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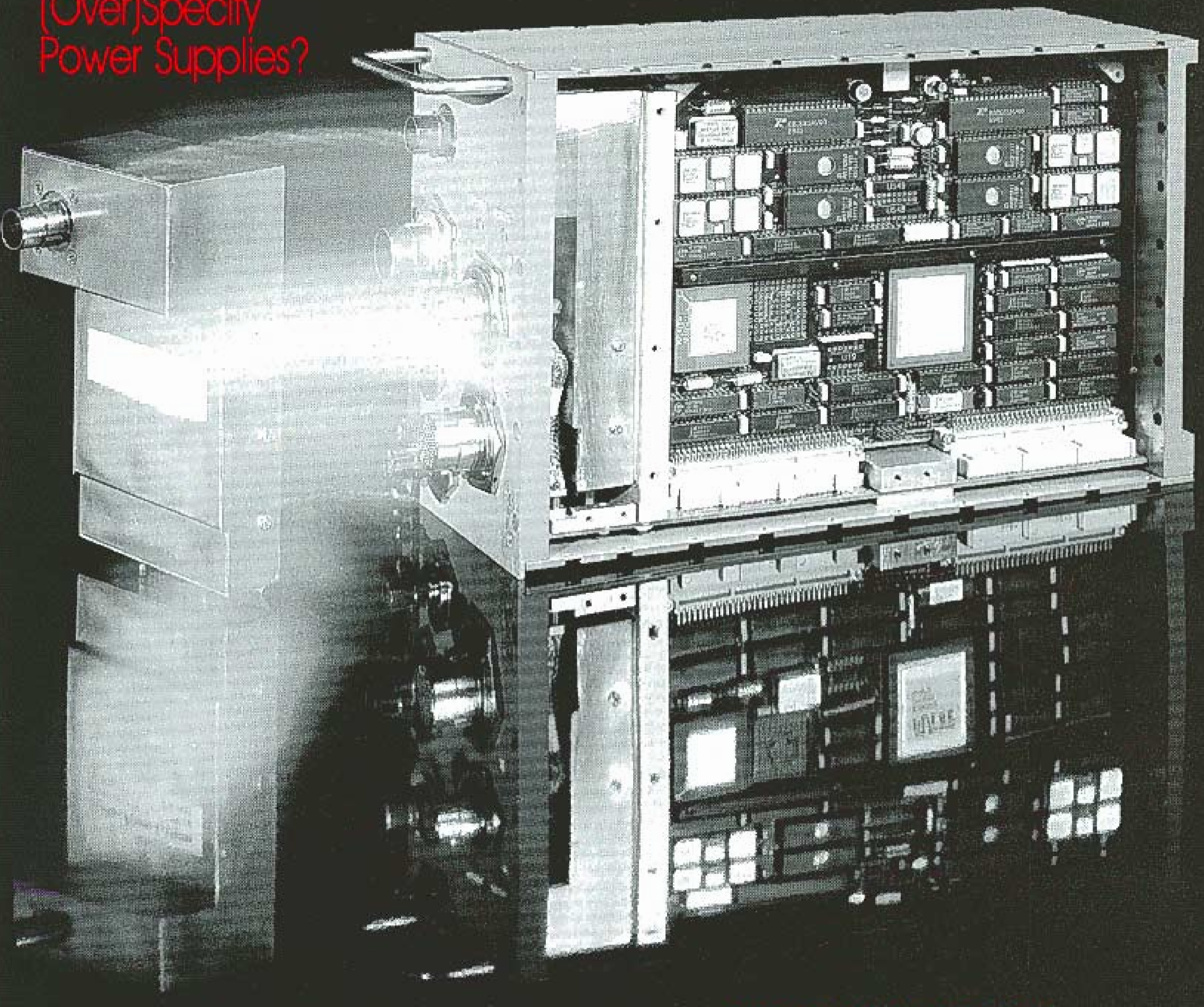
Do You (Over)Specify Power Supplies?



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Housekeeping power supply for military applications

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Military and high-rel power systems place specific isolation requirements upon the designer. Four circuits can cover a wide output range possible in such bias/housekeeping power supplies.

