FEB111-001 User's Guide
PWM and PFC Combo 100W Evaluation Board

Featured Fairchild Product: ML4824

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Contents

1. General Board Description

The FEB111-001 Evaluation Board is a power factor corrected, 100 Watt, off-line switching power supply with a single output of +12 VDC. The supply operates over the universal input range of 85 VAC to 265 VAC.

The ML4824 is a combination ("Combo") power supply controller IC which consists of a PFC input stage and a PWM output stage. The PFC "front end" is of the average-current, continuous-conduction type. The PWM section allows the construction of either a current- or voltage-mode regulator as the power supply's "back end." The Evaluation Board uses a two-switch, current-mode forward converter following the power factor corrector to produce its 12V output. Both stages operate at 100 kHz, using Fairchild's patented leading/trailing edge modulation technique.

1.1 Contents of FEB111-001 Evaluation Kit

1. FEB111-001 evaluation board
2. FEB111-001 evaluation board users guide
3. CD ROM containing the following datasheets and applications notes
   - FEB111-001 evaluation board users guide
   - ML4824 Data Sheet.
   - Additional Fairchild data sheets for parts listed on the Bill of Materials
   - AN-42009 - ML4824 Combo Controller Applications
   - AN-42045 - ML4824, A Novel Method for an Off-Line PFC-PWM Combo Controller
   - AN-42034 - Synchronizing the ML4824 to Wide Frequency Ranges
   - AN-42030 - Theory and Application of the ML4821 Average Current Mode PFC Controller

1.2 Power Supply Specification Table

Parameter	Min	Typ	Max	Units
V_{IN}	85		265	V_{AC}
V_{OUT}		12.09		V_{DC}
I_{LIMIT}		10.50		A_{DC}
Efficiency		83		%
T.H.D.	83	8.5		% I_{AC}
P.F.		.996		

Conditions – V_{IN} = 120V, I_{LOAD} = 8.83A

1.3 Schematic

2. Test Procedure

2.1 Theory of Operation

For a complete theory of operation refer to Application Notes AN-42009 and AN-42045. In a departure from the example given in AN-42009, the voltage loop bandwidth of the PFC "front end" has been set to approximately 15 Hz. This allows the use of a smaller boost capacitor (C5) while maintaining good values for power factor and harmonic distortion at low line frequencies (*e.g.*, 47 Hz).

2.2 Test Driving the ML4824 Evaluation Board:

The following steps will demonstrate the functionality of the FEB111-001 Evaluation Board, and allow the measurement of its Power Factor (P.F.) and Total Harmonic Distortion (T.H.D.) under various conditions of AC input voltage and DC output loading:

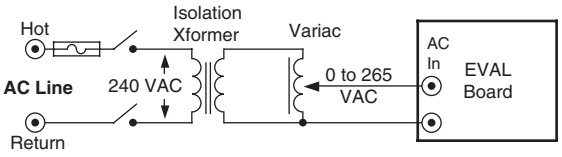


Figure 1

1. Connect a variable autotransformer (such as a Variac) to the output of an isolation transformer, and to the input of the ML4824EVAL Board. Both transformers should be rated for 500 VA or greater, and in combination should be rated for an output voltage range of 0 VAC to approximately 265 VAC. The connections should be made as in Figure 1, with the Isolation Transformer NOT plugged into the AC line until step 5, below.
2. Ensure that the variable autotransformer is set to "zero output."
3. Connect an AC Voltmeter across the Evaluation Board's AC Input terminals. Set the meter range to 300 VAC or greater.
4. Connect a DC Voltmeter between the Evaluation Board's DC output terminals (+12V Out and +12V Return). Set the meter range to 15 VDC or greater.
5. Connect the input of the isolation transformer to the AC power line.
6. Slowly increase the AC input voltage to at least 85 VAC (**DO NOT exceed 265 VAC).**
7. The unloaded output voltage of the ML4824 Evaluation Board should be between 11.4V and 12.6V (12V (5%).
8. Connect an 8.33 amp load across the Evaluation Board's +12 VDC output terminals. The fully-loaded (100W) output should remain between 11.4V and 12.6V while the line voltage is varied over the range of 85 VAC to 265 VAC.
9. With V_{IN} = 120 VAC, increase the current loading on the output until the foldback current limit circuit trips. This should occur at a load current of approximately 10.5 Amperes.
10. Turn the input voltage down to zero volts. Remove the load on the output. Bring the input voltage back to 120 VAC. Verify that the overcurrent condition has been "cleared," and that the output of the ML4824 Evaluation Board is again at +12 VDC (5% for any load between 0 Amperes and 8.33 Amperes DC.
11. Disconnect the isolation transformer from the power line. Wait at least three (3) minutes for high voltages stored on the board to bleed down.
12. Connect an AC Power Analyzer (a Power Factor Meter) between the output of the variable autotransformer and the AC input to the Evaluation Board, in accordance with the manufacturer's instructions. **Follow these instructions carefully!** Failure to do so can result in erroneous readings, equipment damage, or personal injury. (Note: Different AC Power Analyzers/Power Factor Meters may give different results on the same PFC board. We have had good results with the DSP-based Voltech series of AC Power Analyzers, including the Model PM1000).
13. Connect the isolation transformer to the power line. Slowly raise the voltage at the output of the variable autotransformer until the input to the Evaluation Board is between 85 VAC and 265 VAC.

