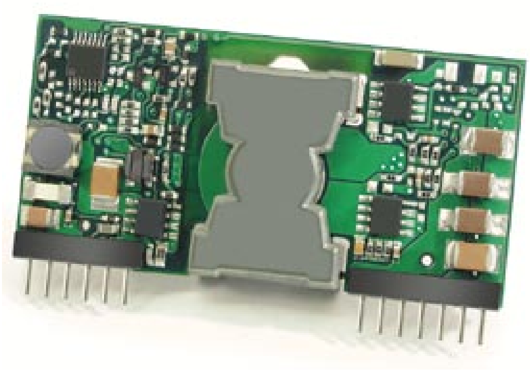


A SUBSIDIARY OF C&D TECHNOLOGIES

Single Output
SBC Models

48V$_{IN}$, 12V/22A Output
High Efficiency, SIP Bus Converter

Features

- 264 Watts total output power
- 95% Ultra-high efficiency @ full load
- 48V Input (40.5 to 57V range)
- 12V/22A Output for Intermediate Bus Architectures with POL converters
- Input Over/Under Voltage Shutdown
- Synchronous-rectifier topology
- 150kHz fixed switching frequency
- Output current sharing
- Fully isolated, 2250V (BASIC)
- Low 60mVp-p ripple/noise
- 1.25" x 2.5" x 0.465" SIP package
- Stable no-load condition
- Thermal shutdown
- Fully I/O protected
- IEC/EN/UL/cUL60950 certification pending

The SBC-12/22-L48 DC/DC converter is one of DATEL's new generation, fully isolated, Intermediate Bus Converters, designed and optimized for total on-board solutions in combination with our non-isolated point of load converters of the HEN, LEN, LQN, LSM and LSN series.

The SBC's convert the standard 48V (40.5 to 57V limited range) to a non-regulated 12V (10.125 to 14.25V range) bus voltage with a total output power of 264 Watts. Taking full advantage of a synchronous-rectifier topology, the SBC-series achieve efficiency of 95%, minimizing power losses and enabling full-power operation to ambient temperatures up to +55°C with nominal air flow.

These high-density SIP-package, open-frame DC/DC's occupy as little as 1.16 square inches (7.5 cm^2) of board space and are only 1.25" inches (31.75 mm) high.

Assembled using fully automated, SMT-on-pcb techniques, SBC's provide fixed frequency conversion, output On/Off control with choice of positive or negative logic, stable no-load operation, current sharing capability, and low output ripple/noise (60mVp-p).

The fully functional SBC bus converters feature full I/O fault protection including input overvoltage and undervoltage shutdown, internal fuse (optional, includes power limiting instead of current limiting), output overvoltage, output current limiting, short-circuit protection.

All models have IEC/EN/UL60950 certification pending.

Refer to the DATEL application note, *Bus Converters Aim to Boost Efficiency In IBA-Based Power Designs*.

