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# FSQ0170RNA, FSQ0270RNA Green Mode Fairchild Power Switch (FPS™)

## Features

- Internal Avalanche Rugged 700V SenseFET
- Consumes only 0.8W at 230 V<sub>AC</sub> & 0.5W Load with Burst-Mode Operation
- Precision Fixed Operating Frequency, 100kHz
- Internal Start-up Circuit and Built-in Soft-Start
- Pulse-by-Pulse Current Limiting and Auto-Restart Mode
- Over-Voltage Protection (OVP), Overload Protection (OLP), Internal Thermal Shutdown Function (TSD)
- Under-Voltage Lockout (UVLO)
- Low Operating Current (3mA)
- Adjustable Peak Current Limit

## Applications

- Auxiliary Power Supply for PC and Server
- SMPS for VCR, SVR, STB, DVD & DVCD Player, Printer, Facsimile & Scanner
- Adapter for Camcorder

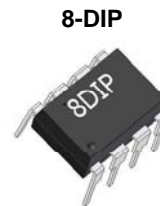
## Related Application Notes

- AN-4134: *Design Guidelines for Off-line Forward Converters Using Fairchild Power Switch (FPS™)*
- AN-4137: *Design Guidelines for Off-line Flyback Converters Using Fairchild Power Switch (FPS™)*
- AN-4141: *Troubleshooting and Design Tips for Fairchild Power Switch (FPS™) Flyback Applications*
- AN-4147: *Design Guidelines for RCD Snubber of Flyback*
- AN-4148: *Audible Noise Reduction Techniques for FPS™ Applications*

## Description

The FSQ0170RNA, and FSQ0270RNA, consists of an integrated current mode Pulse Width Modulator (PWM) and an avalanche-rugged 700V Sense FET. It is specifically designed for high-performance off-line Switch Mode Power Supplies (SMPS) with minimal external components. The integrated PWM controller features include: a fixed-frequency generating oscillator, Under-Voltage Lockout (UVLO) protection, Leading Edge Blanking (LEB), an optimized gate turn-on/turn-off driver, Thermal Shutdown (TSD) protection, and temperature compensated precision current sources for loop compensation and fault protection circuitry.

Compared to a discrete MOSFET and controller or RCC switching converter solution, the FSQ0170RNA, and FSQ0270RNA reduces total component count, design size, and weight while increasing efficiency, productivity, and system reliability. These devices provide a basic platform that is well suited for the design of cost-effective flyback converters, as in PC auxiliary power supplies.



## Ordering Information

Product Number	Package	Marking Code	BV <sub>DSS</sub>	f <sub>osc</sub>	R <sub>DS(ON)</sub> (MAX.)
FSQ0170RNA	8DIP	Q0170RA	700V	100kHz	11Ω
FSQ0270RNA	8DIP	Q0270RA	700V	100kHz	7.2Ω

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## Pin Configuration

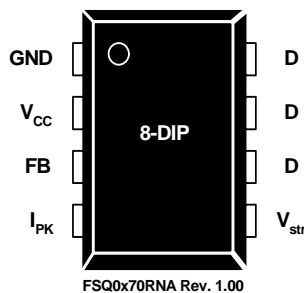


Figure 3. Pin Configuration (Top View)

## Pin Definitions

Pin #	Name	Description
1	GND	<b>Ground.</b> SenseFET source terminal on primary side and internal control ground.
2	$V_{CC}$	<b>Power Supply.</b> Positive supply voltage input. Although connected to an auxiliary transformer winding, current is supplied from pin 5 ( $V_{str}$ ) via an internal switch during start-up, see Figure 2. It is not until $V_{CC}$ reaches the UVLO upper threshold (12V) that the internal start-up switch opens and device power is supplied via the auxiliary transformer winding.
3	FB	<b>Feedback.</b> The feedback voltage pin is the non-inverting input to the PWM comparator. It has a 0.9mA current source connected internally while a capacitor and opto-coupler are typically connected externally. A feedback voltage of 6V triggers overload protection (OLP). There is a time delay while charging external capacitor $C_{FB}$ from 3V to 6V using an internal 5 $\mu$ A current source. This time delay prevents false triggering under transient conditions, but still allows the protection mechanism to operate under true overload conditions.
4	$I_{PK}$	<b>Peak Current Limit.</b> This pin adjusts the peak current limit of the SenseFET. The 0.9mA feedback current source is diverted to the parallel combination of an internal 2.8k $\Omega$ resistor and any external resistor to GND on this pin. This determines the peak current limit. If this pin is tied to $V_{CC}$ or left floating, the typical peak current limit is 0.8A (FSQ0170RNA), 0.9A (FSQ0270RNA).
5	$V_{str}$	<b>Start-up.</b> This pin connects to the rectified AC line voltage source. At start-up, the internal switch supplies internal bias and charges an external storage capacitor placed between the $V_{CC}$ pin and ground. Once the $V_{CC}$ reaches 12V, the internal switch is opened.
6	Drain	<b>SenseFET drain.</b> High-voltage power SenseFET drain connection.
7	Drain	<b>SenseFET drain.</b> High-voltage power SenseFET drain connection.
8	Drain	<b>SenseFET drain.</b> High-voltage power SenseFET drain connection.

