LAMBDA ADVANCED ANALOG INC.

AFL12000D Series

Dual Output, Hybrid - High Reliability
DC/DC Converters

DESCRIPTION

The AFL Series of DC/DC converters feature high power density with no derating over the full military temperature range. This series is offered as part of a complete family of converters providing single and dual output voltages and operating from nominal +28, +50, +120 or +270 volt inputs with output power ranging from 80 to 120 watts. For applications requiring higher output power, individual converters can be operated in parallel. The internal current sharing circuits assure accurate current distribution among the paralleled converters. This series incorporates Lambda Advanced Analog's proprietary magnetic pulse feedback technology providing optimum dynamic line and load regulation response. This feedback system samples the output voltage at the pulse width modulator fixed clock frequency, nominally 550 KHz. Multiple converters can be synchronized to a system clock in the 500 KHz to 700 KHz range or to the synchronization output of one converter. Undervoltage lockout, primary and secondary referenced inhibit, soft-start and load fault protection are provided on all models.

These converters are hermetically packaged in two enclosure variations, utilizing copper core pins to minimize resistive DC losses. Three lead styles are available, each fabricated with Lambda Advanced Analog's rugged ceramic lead-to-package seal assuring long term hermeticity in the most harsh environments.

Manufactured in a facility fully qualified to MIL-PRF-38534, these converters are available in four screening grades to satisfy a wide range of requirements. The CH grade is fully compliant to the requirements of MIL-PRF-38534 for class H. The HB grade is fully processed and screened to the class H requirement, may not necessarily meet all of the other MIL-PRF-38534 requirements, e.g., element evaluation and Periodic Inspections (PI) not required. Both grades are tested to meet the complete group "A" test specification over the full military temperature range without output power deration. Two grades with more limited screening are also available for use in less demanding applications. Variations in electrical, mechanical and screening can be accommodated. Contact Lambda Advanced Analog with specific requirements.

FEATURES

- **80 To 160 Volt Input Range**
- **± 5, ± 12, and ± 15 Volt Outputs Available**
- **High Power Density - up to 70 W / in^3**
- **Up To 100 Watt Output Power**
- **Parallel Operation with Power Sharing**
- **Low Profile (0.380") Seam Welded Package**
- **Ceramic Feedthru Copper Core Pins**
- **High Efficiency - to 87%**
- **Full Military Temperature Range**
- **Continuous Short Circuit and Overload Protection**
- **Output Voltage Trim**
- **Primary and Secondary Referenced Inhibit Functions**
- **Line Rejection > 50 dB - DC to 50KHz**
- **External Synchronization Port**
- **Fault Tolerant Design**
- **Single Output Versions Available**
- **Standard Military Drawings Available**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	-0.5V to 180V		
Soldering Temperature	300°C for 10 seconds		
Case Temperature	Operating	-55°C to +125°C	
	Storage	-65°C to +135°C	

Static Characteristics -55°C ≤ T_{CASE} ≤ +125°C, 80V ≤ V_{IN} ≤ 160V unless otherwise specified.

Parameter		Group A Subgroups	Test Conditions	Min	Nom	Max	Unit
INPUT VOLTAGE			Note 6	30	50	80	V
OUTPUT VOLTAGE			V_{IN} = 120 Volts, 100% Load				
	AFL12005D	1	Positive Output	4.95	5.00	5.05	V
		1	Negative Output	-5.05	-5.00	-4.95	V
	AFL12012D	1	Positive Output	11.88	12.00	12.12	V
		1	Negative Output	-12.12	-12.00	-11.88	V
	AFL12015D	1	Positive Output	14.85	15.00	15.15	V
		1	Negative Output	-15.15	-15.00	-14.85	V
	AFL12005D	2, 3	Positive Output	4.90		5.10	V
		2, 3	Negative Output	-5.10		-4.90	V
	AFL12012D	2, 3	Positive Output	11.76		12.24	V
		2, 3	Negative Output	-12.24		-11.76	V
	AFL12015D	2, 3	Positive Output	14.70		15.30	V
		2, 3	Negative Output	-15.30		-14.70	V
OUTPUT CURRENT			V_{IN} = 80, 120, 160 Volts - Notes 6, 11				
	AFL12005D		Either Output			12.8	A
	AFL12012D		Either Output			6.4	A
	AFL12015D		Either Output			5.3	A
OUTPUT POWER			Total of Both Outputs. Notes 6,11				
	AFL12005D			80			W
	AFL12012D			96			W
	AFL12015D			100			W
MAXIMUM CAPACITIVE LOAD			Each Output Note 1	10,000			µfd
OUTPUT VOLTAGE TEMPERATURE COEFFICIENT			V_{IN} = 120 Volts, 100% Load - Notes 1, 6	-0.015		+0.015	%/°C
OUTPUT VOLTAGE REGULATION			Note 10				
	Line	1, 2, 3	No Load, 50% Load, 100% Load	-0.5		+0.5	%
	Load	1, 2, 3	V_{IN} = 80, 120, 160 Volts.	-1.0		+1.0	%
	Cross		V_{IN} = 80, 120, 160 Volts. Note 12				
	AFL12005D	1, 2, 3	Positive Output	-1.0		+1.0	%
			Negative Output	-8.0		+8.0	%
	AFL12012D	1, 2, 3	Positive Output	-1.0		+1.0	%
			Negative Output	-5.0		+5.0	%
	AFL12015D	1, 2, 3	Positive Output	-1.0		+1.0	%
			Negative Output	-5.0		+5.0	%

