

FEB109-001 User's Guide 300 Watt Power Factor Corrected Supply

Featured FSC Products: ML4821

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Contents

1. General Board Description	3
1.1 Contents of the FEB109-001	3
1.2 Power Supply Specification Table	3
1.3 Theory of Operation	4
2. FEB109-001 Schematic	5
3. Test Procedure.....	6
3.1 Circuit Startup	6
3.2 Using the ML4821 Eval Board	6
3.2.1 Equipment Needed:	6
3.2.2 Procedural Steps for Testing Evaluation Board:	6
3.2.3 Starting up the Circuit.	7
3.2.4 Performance Data	7
3.2.5 Test Points.....	8
4. Test Results	8
4.1 Input Current	9
4.2 Output Voltage	10
4.3 Inductor Current	11
5. ML4821 Evaluation Kit Parts List (Continued)	13
6. Printed Circuit Board	13
6.1 Layout Considerations	13
6.2 Layout	13
7. Featured Products.....	13
7.1 ML4821 PFC Details	13
7.1.1 Description	13
7.1.2 Main Features of the ML4821	14
8. References/Resources	14
8.1 Application Notes.....	14

1. General Board Description

The ML4821 Evaluation Board is a 300 Watt power factor corrected (PFC) off-line switch mode power supply. This board provides a 385 VDC output while operating from a universal (85 to 264 VAC) input.

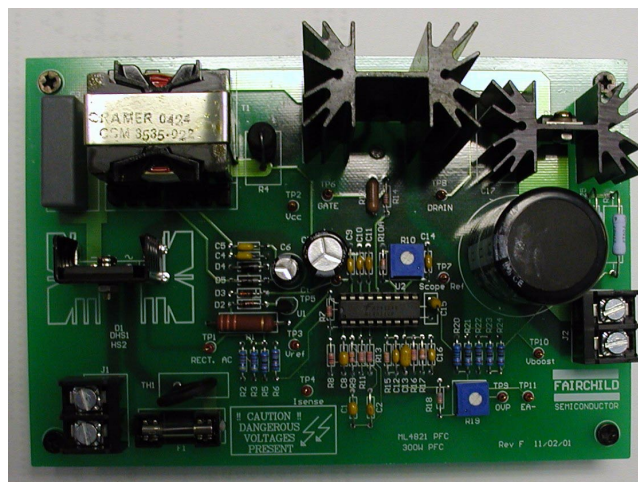
1.1 Contents of the FEB109-001

The FEB109-001 evaluation kit contains the following items:

1. FEB109-001 Evaluation Board.
2. FEB109-001 Evaluation Kit Users Guide.
3. CD ROM containing the following:
 - FEB109-001 Evaluation Kit Users Guide
 - ML4821 Data sheet.
 - GBU8J Data sheet
 - 1N4148 Data sheet
 - 1N5248B Data sheet
 - UF4003 Data sheet
 - UF4005 Data sheet
 - ISL9R860P2 Data sheet
 - HGTP7N60A4 Data sheet
 - KA78L15A Data sheet
 - Application Note AN-42030 Theory and Application of the ML4821 Average Current Mode PFC Controller
 - Application Note AN-42047 Power Factor Correction (PFC) Basics

1.2 Power Supply Specification Table

	85VAC	120VAC	230VAC	264VAC
VOUT	390	390	389	389
Efficiency	86.5%	89.9%	91.2%	93.2%
T.H.D. (A)	3.6%	4.2%	9.3%	10.4%
P.F.	0.998	0.997	0.989	0.987



CAUTION!

The ML4821 Evaluation Board employs high voltages and currents capable of causing injury or death. Some components may shatter or explode if they fail. Appropriate precautions must be taken to prevent injury should such situations occur. The use of protective eyewear is strongly encouraged.

To safely observe circuit waveforms, an isolation transformer should be used between the Evaluation Board and the AC line.