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only

Symbol	Characteristic	Value	Unit
$V_{DRAIN}$	Drain Pin Voltage	700	V
$V_{STR}$	Vstr Pin Voltage	700	V
$I_{DM}$	Drain Current Pulsed <sup>(5)</sup>	FSQ0170RNA	4
		FSQ0270RNA	8
$E_{AS}$	Single Pulsed Avalanche Energy <sup>(6)</sup>	FSQ0170RNA	50
		FSQ0270RNA	140
$V_{CC}$	Supply Voltage	20	V
$V_{FB}$	Feedback Voltage Range	-0.3 to $V_{CC}$	V
$P_D$	Total Power Dissipation	1.5	W
$T_J$	Operating Junction Temperature	Internally limited	°C
$T_A$	Operating Ambient Temperature	-25 to +85	°C
$T_{STG}$	Storage Temperature	-55 to +150	°C

### Notes:

5. Non-repetitive rating: Pulse width is limited by maximum junction temperature.
6. L = 51mH, starting  $T_J = 25^\circ\text{C}$ .

## Thermal Impedance

$T_A = 25^\circ\text{C}$ , unless otherwise specified. All items are tested with the standards JESD 51-2 and 51-10 (DIP).

Symbol	Parameter	Value	Unit
$\theta_{JA}$	Junction-to-Ambient Thermal Resistance <sup>(7)</sup>	80	°C/W
$\theta_{JC}$	Junction-to-Case Thermal Resistance <sup>(8)</sup>	20	°C/W
$\theta_{JT}$	Junction-to-Top Thermal Resistance <sup>(9)</sup>	35	°C/W

### Notes:

7. Free standing with no heatsink; without copper clad.  
(Measurement Condition - Just before junction temperature  $T_J$  enters into OTP.)
8. Measured on the DRAIN pin close to plastic interface.
9. Measured on the PKG top surface.

## Electrical Characteristics

$T_A = 25^\circ\text{C}$  unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
<b>SenseFET Section<sup>(10)</sup></b>						
$I_{DSS}$	Zero-Gate-Voltage Drain Current	$V_{DS} = 700\text{V}, V_{GS} = 0\text{V}$			50	$\mu\text{A}$
		$V_{DS} = 560\text{V}, V_{GS} = 0\text{V}, T_C = 125^\circ\text{C}$			200	
$R_{DS(ON)}$	Drain-Source On-State Resistance <sup>(11)</sup>	$V_{GS} = 10\text{V}, I_D = 0.5\text{A}$	FSQ0170RNA	8.8	11	$\Omega$
			FSQ0270RNA	6.0	7.2	
$C_{ISS}$	Input Capacitance	$V_{GS} = 0\text{V}, V_{DS} = 25\text{V}, f = 1\text{MHz}$	FSQ0170RNA	250		$\text{pF}$
			FSQ0270RNA	550		
$C_{OSS}$	Output Capacitance	$V_{GS} = 0\text{V}, V_{DS} = 25\text{V}, f = 1\text{MHz}$	FSQ0170RNA	25		$\text{pF}$
			FSQ0270RNA	38		
$C_{RSS}$	Reverse Transfer Capacitance	$V_{GS} = 0\text{V}, V_{DS} = 25\text{V}, f = 1\text{MHz}$	FSQ0170RNA	10		$\text{pF}$
			FSQ0270RNA	17		
$t_{d(on)}$	Turn-On Delay Time	$V_{DS} = 350\text{V}, I_D = 1.0\text{A}$	FSQ0170RNA	12		$\text{ns}$
			FSQ0270RNA	20		
$t_r$	Rise Time	$V_{DS} = 350\text{V}, I_D = 1.0\text{A}$	FSQ0170RNA	4		$\text{ns}$
			FSQ0270RNA	15		
$t_{d(off)}$	Turn-Off Delay Time	$V_{DS} = 350\text{V}, I_D = 1.0\text{A}$	FSQ0170RNA	30		$\text{ns}$
			FSQ0270RNA	55		
$t_f$	Fall Time	$V_{DS} = 350\text{V}, I_D = 1.0\text{A}$	FSQ0170RNA	10		$\text{ns}$
			FSQ0270RNA	25		
<b>Control Section</b>						
$f_{OSC}$	Switching Frequency		92	100	108	KHz
$\Delta f_{OSC}$	Switching Frequency Variation <sup>(10)</sup>	$-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$		$\pm 5$	$\pm 10$	%
$D_{MAX}$	Maximum Duty Cycle	Measured at $0.1 \times V_{DS}$	55	60	65	%
$D_{MIN}$	Minimum Duty Cycle		0	0	0	%
$V_{START}$	UVLO Threshold Voltage	$V_{FB} = \text{GND}$	11	12	13	V
$V_{STOP}$		$V_{FB} = \text{GND}$	7	8	9	
$I_{FB}$	Feedback Source Current	$V_{FB} = \text{GND}$	0.7	0.9	1.1	mA
$t_{S/S}$	Internal Soft-Start Time <sup>(10)</sup>	$V_{FB} = 4\text{V}$		10		ms

