internal Green Mode Stops SR Switching for Lower No-Load Power Consumption
- 300 µA Ultra-Low Green Mode Operating Current
- Synchronous Rectification Controller
- Suited for High-Side and Low-Side of Flyback Converters in QR, DCM, and CCM Operation
- Suited for Forward Free-wheeling Rectification
- PWM Frequency Tracking with Secondary-Side Winding Voltage Detection
- 140 kHz Maximum Operation Frequency
- VDD Pin Over-Voltage Protection (OVP)
- LPC Pin Open/Short Protection
- RES Pin Open/Short Protection
- RP Pin Open/Short Protection
- Internal Over-Temperature Protection (OTP)

1.3. External Components Design

Definition of the System Parameters

- Maximum input voltage, $V_{IN.MAX}$
- Minimum input voltage, $V_{IN.MIN}$
- Output voltage, V_{OUT}
- Turns of the primary-side winding, N_1
- Turns of the secondary-side winding, N_2
- Turns of the auxiliary-side winding, N_3
- Turn-ratio n_1 is equal to N_1/N_2
- Turn-ratio n_2 is equal to N_2/N_3
- The ratio of LPC resistors, $R_{atioLPC}= (R_1+R_2)/R_2$
- The ratio of RES resistors, $R_{atioRES}= (R_3+R_4)/R_4$

Flyback Low-Side Rectification

Refer to the typical application circuit in Figure 1 for the following design procedure.

Step 1. Confirm the Applicability of the FAN6224

If the system parameters n_1, $V_{IN.MAX}$, $V_{IN.MIN}$, and V_{OUT} satisfy:

$$\frac{\left(\frac{V_{IN.MIN}}{n_1}+V_{OUT}\right)}{1.54} > \frac{\left(\frac{V_{IN.MAX}}{n_1}+V_{OUT}\right)}{4.8} \tag{2}$$

then FAN6224 is applicable for this system. If (2) is not satisfied, some of the parameters need to be redesigned.

Step 2. Select the Capacitance of C_{RP}

For low-frequency systems (under 100 kHz), C_{RP} is recommended as 10 nF; for high-frequency systems (from 100 kHz to 140 kHz), C_{RP} is recommended as 1 nF.

Step 3. Calculate the Operating Range of $Ratio_{LPC}$

The maximum of $Ratio_{LPC}$ is:

$$Ratio_{LPC} < \frac{\left(\frac{V_{IN.MIN}}{n_1} + V_{OUT}\right)}{1.54} \quad (3)$$

The minimum of $Ratio_{LPC}$ is:

$$Ratio_{LPC} > \frac{\left(\frac{V_{IN.MAX}}{n_1} + V_{OUT}\right)}{4.8} \quad (4)$$

Step 4. Calculate the Resistance of R_1

Choose R_2 to be equal to several-tens kilo-ohms and $Ratio_{LPC}$ to be close to its maximum value. R_1 is obtained as below:

$$R_1 = R_2 \cdot \left(Ratio_{LPC} - 1\right) \quad (5)$$

Step 5. Calculate $Ratio_{RES}$

Choose K to be in the range of 4 to 4.5. The dead-time is larger when K is larger and vice versa. $Ratio_{RES}$ is calculated as below:

$$Ratio_{RES} = \frac{Ratio_{LPC}}{K} \quad (6)$$

Verify that $Ratio_{RES}$ satisfies:

$$2 < \frac{V_{OUT}}{Ratio_{RES}} < 4.8 \quad (7)$$

If (7) is not satisfied, select another proper $Ratio_{RES}$. Calculate $Ratio_{LPC}$ by (6) and verify $Ratio_{LPC}$ satisfies (3) and (4). If (3) and (4) cannot be satisfied, some of the system parameters, such as n_1, $V_{IN.MAX}$, $V_{IN.MIN}$, and V_{OUT} need to be redesigned.

Step 6. Calculate the Resistance of R_3

Choose R_4 to be equal to several-tens kilo-ohms and the $Ratio_{RES}$ is based on the calculated result of (6) and (7). R_3 is obtained as below:

$$R_3 = R_4 \cdot \left(Ratio_{RES} - 1\right) \quad (8)$$

Flyback High-Side Rectification

Refer to the typical application circuit in Figure 2 for the following design procedure.