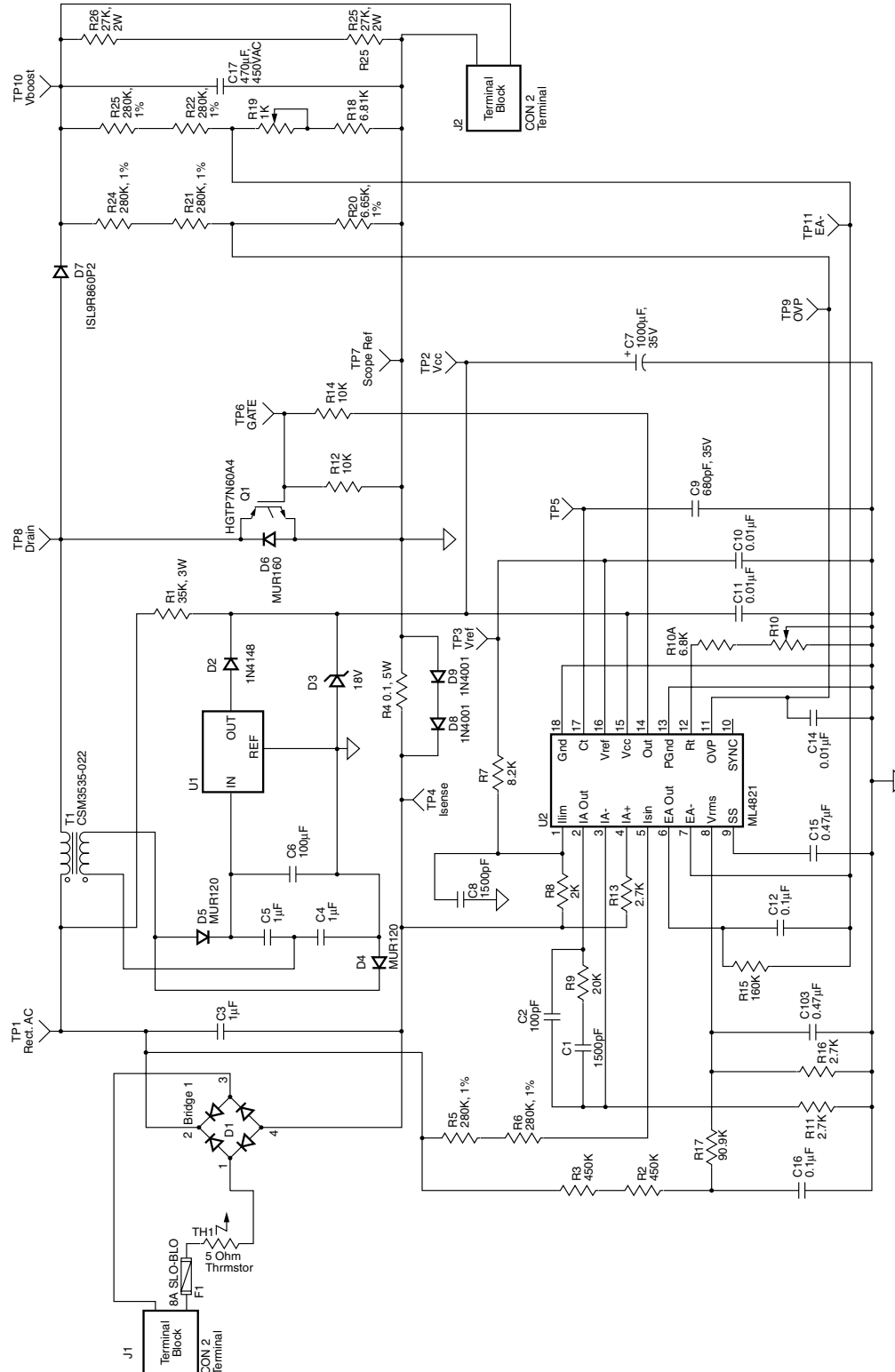
Do Not operate this board outside the design limits (input 85–264VAC, output <300W).

Replace circuit components only with those recommended in the parts list of this User's Guide.