## Electrical Characteristics (Continued)

T<sub>A</sub> = 25°C unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit	
<b>Burst-Mode Section</b>							
V <sub>BURH</sub>	Burst-Mode Voltage	T <sub>J</sub> = 25°C	0.5	0.6	0.7	V	
V <sub>BURL</sub>			0.3	0.4	0.5	V	
V <sub>BUR(HYS)</sub>			100	200	300	mV	
<b>Protection Section</b>							
I <sub>LIM</sub>	Peak Current Limit	FSQ0170RNA	di/dt = 170mA/μs	0.70	0.80	0.90	A
		FSQ0270RNA	di/dt = 200mA/μs	0.79	0.90	1.01	
t <sub>CLD</sub>	Current Limit Delay Time <sup>(10)</sup>			500		ns	
T <sub>SD</sub>	Thermal Shutdown Temperature <sup>(10)</sup>		125	140		°C	
V <sub>SD</sub>	Shutdown Feedback Voltage		5.5	6.0	6.5	V	
V <sub>OVP</sub>	Over-Voltage Protection		18	19		V	
I <sub>DELAY</sub>	Shutdown Delay Current	V <sub>FB</sub> = 4V	3.5	5.0	6.5	μA	
t <sub>LEB</sub>	Leading Edge Blanking Time <sup>(10)</sup>		200			ns	
<b>Total Device Section</b>							
I <sub>OP</sub>	Operating Supply Current (Control Part Only)	V <sub>CC</sub> = 14V	1	3	5	mA	
I <sub>CH</sub>	Startup Charging Current	V <sub>CC</sub> = 0V, R <sub>STR</sub> < 100kΩ <sup>(12)</sup>	0.70	0.85	1.00	mA	
V <sub>STR</sub>	V <sub>str</sub> Supply Voltage	V <sub>CC</sub> = 0V		24		V	

### Notes:

10. These parameters, although guaranteed, are not 100% tested in production.
11. Pulse test: Pulse width ≤ 300μs, duty ≤ 2%.
12. R<sub>STR</sub> is connected between the rectified AC line voltage source and VSTR pin.

### Typical Performance Characteristics (Control Part)

These characteristic graphs are normalized at  $T_A = 25^\circ\text{C}$ .

