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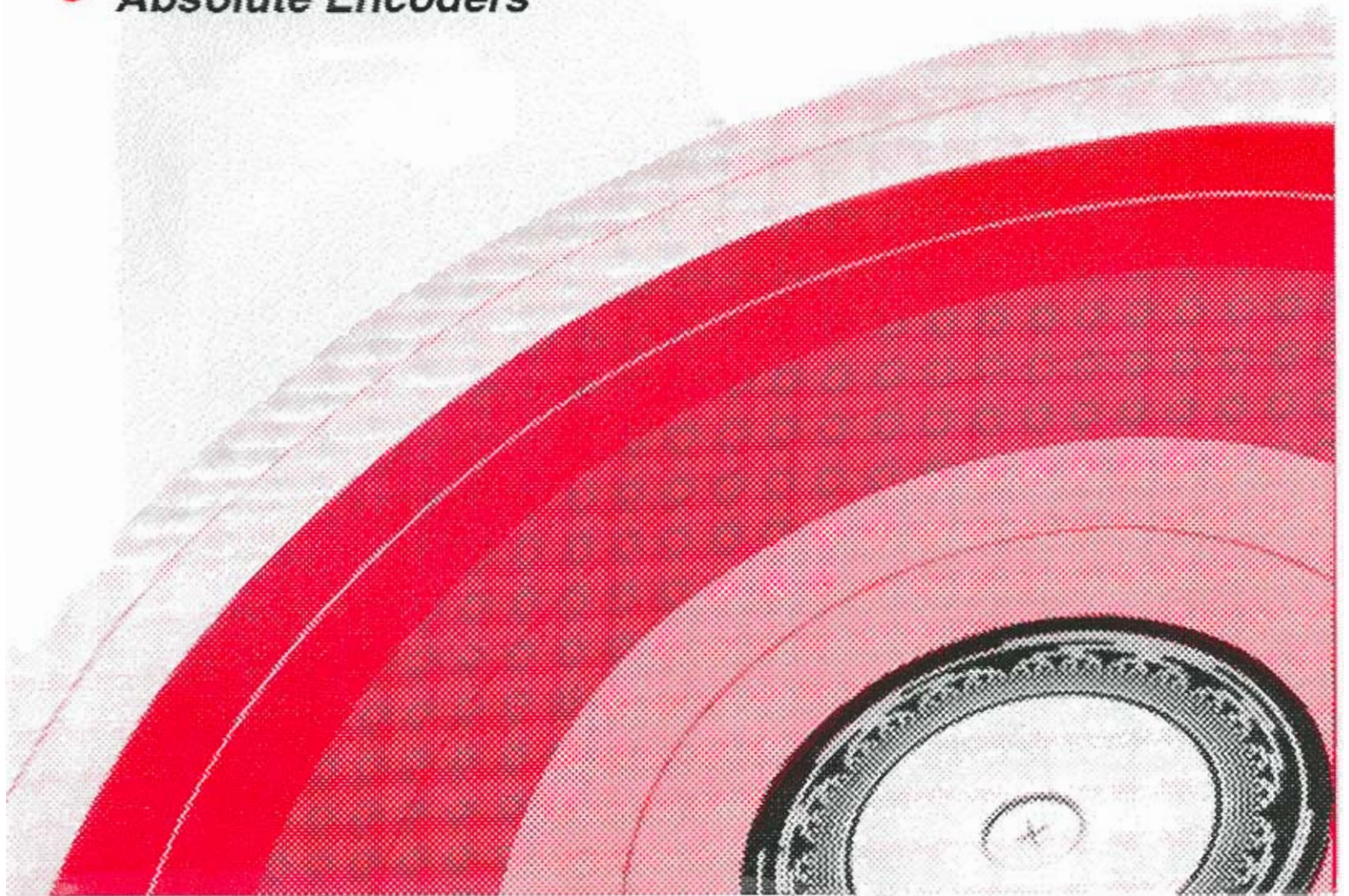

Modular Concept Simplifies Design of 16-Output Supply

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Design tradeoffs led to a modular design approach for a military airborne power supply with 16 outputs and 520W total power out.

We often get requests for the design of a power supply that must be completed "yesterday." In this case it was almost that bad, we had five weeks to produce a design whose first specification revision was handwritten by the customer on one page with only basic electrical requirements and preliminary outline dimensions. The customer needed a working breadboard for integration tests in their system. Most of the specification requirements (*Table I*) were not finalized, so we had to produce a quick and flexible design without taking too many risks with new technologies. Having to provide 16 different output voltages complicated the design. A working breadboard that met all specification requirements was completed within five weeks.