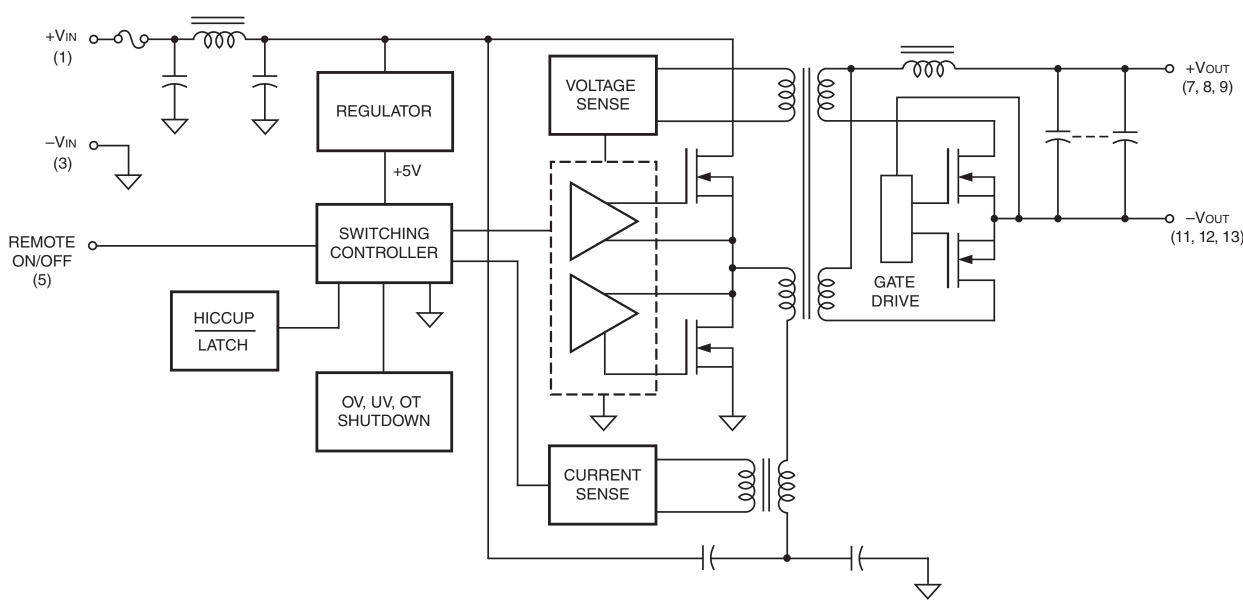


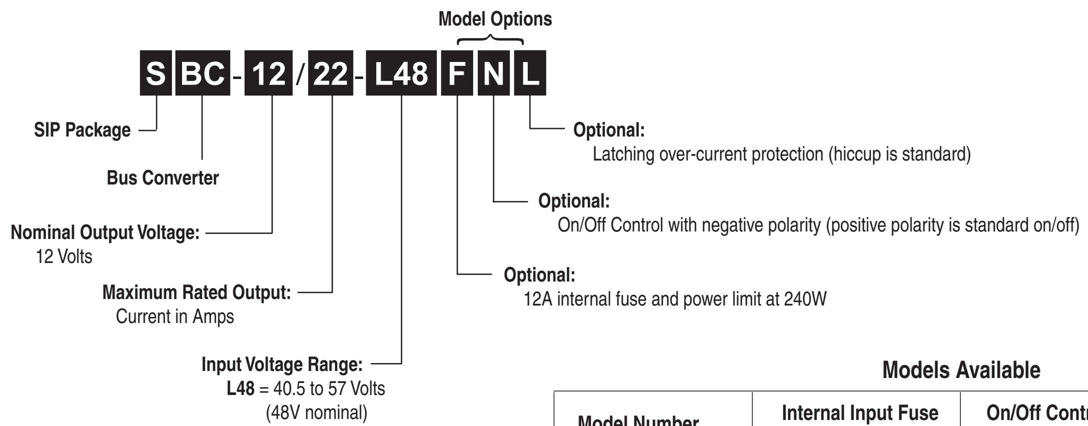
Figure 1. Simplified Schematic

Performance Specifications ① ③

Model	Output							Input			Efficiency		Package/ Pinout
	V_{OUT} (Volts)	I_{OUT} ⑤ (Amps)	R/N (mVp-p) ②		Regulation (Max.) ③			V_{IN} (Volts)		I_{IN} ④ (mA/A)			
			Typ.	Max.	Load	Line	Temp.	Nom.	Range		Min.	Typ.	
SBC-12/22-L48	12	22	60	100	0 to –6% ⑥	$V_{OUT} = V_{IN}/4$ ratiometric	±2%	48	40.5-57	125/5.5	93%	95%	B6/P64

① Typical at T_A = +25°C under nominal line voltage and nominal-load conditions, unless noted.
② Ripple/Noise (R/N) is tested/specified over a 20MHz bandwidth . All models are specified with an external 0.1μF multi-layer ceramic capacitor installed across their output pins.
③ Devices have no minimum-load requirements and will regulate under no-load conditions.
④ Nominal line voltage, no-load/full-load conditions. At V_{IN} = 40.5V, I_{OUT} = 7.01A maximum.
⑤ I_{OUT} max. at low line is 25 Amps; 20 Amps at high line, except F models with a 240W power limit. (See Performance Curves.)
⑥ Load regulation is measured with V_{IN} = nominal, I_{OUT} = 0 to maximum and does not include initial accuracy.

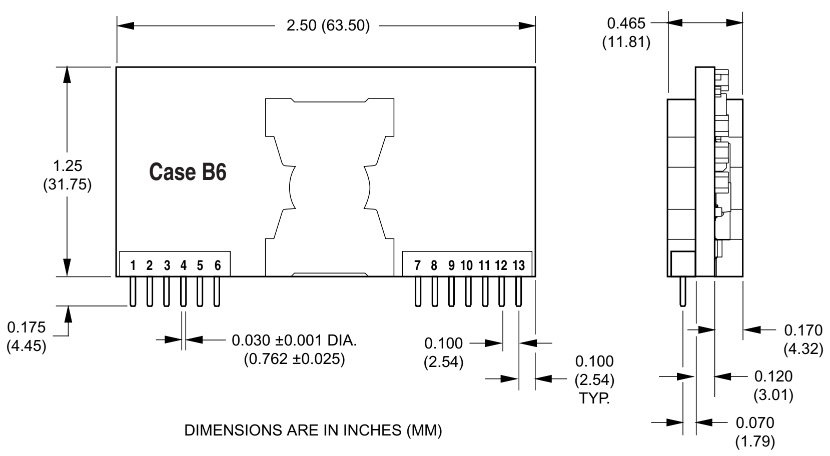
PART NUMBER STRUCTURE



Models Available

Model Number	Internal Input Fuse and 240W Limit	On/Off Control Input	Out of Limit Response
SBC-12/22-L48	Not included	Positive logic	Hiccup (auto reset)
SBC-12/22-L48N	Not included	Negative logic	Hiccup (auto reset)
SBC-12/22-L48L	Not included	Positive logic	Latching (manual restart)
SBC-12/22-L48NL	Not included	Negative logic	Latching (manual restart)
SBC-12/22-L48F	Installed	Positive logic	Hiccup (auto reset)
SBC-12/22-L48FN	Installed	Negative logic	Hiccup (auto reset)
SBC-12/22-L48FL	Installed	Positive logic	Latching (manual restart)
SBC-12/22-L48FNL	Installed	Negative logic	Latching (manual restart)

MECHANICAL SPECIFICATIONS



I/O Connections			
Pin	Function P64	Pin	Function P64
1	+Input	7	+Output
2	N/C	8	+Output
3	–Input	9	+Output
4	N/C	10	N/C
5	On/Off Control	11	–Output
6	N/C	12	–Output
		13	–Output

Performance/Functional Specifications

Typical @ T_A = +25°C under nominal line voltage and full-load conditions unless noted. ①