Static Characteristics (Continued)

Parameter	Group A Subgroups	Test Conditions	Min	Nom	Max	Unit
OUTPUT RIPPLE VOLTAGE		V_{IN} = 80, 120, 160 Volts, 100% Load, BW = 10MHz				
AFL12005D	1, 2, 3				60	mV_{pp}
AFL12012D	1, 2, 3				80	mV_{pp}
AFL12015D	1, 2, 3				80	mV_{pp}
INPUT CURRENT		V_{IN} = 120 Volts				
No Load	1	I_{OUT} = 0			20	mA
	2, 3				25	mA
Inhibit 1	1, 2, 3	Pin 4 Shorted to Pin 2			3	mA
Inhibit 2	1, 2, 3	Pin 12 Shorted to Pin 8			5	mA
INPUT RIPPLE CURRENT		V_{IN} = 120 Volts, 100% Load				
AFL12005D	1, 2, 3				60	mA_{pp}
AFL12012D	1, 2, 3				70	mA_{pp}
AFL12015D	1, 2, 3				80	mA_{pp}
CURRENT LIMIT POINT		V_{OUT} = 90% V_{NOM} , Current split equally on positive and negative outputs. Note 5				
Expressed as a Percentage of Full Rated Load	1		115		125	%
	2		105		115	%
	3		125		140	%
LOAD FAULT POWER DISSIPATION		V_{IN} = 120 Volts				
Overload or Short Circuit	1, 2, 3				32	W
EFFICIENCY		V_{IN} = 120 Volts, 100% Load				
AFL12005D	1, 2, 3		78	82		%
AFL12012D	1, 2, 3		82	85		%
AFL12015D	1, 2, 3		83	87		%
ENABLE INPUTS (Inhibit Function)						
Converter Off	1, 2, 3	Logical Low on Pin 4 or Pin 12	-0.5		0.8	V
Sink Current		Note 1			100	µA
Converter On	1, 2, 3	Logical High on Pin 4 and Pin 12 - Note 9	2.0		50	V
Sink Current		Note 1			100	µA
SWITCHING FREQUENCY	1, 2, 3		500	550	600	KHz
SYNCHRONIZATION INPUT						
Frequency Range	1, 2, 3		500		700	KHz
Pulse Amplitude, Hi	1, 2, 3		2.0		10	V
Pulse Amplitude, Lo	1, 2, 3		-0.5		0.8	V
Pulse Rise Time		Note 1			100	nSec
Pulse Duty Cycle		Note 1	20		80	%
ISOLATION	1	Input to Output or Any Pin to Case (except Pin 3). Test @ 500VDC	100			MΩ
DEVICE WEIGHT		Slight Variations with Case Style		85		gms
MTBF		MIL-HDBK-217F, AIF @ T_C = 40°C	300			KHrs

Dynamic Characteristics -55°C ≤ T_{CASE} ≤ +125°C, V_{IN} = 120 Volts unless otherwise specified.