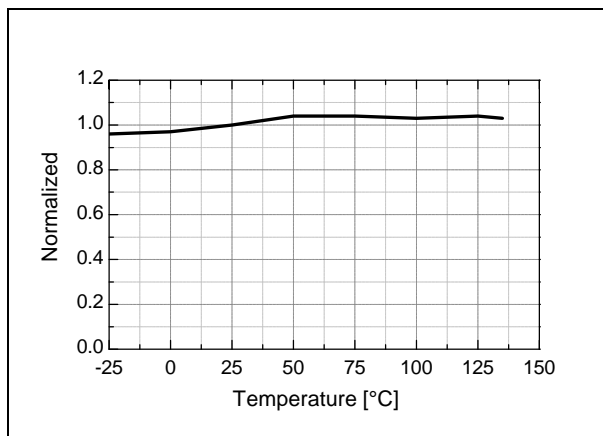


Figure 4. Operating Frequency ( $f_{OSC}$ ) vs.  $T_A$

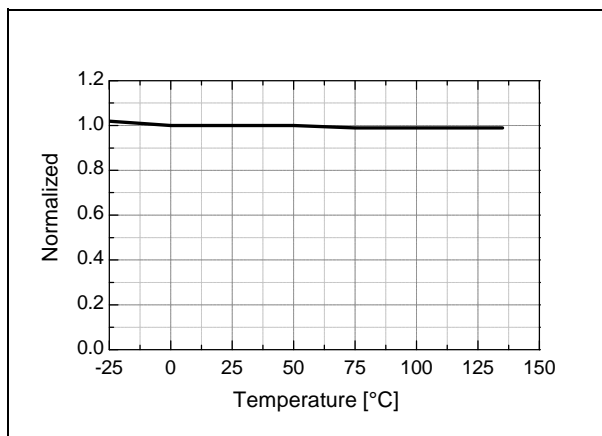


Figure 5. Over-Voltage Protection ( $V_{OVP}$ ) vs.  $T_A$

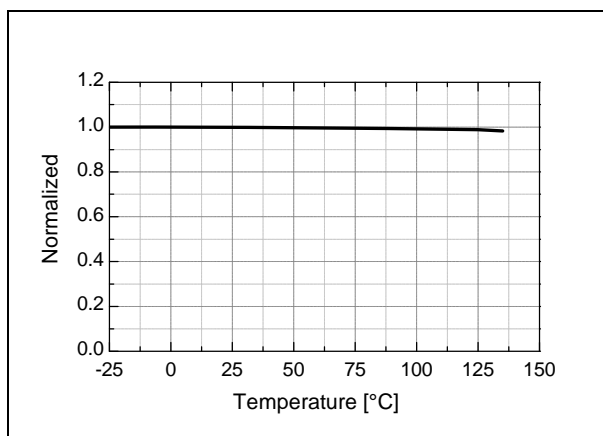


Figure 6. Maximum Duty Cycle ( $D_{MAX}$ ) vs.  $T_A$

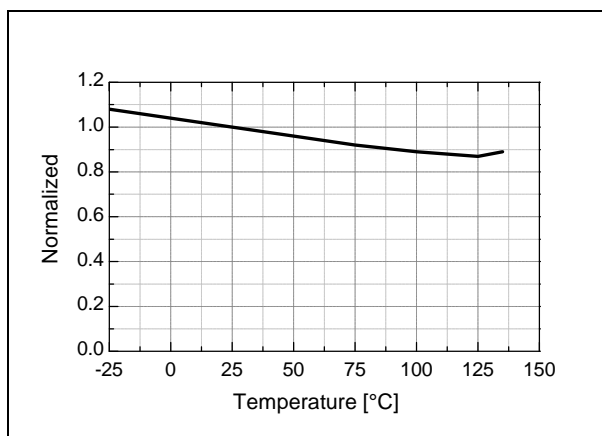


Figure 7. Operating Supply Current ( $I_{OP}$ ) vs.  $T_A$

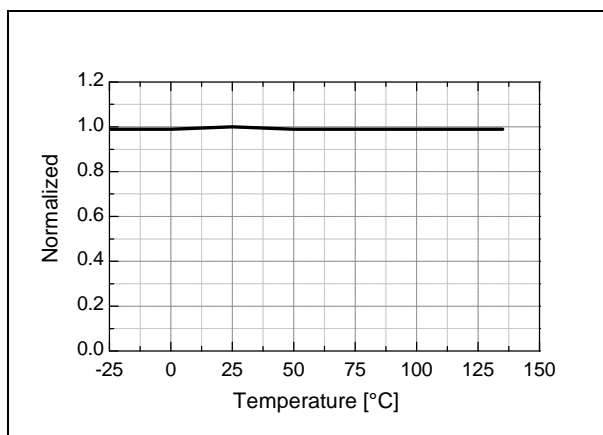


Figure 8. Start Threshold Voltage ( $V_{START}$ ) vs.  $T_A$

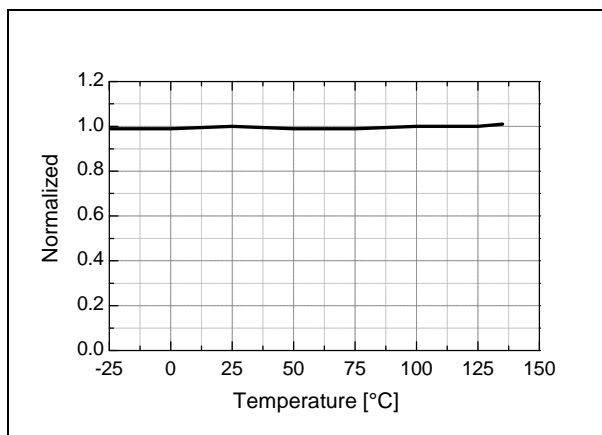


Figure 9. Stop Threshold Voltage ( $V_{STOP}$ ) vs.  $T_A$



### Typical Performance Characteristics (Continued)

These characteristic graphs are normalized at  $T_A = 25^\circ\text{C}$ .

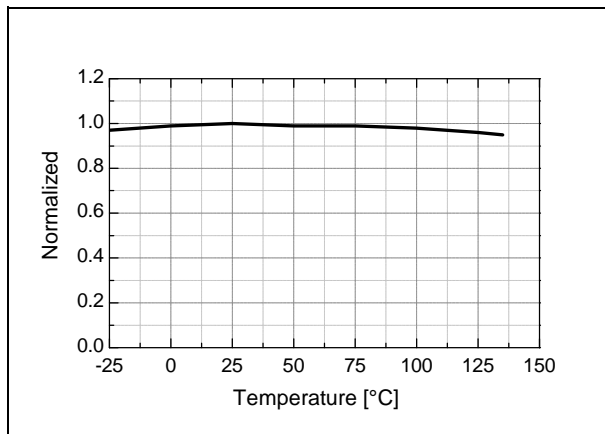


Figure 10. Feedback Source Current ( $I_{FB}$ ) vs.  $T_A$

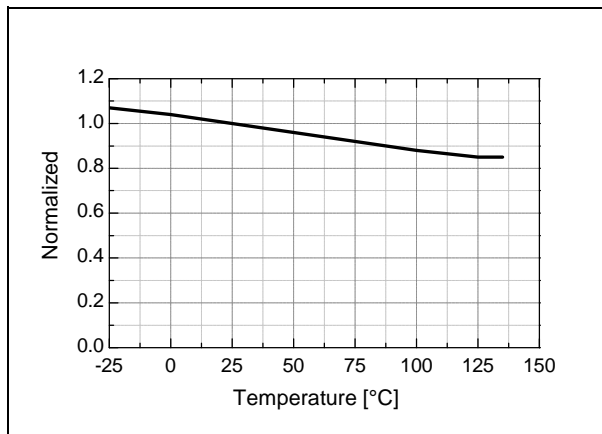


Figure 11. Startup Charging Current ( $I_{CH}$ ) vs.  $T_A$

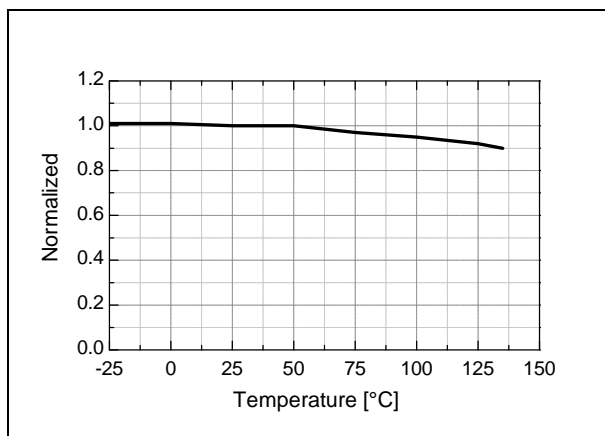


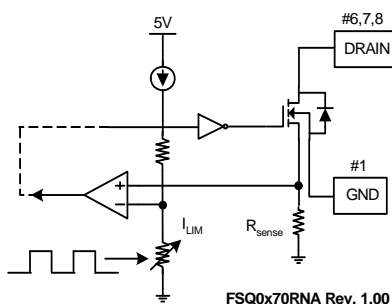
Figure 12. Peak Current Limit ( $I_{LIM}$ ) vs.  $T_A$



IC to detect the temperature of the SenseFET. When the temperature exceeds approximately 140°C, thermal shutdown is activated.