Input	
Input Voltage Range	40.5-57 Volts (48V nominal)
Overvoltage Shutdown	57.5-60 Volts @ I_{OUT} = 20A (15A F models)
Start-Up Threshold ②	37-40.5 Volts @ I_{OUT} = 25A (20A F models)
Undervoltage Shutdown ②	36-39.5 Volts @ I_{OUT} = 25A (20A F models)
Input Current	See Performance Specifications
Short Circuit Current	200mA maximum
Input Reflected Ripple Current ③	5mAp-p
Recommended External Fuse	12 Amps
Internal Filter Type	Pi
Reverse Polarity Protection	None (see Absolute Max. Ratings)
On/Off Control ④ Positive Logic Negative Logic ("N" Suffix)	 On= open (internal pull-up) Off= 0 to 0.8V (0.8mA max.) On = pulled low to 0-0.8V (0.8mA max.) Off = open (internal pull-up)
Output	
Total Output Power, V_{IN} min./nom./max.	235/250/275 Watts maximum ⑩
Accuracy @ 48V_{IN}, no load	12V +1, –2% maximum
Minimum Loading	No minimum load
Ripple/Noise (20MHz BW) ③	See Performance Spec
Line/Load Regulation	See Performance Spec
Equivalent Output Impedance	0.025Ω
Efficiency	See Performance Spec
Current Share Accuracy: 2 units paralleled on input/output	 ±10%
Isolation Voltage: Input/Output	 2250Vdc min. (BASIC safety rating)
Isolation Resistance	10MΩ
Isolation Capacitance	470pF
Current Limit Inception	30.5 Amps @ V_{OUT} = 11 Volts
Short Circuit Current	See hiccup discussion
Capacitive Loading (Resistive Load)	10,000µF ⑤
Temperature Coefficient	±2% over temperature range
Dynamic Characteristics	
Dynamic Load Response (10-15-10A) load step to within ±3% of V_{OUT})	 200µsec
Start up time: ⑥ V_{IN} to V_{OUT} On/Off to V_{OUT}	 80msec 15msec
Switching Frequency, Fixed	150 ± 20kHz
Switching Frequency, Effective	300 ±40kHz
Environmental	
Calculated MTBF ⑦	>2.5 million hours
Operating PCB Temperature ⑧ without Derating, 300 lfm airflow	 –40 to +45°C (20A)
Thermal Shutdown	+115 to +125°C
Storage Temperature	–55 to +125°C
Physical	
Dimensions	See Mechanical Dimensions
Pin Material	Copper, solder coated over nickel underplate
Weight	1.62 ounces (46 grams)
Primary to Secondary Insulation Level	Basic
Safety	UL/cUL 60950, incl. CSA-22.2, No. 234 IEN/EN 60950

① All models are tested and specified with 1µF/10µF ceramic/tantalum output and no external input capacitors, and 100 lfm air flow, unless otherwise noted. All models will effectively regulate under no-load conditions (with perhaps a slight increase in output ripple/noise).
② See Technical Notes/Performance Curves for additional explanations and details.
③ Input Ripple Current is tested/specified over a 5-20MHz bandwidth with an external 33µF input capacitor and a simulated source impedance of 220µF and 12µH. See I/O Filtering, Input Ripple Current and Output Noise for details.
④ The On/Off Control is designed to be driven with open collector transistor or by appropriate voltage levels. CAUTION: Prevent damaging overvoltage at the On/Off Input. Use –V_{IN} as On/Off Control signal return.
⑤ Capacitive load must be low ESR, 0.02Ω maximum. No inductive reactance. 2000µF maximum for electrolytic capacitors.
⑥ For Start-Up-Time specifications, output settling time is defined as the output voltage having reached ±1% of its final value and the load current having reached at least 80% of its final value.
⑦ MTBF is calculated using Belcore TELCORDIA SR-332 Method 1 Case 3, ground fixed, T_{CASE} = +40°C and full-load conditions. Contact DATEL for demonstrated life test data.
⑧ All models are fully operational and meet all published specifications, including "cold start," at –40°C.
⑨ The outputs are not intended to sink appreciable reverse current. Damage may result.
⑩ 240 Watt limit for F models. See discussion below.

Absolute Maximum Ratings	
Input Voltage: Continuous or transient	 60 Volts
Input Reverse-Polarity Protection	None, reverse input current must not exceed 1.5A
Output Current ⑨	Current limited. Devices can withstand an indefinite output short circuit without damage.
Storage Temperature	–55 to +125°C
Lead Temperature (soldering, 10 sec.)	+300°C (soldering 10 seconds max.)

These are stress ratings. Exposure of devices to any of these conditions may adversely affect long-term reliability. Proper operation under conditions other than those listed in the Performance/Functional Specifications Table is not implied.

Intended for Distributed Bus Architecture (DBA) and Intermediate Bus Architecture (IBA) applications, the SBC-12/22-L48 is a 48Vdc (nominal) to 12Vdc isolated unregulated DC/DC bus converter. Delivering up to 22 Amps output, the converter accepts an input from 40.5 to 57 Volts with very high efficiency of up to 94.5% at full load. Total maximum output power is 264 Watts nominal. The fixed frequency switching magnetics offer 2250Vdc isolation. Extensive filtering and careful design yields low 80mV ripple and noise at full load. With proper conditions, several SBC-series may be connected in parallel under "load share" operation to deliver higher current and/or greater system redundancy.

Typical applications for the SBC-series include 48V-powered central office equipment such as DSL modem systems, network controllers and packet switching systems.

The SBC-12/22-L48 circuit consists of switching controller and power MOSFET transistors driving the primary side of the main power transformer and a synchronous rectifier (also composed of MOSFET's) on the secondary side. The input switching controller includes an external input for On/Off control and numerous protective circuits (over temperature, under or overvoltage and overcurrent). A classic Pi filter on the input improves stability and offers immunity from AC disturbances such as battery chargers. The Pi filter also limits switching transients and ripple current reflected back to external equipment. The output stage includes an inductor and capacitor filter array.

The overall circuit operates as a "DC transformer" with open circuit output voltages following the input on a 4-to-1 voltage ratio. Under load, the output exhibits a finite output impedance characteristic (see discussion below), with output voltage typically decaying no more than about 6% under full load.

The SBC-12/22-L48 is fabricated on multi-layer, high-density surface mount printed circuit boards using automated SMT-on-pc board techniques. The mechanical layout is "open frame" which offers superior thermal characteristics and inspection of components.

Like many other DATEL power converters, the SBC-12/22-L48 includes safety specifications UL/IEC/EN 60950 and CSA-C22.2 (no. 234). The converter meets EN55022 and FCC class B conducted emission specifications by using a suitable external filter. The SBC-12/22-L48 will operate continuously up to +45°C. with 300 linear feet per minute forced cooling.

The SBC-12/22-L48 is fully protected against excessive output currents and indefinite short circuits. Two options are offered for overcurrent protection. Either the unit will periodically attempt to restart ("hiccup" mode) or the output will limit (latch mode) until the unit is reset.