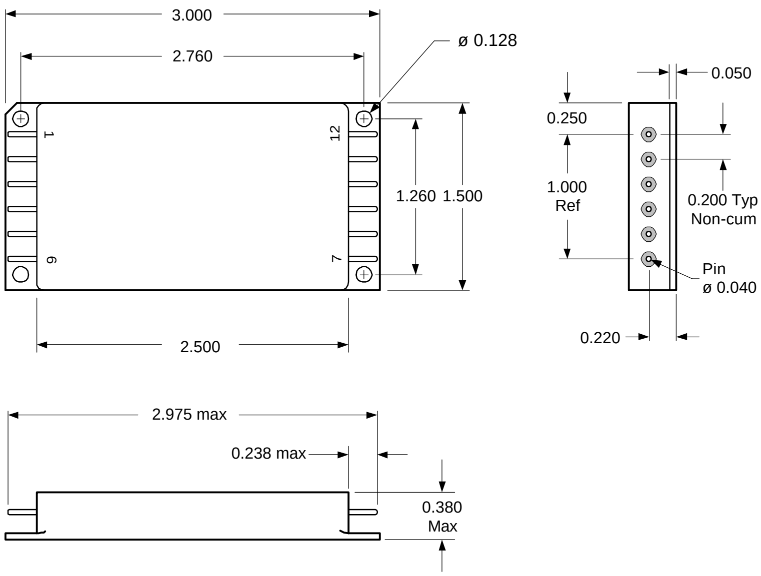
Parameter		Group A Subgroups	Test Conditions	Min	Nom	Max	Unit
LOAD TRANSIENT RESPONSE			Note 2, 8				
AFL12005D Positive Output	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 50% ⇔ 100%	-450		450 200	mV µSec
	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 10% ⇔ 50% 10% ⇒ 50% 50% ⇒ 10%	-450		450 200 400	mV µSec µSec
AFL12005D Negative Output	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 50% ⇔ 100%	-450		450 200	mV µSec
	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 10% ⇔ 50% 10% ⇒ 50% 50% ⇒ 10%	-450		450 200 400	mV µSec µSec
AFL12012D Positive Output	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 50% ⇔ 100%	-750		750 200	mV µSec
	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 10% ⇔ 50% 10% ⇒ 50% 50% ⇒ 10%	-750		750 200 400	mV µSec µSec
AFL12012D Negative Output	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 50% ⇔ 100%	-750		750 200	mV µSec
	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 10% ⇔ 50% 10% ⇒ 50% 50% ⇒ 10%	-750		750 200 400	mV µSec µSec
AFL12015D Positive Output	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 50% ⇔ 100%	-750		750 200	mV µSec
	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 10% ⇔ 50% 10% ⇒ 50% 50% ⇒ 10%	-750		750 200 400	mV µSec µSec
AFL12015D Negative Output	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 50% ⇔ 100%	-750		750 200	mV µSec
	Amplitude Recovery	4, 5, 6 4, 5, 6	Load Step 10% ⇔ 50% 10% ⇒ 50% 50% ⇒ 10%	-750		750 200 400	mV µSec µSec
LINE TRANSIENT RESPONSE			Note 1, 2, 3				
	Amplitude Recovery		V_{IN} Step = 80 ⇔ 160 Volts	-500		500 500	mV µSec
TURN-ON CHARACTERISTICS			Note 4				
	Overshoot Delay	4, 5, 6 4, 5, 6	Enable 1, 2 on. (Pins 4, 12 high or open)	 50	 75	250 120	mV mSec
LOAD FAULT RECOVERY			Same as Turn On Characteristics.				
LINE REJECTION			MIL-STD-461D, CS101, 30Hz to 50KHz Note 1	50	60		dB

Notes to Specifications:

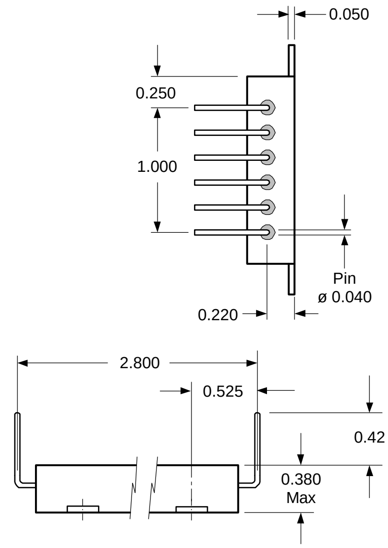
1. Parameters not 100% tested but are guaranteed to the limits specified in the table.
2. Recovery time is measured from the initiation of the transient to where V_{OUT} has returned to within ±1% of V_{OUT} at 50% load.
3. Line transient transition time ≥ 100 µSec.
4. Turn-on delay is measured with an input voltage rise time of between 100 and 500 volts per millisecond.
5. Current limit point is that condition of excess load causing output voltage to drop to 90% of nominal.
6. Parameter verified as part of another test.
7. All electrical tests are performed with the remote sense leads connected to the output leads at the load.
8. Load transient transition time ≥ 10 µSec.
9. Enable inputs internally pulled high. Nominal open circuit voltage ≈ 4.0VDC.
10. Load current split equally between $+V_{out}$ and $-V_{out}$.
11. Output load must be distributed so that a minimum of 20% of the total output power is being provided by one of the outputs.
12. Cross regulation measured with load on tested output at 20% while changing the load on other output from 20% to 80%.