Operation of the FEB111-001 Evaluation Board may now be evaluated over the full input voltage range. If a variable load is used, operation may also be tested over the full output current range (0 ADC (I_{LOAD} (8.33 ADC).

3. Performance Data

A typical FEB111-001 Evaluation Board will have the following performance characteristics:

VAC	85	120	265	Units
VOUT	12.09	12.09	12.09	VDC
ILIMIT	10.32	10.50	9.92	ADC
Efficiency	81	83	84	%
T.H.D.	6.0	8.5	9.5	% IAC
P.F.	0.997	0.996	0.998	

Test Conditions: I_{LOAD} = 8.33 ADC, T_A = 25°C

Equipment: Voltech PM1000 AC Power Analyzer
Kikusui PLZ152WA Electronic Load
Fluke Model 8050A DMM

3.1 Typical Waveforms

The FEB111-001 Evaluation Board functions as a continuous-current, average-mode (CCAM) PFC followed by a synchronized PWM (DC/DC converter) stage. This is augmented by the leading/trailing edge modulation used in the ML4824. For more information on CCAM power factor correction and its resulting waveforms, please refer to AN-42030 (while AN-42030 specifically covers the ML4821 PFC IC, the ML4821 and the PFC stages of the ML4824 are very similar in concept and performance).

4. Parts List

4.1 ML4824 Evaluation Kit (Rev. B) Parts List

Item	Qty	Ref	Description	Vendor	Part #
Resistors					
1	2	R1A, 1B	499K, 1%, 0.25W, Metal Film, Thru Hole	Any	
2	2	R2A, 2B	453K, 1%, 0.25W, Metal Film, Thru Hole	Any	
3	1	R3	75K, 1%, 1206 - Surf Mnt.	Any	
4	1	R4	13K, 1%, 1206 - Surf Mnt.	Any	
5	4	R5A, 5B, 5C, 5D	1.2 Ohm, 5%, 0.25W, Thru Hole	Any	
6	1	R6	41.2K, 1%, 1206 - Surf Mnt.	Any	
7	2	R7A, 7B	178K, 1%, 0.25W, Metal Film, Thru Hole	Any	
8	1	R8	2.37K, 1%, 1206 - Surf Mnt.	Any	
9	1	R9	1K, 5%, 1206 - Surf Mnt.	Any	
10	1	R10	6.2K, 5%, 1206 - Surf Mnt.	Any	
11	1	R11	750K, 5%, 1206 - Surf Mnt.	Any	
12	1	R12	27K, 5%, 1206 - Surf Mnt.	Any	