TECHNICAL NOTES

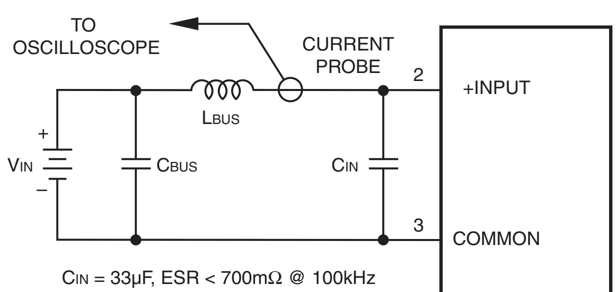
I/O Filtering and Noise Reduction

The SBC-12/22-L48 is tested and specified with external output capacitors. These capacitors are necessary to accommodate our test equipment and may not be required to achieve desired performance in your application. The SBC-12/22-L48 is designed with high-quality, high-performance *internal* I/O caps, and will operate within spec in most applications with *no additional external components*.

In particular, the SBC-12/22-L48 input capacitors are specified for low ESR and are fully rated to handle the units' input ripple currents. Similarly, the internal output capacitors are specified for low ESR and full-range frequency response.

In critical applications, input/output ripple/noise may be further reduced using filtering techniques, the simplest being the installation of external I/O caps.

External input capacitors serve primarily as energy-storage devices. They minimize high-frequency variations in input voltage (usually caused by IR drops in conductors leading to the DC/DC) as the switching converter draws pulses of current. Input capacitors should be selected for bulk capacitance (at appropriate frequencies), low ESR, and high rms-ripple-current ratings.



C_{IN} = 33µF, ESR < 700mΩ @ 100kHz
C_{BUS} = 220µF, ESR < 100mΩ @ 100kHz
L_{BUS} = 12µH

Figure 2. Measuring Input Ripple Current

The switching nature of modern DC/DC's requires that the dc input voltage source have low ac impedance at the frequencies of interest. Highly inductive source impedances can greatly affect system stability. Your specific system configuration may necessitate additional considerations.

Input Fusing

Most applications and or safety agencies require the installation of fuses at the inputs of power conversion components. The SBC-12/22-L48 Series may have an optional input fuse. Therefore, if input fusing is mandatory, either a normal-blow or a fast-blow fuse with a value no greater than twice the maximum input current should be installed within the ungrounded input path to the converter.

As a rule of thumb however, we recommend to use a normal-blow or slow-blow fuse with a typical value of about twice the maximum input current, calculated at low line with the converter's minimum efficiency.

Input Overvoltage and Reverse-Polarity Protection

The SBC-12/22-L48 does not incorporate input reverse-polarity protection. Input voltages in excess of the specified absolute maximum ratings and input polarity reversals of longer than "instantaneous" duration can cause permanent damage to these devices.

Start-Up Time

The V_{IN} to V_{OUT} Start-Up Time is the interval between the time at which a ramping input voltage crosses the lower limit of the specified input voltage range and the fully loaded output voltage enters and remains within its specified accuracy band. Actual measured times will vary with input source impedance, external input capacitance, and the slew rate and final value of the input voltage as it appears to the converter.

The On/Off to V_{OUT} Start-Up Time assumes the converter is turned off via the On/Off Control with the nominal input voltage already applied to the converter. The specification defines the interval between the time at which the converter is turned on and the fully loaded output voltage enters and remains within its specified accuracy band.

Output Reverse Conduction

Many DC/DC's using synchronous rectification suffer from Output Reverse Conduction. If those devices have a voltage applied across their output before a voltage is applied to their input (this typically occurs when another power supply starts before them in a power-sequenced application), they will either fail to start or self destruct. In both cases, the cause is the "freewheeling" or "catch" FET biasing itself on and effectively becoming a short circuit.

The SBC-12/22-L48 will withstand higher external sources several volts above the nominal output. However, if there is a chance of consistent over-voltage, users should provide an external voltage clamp or other protection.

Optional Internal Input Fuse and Output Power Limit ("F" Suffix)

Refer to the Part Number Structure and Models Available to specify an optional 12 Amp surface mount input fuse installed internally for "F" models. Since this fuse is rated at approximately twice the normal maximum input current, it would only open if the converter developed an electrical problem. Therefore the fuse is primarily designed to protect your external input circuit and to meet safety certification requirements.

In addition to the input fuse, the F models also include a maximum output power shutdown mode of 240 Watts. Both the output current and voltage are measured and the converter will shut down when output power exceeds 240 Watts. This capability is also available on other ("non-F") models under special order. Contact DATEL.

Undervoltage Shutdown

When the input voltage falls below the undervoltage threshold, the converter will terminate its output. However, this is not a latching shutdown mode. As soon as the input voltage rises above the Start-Up Threshold (typically about a Volt higher than shutdown), the converter will restore normal operation. This small amount of hysteresis prevents most uncommanded power cycling. Since some input sources with higher output impedance will increase their output voltage greater than this hysteresis as soon as the load is removed, it is possible for this undervoltage shutdown to cycle indefinitely. To prevent this, be sure that the input supply always has adequate voltage at full load.

Determining Net Output Voltage

At a fixed ambient temperature and constant airflow environment, the output voltage is determined primarily by three variables – input voltage, initial accuracy and output voltage decay due to the load current ("load regulation"). Since the output "load regulation" variation due to current load only goes negative starting from no load, these 3 variables can be combined in a single linear equation as follows:

$V_{OUT} = (V_{IN}/4 \times (1 \pm \text{InitialAccuracy}/100) \times (1 - \text{LoadReg}/100 \times I_{OUT}/I_{MAX})$

where,

V_{OUT} is the net output voltage from the converter.

V_{IN} is the instantaneous net input voltage seen at the converter's input terminals.

InitialAccuracy is the starting no-load accuracy in percent.