1.3 Theory of Operation

The complete theory of operation of the ML4821 is detailed in Application Note AN42030. Stated briefly, the ML4821 Evaluation Board is a continuous conduction, boost-type PFC using average current control. The input current is forced to be sinusoidal and in phase with the input voltage. In this way it presents an almost pure resistive load to the input line. This is accomplished by sampling the input voltage, converting it to a current, and using this current to modulate the conduction cycle of the boost circuit.

2. FEB109-001 Schematic



3. Test Procedure

3.1 Circuit Startup

During initial startup AC power is applied to the inputs. Current is delivered to charge C7 through TH1 from the rectified line voltage. When the voltage across C7 reaches the IC starting threshold (approximately 16V) the ML4821 will start. Operating power is generated by the auxiliary winding on inductor T1, rectified, and then regulated to supply the IC with approximately 14V.

3.2 Using the ML4821 Eval Board

To safely evaluate the ML4821 Evaluation Board a certain procedure must be followed. A list of the equipment needed and the procedural steps is given here. It is strongly recommended that these steps be followed precisely to help ensure the safety of the user.

Note: This Evaluation Board is sent from Fairchild Semiconductor pre-tested.

3.2.1 Equipment Needed:

- a. Variable autotransformer of at least 1 kVA rating.
- b. Isolation transformer of at least 1 kVA rating
- c. Oscilloscope (BW \geq 20MHz, 2 or more channels)
- d. Digital Multimeter(s) (e.g., Fluke 8050A) capable of reading each of the following:
 1. 410 Volts DC.
 2. 30 Volts DC.
 3. 300 Volts RMS AC.
- e. Bench power supplies that can provide the following:
 1. 410 Volts DC.
 2. 17 Volts, 100 mA
 3. 0-5 Volts, 100 mA
- f. AC Power Analyzer (e.g., Voltech PM1000)

The board, as shipped, is configured to provide a 385 VDC output.

3.2.2 Procedural Steps for Testing Evaluation Board:

1. Set up in a work area clear of obstructive materials.
2. Connect an isolation transformer to the input of a variable autotransformer, such as a Variac. For testing universal input conditions use a 0 to 240 Volt output autotransformer with a 1:1 isolation transformer as shown in Figure 1.

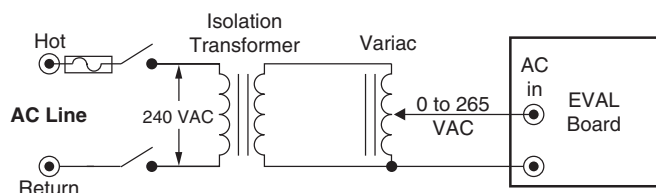


Figure 1. Variable Isolated AC Supply

Do not operate with an input voltage that is outside of the design specifications (85 to 264 VAC).

3. Connect an AC power analyzer to the input.
4. Ensure that there is no voltage at the output of the isolation transformer.
5. Connect a DC voltmeter across the output terminal block (J2) on the board. Make sure that the meter can safely read 410 volts without damage.
6. Connect the autotransformer to the Evaluation Board in the following manner:
 - a. Autotransformer AC Out “L” to the fused AC input terminal (J1).
 - b. Autotransformer AC Out “N” to the other AC input terminal (J1).

3.2.3 Starting up the Circuit.

7. With the input leads attached and a voltage meter on the output slowly increase the Evaluation Board input voltage to at least 85 VRMS (Do not exceed 264 VAC!).
8. The unloaded output voltage for a 385 V bus should be approximately 410 V.
9. Disconnect power to the input of the board.
10. Connect a 475 ohm load of appropriate wattage to the output. **Use caution as a residual charge may still be present on the output for several seconds. If possible discharge the output with a suitable resistor.**
11. Reconnect the input power. The bus voltage should be 385 VDC \pm 10 Volts across the full input voltage range.

3.2.4 Performance Data

Using an adjustable AC source similar to the source described in Test Procedure step 2 (Figure 1) allows measurement of the Evaluation Board's performance across the full input voltage range.