Step 1. Confirm the Applicability of FAN6224

If the system parameters n_1, $V_{IN.MAX}$, $V_{IN.MIN}$, and V_{OUT} satisfy:

$$\frac{\left(\frac{V_{IN.MIN}}{n_1}+V_{OUT}\right)}{1.54} > \frac{\left(\frac{V_{IN.MAX}}{n_1}+V_{OUT}\right)}{4.8} \tag{9}$$

FAN6224 is applicable for this system. If (9) is not satisfied, some of the parameters need to be redesigned.

Step 2. Calculate the Auxiliary Winding N_3

$$N_3 = \frac{V_{DD} \cdot N_2}{V_{OUT}} \tag{10}$$

Step 3. Select the Capacitance of C_{RP}

For low-frequency systems (under 100 kHz), C_{RP} is recommended as 10 nF; for high-frequency systems (from 100 kHz to 140 kHz), C_{RP} is recommended as 1 nF.

Step 4. Calculate the Operating Range of $Ratio_{LPC}$

The maximum of $Ratio_{LPC}$ is:

$$Ratio_{LPC} < \frac{\left(\frac{V_{IN.MIN}}{n_1}+V_{OUT}\right)}{1.54} \tag{11}$$

The minimum of $Ratio_{LPC}$ is:

$$Ratio_{LPC} > \frac{\left(\frac{V_{IN.MAX}}{n_1}+V_{OUT}\right)}{4.8} \tag{12}$$

Step 5. Calculate the Resistance of R_1

Choose R_2 to be equal to 12 kΩ and $Ratio_{LPC}$ to be close to its maximum value. R_1 is obtained as below.

$$R_1 = R_2 \cdot \left(Ratio_{LPC} - 1\right) \tag{13}$$

Step 6. Calculate $Ratio_{RES}$

Choose K to be in the range of 4 to 4.5. The dead-time is larger when K is larger and vice versa. $Ratio_{RES}$ is calculated as below:

$$Ratio_{RES} = \frac{Ratio_{LPC}}{n_2 \cdot K} \tag{14}$$

Verify $Ratio_{RES}$ satisfies:

$$2 < \frac{V_{OUT}}{Ratio_{RES} \cdot n_2} < 4.8 \tag{15}$$

If (15) is not satisfied, select another proper $Ratio_{RES}$. Calculate $Ratio_{LPC}$ by (14) and verify that $Ratio_{LPC}$ satisfies (11) and (12). If (11) and (12) cannot be satisfied, some of the system parameters, such as n_1, $V_{IN.MAX}$, $V_{IN.MIN}$, and V_{OUT} need to be redesigned.

Step 7. Calculate the Resistance of R_3

Choose R_4 to be equal to 27 kΩ and the $Ratio_{RES}$ is based on the calculated result of (14) and (15). R_3 is obtained as below:

$$R_3 = R_4 \cdot (Ratio_{RES} - 1) \tag{16}$$

1.4. Design Example for Flyback High-Side Rectification

Step 1. Define System Parameters

- Maximum input voltage, $V_{IN.MAX}$: 373 V
- Minimum input voltage, $V_{IN.MIN}$: 86 V
- Output voltage, V_{OUT}: 19 V
- Turns of the primary-side winding, N_1: 38 turns
- Turns of the secondary-side winding, N_2: 8 turns
- Turn-ratio n_1: 4.75
- Turn-ratio n_2: 1.33

Put $V_{IN.MAX}$, $V_{IN.MIN}$, n_1, and V_{OUT} into (9):

$$\frac{\left(\frac{86}{4.75} + 19\right)}{1.54} > \frac{\left(\frac{373}{4.75} + 19\right)}{4.8}$$

FAN6224 is applicable for this system.

Step 2. Calculate the Auxiliary Winding, N_3

$$N_3 = \frac{V_{DD} \cdot N_2}{V_{OUT}} = 6.3$$

V_{DD} is set between 11.5 V and 26 V. Select 15 V and N_3 can be obtained from (10).

N_3 is selected as 6 turns.