LoadReg is the absolute value of the output load regulation amount in percent.

I_{OUT} is the measured output current.

I_{MAX} is the maximum rated full scale output current.

The initial open circuit accuracy is typically +1, –2% from the ideal $V_{IN}/4$ ratio. V_{IN} is assumed to be fixed and unchanging but in the real world, any finite external source impedance or external input regulation at the V_{IN} input will vary V_{IN} over the full output current range, thereby also changing V_{OUT}. In addition, changes in ambient temperature and cooling airflow may alter this equation slightly.

Thermal Considerations and Thermal Protection

The typical output-current thermal-derating curves shown below enable designers to determine how much current they can reliably derive from each model of the SBC-12/22-L48 under known ambient-temperature and air-flow conditions. Similarly, the curves indicate how much air flow is required to reliably deliver a specific output current at known temperatures.

The highest temperatures in SBC-12/22-L48's occur at their output inductor, whose heat is generated primarily by I^2R losses. The derating curves were developed using thermocouples to monitor the inductor temperature and varying the load to keep that temperature below +110°C under the assorted conditions of air flow and air temperature. Once the temperature exceeds +120°C (approx.), the thermal protection will disable the converter using the hiccup shutdown mode.

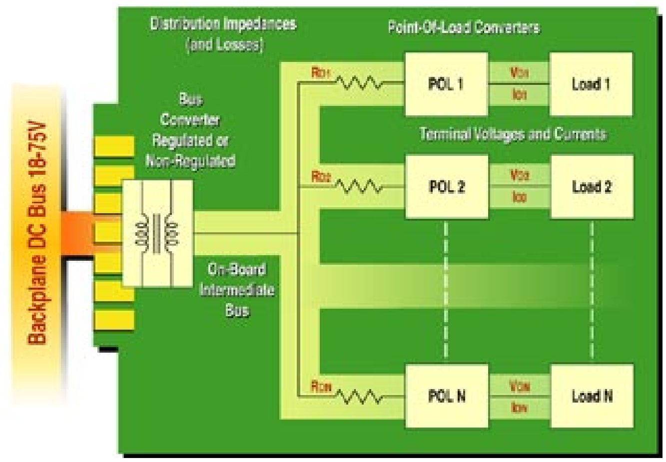


Figure 3. Intermediate Bus Architecture

Distributed Bus Architecture

A revolution is at hand for powering dedicated mixed circuit systems. Instead of installing a single large isolated power supply or multiple isolated converters, the new architecture uses one isolated power bus converter driving multiple Point-of-Load non-isolated DC/DC converters which are positioned right where the power load is needed. While conceptually similar to having a single master power supply and distrubuted linear regulators, the bus converter concept offers significantly lower cost, higher efficiency and therefore lower temperatures, better reliability and longer service life. Bulky, expensive heat sinks are eliminated and even a costly fan can be downsized or deleted.

To achieve these results, the isolation is concentrated in the bus converter and the precise voltage regulation resides in the POL converters. Since the high current power switching is located in the bus converter, designers can arrange the best possible noise shielding, isolation layout and thermal distribution. And, since all the regulation is placed in the POL converters, the total system offers very high efficiency, important for battery-operated and standby applictions. Typically, DATEL's surface mount POL converters are actually smaller than equivalent linear regulators, heat sinks and their discrete components. Another benefit to the distributed power architecture is that it eliminates digital crosstalk in tightly packed systems.

A further advantage is that multiple power voltages are implemented simply by connecting POL's with different output voltages. Today's modern systems require several low power voltages. Many large ASIC's, gate arrays and programmable logic are powered from 3.3 Volts or lower. CPU's use 2.5 or lower voltages at considerable current. And legacy logic or I/O ports may run from 5 Volts. It makes sense to provide separate power converters for each of these sections. But they do not all need to be isolated, saving cost, board area and heat buildup.

The SBC-12/22-L48 accepts a single input power voltage centered on 48 Volts, ranging from 40.5 to 57 Volts DC and provides a single isolated output of 12 Volts up to 22 Amps. Isolation is rated at 2250 Volts. The bus converter operates ratiometrically as a "DC transformer," giving a 4-to-1 relationship (no load) between the input and output voltages. With varying output load, a small decrease in output voltage is compensated for by the regulation in the POL converters.

Fabricated on a Single Inline Package, the SBC-12/22-L48 is fully short circuit protected. It is important to always see the SBC as part of a complete power supply system including the POL converters. While the SBC has its own specifications, what really counts is their effect when fully integrated with their companion POL's.

Operation at Low Input Voltage

Certain combinations of high output current and low input voltage plus reduced airflow may subject the SBC-12/22-L48 to maximum power limits. And because of the unregulated ratiometric operation, be aware that with low input voltage (40.5V minimum), the no-load output voltage will be about 10V. But with full output load and low input voltage, the output voltage will decay approximately 6% lower or about 9.4 Volts. The correct type of POL converter will accommodate this voltage range.

Another effect to be aware of is non-linear current consumption under low input voltage conditions from input sources with higher impedance. As the input voltage drops, more current is required to maintain constant output power. If the input source has non-zero input impedance, this will reduce the apparent voltage seen at the SBC-12/22-L48's input terminals. However this causes an even further voltage drop at the inputs, necessitating even more input current. This unstable situation can result in undervoltage shutdown.

The solution is to power the SBC-12/22-D48 from a source with adequate current and low output impedance. The input source must supply full input current at 40.5V input or greater. Two ways to do this are to use large freshly-charged batteries as the input source or use a regulated 48Vdc supply. The hallmark of discharged batteries is high internal cell impedance, meaning limited current capacity.

Short Circuit, OverCurrent Condition and Undervoltage Shutdown

If the load exceeds the maximum rated output current, the SBC-12/22-L48 will enter a state of reduced output voltage and limited output current, essentially delivering constant power (also called power limiting). Operation of the unit after this condition depends on the latching/hiccup model variation. When the converter is in current limit mode, the output voltage will drop as the output current demand increases. If the output current exceeds the current limit, the PWM controller will shut down and the unit will enter short circuit mode.