Under the specified test conditions, the performance results listed here typify what can be expected of the ML4821 evaluation board.

Table 2. ML4821 EVAL Board Test Results

	85VAC	120VAC	230VAC	264VAC
Vout (DC)	390VDC	390VDC	389VDC	389VDC
Efficiency	86.5%	89.9%	91.2%	93.2%
T.H.D. (A)	3.6%	4.2%	9.3%	10.4%
P.F.	0.998	0.997	0.989	0.987

Test Conditions: Load: 500 Ω (300W continuous output power) on 390 Volt output

Equipment: Voltech PM100 AC Power Analyzer for AC source measurements; Fluke 8050A for output current and voltage measurements.

3.2.5 Test Points

The ML4821 evaluation board includes test points to provide easier access to areas of interest for determining circuit performance. The test points, as labeled on the evaluation board are:

TP1	Rectified AC
TP2	V _{cc}
TP3	V _{ref}
TP4	I _{sense}
TP5	Oscillator Ramp
TP6	IGBT Gate
TP7	Scope Ref. (GND)
TP8	IGBT Drain
TP9	OVP
TP10	V _{boost} (PFC output)
TP11	EA – (Feedback Error Amp)

Use caution around TP1, TP8 and TP10 as they are exposed high voltage.

4. Test Results

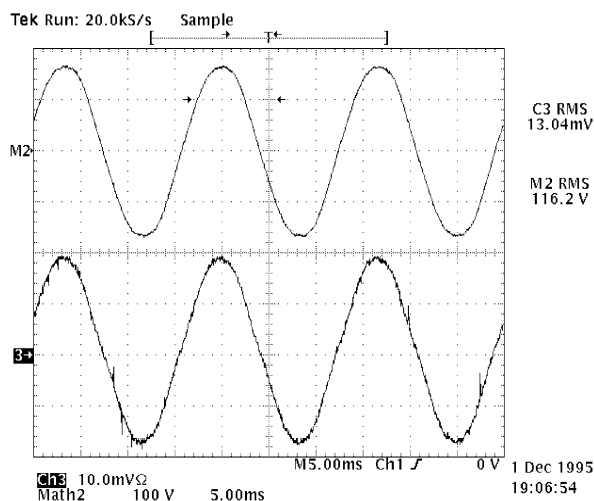
When evaluating a functional ML4821 Evaluation Board, there are several waveforms that are valuable to the user. These waveforms are described herein and an example of each shown in a figure following. All the equipment used to capture these waveforms is listed here.

1. Tektronix TDS-640A Digital Storage Oscilloscope
2. Tektronix A6302/AM503 Current Probe Amplifier Assembly
3. Voltech PM1000 AC Power Analyzer
4. Fluke 8050A Digital Multimeter
5. Kikusui PLZ-152WA Electronic Load

4.1 Input Current

The function of a PFC is to force the line input current to follow the phase of the line input voltage. This presents the input with an equivalent resistive load, causing the line input current to be sinusoidal. Such a sinusoidal input current reduces the harmonics normally generated by powering a reactive load.

Figure 2 illustrates the phase correlation between the input line current (bottom trace) and the input line voltage (top trace).



**Figure 2. Input Current and Voltage Waveform
(120 VRMS Input, 300W Output)**

Scope Settings: Horiz = 5 ms/div
CH1 = 2A/div
CH2 = 100V/div

Test Conditions: Output Load 305 Watts

4.2 Output Voltage

The output of the evaluation board is a DC voltage. The set configuration for this board is 385 V. Figure 3 shows the typical output voltage (upper trace, CH1), the detail of the 120 Hz output ripple (middle trace, CH2), and the line input current (lower trace, CH3).