Step 3. Calculate the Operating Range of $Ratio_{LPC}$

The maximum of $Ratio_{LPC}$ is obtained from (11):

$$Ratio_{LPC} < \frac{\frac{V_{IN.MIN}}{n_1} + V_{OUT}}{1.54} = 24.1$$

The minimum of $Ratio_{LPC}$ is obtained from (12):

$$Ratio_{LPC} > \frac{\frac{V_{IN.MAX}}{n_1} + V_{OUT}}{4.8} = 16.9$$

$Ratio_{LPC}$ is selected as 23.5. In practice, $Ratio_{LPC}$ close to its maximum value is a good start. In the following steps, if the calculated $Ratio_{RES}$ is over its operating range, return to this step and reconsider the selection of $Ratio_{LPC}$.

Step 4. Calculate the Resistance of R_1

The resistance of R_2 is first selected as 12 kΩ, as long as it is large enough to clamp negative voltage of the LPC pin. R_1 is obtained from (13):

$$R_1 = R_2 \cdot (Ratio_{LPC} - 1) = 270\text{ k}\Omega$$

Step 5. Calculate $Ratio_{RES}$

Select a proper scale-down ratio (K) between 4 and 4.5. The selection is based on the adjustment of dead-time and can be fine-tuned later. In this case, 4.11 is selected and $Ratio_{RES}$ is calculated by (14):

$$Ratio_{RES} = \frac{Ratio_{LPC}}{n_2 \cdot K} = \frac{23.5}{1.33 \cdot 4.11} = 4.3$$

Verify that $Ratio_{RES}$ satisfies (15). If it does not fit into the operating range, go back to Step 3 and reconsider the selection of $Ratio_{LPC}$. In this case:

$$2 < \frac{V_{OUT}}{Ratio_{RES} \cdot n_2} = \frac{19}{4.3 \cdot 1.33} = 3.32 < 4.8$$

The result is acceptable.

Step 6. Calculate the Resistance of R_3

The resistance of R_4 is first selected as 27 kΩ, as long as it is large enough to clamp negative voltage of the RES pin. R_3 is obtained from (16):

$$R_3 = R_4 \cdot (Ratio_{RES} - 1) = 89.1\text{ k}\Omega$$

As a result, the resistance of R_1, R_2, R_3, and R_4 are calculated. If the dead-time is checked, then the four resistors are determined. The process of fine-tuning the dead-time is explained in the following section.

1.5. Fine-Tuning the Dead-Time

If SR dead-time is too large, it is recommended to decrease R_1 or increase R_2. Either way, V_{LPC} is increased and the discharge time of C_T capacitor ($t_{CT.DIS}$) is prolonged to decrease the dead-time, as shown in Figure 4. However, note that (12) must be satisfied when increasing V_{LPC}.

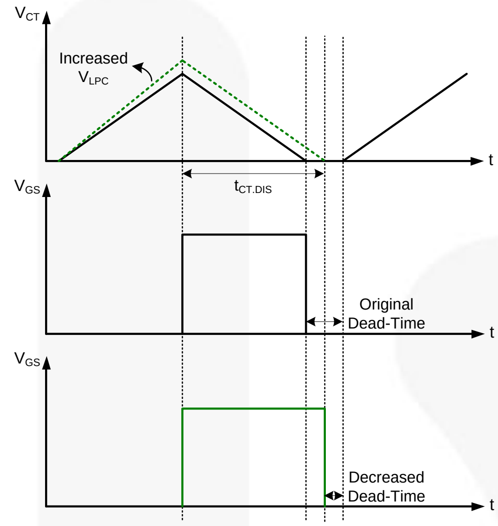

Figure 4. Decrease SR Dead-Time

In contrast, if SR dead-time is too small, it is suggested to decrease R_3 or increase R_4. Either way, V_{RES} is increased and the discharge time of C_T capacitor ($t_{CT.DIS}$) is reduced to increase the dead-time, as shown in Figure 5. However, note that (15) must be satisfied when increasing V_{RES}.