AFL12000D Case Outlines

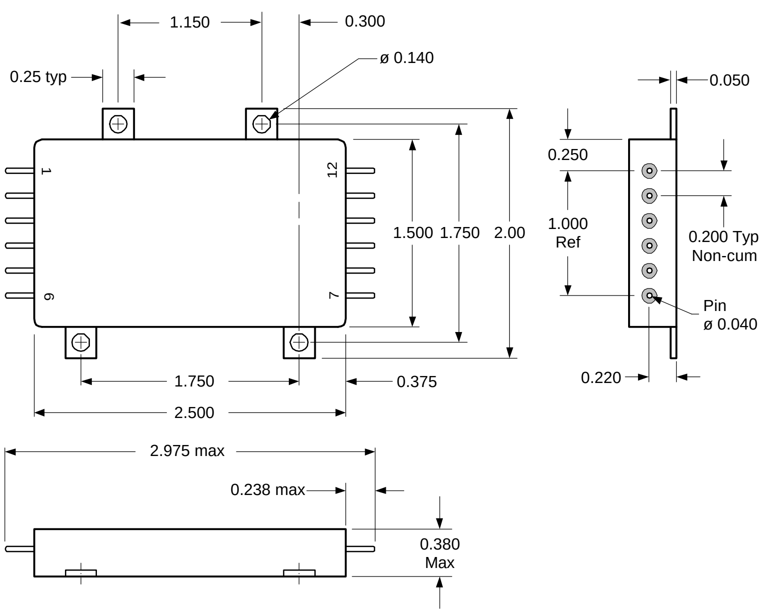
Case X



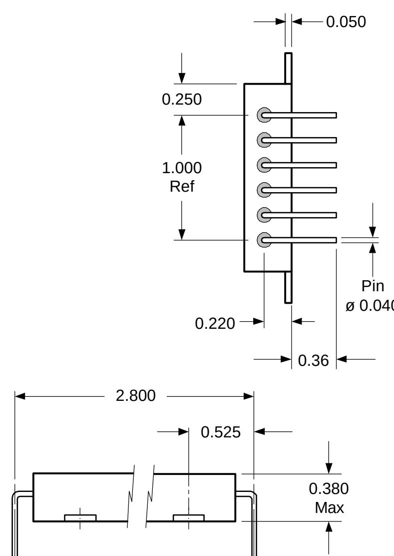
Case W
Pin Variation of Case Y



Case Y



Case Z
Pin Variation of Case Y



Tolerances, unless otherwise specified: .XX = ±0.010
.XXX = ±0.005

AFL12000D Pin Designation

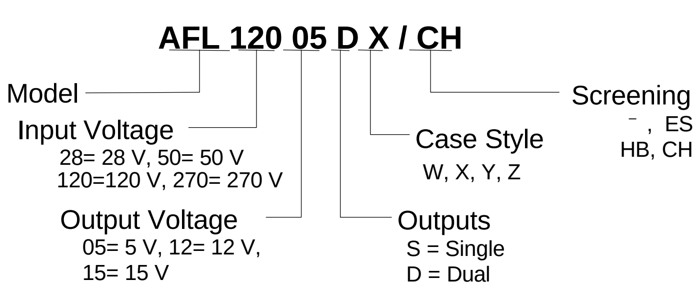
Pin No.	Designation
1	Positive Input
2	Input Return
3	Case
4	Enable 1
5	Sync Output
6	Sync Input
7	Positive Output
8	Output Return
9	Negative Output
10	Output Voltage Trim
11	Share
12	Enable 2

Available Screening Levels and Process Variations for AFL 12000D Series.