**4.3 Over-Voltage Protection (OVP):** In the event of a malfunction in the secondary-side feedback circuit, or an open feedback loop caused by a soldering defect, the current through the opto-coupler transistor becomes almost zero (see Figure 14).  $V_{FB}$  climbs up in a similar manner to the overload situation, forcing the preset maximum current to be supplied to the SMPS until the overload protection is activated. Because excess energy is provided to the output, the output voltage may exceed the rated voltage before the overload protection is activated, resulting in the breakdown of the devices in the secondary side. To prevent this situation, an Over-Voltage Protection (OVP) circuit is employed. In general,  $V_{CC}$  is proportional to the output voltage and the FPS uses  $V_{CC}$  instead of directly monitoring the output voltage. If  $V_{CC}$  exceeds 19V, the OVP circuit is activated, resulting in termination of the switching operation. To avoid undesired activation of OVP during normal operation,  $V_{CC}$  should be designed to be below 19V.

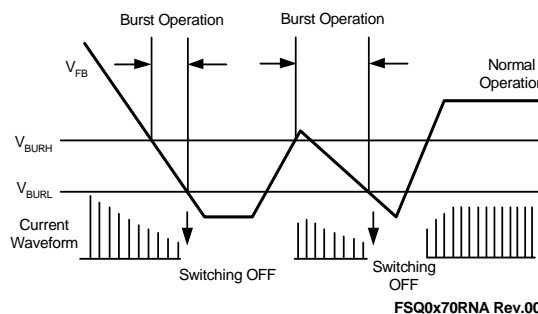
**5. Soft-Start:** The FPS has an internal soft-start circuit that slowly increases the SenseFET current after start-up, as shown in Figure 16. The typical soft-start time is 10ms, where progressive increments of the SenseFET current are allowed during the start-up phase. The pulse width to the power switching device is progressively increased to establish the correct working conditions for transformers, inductors, and capacitors. The voltage on the output capacitors is progressively increased to smoothly establish the required output voltage. This also helps prevent transformer saturation and reduces the stress on the secondary diode during startup.



**Figure 16. Soft-Start Function**

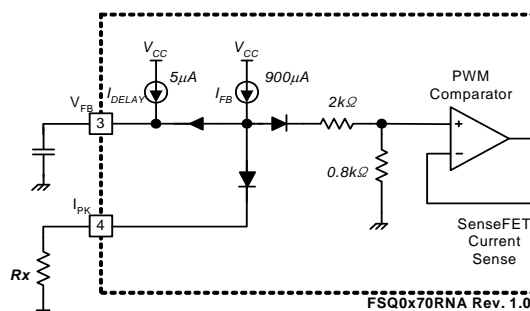
**6. Burst Operation:** To minimize power dissipation in standby mode, the FPS enters burst-mode operation. Feedback voltage decreases as the load decreases, as shown in Figure 17, and the device automatically enters burst-mode when the feedback voltage drops below  $V_{BURH}$  (typically 600mV). Switching continues until the feedback voltage drops below  $V_{BURL}$  (typically 400mV).

At this point, switching stops and the output voltage starts to drop at a rate dependent on the standby current load. This causes the feedback voltage to rise. Once it passes  $V_{BURH}$ , switching resumes. The feedback voltage then falls and the process is repeated. Burst-mode operation alternately enables and disables switching of the SenseFET and reduces switching loss in standby mode.



**Figure 17. Burst Operation Function**

**7. Adjusting Peak Current Limit:** As shown in Figure 18, a combined 2.8kΩ internal resistance is connected to the non-inverting lead on the PWM comparator. An external resistance of  $R_x$  on the current limit pin forms a parallel resistance with the 2.8kΩ when the internal diodes are biased by the main current source of 900μA.



**Figure 18. Peak Current Limit Adjustment**

For example, FSQ0270RNA has a typical SenseFET peak current limit ( $I_{LIM}$ ) of 0.9A.  $I_{LIM}$  can be adjusted to 0.6A by inserting  $R_x$  between the  $I_{PK}$  pin and the ground. The value of the  $R_x$  can be estimated by the following equations:

$$0.9A: 0.6A = 2.8k\Omega : Xk\Omega,$$

$$X = R_x \parallel 2.8k\Omega$$

where X represents the resistance of the parallel network.

## Application Information

### Methods of Reducing Audible Noise

Switching-mode power converters have electronic and magnetic components, which generate audible noise when the operating frequency is in the range of 20~20,000Hz. Even though they operate above 20KHz, they can make noise, depending on the load condition. The following sections discuss methods to reduce noise.

#### Glue or Varnish

The most common method of reducing noise involves using glue or varnish to tighten magnetic components. The motion of core, bobbin, and coil and the chattering or magnetostriction of core can cause the transformer to produce audible noise. The use of rigid glue and varnish helps reduce the transformer noise. Glue or varnish can also crack the core because sudden changes in the ambient temperature cause the core and the glue to expand or shrink in a different ratio.

#### Ceramic Capacitor

Using a film capacitor instead of a ceramic capacitor as a snubber capacitor is another noise reduction solution. Some dielectric materials show a piezoelectric effect, depending on the electric field intensity. Hence, a snubber capacitor becomes one of the most significant sources of audible noise. Another possibility is to use a Zener clamp circuit instead of an RCD snubber for higher efficiency as well as lower audible noise.

#### Adjusting Sound Frequency

Moving the fundamental frequency of noise out of the 2~4kHz range is the third method. Generally, humans are more sensitive to noise in the range of 2~4kHz. When the fundamental frequency of noise is located in this range, the noise sounds louder although the noise intensity level is identical (see Figure 19).