The SBC-12/22-L48 offers two modes for short circuit or overcurrent operation. These modes are selected in the Ordering Guide. In the "hiccup" autorestart mode, the output will shut off but will periodically attempt to restart with a full-current output pulse. If the overcurrent condition is removed, the converter will now automatically resume normal operation. If the short circuit or overcurrent condition remains, the converter will automatically remove output power and periodically try again.

In the latching overcurrent mode, the output will remain off until the On/Off control input is toggled or the input power is recycled. It will not automatically recover even if the output current goes completely to zero. The latching feature induces power hysteresis which prevents rapid cycling between full power and power limiting. Such cycling may be disruptive to some applications.

Thermal Shutdown

Extended operation at excessive temperature will initiate overtemperature shutdown triggered by a temperature sensor inside the PWM controller. This operates similarly to overcurrent and short circuit mode. The inception point of the overtemperature condition depends on the average power delivered, the ambient temperature and the extent of forced cooling airflow. Thermal shutdown uses only the hiccup mode (autorestart).

Output Impedance

Given a constant input voltage, the SBC-12/22-L48 output voltage varies under load. The SBC-12/22-L48, like most bus converters, is unregulated. This is acceptable in many applications because all the regulation takes place in the POL converters positioned right at the load. Although the SBC-12/22-L48 does not have tight regulation, it still holds the output voltage within a limited margin from no load to full load.

An easy way to understand this effect is to treat the SBC-12/22-L48 output as an ideal zero impedance voltage source in series with a finite internal source resistor. Holding the input voltage constant, the equation to develop this internal source impedance is the following:

$$(V_{ZERO\ LOAD} - V_{FULL\ LOAD}) / (I_{FULL\ LOAD} - I_{ZERO\ LOAD}) = Z_{SOURCE}$$

Where the V terms are output voltages, the I terms are output currents and Z_{SOURCE} is the output impedance.

If for example the output voltage dropped 5% from no load to full load (with constant 48V input), typical values are:

$$(12.0V - 11.4V) / (22A - 0) = 27.3m\Omega$$

Assuming a very "stiff" unchanging input voltage (not always realistic), the SBC-12/22-L48 in this example looks like an ideal voltage source in series with about a 0.027 Ohm resistor. The actual performance is slightly more complicated than this simple linear equation because the source voltage supply will indeed reduce voltage with increasing current, cooling and temperature variation (due to the source's finite internal impedance and/or regulation). And the efficiency will change with output load. But the finite internal impedance model is very useful to start analysis because the zero load and full load output voltages of the SBC-12/22-L48 are easily measured using an accurate power resistor and a digital voltmeter.

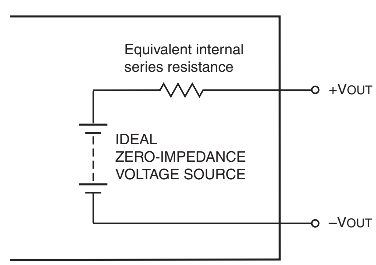


Figure 4. Equivalent Voltage Source Model

Load Sharing

Load sharing occurs when two or more SBC-12/22-L48's are connected in parallel at both the input and output terminals to supply greater output current than one unit alone or to offer system redundancy for moderate loads. If one converter fails, the other converter(s) will carry the load until the system is repaired.

The SBC-12/22-L48's design allows load sharing using the "droop" method, also called the "direct connect" technique. Simply put, at light loads, the converter with slightly higher output voltage will carry more of the output current. Since the SBC-12/22-L48's synchronous rectifier design will not accept appreciable reverse output current, starting at zero load, the SBC-12/22-L48 with the higher output voltage will carry more of the full load until the voltage at the output drops to that of the lower SBC-12/22-L48's. If there are several SBC-12/22-L48's all connected in parallel, each SBC-12/22-L48 will "turn on," contributing current as the output load increases and the output voltage lowers.

The SBC-12/22-L48 output voltage between parallel-connected units tracks very closely to changes in the input voltage. And if two or more converters share the same identical input voltage, small open circuit voltage differences occur between the outputs.

Rough approximation load sharing calculations use a combination of open circuit voltage and output impedance.

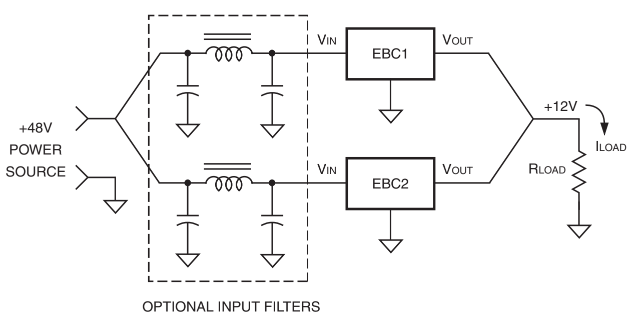


Figure 5. Load Sharing Block Diagram

Loadsharing Guidelines

If you wish to operate two or more SBC-12/22-L48's in load sharing, use these guidelines:

[1] Operate both converters connected in parallel to the same 48V input power source. This simplifies the design and makes more balanced power sharing. Using two different 48V input supplies must be carefully analyzed to avoid overloading one of the converters.

Make sure the single 48V input source can supply the total current needed by all the parallel-connected SBC-12/22-L48's. (Actually, it is possible to rate the full system at more than the current capacity of a single SBC-12/22-L48. However, you now lose the redundancy protection feature.)

[2] Use conservative loading. Do not assume for example that two parallel SBC-12/22-L48's can always supply "times two" amounts of output current. Allow for limits in input voltage and other factors.

If one SBC-12/22-L48 overloads while in load share, it will protect itself by entering the overcurrent mode. If the whole system is running close to maximum output current, the remaining good SBC-12/22-L48 will soon also enter overcurrent mode. These two events probably will not happen together, possibly leaving the system operating in degraded mode for awhile. The solution here is conservative design to avoid getting close to the load limits.