Requirement	MIL-STD-883 Method	No Suffix	ES Suffix	HB Suffix	CH Suffix
Temperature Range		-20°C to +85°C	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C
Element Evaluation					MIL-PRF-38534
Internal Visual	2017		Yes	Yes	Yes
Temperature Cycle	1010		Cond B	Cond C	Cond C
Constant Acceleration	2001		500g	Cond A	Cond A
Burn-in	1015	96hrs @ 125°C	96hrs @ 125°C	160hrs @ 125°C	160hrs @ 125°C
Final Electrical (Group A)	MIL-PRF-38534	25°C	25°C	-55, +25, +125°C	-55, +25, +125°C
Seal, Fine & Gross	1014		Cond A, C	Cond A, C	Cond A, C
External Visual	2009		Yes	Yes	Yes

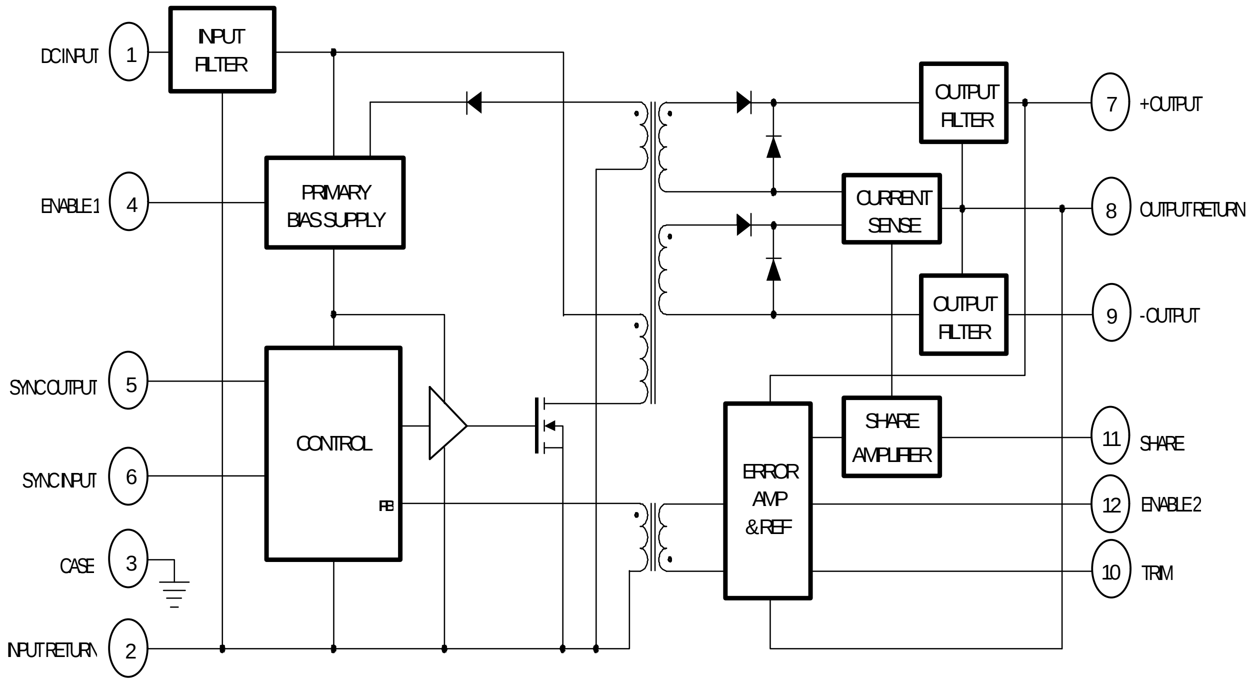
per Commercial Standards

Part Numbering



AFL12000D Circuit Description

Figure I. AFL Dual Output Block Diagram



Circuit Operation and Application Information

The AFL series of converters employ a forward switched mode converter topology. (refer to Figure I.) Operation of the device is initiated when a DC voltage whose magnitude is within the specified input limits is applied between pins 1 and 2. If pins 4 and 12 are enabled (at a logical 1 or open) the primary bias supply will begin generating a regulated housekeeping voltage bringing the circuitry on the primary side of the converter to life. Two power MOSFETs used to chop the DC input voltage into a high frequency square wave, apply this chopped voltage to the power transformer. As this switching is initiated, a voltage is impressed on a second winding of the power transformer which is then rectified and applied to the primary bias supply. When this occurs, the input voltage is excluded from the bias voltage generator and the primary bias voltage becomes internally generated.