4.1 ML4824 Evaluation Kit (Rev. B) Parts List

Item	Qty	Ref	Description	Vendor	Part #
13	2	R13, 16	10K, 5%, 1206 - Surf Mnt.	Any	
14	2	R14, 17	33 Ohm, 5%, 1206 - Surf Mnt.	Any	
15	1	R15	3 Ohm, 5%, 1206 - Surf Mnt.	Any	
16	1	R18	220 Ohm, 10%, 1W, Thru Hole	Any	
17	1	R19	220 Ohm, 5%, 1206 - Surf Mnt.	Any	
18	2	R20A, R20B	2.2 Ohm, 5%, 0.25W, Thru Hole	Any	
19	1	R21	22 Ohm, 5%, 1206 - Surf Mnt.	Any	
20	1	R22	8.66K, 1%, 1206 - Surf Mnt.	Any	
21	1	R23	1.5K, 5%, 1206 - Surf Mnt.	Any	
22	1	R24	1.21K, 1%, 1206 - Surf Mnt.	Any	
23	1	R25	2.26K, 1%, 1206 - Surf Mnt.	Any	
24	1	R26	10 Ohm, 5%, 1206 - Surf Mnt.	Any	
25	1	R27	22K, 10%, 2W, Thru Hole	Any	
26	1	R28	240 Ohm, 5%, 0.5W, Thru Hole	Any	
27	1	R30	4.7k, 5%, 1206 - Surf Mnt.	Any	
Capacitors					
28	1	C1	0.68uF , 275VRMS, X-2 Rated, Thru Hole	Illinois Capacitor Mallory NTE Panasonic	684MKP275K 158X684 MLR684K630 ECQ-U2A684MV
29	1	C2	0.47µF , 25VDC, Z5U, 1206 - Surf Mnt.	Any	
30	4	C3, 13, 23, 25	0.1µF , 50VDC, Z5U, 1206 - Surf Mnt.	Any	
31	1	C4	0.01µF , 1000VDC, Ceramic, Radial, 0.4" spacing	Any	
32	1	C5	100µF, 20%, 400VDC, Electrolytic, Radial	Nichicon Panasonic	LGQ2G151MHSA ECO-S2GA101BA
33	2	C6, C31	1000pF, 10%, 25VDC, X7R, 1206 - Surf Mnt.	Any	
34	1	C7	220pF, 10%, 25VDC, X7R, 1206 - Surf Mnt.	Any	
35	1	C8	82nF, 10%, 25VDC, X7R, 1206 - Surf Mnt.	Any	
36	1	C9	8.2nF, 10%, 25VDC, X7R, 1206 - Surf Mnt.	Any	
37	1	C10	15µF, 20%, 10VDC, Tantalum, C case-Surf Mnt.	AVX	TAJC156M010
38	2	C11,15	0.01µF , 25VDC, Z5U, 1206 - Surf Mnt.	Any	