[3] Make the input wiring lengths and wire gauges identical on both inputs and outputs. If in doubt, make some precision measurements under full load. But if you attempt to measure the current in one of the converters using a series shunt, remember that the current meter itself may introduce enough finite resistance to affect the readings. (Hint: Use a non-contacting "clamp-on" Hall effect DC current meter with zero IR loss.)

[4] If you add the optional input filters, use identical components with the same layout.

[5] Operate both converters in the same temperature and airflow environment. Under load sharing, small differences in cooling can amplify into load imbalances.

[6] Avoid operation near the low input voltage limit of the converter. Another subtle factor here is the external source impedance of the input supply. A source with higher source impedance at full load may make the net input voltage seen by the converter close to its minimum input voltage. Be sure to account for the decrease in effective input voltage under load.

For battery sources, this means that the batteries should be freshly charged and that the AC trickle charger is in good working order. Note that older batteries increase their internal cell impedance even if their no-load output voltage appears acceptable. Remember that what counts here is the voltage seen at the SBC-12/22-L48 input connections with full current.

[7] As with any system design, thoroughly test the SBC-12/22-L48's connected in load sharing before committing the design to a real application.

Example: Applying Output Impedance Analysis to Two Load Sharing SBC-12/22-L48's

The output impedance is very similar between SBC-12/22-L48's. So to compute the load sharing, take the two open circuit output voltages of two SBC-12/22-L48's and compute their effective source resistance at full load.

Assume for example that two SBC-12/22-L48's share a common 48V zero impedance input voltage source and one SBC-12/22-L48 produces 12.00V output at no load while the other produces 12.1V, a 100mV difference. Assume further that both SBC-12/22-L48's have an identical 27mΩ measured output impedance.

In the following diagram, rate the output load current at 36 Amps maximum total. We know that both SBC-12/22-L48 currents must be summed to deliver this total output current. The unbalance in the two SBC-12/22-L48 currents feeding the common full load is computed as follows:

$V_{SBC1OPEN}$ = 12.00V (open circuit voltage)

$V_{SBC2OPEN}$ = 12.1V (open circuit voltage)

$R_{SBC1} = R_{SBC2}$ = 0.027 Ohms (internal source impedance)

$I_{TOTALLOAD}$ = 36A (maximum output load current for this example)

V_{LOAD} is the actual maximum net voltage appearing at the load, to be determined.

$$(V_{EBC1OPEN} - V_{LOAD}) / R_{EBC1} + (V_{EBC2OPEN} - V_{LOAD}) / R_{EBC2} = I_{TOTALLOAD} = 36A$$

But we have assumed that $R_{EBC1} = R_{EBC2}$ therefore the equation can be rewritten as:

$(V_{EBC1OPEN} + V_{EBC2OPEN} - 2 \times V_{LOAD}) / 0.027$ Ohms = 36A or,

$(V_{EBC1OPEN} + V_{EBC2OPEN} - 2 \times V_{LOAD}) = 0.972$

Rearranging terms,

$V_{LOAD} = (V_{EBC1OPEN} + V_{EBC2OPEN} - 0.972) / 2$ or,

$V_{LOAD} = (12.0 + 12.1 - 0.972) / 2 = 11.564V$

And, now that we know the full current load voltage,

$I_{EBC1} = (V_{EBC1OPEN} - V_{LOAD}) / R_{ebc1} = (12.00 - 11.564) / 0.027 = 16.148A$

$I_{EBC2} = 36A - I_{EBC1} = 19.852A$

In this example, the two EBC-12/22-L48's differ by about 3.05A at full load.

Note that we could have increased the output current beyond 36A. However, the analysis becomes more complicated if there is a real-world IR voltage drop at the 48V input side. The analysis above can be extended for the worst-case conditions of low input line voltage. This same method will also work if you measure differences in the output impedance and/or you are load sharing more than two bus converters. And if you do not know the output current but you can measure your application's load resistance, substitute V_{LOAD}/R_{LOAD} for $I_{TOTALLOAD}$.

Remote On/Off Control

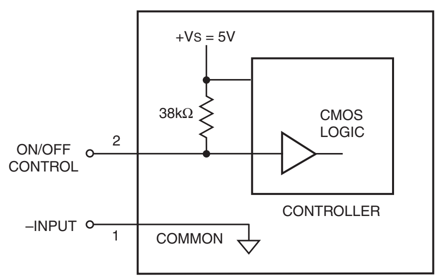


Figure 6. On/Off Control Equivalent Circuit

The SBC-12/22-L48 may be turned off or on using the external remote on/off control. Allow at least 15 milliseconds for either transition. This terminal consists of a digital input to the internal PWM controller and a 38 kilOhm pullup resistor to +5V. CAUTION!! The PWM is easily damaged by an On/Off Control overvoltage spike input. Use external voltage clamps if necessary.

The on/off input circuit should be CMOS logic referred to the –Input power terminal however TTL or TTL-LS logic will also work or a switch to ground. If preferred, you can even run this using a bipolar transistor in "open collector" configuration or an "open drain" FET transistor. You may also leave this input unconnected and the converter will run whenever input power is applied.

This control is required for restart if you have selected the Latch On/Off Control model option.