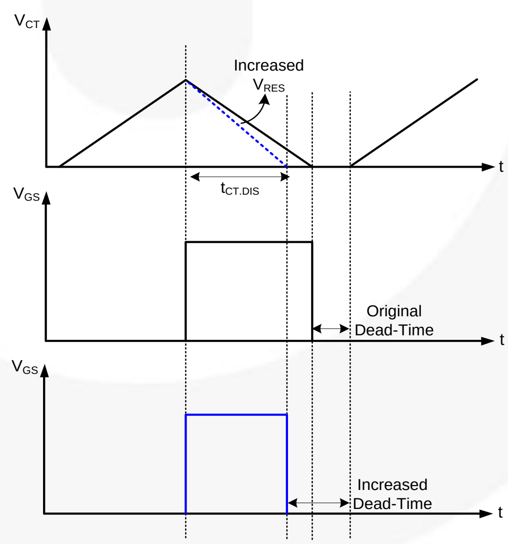

Figure 5. Increase SR Dead-Time

1.6. Assembly of the Daughter Card and System

Modification of Power Stage for Low-Side Rectification

Figure 6 shows the flyback system for low-side application. To mount the daughter card on the low-side, the modification items are:

Step 1. Remove the Schottky diode and short the trace.
Step 2. Cut the connection of transformer terminal (A) and output ground (B).

Figure 7 shows the daughter card schematic. The components of the daughter card include a SR MOSFET (100 V / 8.5 mΩ), the SR controller (FAN6224), and detection circuits. The connection method is:

- A’ (PAD4) connects to A
- B’ (PAD5) connects to B
- C’ (PAD1) connects to C
- For low-side application, R_{13} is 0 Ω to short the AUX and V_{DD} terminal.

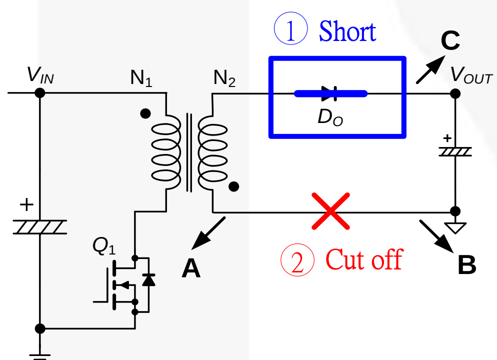

Figure 6. Low-Side Application

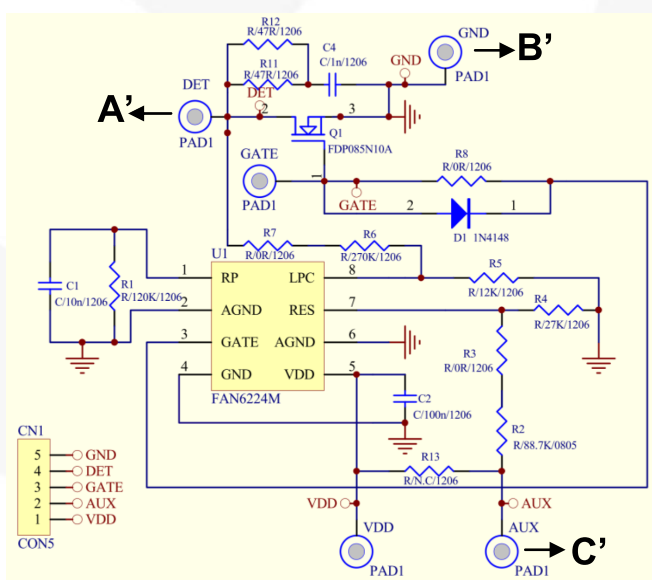

Figure 7. Daughter Card Schematic

1.7. Modification of Power Stage for High-Side Rectification

Figure 8 shows the flyback system for high-side application. To mount the daughter card on the high-side, cut the connection of transformer terminal (A) and output terminal (B).

Figure 9 shows the daughter card schematic. The components of the daughter card include a SR MOSFET (100 V / 8.5 mΩ), the SR controller (FAN6224), and detection circuits. The connection method is:

- A' (PAD5) connects to A
- B' (PAD4) connects to B
- C' (PAD1) connects to C
- D' (PAD2) connects to D
- For high-side application, R_{13} is open.