The switched voltage impressed on the secondary output transformer windings is rectified and filtered to provide the positive and negative converter output voltages. An error amplifier on the secondary side compares the positive output voltage to a precision reference and generates an error signal proportional to the difference. This error signal is magnetically coupled through the feedback transformer into the control section of the converter varying the pulse width of the square wave signal driving the MOSFETs, narrowing the pulse width if the output voltage is too high and widening it if it is too low. These pulse width variations provide the necessary corrections to maintain the magnitude of output voltage within its' specified limits.

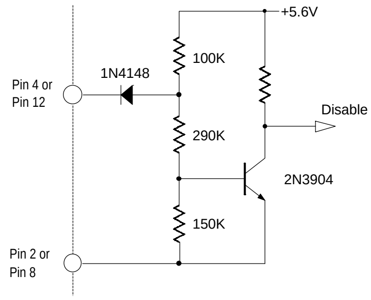
Because the primary and secondary sides are coupled by magnetic elements, full isolation from input to output is achieved.

Although incorporating several sophisticated and useful ancillary features, basic operation of the AFL12000D series can be initiated by simply applying an input voltage to pins 1 and 2 and connecting the appropriate loads between pins 7, 8, and 9. Of course, operation of any converter with high power density should not be attempted before secure attachment to an appropriate heat dissipator. (See **Thermal Considerations,** page 9)

Inhibiting Converter Output

As an alternative to application and removal of the DC voltage to the input, the user can control the converter output by providing TTL compatible, positive logic signals to either of two enable pins (pin 4 or 12). The distinction between these two signal ports is that enable 1 (pin 4) is referenced to the input return (pin 2) while enable 2 (pin 12) is referenced to the output return (pin 8). Thus, the user has access to an inhibit function on either side of the isolation barrier. Each port is internally pulled "high" so that when not used, an open connection on both enable pins permits normal converter operation. When their use is desired, a logical "low" on either port will shut the converter down.

Figure II. Enable Input Equivalent Circuit



Internally, these ports differ slightly in their operation. In use, a low on Enable 1 completely shuts down all circuits in the converter, while a low on Enable 2 shuts down the secondary side while altering the controller duty cycle to near zero. Externally, the use of either port is transparent to the user save for minor differences in idle current. (See specification table).

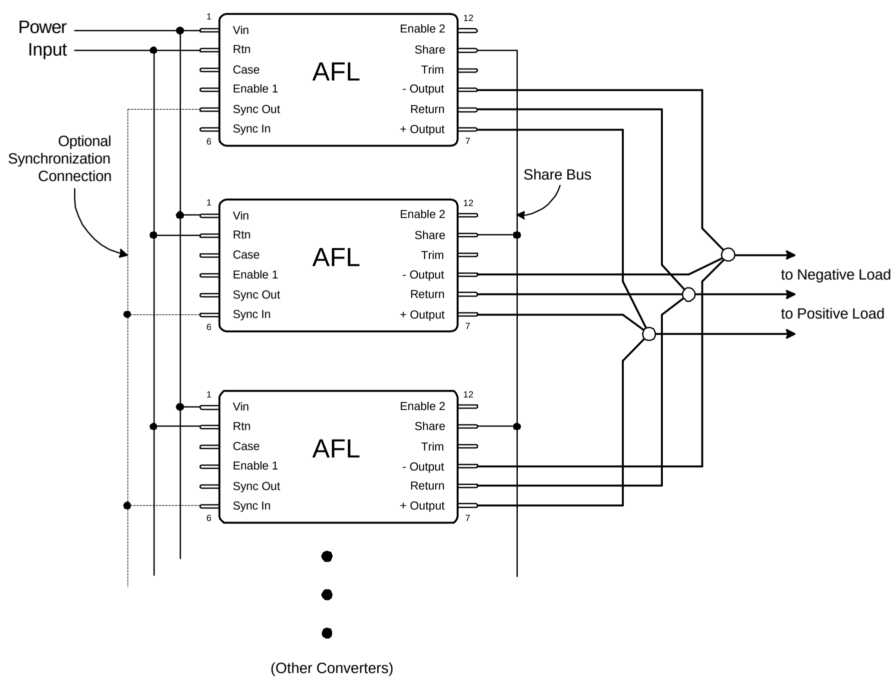
Synchronization of Multiple Converters

When operating multiple converters, system requirements often dictate operation of the converters at a common frequency. To accommodate this requirement, the AFL series converters provide both a synchronization input and synchronization output.