Definitions

Line Regulation

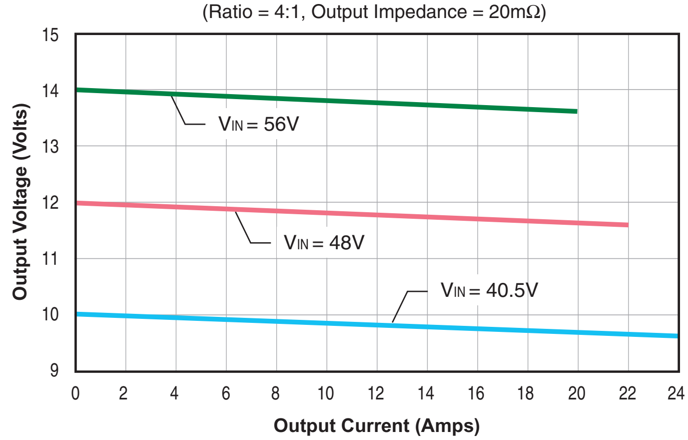
This is the change in the output if the input changes. With a bus converter, this specification is essentially unregulated. Changes in the input voltage are almost fully reflected in proportional 4:1 (ratiometric) changes in the output voltage. Therefore line regulation has much less meaning compared to other DC/DC converters. In other words, line regulation is one of the specifications which is forfeited in order to achieve the high efficiency and small size of the bus converter architecture.

Load Regulation

This specification is what most regulated DC/DC's provide – a mostly non-changing output with excursions from zero to full output load. Here again, the bus converter is essentially unregulated. However, there is, in effect, output "load regulation" if you consider equivalent internal source impedance. Low output impedance means that the output voltage does not vary much from no load to full load at fixed input voltage.

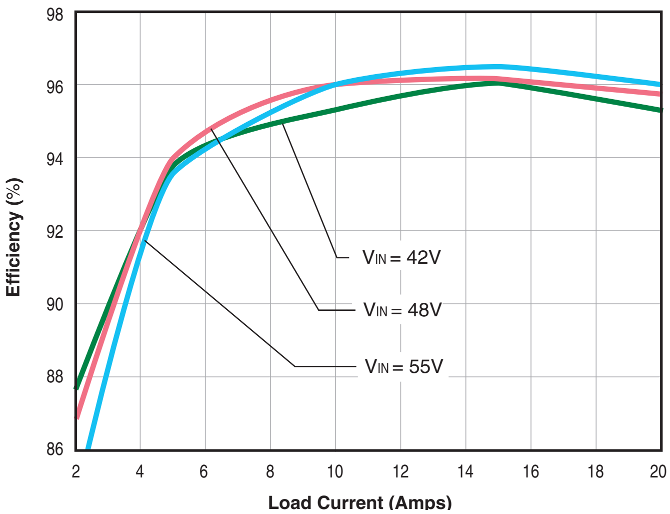
Typical Performance Curves

Output Voltage vs. Output Current
(Ratio = 4:1, Output Impedance = 20mΩ)

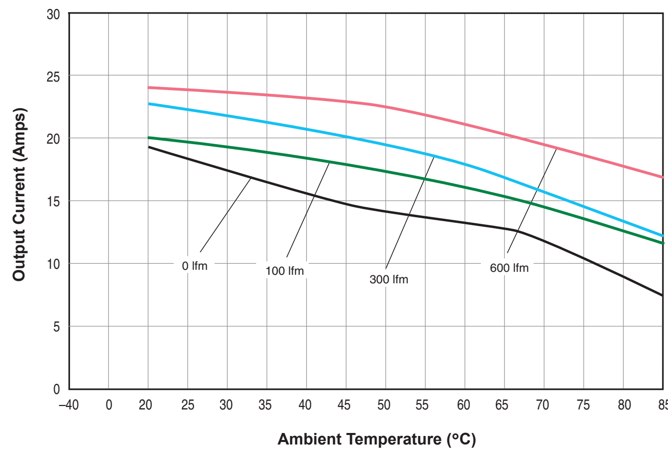


Typical Performance Curves

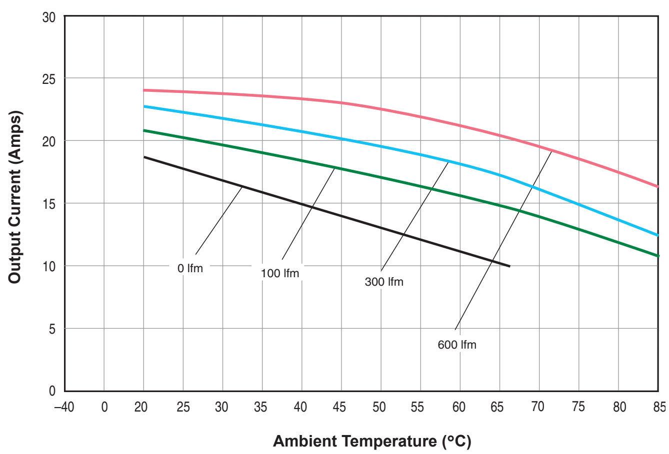
SBC-12/22-L48
Efficiency vs. Line Voltage and Load Current



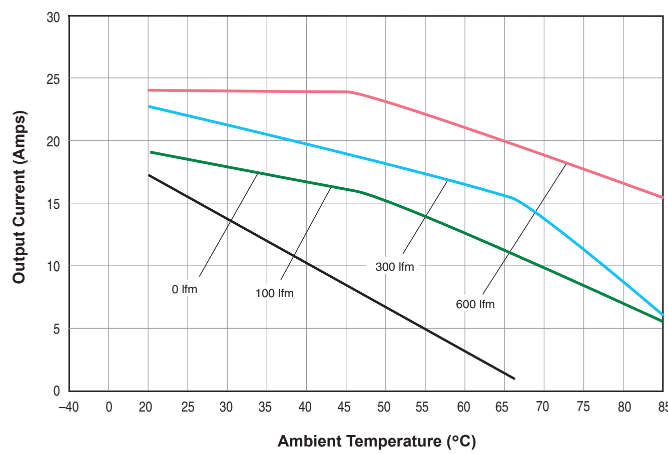
SBC-12/22-L48 Temperature Derating
V_{IN} = 40.5V (air flow direction from output pins to input pins)



SBC-12/22-L48 Temperature Derating
V_{IN} = 48V (air flow direction from output pins to input pins)



SBC-12/22-L48 Temperature Derating
V_{IN} = 57V (air flow direction from output pins to input pins)



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