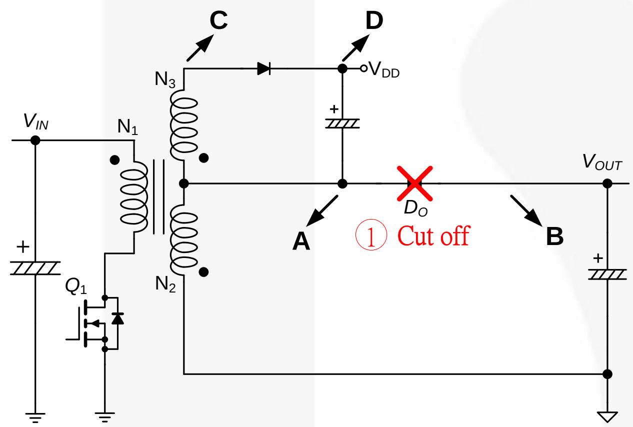

Figure 8. High-Side Application

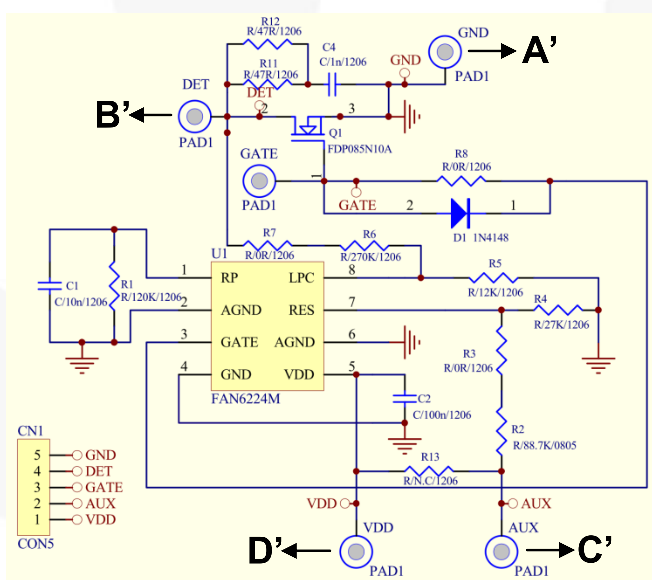

Figure 9. Daughter Card Schematic

2. Photographs

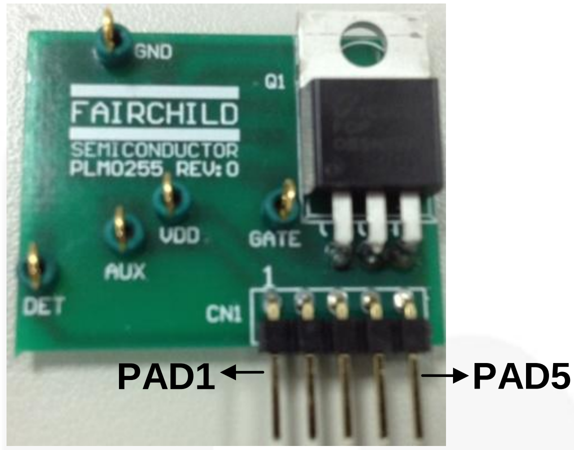

Figure 10. Top View

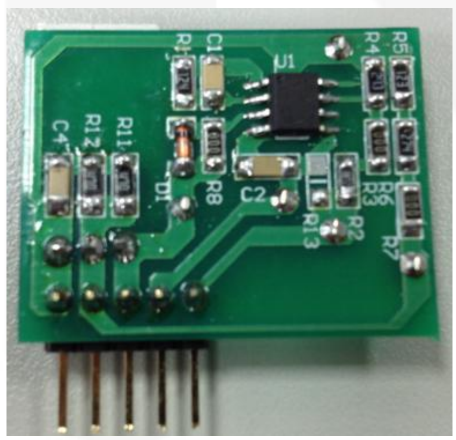

Figure 11. Bottom View

3. Schematic

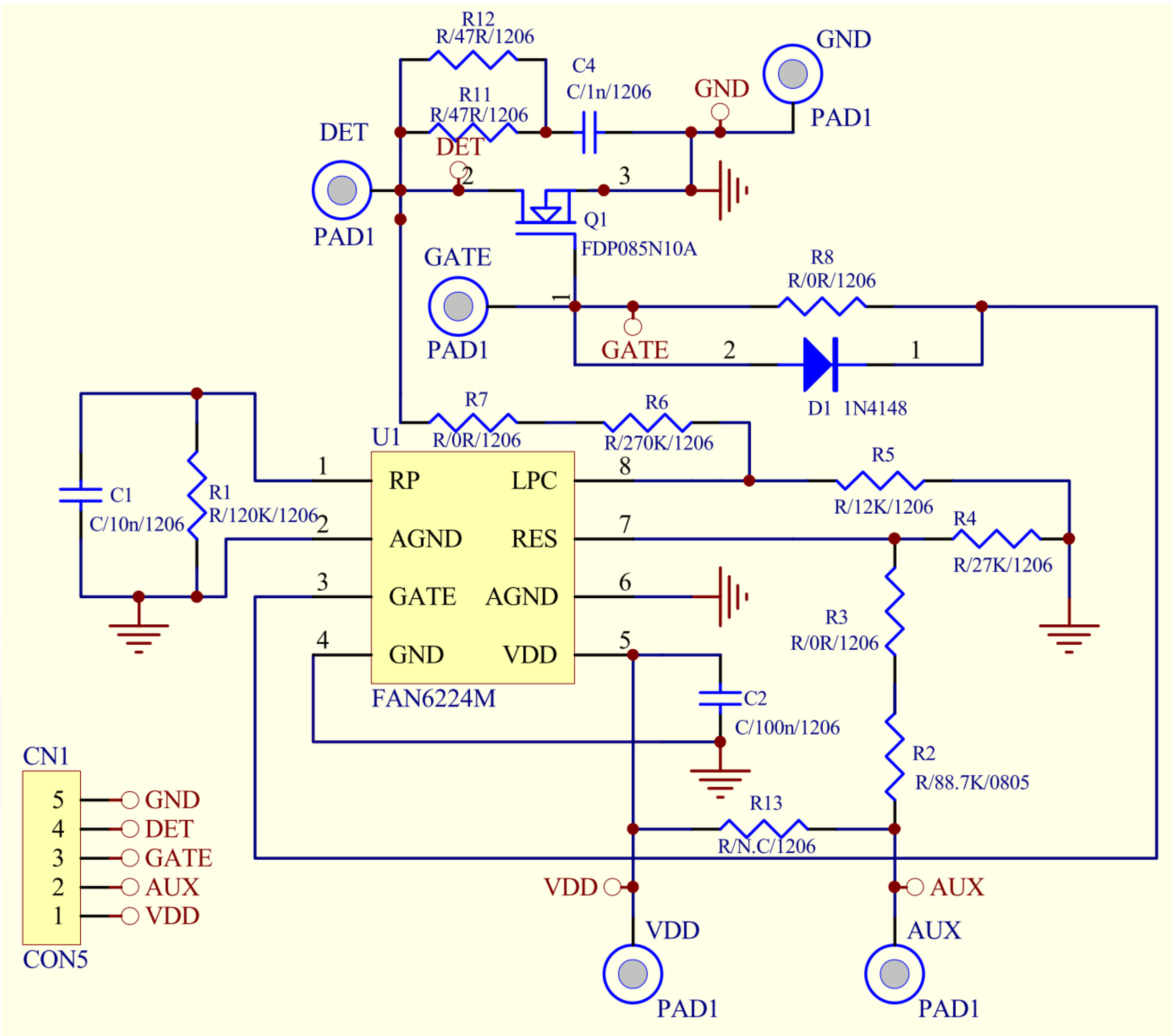

Figure 12. Schematic

4. Printed Circuit Board

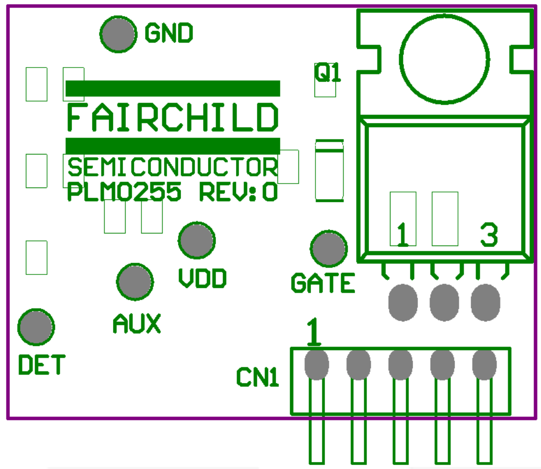

Figure 13. Top Overlayer

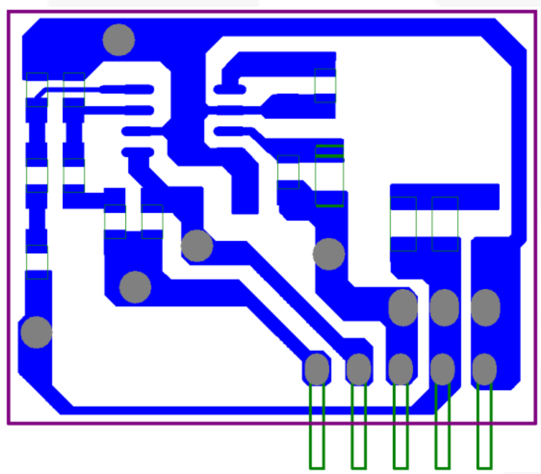

Figure 14. Bottom Layer

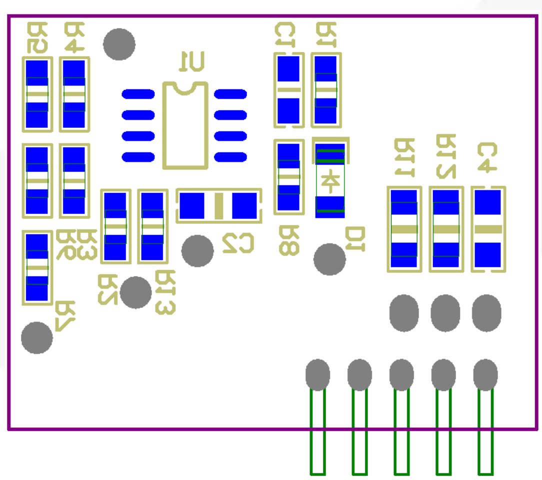

Figure 15. Bottom Overlayer