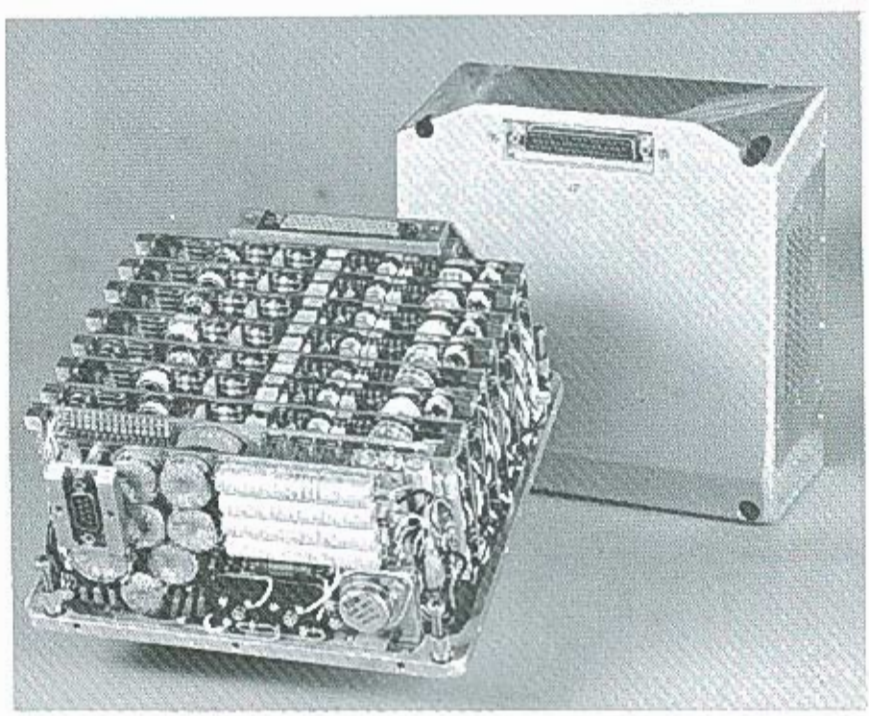

Figure 1. 16-Output Supply.

Using standard off-the-shelf DC-DC converters could be a good approach, especially because of the short turnaround requirement. PC board-mounted converters require too much space. Potted converters create a weight problem and they use many nonstandard parts. And, hybrid converters are too expensive: about $500 per output, $8,000 for the converters only!

A main switching converter with fifteen additional outputs generated from the main transformer secondaries could save components, but the transformer would be very expensive to build and would contain complex windings, causing beat problems. The no-load operating requirement on the main output would require a pre-load circuit.

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Table 1. Power Supply Specifications.

Parameter	Value
Input Voltage	115/208 VAC
Input Frequency	400 Hz, 3-phase (MIL-STD-704)
Output 1	+5V @ 8A
Output 2	+5V @ 4.5A
Output 3	-5V @ 2A
Output 4	+5V @ 2A
Output 5	+5V @ 0.7A
Output 6	+5V @ 0.5A
Output 7	+10V @ 1.5A
Output 8	+15V @ 1.6A
Output 9	-15V @ 1.6A
Output 10	+15V @ 0.6A
Output 11	-15V @ 0.6A
Output 12	+28V @ 5A
Output 13	+30V @ 3A
Output 14	-30V @ 3A
Output 15	+9V @ 0.8A
Output 16	-9V @ 0.8A
Total Output Power	520W
Ripple/Noise	40 mV p-p @ BW=20 MHz
Efficiency	80% min.
Protection	Overvoltage
BIT	Outputs Indicator
Inhibit	On some outputs
EMI	Per MIL-STD-461
Isolation	All outputs must be isolated from the input and from all other outputs
Environmental	Altitude, Vibration, Shock, Acceleration, Fungus, Humidity, Salt
Cooling	Forced air
Weight	Less than 8 lbs.
Size	7x7x3.5 in.
Components	QPL/JTX/DESC, 0.01% Failure rate for passive
MTBF	25,000 Hrs., Airborne Inhibit

Use of linear post regulators could reduce the cost, but the power supply would not meet the efficiency requirement. Buck post regulators would increase complexity to the levels of independent switchers without any real saving in size and cost. Magnetic amplifiers as post regulators would have problems of short-circuit protection and poor dynamic cross regulation.

Synchronization between converters is generally recommended to reduce output noise switching frequency. Increased output noise is a result of crosstalk conducted and radiated between the switchers. To reduce size and component problems we decided not to synchronize the converters. Even though there is a very small distance between the boards, the output noise is below the specification limit of 40mV @ 20 MHz.

Packaging

The power supply has 10 PC boards as shown in . The first two boards include the EMI filter, input rectifiers, input capacitors and housekeeping power supply. The next seven boards include the sixteen converters, two boards with three outputs each and five boards with two outputs each. The tenth board is used for the output connector, BIT circuits and output filters.