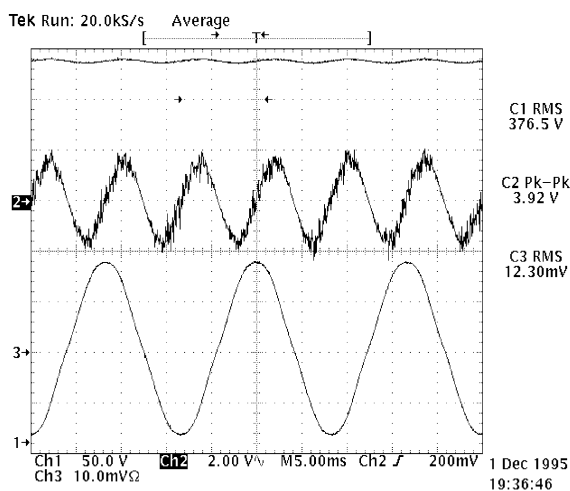


Figure 3. Output Bus Voltage, Output Ripple

Scope Settings: Horiz = 2.50 ms/div
CH1 = 100 V/div
CH2 = 2 V/div
CH3 = 2 A/div

4.3 Inductor Current

The current through the inductor is comprised of the rectified sinusoidal current with the ripple current superimposed on it. The top trace of Figure 4 demonstrates the expanded view of the ripple current, zoomed in 200 times. The ripple current is a function of the PWM boost control. The rising ramp is a result of the current conducted through the IGBT. The falling ramp occurs as the de-energizing inductor forces current to the boost capacitor and load.