When the FPS acts in burst mode and the burst operation is suspected to be a source of noise, this method may be helpful. If the frequency of burst mode operation lies in the range of 2~4kHz, adjusting the feedback loop can shift the burst operation frequency. To reduce the burst operation frequency, increase a feedback gain capacitor ( $C_F$ ), opto-coupler supply resistor ( $R_D$ ); and feedback capacitor ( $C_B$ ), and decrease a feedback gain resistor ( $R_F$ ), as shown in Figure 20.

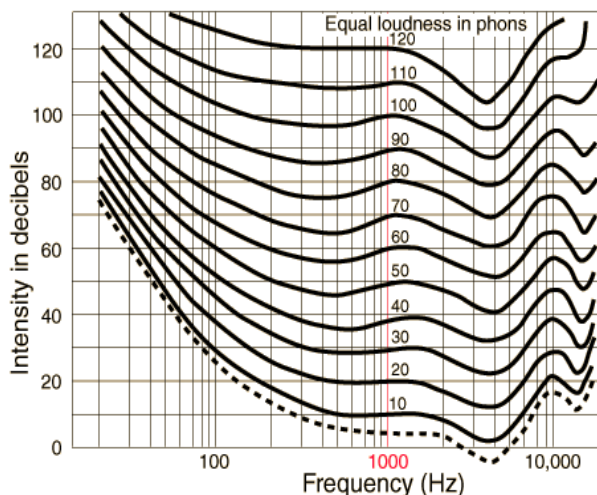


Figure 19. Equal Loudness Curves

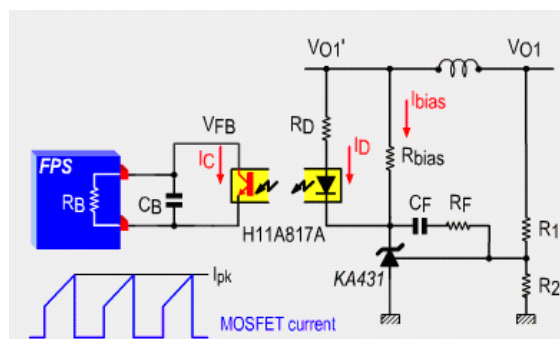


Figure 20. Typical Feedback Network of FPS

#### Other Reference Materials

AN-4134: Design Guidelines for Off-line Forward Converters Using Fairchild Power Switch (FPS™)

AN-4137: Design Guidelines for Off-line Flyback Converters Using Fairchild Power Switch (FPS™)

AN-4140: Transformer Design Consideration for Off-line Flyback Converters using Fairchild Power Switch (FPS™)

AN-4141: Troubleshooting and Design Tips for Fairchild Power Switch (FPS™) Flyback Applications

AN-4147: Design Guidelines for RCD Snubber of Flyback

AN-4148: Audible Noise Reduction Techniques for FPS™ Applications



## 2. Transformer

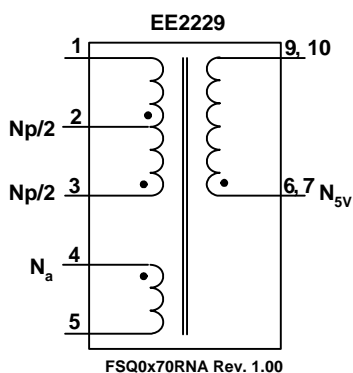


Figure 22. Transformer Schematic Diagram

## 3. Winding Specification

	Pin (S → F)	Wire	Turns	Winding Method
$N_p/2$	3 → 2	$0.3\phi \times 1$	72	Solenoid winding
Insulation: Polyester Tape $t = 0.025\text{mm}$ , 1 Layers				
$N_a$	4 → 5	$0.25\phi \times 2$	22	Solenoid winding
Insulation: Polyester Tape $t = 0.025\text{mm}$ , 2 Layers				
$N_{5V}$	6, 7 → 9, 10	$0.65\phi \times 2$	8	Solenoid winding
Insulation: Polyester Tape $t = 0.025\text{mm}$ , 2 Layers				
$N_p/2$	2 → 1	$0.3\phi \times 1$	72	Solenoid winding
Insulation: Polyester Tape $t = 0.025\text{mm}$ , 2 Layers				

## 4. Electrical Characteristics

	Pin	Specification	Remark
Inductance	1–3	$1.20\text{mH} \pm 5\%$	100kHz, 1V
Leakage	1–3	$< 30\mu\text{H}$ Max	Short all other pins