Most off-line power supplies and dc-to-dc converters require galvanic isolation from input to output, input to chassis, and output to chassis. The main reasons for the isolation requirement are safety- most relevant in off-line power supplies – and systems requirements to connect one of the output poles to the chassis, which is most relevant in military applications. Navy Design Guidelines-NAVMAT P 4855-1, section 4 also recommends building "an internal housekeeping power supply to isolate sensitive circuits from the hostile power line, to improve human safety and to allow control of the power-up and power-down cycle".

This article describes four circuits used for bias/housekeeping power supplies within transformer-isolated ac-to-dc power supplies and in dc-to-dc converters with an overall control feedback loop. Advantages and disadvantages of each circuit, MTBF calculations, cost, size and weight are discussed. Finally, conclusions and recommendations to the designer are included.

Output power of each housekeeping power supply is about three watts. These four circuits are used in military and high-reliability power systems from 10 watts to 3000 watts of output power, with single and multiple outputs, protection and BIT circuits.

Circuit Descriptions

In **Figure** 1, showing circuit "A", T1 is a step-down transformer which provides voltage isolation and, together with diodes CR1-CR4 and C1, creates unregulated dc voltage. Voltage regulation is provided by zener CR5 and the pass Darlington transistor Q1. The advantages of this circuit are its low cost, absence of additional switching noise and small number of components, which increases MTBF. However, it requires a bulky transformer, and different transformers are required for 1-phase or 3-phase inputs. There are also high power losses due to its linear operating mode, causing lower than 50% efficiency, and a large capacitor is required to filter the line ripple.

In **Figure** 2, we see circuit "B". Dc input voltage of 160V, from the rectified and filtered 115Vac line, applied across power transformer T1 and FET Q1 provides flyback energy storage, voltage isolation, output step-down voltage and bootstrap winding. R1 provides a small current to charge C5. When the converter is running, this bias current is supplied entirely by the converter. The peak primary current is sensed in transformer T2, which provides the current limit and current feedback. R2 and R3 together act as a feedback voltage divider.

The advantages of this circuit are high efficiency – over 60%, current-limiting protection, easy modification for 115Vac 1-phase or 3-phase inputs, possession of a 160Vdc input option, and the capability to have more outputs added to the HKPS.

The major disadvantage is a high number of parts, causing a high price and low MTBF. When operating from a 230Vac input, a high-voltage FET or a two-transistor flyback topology is required.

In **Figure** 3 (circuit "C"), unregulated 28Vdc is applied across power transformer T1 and FET Q1. T1 provides flyback energy storage, voltage isolation, output step-down voltage and bootstrap winding. R1 and CR2 provide the start-up voltage for U1. When the converter is running, the voltage is supplied entirely by the bootstrap winding. The peak primary current is sensed in transformer T2 to provide the current limit and feedback. R2 and R3 act as a feedback voltage divider.

The advantages are high efficiency – over 60%, current-limiting protection, and constant switching frequency, usually higher than that of the main power supply. The major