4.1 ML4824 Evaluation Kit (Rev. B) Parts List

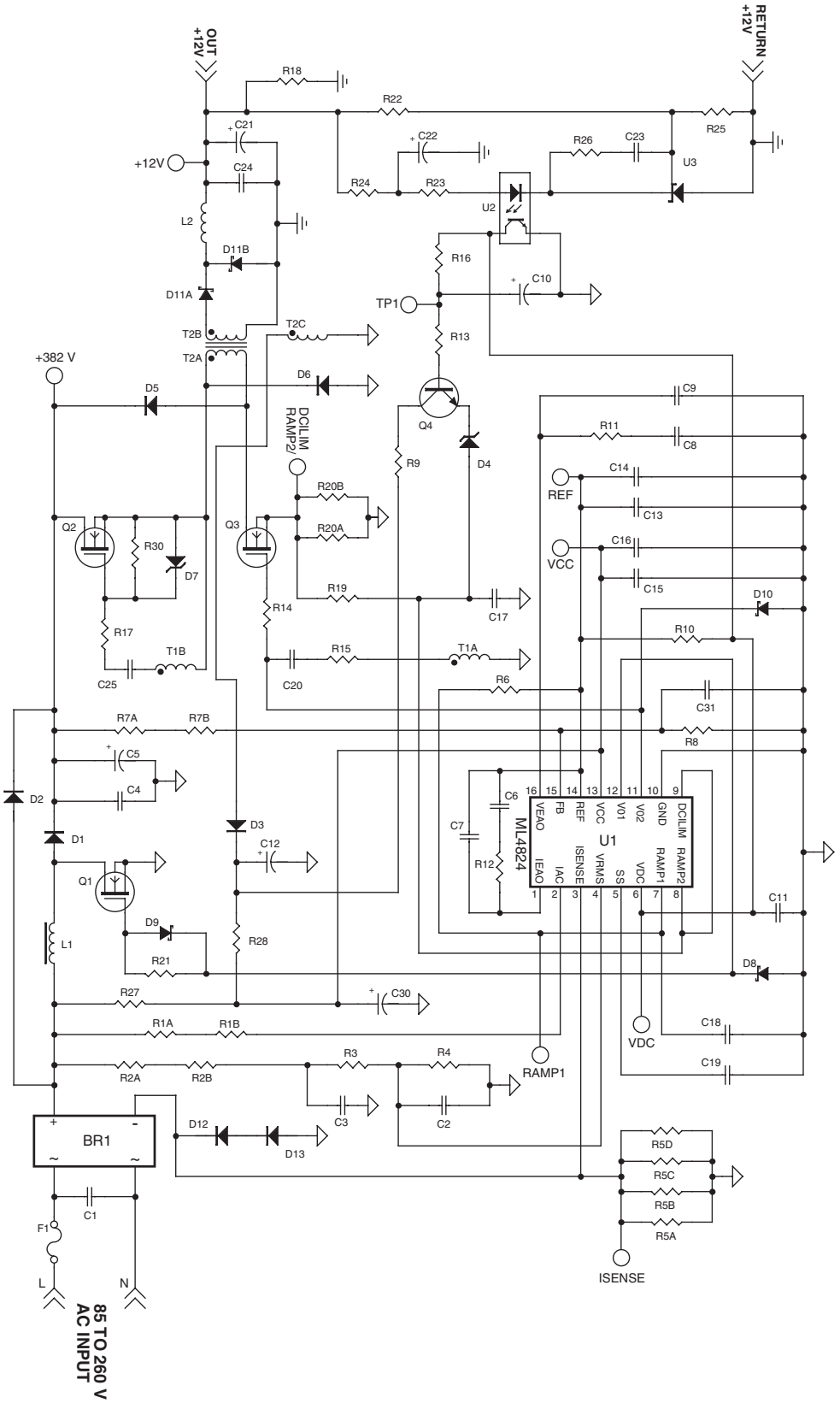
Item	Qty	Ref	Description	Vendor	Part #
39	1	C12	10µF, 20%, 35VDC, Electrolytic, Radial	Panasonic	ECE-A1VU100
40	5	C14,16,19,20,24	1µF , 25VDC, Z5U, 1206 - Surf Mnt.	Any	
41	1	C17	220pf, 10%, 25VDC, X7R, 1206 - Surf Mnt.	Any	
42	1	C18	470pf , 25VDC, NPO, 1206 - Surf Mnt.	Any	
43	1	C21	1800µF, 20%, 25VDC, Electrolytic, Radial	Nichicon Panasonic Nichicon	UPL1E182MRH ECA-1EFQ182L or ECA-1EFQ182
44	1	C22	4.7µF, 20%, 25VDC, Tantalum, C case-Surf Mnt.	AVX	TAJC475M025 (or equivalent)
45	1	C30	330µF, 20%, 25VDC, Electrolytic, Radial	Panasonic	ECA-1EFQ331
Diodes / Rectifiers					
46	1	BR1	Bridge Rectifier, 600V, 4A , KBL	Fairchild	KBL06
47	1	D1	Stealth™ Rectifier 600V, 4A, 20ns, TO-220AC	Fairchild	ISL9R460P2
48	1	D2	Rectifier, 600V, 3A, DO-201	Fairchild	1N5406
49	3	D3, 5, 6	Fast Recovery, 600V, 1A, 250ns, SMA	Fairchild	RGF1J
50	1	D4	Zener, 5.1V, 0.35W, SOT23	Fairchild	MMBZ5231B
51	1	D7	Zener, 15V, 0.35W, SOT23	Fairchild	MMBZ5245B
52	3	D8, 9, 10	Schottky, 40V, 1A, SMB	Fairchild	MBRS140
53	1	D11	Dual Common Cathode Schottky, 45V, 30A, TO-220	Fairchild	MBR2545CT
Semiconductors					
54	1	U1	IC PFC/PWM Combo, DIP	Fairchild	ML4824CP-1
55	1	U2	IC OptoIsolator, DIP-6	Fairchild Fairchild	MOC8102 MOC8112
56	1	U3	IC Shunt Regulator, SO-8, FSID: TL431CD	Fairchild	TL431CD
57	1	Q1	600V 3A SMPS™ IGBT (note 1) or MOSFET 0.85Ohm, 500V, TO-220	Fairchild Fairchild Fairchild	HGTP3N60A4D FQP9N50 IRF840B
58	2	Q2,3	MOSFET 1.5Ohm, 500V, TO-220	Fairchild Fairchild	FQP6N50 FQP5N50
59	1	Q4	Bipolar Transistor , SOT-23	Fairchild	MMBT3904
Magnetics					
60	1	T1	Transformer - Gate Drive 675µH, 1:1	Premier Magnetics Inductive Tech.	TSD-736 320-0874