The sync input port permits synchronization of an AFL converter to any compatible external frequency source operating between 500 and 700 KHz. This input signal should be referenced to the input return and have a 10% to 90% duty cycle. Compatibility requires transition times less than 100 ns, maximum low level of +0.8 volts and a minimum high level of +2.0 volts. The sync output of another converter which has been designated as the master oscillator provides a convenient frequency source for this mode of operation. When external synchronization is not indicated, the sync in pin should be left unconnected thereby permitting the converter to operate at its' own internally set frequency.

The sync output signal is a continuous pulse train set at 550 ±50 KHz, with a duty cycle of 15 ±5%. This signal is referenced to the input return and has been tailored to be compatible with the AFL sync input port. Transition times are less than 100 ns and the low level output impedance is less than 50 ohms. This signal is active when the DC input voltage is within the specified operating range and the converter is not inhibited. The sync output has adequate drive reserve to synchronize at least five additional converters. A typical connection is illustrated in Figure III.

Figure III. Preferred Connection for Parallel Operation



Parallel Operation — Current and Stress Sharing

Figure III. illustrates the preferred connection scheme for operation of a set of AFL converters with outputs operating in parallel. Use of this connection permits equal current sharing among the members of a set whose load current exceeds the capacity of an individual AFL. An important feature of the AFL series operating in the parallel mode is that in addition to sharing the current, the stress induced by temperature will also be shared. Thus if one member of a paralleled set is operating at a higher case temperature, the current it provides to the load will be reduced as compensation for the temperature induced stress on that device.

When operating in the shared mode, it is important that symmetry of connection be maintained as an assurance of optimum load sharing performance. Thus, converter outputs should be connected to the load with equal lengths of wire of the same gauge and should be connected to a common physical point, preferably at the load along with the converter return leads. All converters in a paralleled set must have their share pins connected together. This arrangement is diagrammatically illustrated in Figure III. showing the output and return pins connected at a star point which is located close as possible to the load.

As a consequence of the topology utilized in the current sharing circuit, the share pin may be utilized in other functions. For applications requiring only a single converter, the voltage appearing on the share pin may be used as a "total current monitor". The share pin open circuit voltage is nominally +1.00v at no load and increases linearly with increasing total output current to +2.20v at full load. Note that the current we refer to here is the total device output current, that is, the sum of the positive and negative output currents.

Thermal Considerations

Because of the incorporation of many innovative technological concepts, the AFL series of converters is capable of providing very high output power from a package of very small volume. These magnitudes of power density can only be obtained by combining high circuit efficiency with effective methods of heat removal from the die junctions. This requirement has been effectively addressed inside the device; but when operating at maximum loads, a significant amount of heat will be generated and this heat must be conducted away from the case. To maintain the case temperature at or below the specified maximum of 125°C, this heat must be transferred by conduction to an appropriate heat dissipater held in intimate contact with the converter base-plate.

Since the effectiveness of this heat transfer is dependent on the intimacy of the baseplate-heatsink interface, it is strongly recommended that a high thermal conductivity heat transferring medium is inserted between the baseplate and heatsink. The material most frequently utilized at the factory during all testing and burn-in processes is sold under the trade name of Sil-Pad® 400[1]. This particular product is an insulator but electrically conductive versions are also available. Use of these materials assures maximum surface contact with the heat dissipater thereby compensating for any minor surface variations. While other available types of heat conductive materials and thermal compounds provide similar effectiveness, these alternatives are often less convenient and are frequently messy to use.

A conservative aid to estimating the total heat sink surface area ($A_{HEAT\ SINK}$) required to set the maximum case temperature rise (ΔT) above ambient temperature is given by the following expression:

$$A_{\text{HEAT SINK}} \approx \left\{ \frac{\Delta T}{80 P^{0.85}} \right\}^{-1.43} - 3.0$$

where ΔT = case temperature rise above ambient,

P = device dissipation in watts = $Pout\left\{\frac{1}{Eff} - 1\right\}$

As an example, assume that it is desired to operate an AFL12015D while maintaining the case temperature at $T_C \le +85°C$ in an area where the ambient temperature is held to a constant +25°C; then