Env: Ground, Fixed FR = 0.382926 f/million hrs.		Ambient T: 65°C		MTBF = 2611472.0000 hrs.	Parts = 22	
Rec#	Part Number	Part Type	Qty	Ref Des	Total FR	%FR
1.	UC1844/883B	IC(Linear)	1	U1	0.195146	50.96
2.	JTX 2N6802	Transistor	1	Q1	0.016100	4.20
3.	JTX 1N4454	Diode	1	CR1	0.000229	0.06
4.	JTX 1N4454	Diode	1	CR2	0.000175	0.05
5.	JTX 1N5615	Diode	1	CR3	0.000392	0.10
6.	JTX 1N4454	Diode	1	CR4	0.000175	0.05
7.	RCR32G563JS	Resistor	1	R1	0.005003	1.31
8.	RNC50H1502FR	Resistor	1	R2	0.000300	0.08
9.	RNC50H3201FR	Resistor	1	R3	0.000265	0.07
10.	RLR05C4992FR	Resistor	1	R4	0.000230	0.06
11.	RLR05C7501FR	Resistor	1	R5	0.000230	9.06
12.	RLR05C10R0FR	Resistor	1	R6	0.000294	0.08
13.	RLR05C1002FR	Resistor	1	R7	0.000230	0.06
14.	RLR05C2000FR	Resistor	1	R8	0.000230	0.06
15.	M39014/01-1357	Capacitor	1	C1	0.000030	0.01
16.	M39014/01-1593	Capacitor	1	C2	0.000031	0.01
17.	M39014/01-1357	Capacitor	1	C3	0.000030	0.01
18.	M39014/01-1563	Capacitor	1	C4	0.000032	0.01
19.	M39003/01-2784	Capacitor	1	C5	0.000966	0.25
20.	M39003/01-2784	Capacitor	1	C6	0.000966	0.25
21.	001	Inductive	1	T1	0.136312	35.60
22.	002	Inductive	1	T2	0.025558	6.67

Table 2.
MTBF calculations for Circuit B

Env: Ground, Fix FR = 0.395417 f/million hrs.		Ambient T: 65°C		MTBF = 2528978.5000 hrs.	Parts = 23	
Rec#	Part Number	Part Type	Qty	Ref Des	Total FR	%FR
1.	SG1845/883B	IC (Linear)	1	U1	0.195146	49.35
2.	JTX 2N6788	Transistor	1	Q1	0.016100	4.07
3.	JTX 1N4454	Diode	1	CR1	0.000382	0.10
4.	JTX 1N961	Diode	1	CR2	0.003708	0.94
5.	JTX 1N4454	Diode	1	CR3	0.000229	0.06
6.	JTX 1N4454	Diode	1	CR4	0.000175	0.04
7.	JTX 1N4454	Diode	1	CR5	0.000392	0.10
8.	RCR32G302JS	Resistor	1	R1	0.000442	0.11
9.	RNC50H1002FR	Resistor	1	R2	0.000300	0.08
10.	RNC50H1621FR	Resistor	1	R3	0.000265	0.07
11.	RLR05C4992FR	Resistor	1	R4	0.000206	0.05
12.	RLR05C7501FR	Resistor	1	R5	0.000206	0.05
13.	RLR05C10R0FR	Resistor	1	R6	0.000260	0.07
14.	RLR05C1002FR	Resistor	1	R7	0.000216	0.05
15.	RLR05C1000FR	Resistor	1	R8	0.000216	0.05
16.	M39014/01-1357	Capacitor	1	C1	0.000099	0.02
17.	M39014/01-1593	Capacitor	1	C2	0.000212	0.05
18.	M39014/01-1357	Capacitor	1	C3	0.000099	0.02
19.	M39014/01-1320	Capacitor	1	C4	0.000102	0.03
20.	M39003/01-2784	Capacitor	1	C5	0.002006	0.51
21.	M39003/01-2784	Capacitor	1	C6	0.002006	0.51
22.	001	Inductive	1	T1	0.149055	37.70
23.	002	Inductive	1	T2	0.023593	5.97

Table 3.
MTBF calculations for Circuit C

disadvantages are high price and low MTBF, due to a high number of parts.

In **Figure 4**, circuit D, Q1 and CR1 supply regulated 15Vdc to the free-running (Royer) converter. This converter is a self-oscillating circuit. Transistors Q2 and Q3 are driven from positive feedback windings on T1. R1 starts the oscillation by turning on Q2 and turning off Q1. The transformer core saturates at the end of each-half cycle.

Just as in the Figure 1 circuit, low cost and high MTBF are created through a low parts count. Linear regulator Q1, however, causes high power dissipation at high line input, and the oscillator generates noise, which is often of a lower frequency than that of the main switching converter. In addition, large I_c peaks generated during saturation periods cause high peak power dissipation in the transistor.

MTBF Calculation

The MTBF calculations were done for the four circuits in accordance with MIL-HDBK-217E, using the Recalc-2 computer software program. The chosen environmental conditions were ambient temperature of −65°C and Ground-Fix.

