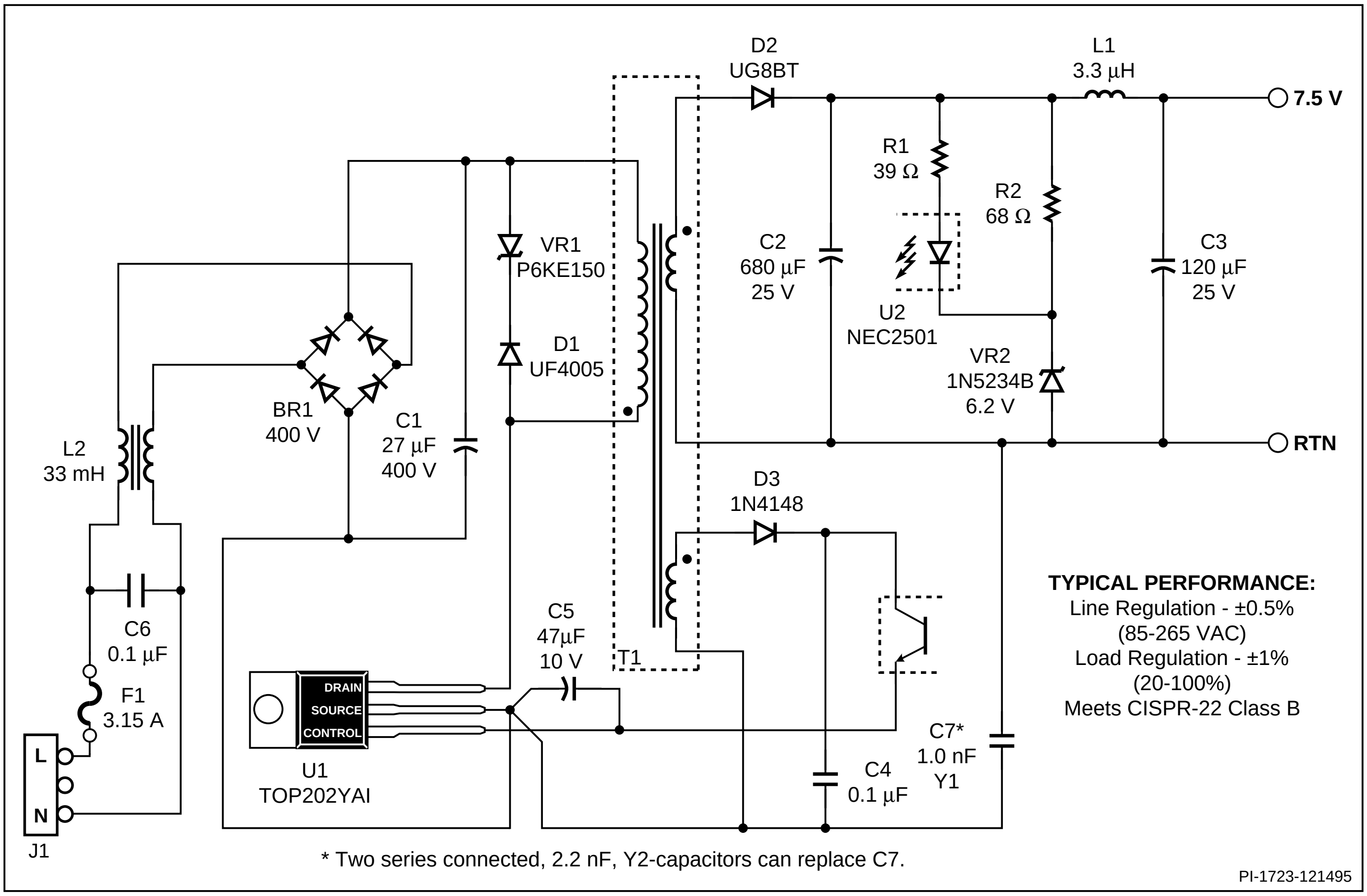
A Low Cost, Low Part Count ***TOPSwitch***® Supply