5. Bill of Materials

Part Number	Manufacturer	Description	Quantity	ID
02-5300005-00	SMD Resistor 1206 0 Ω ±5%	REEL	3	R3,R7,R8
02-5347005-00	SMD Resistor 1206 47 Ω ±5%	REEL	2	R11,R12
02-5312305-00	SMD Resistor 1206 12 kΩ ±5%	REEL	1	R5
02-5327305-00	SMD Resistor 1206 27 kΩ ±5%	REEL	1	R4
02-5288721-00	SMD Resistor 0805 887 kΩ ±1%	REEL	1	R2
02-5312405-00	SMD Resistor 1206 120 kΩ ±5%	REEL	1	R1
02-5327405-00	SMD Resistor 1206 270 kΩ ±5%	REEL	1	R6
03-3410239-00	1206 X7R ±10% 102P 50 V	REEL	1	C4
03-3410339-00	1206 X7R ±10% 103P 50 V	REEL	1	C1
03-3410439-00	1206 X7R ±10% 104P 50 V	REEL	1	C2
07-0414801-00	SMD Diode 1N4148	REEL	1	D1
09-108510F-00	MOS FDP085N10A_F102	Fairchild 96 A/100 V 8.5 mΩ TO-220	1	Q1
11-B6224MF-11	SMD IC FAN6224M	SOP8 Fairchild	1	U1
42-0100532-00	PIN HDR 1*5P 2.54 mm 90°	Header	1	CN1
70-PLM0255-00	PCB PLM0255 REV0	For FAM6224M 1*5	1	
42-0100101-00	Copper (Green)	TEST-1-GR	5	GND,DET AUX,VDD, GATE

Note:

1. The design of component value depends on system parameters. Please follow to the design procedures to determine the appropriate value.

6. Revision History

Rev.	Date	Description
1.0.0	December 2012	Initial Release
1.0.1	May 2013	Modify Fig.7, Fig.9, Fig.12
1.0.2	November 2014	Corrected Link error