The MTBF results were relatively high, from 2.5 million hours to 6 million hours.

It seems that the flyback HKPS – circuits B and C – have about half of the MTBF hours of the other two circuits. The major cause is the high part count in the flyback circuits.

Circuit B has about 500,000 hours more than circuit C, owing to the additional zener diode CR2 in circuit C.

Cost Comparisons

The price comparisons shown in **Table 5** present estimated prices of the electrical components used in the four different HKPS circuits. The prices are based on hundred-piece prices from "book prices" and information from distributors.

Higher part counts cause the flyback circuits to be 25-30% more expensive than the linear and free-running circuits.

Conclusions

Based on the MTBF and price comparisons, it seems that the flyback HKPS are less reliable and more

Env: Ground, Fix FR = 0.176805 f/million hrs.		Ambient T: 65°C		MTBF = 5655933.5000 hrs.	Parts = 16	
Rec#	Part Number	Part Type	Qty	Ref Des	Total FR	%FR
1.	JTX 2N6301	Transistor	1	Q1	0.002264	1.28
2.	JTX 2N3019	Transistor	1	Q2	0.000893	0.50
3.	JTX 2N3019	Transistor	1	Q3	0.000893	0.50
4.	JTX 1N965	Diode	1	CR1	0.002659	1.50
5.	JTX 1N4454	Diode	1	CR2	0.000261	0.15
6.	JTX 1N4454	Diode	1	CR3	0.000261	0.15
7.	JTX 1N5615	Diode	1	CR4	0.000301	0.17
8.	JTX 1N5615	Diode	1	CR5	0.000301	0.17
9.	JTX 1N5615	Diode	1	CR6	0.000301	0.17
10.	JTX 1N5615	Diode	1	CR7	0.000301	0.17
11.	RCR32G910JS	Resistor	1	R1	0.000150	0.08
12.	RCR32G100JS	Resistor	1	R2	0.000150	0.08
13.	RCR32G302JS	Resistor	1	R3	0.000099	0.06
14.	M39003/01-2784	Capacitor	1	C1	0.001647	0.93
15.	M39003/01-2784	Capacitor	1	C2	0.001647	0.93
16.	001	Inductive	1	T1	0.164677	93.14

Table 4.
MTBF calculations for Circuit D

Component Price				
Part Type	Circuit A:	Circuit B:	Circuit C:	Circuit D:
IC (Linear)	–	$ 5.50	$ 5.50	–
Transistor	$ 1.00	$ 6.00	$ 5.00	$ 7.00
Diode	$ 4.25	$ 2.25	$ 3.00	$ 4.75
Resistor	$ 0.15	$ 1.40	$ 1.40	$ 1.50
Capacitor	$ 4.50	$ 3.20	$ 3.20	$ 2.00
Inductive	$20.00	$20.00	$20.00	$15.00
Total	$29.90	$38.35	$38.10	$30.25

Table 5.
Comparison of estimated component prices for four HKPS circuits

expensive than the linear and free-running HKPS. However, since the HKPS is a small portion of the power system, the effect on the system MTBF and total cost will be very small.

Flyback HKPS are notable for their small size and light weight, about 60% less than linear HKPS. For military – especially airborne – applications, this is an important advantage.

Flyback HKPS in off-line applications use high-voltage dc from rectified input, so the same HKPS can be used in power supplies with 115Vac, 1-phase or 3-phase/4-wire inputs for airborne applications or can be used for 160Vdc input in UPS backup systems.

A further advantage of the flyback HKPS is its ability to control its soft-start/start-up time. This feature is especially important for power supplies using input inrush current-limiting circuits and overvoltage protection circuits using the V_{cc} from the HKPS.

Based on the above data, the flyback topology is recommended for most military HKPS applications. ☐

About the author: As Chief Engineer of Century Electronics in Culver City, CA, David Ahronowitz is responsible for the custom and standard products lines. Mr. Ahronowitz has been involved in power conversion design for military applications for more than 10 years. He holds a BSEE from Tel Aviv University in Israel, and has authored several technical papers.