Design Note DN-11

Cost is the most important parameter for small switching power supplies. The pulse width modulated flyback power supply topology dominates the off-line power supply market below 50 Watts simply because costs are lower than other approaches. The challenge is to find the lowest cost implementation of a flyback power supply that meets the technical requirements. A *TOPSwitch* power supply has 30% to 50% fewer components when compared with typical discrete implementations. Less components means a lower power supply bill of material cost as well as reduced manufacturing costs associated with installing each component. Power supply size is also reduced and overall reliability is increased.

This Design Note presents a very low cost, minimum component count (22 components total) implementation using the TOP202YAI for a power supply operating over the universal input voltage range of 85 to 265 VAC and delivering 15 W of output power at 7.5 VDC. This power supply is designed to meet UL1950/IEC950 safety requirements for Information Technology Equipment. This power supply is also designed to meet FCC and European Class B EMI requirements. Other power levels are possible with the same basic circuit by selecting a higher or lower power *TOPSwitch* and scaling the remaining components.



TYPICAL PERFORMANCE:
Line Regulation - ±0.5%
(85-265 VAC)
Load Regulation - ±1%
(20-100%)
Meets CISPR-22 Class B

* Two series connected, 2.2 nF, Y2-capacitors can replace C7.

Figure 1. Schematic Diagram of a 7.5 V, 15 W Universal Input Minimum Part Count Power Supply Utilizing the TOP202.

Component Listing

Reference	Value	Part Number	Manufacturer
BR1	400V, 1.5 A	KBP04M	General Instrument
C1	47 µF, 400 V	KMG400VB47 018 X 20L	Nippon Chemicon
C2	680 µF, 25 V	2SSPX 680 012.5 X 20L	Nitsuko
C3	120 µF, 25 V	ECA-1EFQ121	Panasonic
C4	0.1 µF, 50 V	RPE131R104M50	Murata
C5	47 µF, 10 V	KME10VB47 05 x 11L	Nippon Chemicon
C6	0.1 µF, 250 VAC, X	CFKC22E104M	Nitsuko
C7*	1.0 nF, 400 VAC, Y1	DE1110E102M ACT4K-KD	Murata
		(or WKP102MCPE.OK	Roederstein)
		(or PME294RB4100M	Rifa)
D1	600 V, 1A, UFR	UF4005	General Instrument
D2	100 V, 6A, UFR	UG8BT	General Instrument
D3	75 V, Switching	1N4148	National Semiconductor
L1	3.3 µH, 6 A		Coiltronics
L2	20 mH		
R1	39 Ω, 1/8 W	5063JD39R00J	Philips
R2	68 Ω, 1/8 W	5063JD68R00J	Philips
T1			Custom
U1		TOP202YAI	Power Integrations
U2		NEC2501	NEC
VR1	150 V Zener TVS	P6KE150	General Instrument
VR2	6.2 V Zener	1N5234B	Motorola
F1	3.15 A, 250 VAC	K19372	Wickman

Figure 2. Parts List for the Minimum Part Count Power Supply (Two Series Connected, 2.2 nF, Y2-Capacitors Such as Murata DE7100F222MVA1-KC can replace C7).*

The 7.5 V output is directly sensed by an optocoupler and Zener diode. The output voltage is determined by the Zener diode voltage and the voltage drops across the optocoupler photodiode and resistor R1. This technique is lower cost and more accurate than the popular and well known primary bias technique for indirectly controlling lower voltage outputs. All primary bias circuits have poor load regulation due to transformer leakage inductance. For lower output voltage power supplies, primary bias techniques also require higher cost Schottky output rectifiers with low voltage drops to achieve acceptable load regulation. This simple optocoupler/Zener technique overcomes the load regulation problems caused by leakage inductance and tolerates the higher voltage drop of the P-N junction output rectifier while reducing total cost. Total cost is lower because the cost savings of the P-N junction diode over the Schottky diode is generally greater than the cost of the optocoupler. The schematic diagram of this circuit is given in Figure 1. Manufacturers and part numbers for the components used are shown in Figure 2.