4.1 ML4824 Evaluation Kit (Rev. B) Parts List

Item	Qty	Ref	Description	Vendor	Part #
61	1	T2	Transformer 26.5mH, 1:12.5 Secondary, 1:18.75 bias	Premier Magnetics Inductive Tech.	TSD-735 320-0873
62	1	L1	Inductor 3.1mH, MicroMetals EE375 #52 Powered Iron, 1:1	Premier Magnetics Inductive Tech.	TSD-734 320-0872
63	1	L2	Inductor 50µH, 12A	Hurricane Electronics Premier Magnetics	HL-8786 VPT-05007
Hardware					
64	1	J1	Hardware 2-Screw terminal Strip .375" Pitch	Molex/Beau RDI Tyco	71502-C 6PCV-02 3-1437652-5
65	2	J2, J3	Hardware .25" Jack with nut	E.F. Johnson	108-0740-001
66	14	Test Points	Hardware .025" Square contact post	3M, etc.	
67	3	PJ1, 2, 3	Hardware Oscilloscope Probe Tip Jack and Grounding Collar (not provided)		
68	1	U1 (ref.)	Socket 16-Pin DIP	AMP, etc.	390261-4 or
69	1	U2 (ref.)	Socket 6-Pin DIP	AMP, etc.	390261-1 or
70	2	F1 (ref.)	Hardware Fuse Clips, PC Mount, for 5 x 20 mm fuse	Littelfuse, etc.	111501 or equiv.
71	1	Q1 (ref.)	Heat Sink Single TO-220	Thermalloy	6399B
72	2	D11 (ref.)	Heat Sink Single TO-220	Thermalloy	6398B
73	3	D1,Q2, Q3	Heat Sink Single TO-220	Thermalloy Wakefield	6022PB 288-1AB
74	5	D1,D11, Q1, Q2, Q3 (ref.)	Heat Sink Thermal Insulator for TO-220 Package	Thermalloy	53-77-2
75	5	D1,D11, Q1, Q2, Q3 (ref.)	Hardware Insulating Shoulder Washer for TO-220	Thermalloy	7721-7PPS
76	4		Hardware 6-32, 0.25" x 0.75" Standoff for EVAL P.C Board	Waldom, etc.	
77	4		Hardware 6-32 X 0.25" Screw		
78	4		Hardware 6-32 lock washer		
79	1		PCB ML4824EVAL P.C. Board Rev B1		
80	1	F1	Fuse 3.15 A, 250 VAC, Slow-Blow, 5 x 20 mm	Littlefuse Wickmann	218 Series 19195 Series

Note 1: Board supplied with IGBT. MOSFET alternative provided for reference

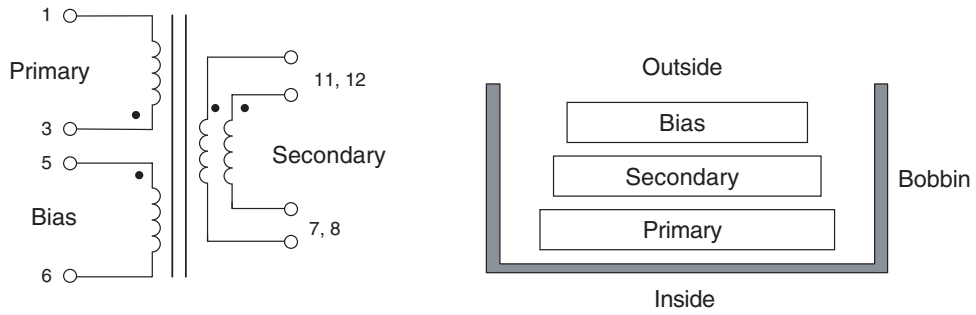
4.2 Schematic



5. Transformer Specification

5.1 ML4824 T2 Forward Transformer Spec.

1. Schematic Diagram. (Top View)



2. Winding Specification

	PIN	WIRE	TURNS
Primary	3 _ 1	28AWG	75
Secondary	11,12 _ 7,8	2x26AWG	4
Bias	6 _ 5	28AWG	4