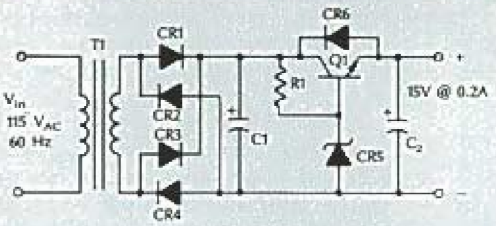

Figure 1.
Circuit A, which shows linear HKPS for off-line power supplies

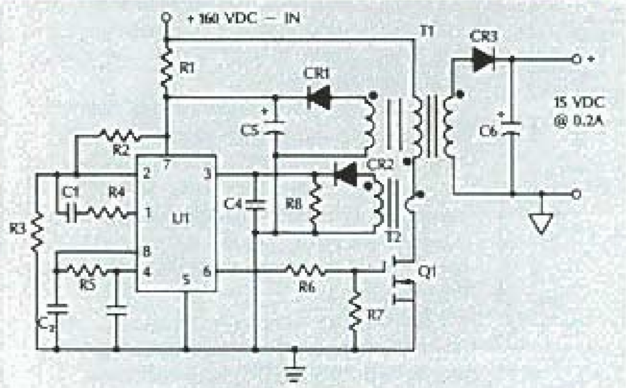

Figure 2.
Circuit B, flyback HKPS for off-line power supplies

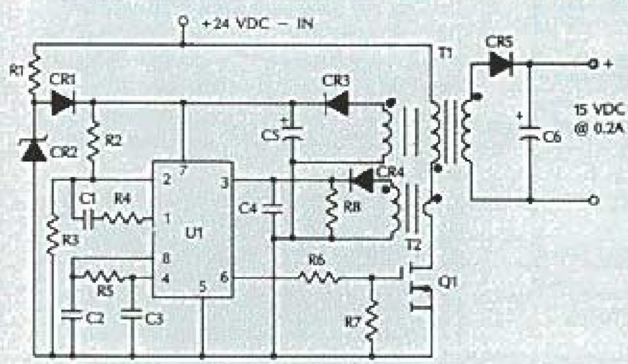

Figure 3.
Circuit C, flyback HKPS for dc-to-dc converters

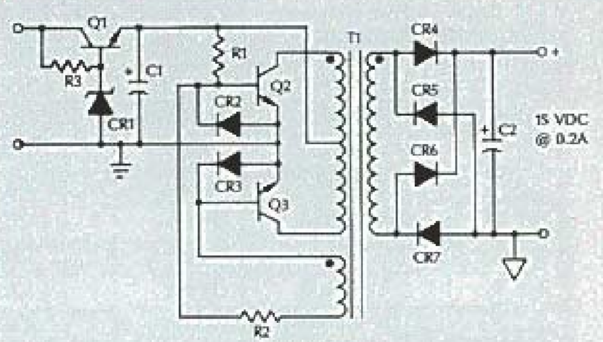

Figure 4.
Circuit D, free-running HKPS for dc-to-dc converters

Figure 5.
Military 200-watt dc/dc converter using HKPS

Env: Ground, Fixed FR = 0.165085 f/million hrs.			Ambient T: 65°C		Parts = 11 MTBF = 6057496.0000 hrs.	
Rec#	Part Number	Part Type	Qty	Ref Des	Total FR	%FR
1.	JTX 2N3019	Transistor	1	Q1	0.002974	1.80
2.	JTX 1N5615	Diode	4	CR1-CR4	0.003014	1.83
3.	JTX 1N965	Diode	1	CR5	0.002127	1.29
4.	JTX 1N5615	Diode	1	CR6	0.000502	0.30
5.	RLR20C1501FR	Resistor	1	R1	0.000242	0.15
6.	M39003/01-2792	Capacitor	1	C1	0.005648	3.42
7.	M39003/01-2784	Capacitor	1	C2	0.001523	0.92
8.	001	Inductive	1	T1	0.149055	90.29

Table 1.
MTBF calculations for Circuit A