AC input voltage is rectified and filtered by BR1 and C1 to create a high-voltage DC bus ranging from 100 to 375 VDC. The primary of T1 is connected between the high-voltage bus and the *TOPSwitch* DRAIN pin. T1 has a primary inductance of typically 620 µH and operates in the discontinuous mode above a DC input voltage of 100 V. D1 and VR1 clamp leading voltage spikes caused by leakage inductance when *TOPSwitch* turns off. The VR1 voltage is selected to clamp the DRAIN voltage spike approximately 50 V above the reflected output voltage at maximum output current loading. Clamping at this level reduces high-frequency ringing on the DRAIN voltage waveform, reduces common-mode EMI, and eliminates the need for additional RC damping or clamp circuits.

The *TOPSwitch* integrated circuit performs all bias, pulse width modulation , high-voltage switching, and circuit protection functions. The low $R_{DS(ON)}$ of the TOP202YAI reduces power loss and increases efficiency. Cost is reduced and weight is saved because a heat sink is not necessary.

The power secondary is rectified and filtered by D2 and C2 to typically 7.5 VDC. L1 and C3 are small, low cost components providing additional filtering to reduce high frequency ripple voltage. C2, L1, and C3 could be replaced by a single, larger, lower ESR capacitor, but total cost would be higher while achieving the same level of high-frequency output ripple voltage.

The bias winding is rectified and filtered by D3 and C4. Bias current flows into the *TOPSwitch* CONTROL pin only when optocoupler U2 is conducting and the output voltage is regulated. C5 filters high frequency currents, sets the auto-restart interval, and provides dominant pole frequency compensation. The ESR of C5 is used as part of the compensation network to reduce component count and cost. Note that C5 is connected to the SOURCE with a Kelvin connection to reduce the effect of SOURCE current switching noise.

Regulation is achieved when the output voltage rises sufficiently above the Zener diode voltage (VR2) to cause optocoupler photodiode current to flow. Optocoupler phototransistor current flows into the CONTROL pin and directly controls the *TOPSwitch* duty cycle. R1 together with the effective impedance of U2, VR2, and the *TOPSwitch* CONTROL pin determine the DC control loop gain. R2 and VR2 provide minimum loading to keep the output voltage from rising when no output current is being drawn. At higher load currents, the effective minimum loading is actually lower because the output voltage is slightly lower. R2 also increases Zener diode VR2 accuracy by increasing Zener current.

TOPSwitch power supplies have lower cost EMI filters due to inherently lower conducted emissions. Controlled turn-on reduces common-mode EMI by limiting the DRAIN voltage dV/dT each time the *TOPSwitch* turns on. The *TOPSwitch* SOURCE-connected thermal tab at primary return potential does not “broadcast” EMI like most discrete MOSFETs with tabs connected to their drains.

L2 and Y1-capacitor C7 attenuate common-mode emission currents caused by high-voltage switching waveforms on the Drain side of the primary winding and the primary to secondary capacitance. L2 and C6 attenuate differential-mode emission currents caused by the fundamental and harmonics of the primary current waveform. Note that there are no additional chokes or inductors in the EMI filter. Common-mode inductor L2 is wound on a U core style split bobbin and has both common-mode and differential-mode inductance.

The Panasonic ELF-18D290H common-mode inductor can be substituted for L2 to increase EMC noise margin by 3 to 6 dB.

The bridge rectifier BR1 can be replaced with a DIP style (General Instrument DF04M) if available at lower cost.

The circuit performance data shown in Figures 3-8 was measured by applying AC voltage to the power supply.