## 5. Core & Bobbin

- Core: EE2229 (Material: PL-7,  $A_e = 35.7 \text{ mm}^2$ )
- Bobbin: BE2229

## 6. Demo Circuit Part List

Part Number	Value	Quantity	Description (Manufacturer)
C6, C8	47nF	2	Ceramic Capacitor
C1	2.2nF (1KV)	1	AC Ceramic Capacitor(X1 & Y1)
C10	1nF (200V)	1	Mylar Capacitor
CS1	1.5nF (50V)	1	Ceramic Capacitor
C2, C3	22 $\mu$ F (400V)	2	Low Impedance Electrolytic Capacitor KMX series
C4, C9	1000 $\mu$ F (16V)	2	Low ESR Electrolytic Capacitor NXC series
C5	470 $\mu$ F (10V)	1	Low ESR Electrolytic Capacitor NXC series
C7	47 $\mu$ F (25V)	1	General Electrolytic Capacitor
CL9	10 $\mu$ F (50V)	1	General Electrolytic Capacitor
L1	330 $\mu$ H	1	Inductor
L2	1 $\mu$ H	1	Inductor
R6	2.4 (1W)	1	Fusible Resistor
J1, J2, J4, L3	0	4	Jumper
R2	4.7k $\Omega$	1	Resistor
R3	560 $\Omega$	1	Resistor
R4	100 $\Omega$	1	Resistor
R5	1.25k $\Omega$	1	Resistor
R11	1.2k $\Omega$	1	Resistor
R9	10k $\Omega$	1	Resistor
R10	2 $\Omega$	1	Resistor
R14	30 $\Omega$	1	Resistor
RL3	1k $\Omega$	1	Resistor
RL1, RL2	1M $\Omega$	2	Resistor
RL4	120k $\Omega$	1	Resistor
RL5	30k $\Omega$	1	Resistor
RL7	40k $\Omega$	1	Resistor
RS1	9 $\Omega$	1	Resistor
ZR1	80 $\Omega$	1	Resistor
U1	FOD817A	1	IC (Fairchild Semiconductor)
U2	TL431	1	IC (Fairchild Semiconductor)
U3	FSQ0270RNA	1	IC (Fairchild Semiconductor)
QL1	2N2907	1	IC (Fairchild Semiconductor)
QL2	2N2222	1	IC (Fairchild Semiconductor)
D2, D3, D4, D5, D6, DS1	1N4007	6	Diode (Fairchild Semiconductor)
D1	SB540	1	Schottky Diode (Fairchild Semiconductor)
ZD1	1N4745	1	Zener Diode (Fairchild Semiconductor)
DL1	1N5233	1	Zener Diode (Fairchild Semiconductor)
ZP1	82V (1W)	1	Zener Diode (Fairchild Semiconductor)
ZDS1	P6KE180A	1	TVS (Fairchild Semiconductor)