The power semiconductors FETs and rectifiers are thermally connected to the baseplate via an L-shaped heat sink. The power FETs and the output rectifiers are selected so they do not exceed the maximum junction temperature requirement of 110°C. This design evenly spreads the heat-generated components and simplifies the assembly of the power supply.

The 115/208 VAC, 400 Hz, three-phase input has an EMI filter and is transient-protected per MIL-STD-461 in the EMI section. From the EMI filter the AC is rectified by a three-phase full-bridge to convert the AC into DC. The rectified 280 VDC is inrush current limited with an active circuit. The DC is ripple smoothed by the input filter capacitor. Filtered 280 VDC from the input capacitor is applied across all the 16 DC-DC forward converters (*Figure 2*) and the housekeeping power supply. The block diagram of a typical forward converter is in *Figure 3*.

The housekeeping power supply is of a flyback type converter that converts the 280VDC to 17 regulated and isolated low voltage outputs. One output is used for the active in-rush current limit circuit, all the other 16 outputs will bias the 16 converters control and drive circuits. By controlling the housekeeping power supply turn-on and -off, it will control the sequencing and the turn on/off of the power supply outputs. Each output is monitored and if overvoltages occur, the faulty converter will be shut off and there will be a BIT indication.

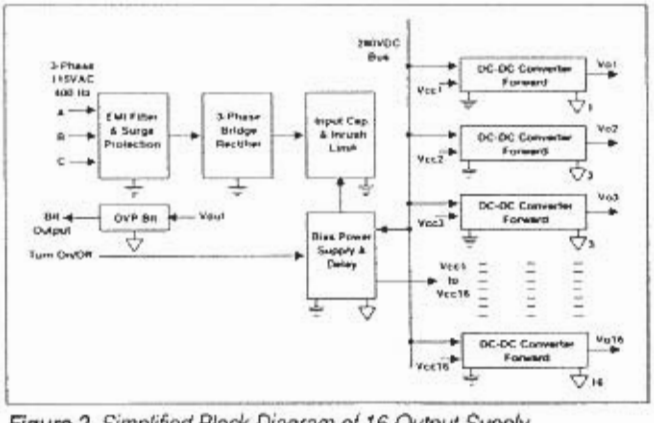

Figure 2. Simplified Block Diagram of 16-Output Supply.

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16-Output Supply

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The 280VDC from the main input capacitor is applied across the power transformer, current sense transformer and the two power FETS. The secondary voltage from the power transformer is rectified and filtered to generate the output DC.

Output regulation is accomplished by using the UC1845, a current-mode PWM IC. It senses the output voltage via a sense resistor network and the primary current via the secondary winding of the current transformer. The oscillator switching frequency is about 200kHz. A drive transformer in the drive section isolates the input from the output, and a pair of NPN and PNP transistors in a totem-pole configuration is used.

There are two current limit circuits for high reliability: a primary current limit, achieved by the current sense transformer and a secondary current limit, achieved by a sense resistor together with an external operation amplifier.

The overvoltage protection circuit uses a dedicated reference voltage and an NPN transistor to create a self-recovery-type OVP, which does not require momentary recycling of input power after recovery from overvoltage on the output. To reduce voltage stress on the FET, two power FETs are connected in series.

The MTBF calculations were performed in accordance with MIL-HDBK-217E, using the Recale-2 computer software program. The environmental conditions were: 55°C Ambient Temperature for Airborne, Uninhabited, Fighter. The MTBF calculation results were 32,798 hours, which is well within the specifications.

An important advantage to this modular design is that the power supply manufacturer can offer this basic power supply for other applications that require different output voltages or currents. New power supply requirements can easily be met by taking out converter boards and a simple packaging change. □

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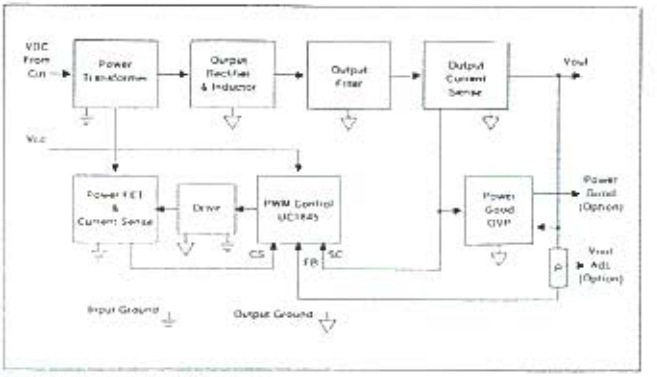

Figure 3. Forward Converter.