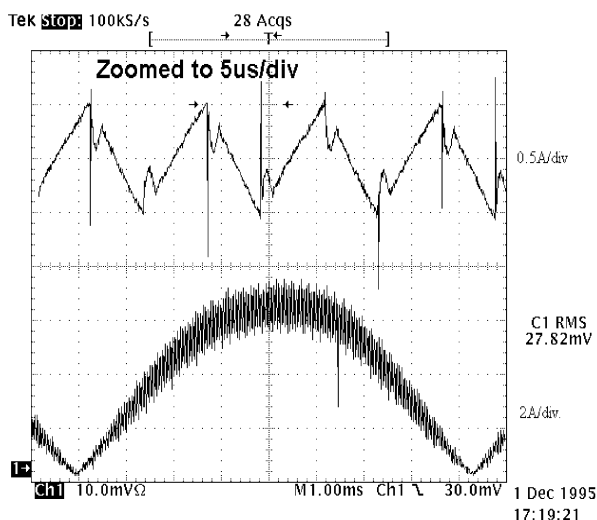


Figure 4. Inductor Current

Vin = 85VAC

Scope Settings: Upper Trace: Horiz. = 0.5 A/div
Vert. = 5 μs/div

Lower Trace: Horiz. = 2 A/div
Vert. = 1 ms/div

5. ML4821 Evaluation Kit Parts List

Item	Qty	Description	Mfg/Part Number	Vendor/ Part Number	Designator
Resistors					
1	1	33k Ω , 5%, 3W, metal oxide film	Panasonic	Digi-Key / P33KW3BK-ND	R1
2	2	453k Ω , 1%, 1/4W, metal film	Any		R2, R3
3	1	0.15 Ω , 5%, 5W	Ohmite	Digi-Key / 15FR150-ND	R4
4	6	280k Ω , 1%, 1/4W, metal film	Any		R5, R6, R21, R22, R23, R24
5	1	8.2k Ω , 5%, 1/4W, carbon film	Any		R7
6	1	2.0k Ω , 5%, 1/4W, carbon film	Any		R8
7	1	20k Ω , 5%, 1/4W, carbon film	Any		R9
8	1	10k Ω , 10%, 1/4W, potentiometer	Bourns / 3386F-1-103	Bourns / 3386F-1-103	R10
9	1	6.8k Ω , 5%, 1/4W, carbon film	Any		R10A
10	2	2.7k Ω , 5%, 2W, carbon film	Any		R11, R13
11	1	10k Ω , 1%, 1/4W, metal film	Any		R12
12	1	10 Ω , 5%, 1/4W, carbon film	Any		R14
13	1	160k Ω , 5%, 1/4W, carbon film	Any		R15
14	1	27k Ω , 5%, 1/4W, carbon film	Any		R16
15	1	91k Ω , 5%, 1/4W, carbon film	Any		R17
16	1	6.8k Ω , 5%, 1/4W, carbon film	Any		R18
17	1	1k Ω , 10%, 1/4W, Potentiometer	Bourns / 3386F-1-102	Bourns / 3386F-1-102	R19
18	1	6.65k Ω , 1%, 1/4W, metal film	Any		R20
19	2	27k Ω , 10%, 2W, metal oxide	Panasonic	Digi-Key / P27KW-2BK-ND	R25, R26
20	1	5.0 Ω , thermistor, 5ARMS	Panasonic / KC004L		TH1
21	1	68 Ω , 5%, 1/4W, Carbon Film	Any		R27
Capacitors					
22	2	1500pF, 10%, 25V, ceramic	Any		C1, C8
23	1	100pF, 10%, 25V, ceramic	Any		C2
24	1	0.68 μ F, 275VRMS, X-2	Illinois Cap / 684MKP275K		C3
25	2	0.1 μ F, 20%, 25V, ceramic	Any		C12, C16
26	1	100 μ F, 20%, 50V, electrolytic	Panasonic / ECA-1HM101B	Digi-Key / P10397TB-ND	C6
27	1	1000 μ F, 20%, 25V, electrolytic	Panasonic / ECA-1EM471B	Digi-Key / P10387TB-ND	C7
28	1	680pF, 5%, 25V, NPO ceramic	Panasonic / ECU-S1H681JCB	Digi-Key / P4935-ND	C9
29	3	0.01 μ F, 20%, 25V, ceramic	Any		C10, C11, C14
30	2	0.47 μ F, 10%, 25V, ceramic	Any		C13, C15
31	1	470 μ F, 20%, 450V, electrolytic	Panasonic / ECO-S2WP471EX	Digi-Key / P7441-ND	C17
32	2	1.0 μ F, 20%, 25V, Ceramic	AVX	SA305E105ZAA	C4, C5
Diodes					
33	1	Bridge Rectifier, 600V, 8A	Fairchild / GBUJ8		D1
34	1	Diode Zener, 18V, 0.5W	Fairchild / 1N5248B		D3

5. ML4821 Evaluation Kit Parts List (Continued)

Item	Qty	Description	Mfg/Part Number	Vendor/ Part Number	Designator
35	2	Diode Ultra Fast, 200V, 1A, 75nsec	Fairchild / UF4003		D4, D5
36	1	Diode Ultra Fast, 600V, 1A, 75nsec	Fairchild / UF4005		D6
37	1	Diode Hyper Fast, 600V, 8A, 20nsec	Fairchild / ISL9R860P2		D7
38	2	Diode Rectifier, 50V, 1A	Fairchild / 1N4001		D8, D9
39	1	Diode Rectifier, 600V, 3A	Fairchild / 1N5406		D10
ICs					
40	1	Power Factor Controller	Fairchild / ML4821CP		U2
Transistors					
41	1	IGBT, 8A, 600V	Fairchild / HGTP7N60A4		Q1
Magnetics					
42	1	1.2mH Boost Inductor	Cramer Coil / CSM3535-022		T1
Fuses					
43	1	8A, Slo-Blo, 250VAC 5 x 20mm	Littlefuse / 19195 series		F1
44	1	Fuse Holder, 5 x 20mm	Keystone / 4527CK	Digi-Key / 4527CK-ND	
Hardware					
45	1	18 pin IC socket	Any		U2 ref
46	1	Single TO-220 Heatsink	Aavid / 529702B02500		Q1 ref
47	1	Single TO-220 Heatsink	Aavid / 593002B03400		D1 ref
48	1	Single TO-220 Heatsink	Thermshield / TS-54039-AD-2.5"		D7 ref
49	2	Heatsink Thermal Insulator	Thermalloy / 53-77-2		D7, Q1 ref
50	2	Insulating shoulder washer for TO-220	Thermalloy / 7721-7PPS		D7, Q1 ref
51	2	Terminal Block – 2 contact	Tyco / 3-1437652-5		J1, J2
52	4	Standoff , 6-32, 0.25" x 0.75	Waldom, Any		S1–S4
53	11	.025" square contact post	3M, Any		TP1–T11
54	6	6-32 x 0.25" Screw	Any		S1–S4, D7, Q1 ref
55	2	6-32 lock washer	Any		D7, Q1 ref