7. Layout

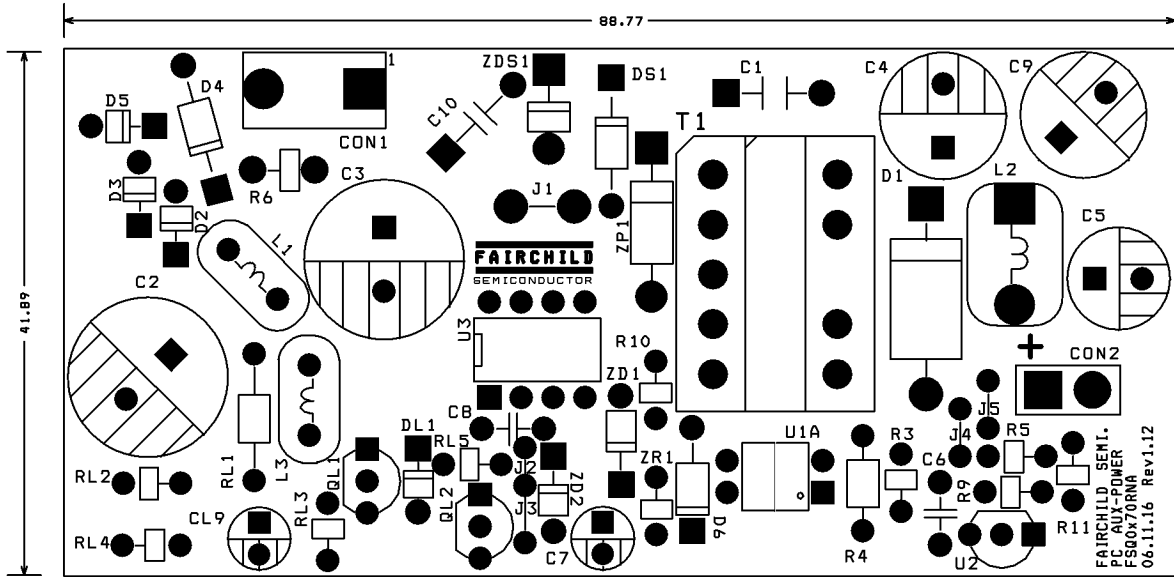


Figure 23. Top Image of PCB

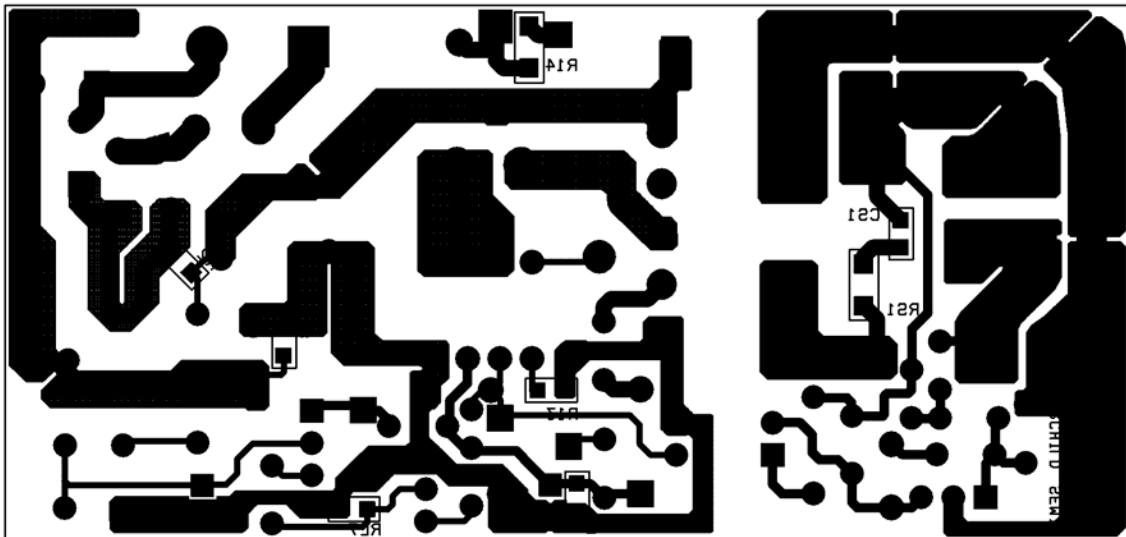
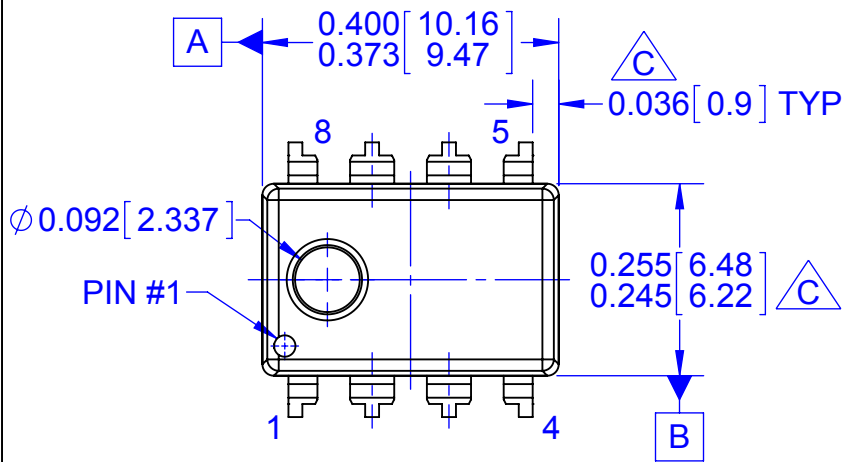
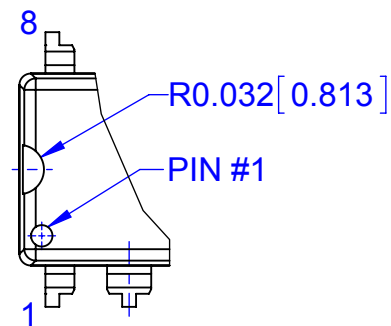


Figure 24. Bottom Image of PCB

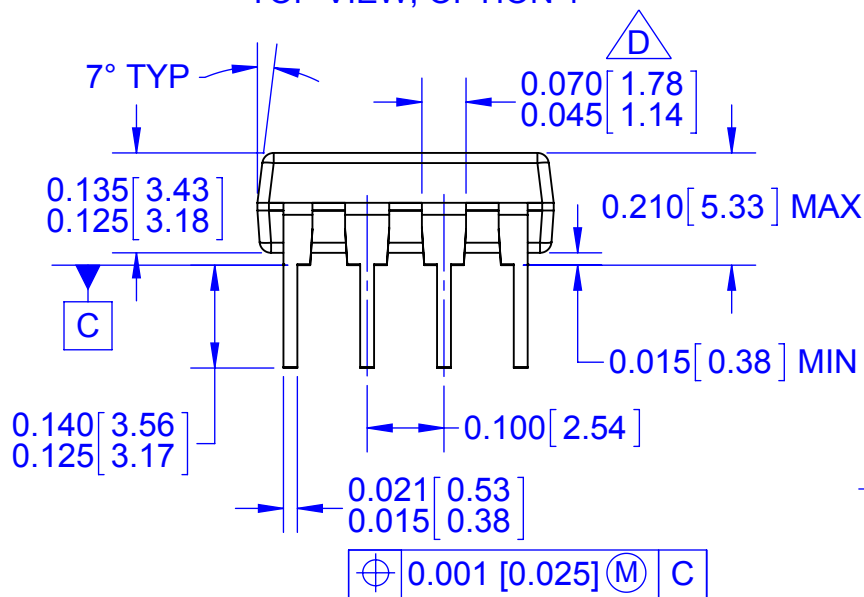




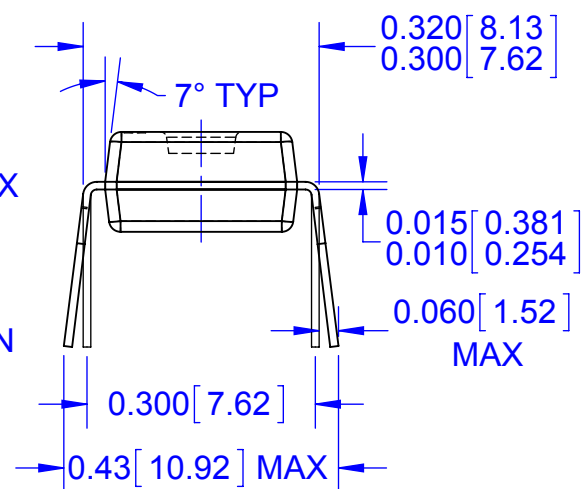
TOP VIEW, OPTION 1



TOP VIEW, OPTION 2



FRONT VIEW



SIDE VIEW

NOTES:

- A. CONFORMS TO JEDEC MS-001, VARIATION BA
- B. CONTROLLING DIMENSIONS ARE IN INCHES.  
REFERENCE DIMENSIONS ARE IN MILLIMETERS.

**C** DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED  
0.010 INCHES OR 0.25MM.

**D** DOES NOT INCLUDE DAMBAR PROTRUSIONS.  
DAMBAR PROTRUSIONS SHALL NOT EXCEED 0.010  
INCHES OR 0.25MM.

E. DIMENSIONING AND TOLERANCING PER ASME  
Y14.5M-2009

F. DRAWING FILENAME: MKT-N08Erev8



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