$$\Delta T = 85 - 25 = 60°C.$$

If the worst case full load efficiency for this device is 83% @ 100W; thus the power dissipation at full load is given by

$$P = 100 \bullet \left\{\frac{1}{.83} - 1\right\} = 100 \bullet (0.205) = 20.5\text{W}$$

and the required heat sink area is

[1]Sil-Pad is a registered Trade Mark of Bergquist, Minneapolis, MN

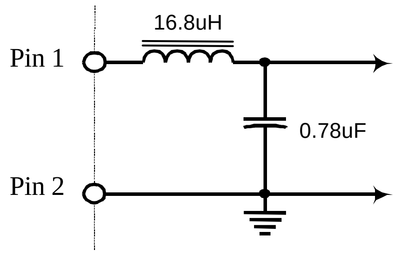
$$A_{\text{HEAT SINK}} = \left\{\frac{60}{80 \bullet 20.5^{0.85}}\right\}^{-1.43} - 3.0 = 56.3\ \text{in}^2$$

Thus, a total heat sink surface area (including fins, if any) of 56 in^2 in this example, would limit case rise to 60°C above ambient. A flat aluminum plate, 0.25" thick and of approximate dimension 4" by 7" (28 in^2 per side) would suffice for this application in a still air environment. Note that to meet the criteria in this example, both sides of the plate require unrestricted exposure to the +25°C ambient air.

Input Filter

The AFL12000D series converters incorporate a single stage LC input filter whose elements dominate the input load impedance characteristic during the turn-on sequence. The input circuit is as shown in Figure IV.

Figure IV. Input Filter Circuit



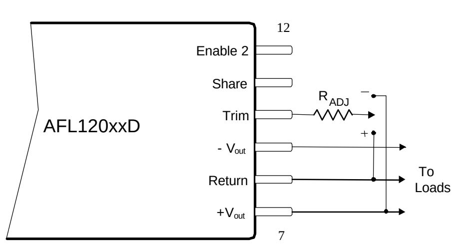
Undervoltage Lockout

A minimum voltage is required at the input of the converter to initiate operation. This voltage is set to 75 ± 3 volts. To preclude the possibility of noise or other variations at the input falsely initiating and halting converter operation, a hysteresis of approximately 4 volts is incorporated in this circuit. Thus if the input voltage drops to 71 ± 3 volts, the converter will shut down and remain inoperative until the input voltage returns to ≈75 volts.

Output Voltage Adjust

By use of the trim pin (10), the magnitude of output voltages can be adjusted over a limited range in either a positive or negative direction. Connecting a resistor between the trim pin and either the output return or the positive output will raise or lower the magnitude of output voltage. The span of output voltage magnitude is restricted to the limits shown in Table I.

Figure V. Connection for V_{OUT} Adjustment



Connect Radj to + to increase, - to decrease.

Table I. Output Voltage Trim Values and Limits

AFL12005D		AFL12012D		AFL12015D	
V_{out}	R_{adj}	V_{out}	R_{adj}	V_{out}	R_{adj}
5.5	0	12.5	0	15.5	0
5.4	12.5K	12.4	47.5K	15.4	62.5K
5.3	33.3K	12.3	127K	15.3	167K
5.2	75K	12.2	285K	15.2	375K
5.1	200K	12.1	760K	15.1	1.0M
5.0	∞	12.0	∞	15.0	∞
4.9	190K	11.7	975K	14.6	1.2M
4.8	65K	11.3	288K	14.0	325K
4.7	23K	10.8	72.9K	13.5	117K
4.6	2.5K	10.6	29.9K	13.0	12.5K
4.583	0	10.417	0	12.917	0

Note that the nominal magnitude of output voltage resides in the middle of the table and the corresponding resistor value is set to ∞. To set the magnitude above nominal, the adjust resistor is connected to output return. To set the magnitude below nominal, the adjust resistor is connected to the positive output. (Refer to Figure V.)

For output voltage settings that are within the limits, but between those presented in Table I, it is suggested that the resistor values be determined empirically by selection or by use of a variable resistor. The value thus determined can then be replaced with a good quality fixed resistor for permanent installation.

When use of the trim feature is elected, the user should be aware that the temperature performance of the converter output voltage will be affected by the temperature performance of the resistor selected as the adjustment element and therefore, the user is advised to employ resistors with an very small temperature coefficient of resistance.

LAMBDA ADVANCED ANALOG INC.

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