Note: Unless specifically noted, all manufacturers and part numbers are suggested and given for reference. Similar parts from other manufacturers may be substituted.

6. Printed Circuit Board

6.1 Layout Considerations

The ML4821 Evaluation Board contains both high impedance/low level and low impedance/high level circuits. Because of this, careful attention must be used for component placement, grounding, and PC trace routing. The ML4821 uses a ground plane with power components (Q1, C17, R4) placed so as not to interfere with the sensitive control areas of the circuit.

When laying out printed circuit boards for off-line power supplies various precautions must be observed to ensure low noise, trouble-free operation. The following list specifies some of the most important items to keep in mind when laying out boards using the ML4821.

1. Return the low side of the timing capacitor (C9) directly to the IC ground pin. If using a ground plane place the low side of the capacitor as close as possible to the ground pin and free from obstruction.
2. Bypass the reference and supply voltage pins directly to the IC ground pin with a 0.01 μ F, or greater, low ESR (e.g. ceramic or film) capacitor. Ground plane rules apply.
3. Make a direct, low resistance connection from the IC ground to the PFC current sense resistor (R4).
4. Return all appropriate compensation components directly to the IC ground pin. Keep compensation component lead lengths as short as possible.
5. Use a ground plane (if permissible) for all ground connection points. Whether using a ground plane or a single point ground layout, use heavy traces to the sense resistor (R4), the source of Q1, and boost capacitor C17.
6. Separate rapidly changing waveforms, such as Q1's drain, from sensitive, high impedance circuits, such as the timing capacitor, PFC current sense input, error amplifier input, etc.
7. Much of this board uses voltages as high as 265 VAC and 385 VDC. Use proper PC board trace spacing, augmented as necessary by non-conductive coatings (e.g., solder mask).

6.2 Layout

7. Featured Products

7.1 ML4821 PFC Details

7.1.1 Description

The ML4821 provides complete control for a "boost" type power factor correction system using the average current sensing method. Special care has been taken in the design of the ML4821 to increase system noise immunity. The circuit includes a precision reference, gain modulator, average current error amplifier, output error amplifier, over-voltage protection comparator, shutdown logic, as well as a high current output. In addition, start-up is simplified by an under-voltage lockout circuit.

In a typical application, the ML4821 controls the AC input current by adjusting the pulse width of the output MOSFET. This modulates the line current so that its shape conforms to the shape of the input voltage. The reference for the current regulator is a product of the sinusoidal line voltage times the output of the error amplifier which is regulating the output DC voltage. Average line voltage compensation is provided in the gain modulator to ensure constant loop gain over a wide input voltage range. This compensation includes a special "brown-out" control which reduces output power below 90V RMS input.

7.1.2 Main Features of the ML4821

- Average current sensing for lowest possible harmonic distortion
- Average line compensation with brown-out control
- Precision buffered 5V reference
- 1A peak current totem-pole output drive
- Overvoltage comparator eliminates output "runaway" due to load removal
- Wide common mode range in current sense comparators for better noise immunity
- Large oscillator amplitude for better noise immunity
- Output driver internally limited to 17V
- "Sleep mode" shutdown input

8. References/Resources

8.1 Application Notes

- Application Note AN-42030 Theory and Application of the ML4821 Average Current Mode PFC Controller
- Application Note AN-42047 Power Factor Correction (PFC) Basics

WARNING AND DISCLAIMER

Replace components on the Evaluation Board only with those parts shown on the parts list in the User's Guide. Contact an authorized Fairchild representative with any questions.

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