3. Core & Bobbin
   Core: EE3026
   Bobbin: EE3026

6. Printed Circuit Board

6.1 Layout Considerations

The FEB111-001 Evaluation Board contains high impedance, low level circuits and low impedance, high level circuits. This mandates careful attention to component placement, grounding and PC trace routing. The FEB111-001 Evaluation Board makes use of two ground planes (one for the PFC/PWM stages, and one for the 12V output stage. This, combined with judicious component layout, achieves stable, noise-free operation. When laying out PC boards for off-line power supplies various precautions must be observed. The following list enumerates some of the most important items to keep in mind when laying out boards using the ML4824:

1. Return the low side of the timing capacitor (C18) directly to the IC ground pin.
2. Bypass the reference and supply voltage pins directly to the IC ground pin with a 0.01 (F or greater, low ESR (e.g., ceramic) capacitor.
3. Make a direct, low resistance connection from the IC ground to the PFC current sense resistor (R1).
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 from the sense resistor and the source of Q1.
6. Separate low impedance switching nodes, such as Q1's drain, from sensitive, high impedance circuits, such as the timing capacitor, error amplifier input/output, *etc*.
7. **Much of the power circuitry on this board uses voltages as high as 265 VAC and 380 VDC.** Use proper PC board trace spacing, augmented as necessary by nonconductive coatings (e.g., solder mask).

The ML4824EVAL Evaluation Board is designed for evaluation purposes only. Therefore, it does not incorporate EMI or RFI filtering or shielding. The attention required by these matters will be determined by individual end user applications.

7. Featured Products

7.1 ML4824 Description

The ML4824 is a controller for power factor corrected, switched mode power supplies. Power Factor Correction (PFC) allows the use of smaller, lower cost bulk capacitors, reduces power line loading and stress on the switching FETs, and results in a power supply that fully complies with IEC1000-2-3 specification. The ML4824 includes circuits for the implementation of a leading edge, average current, "boost" type power factor correction and a trailing edge, pulse width modulator (PWM).

The device is available in two versions; the ML4824-1 ($f_{PWM} = f_{PFC}$) and the ML4824-2 ($f_{PWM} = 2 \times f_{PFC}$). Doubling the switching frequency of the PWM allows the user to design with smaller output components while maintaining the best operating frequency for the PFC. An over-voltage comparator shuts down the PFC section in the event of a sudden decrease in load. The PFC section also includes peak current limiting and input voltage brown-out protection. The PWM section can be operated in current or voltage mode at up to 250kHz and includes a duty cycle limit to prevent transformer saturation.

7.1.1 ML4824 Features

- Internally synchronized PFC and PWM in one IC
- Low total harmonic distortion
- Reduces ripple current in the storage capacitor between the PFC and PWM sections
- Average current, continuous boost leading edge PFC
- Fast transconductance error amp for voltage loop
- High efficiency trailing edge PWM can be configured for current mode or voltage mode operation
- Average line voltage compensation with brownout control
- PFC overvoltage comparator eliminates output "runaway" due to load removal
- Current fed gain modulator for improved noise immunity
- Overvoltage protection, UVLO, and soft start

8. Resources / References

8.1 Application Notes

Application Note AN-42009	"ML4824 Combo Controller Applications"
Application Note AN-42045	"ML4824, A Novel Method for an Off-Line PFC-PWM Combo Controller"
Application Note AN-42034	"Synchronizing the ML4824 to Wide Frequency Ranges"
Application Note AN-42030	"Theory and Application of the ML4821 Average Current Mode PFC Controller"

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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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.

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CoolFET™	FRFET™	MICROCOUPLER™	PowerSaver™	SuperSOT™-3
CROSSVOLT™	GlobalOptoisolator™	MicroFET™	PowerTrench®	SuperSOT™-6
DOME™	GTO™	MicroPak™	QFET®	SuperSOT™-8
EcoSPARK™	HiSeC™	MICROWIRE™	QS™	SyncFET™
E^2CMOS™	I^2C™	MSX™	QT Optoelectronics™	TinyLogic®
EnSigna™	*i-Lo*™	MSXPro™	Quiet Series™	TINYOPTO™
FACT™	ImpliedDisconnect™	OCX™	RapidConfigure™	TruTranslation™
FACT Quiet Series™		OCXPro™	RapidConnect™	UHC™
Across the board. Around the world.™		OPTOLOGIC®	μSerDes™	UltraFET®
The Power Franchise®		OPTOPLANAR™	SILENT SWITCHER®	UniFET™
Programmable Active Droop™		PACMAN™	SMART START™	VCX™