Load Regulation (Figure 3) - the amount of change in the DC output voltage for a given change in the output current is referred to as load regulation. The 7.5 V output stays within ±1% for a 20% to 100% load range. The load current was increased until the power supply entered the auto-restart mode of operation or shut down due to overtemperature. The *TOPSwitch* integrated overtemperature protection circuit will safely shut down the power supply under persisting overload conditions. Below minimum load, the 7.5 V output is controlled by resistor R2.

Line Regulation (Figure 4) - The amount of change in the DC output voltage for a given change in the AC input voltage is called line regulation. The maximum change in output voltage is within ±0.5% for a 85 to 265 VAC input voltage range.

Load Efficiency (Figure 5) - Efficiency is the ratio of the output

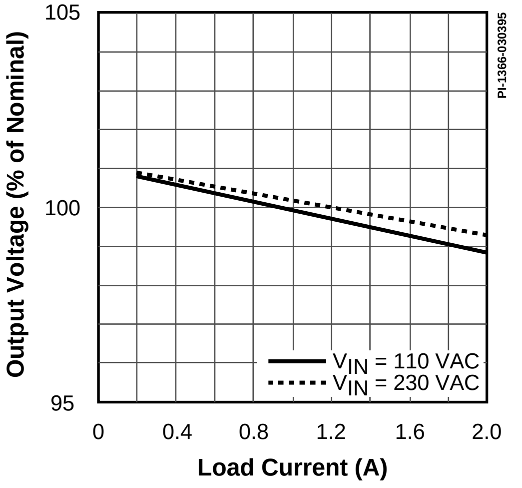


Figure 3. Load Regulation.

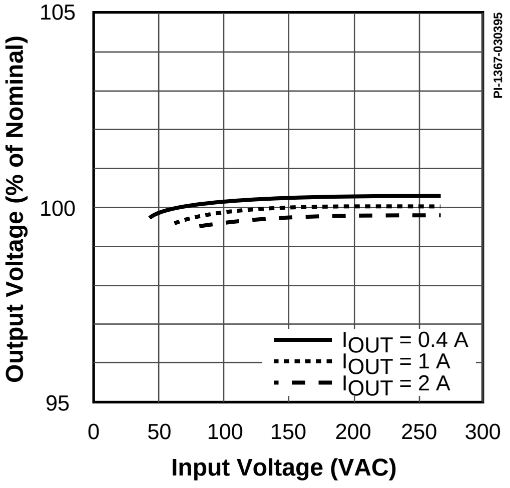


Figure 4. Line Regulation.

power to the real input power. This graph shows how the efficiency changes with load power at 110 VAC and 230 VAC inputs.

Line Efficiency (Figure 6) - This graph shows how the efficiency changes with AC input voltage at 20% and 100% of load.

The power supply transient response to a step load change from 1.5 to 2 A is shown in Figure 7. Note that the response is quick and well damped.

The output voltage turn-on transient is shown in Figure 8. There is slight overshoot on turn on with the unmodified circuit of Figure 1. Adding a 22 µF, 10 V capacitor in parallel with VR2 eliminates the overshoot as shown.

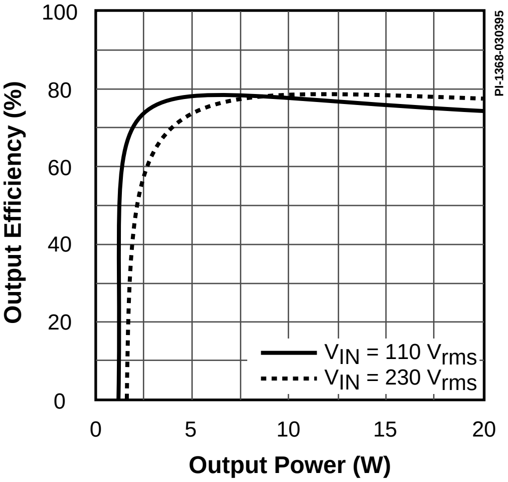


Figure 5. Efficiency vs. Output Power.

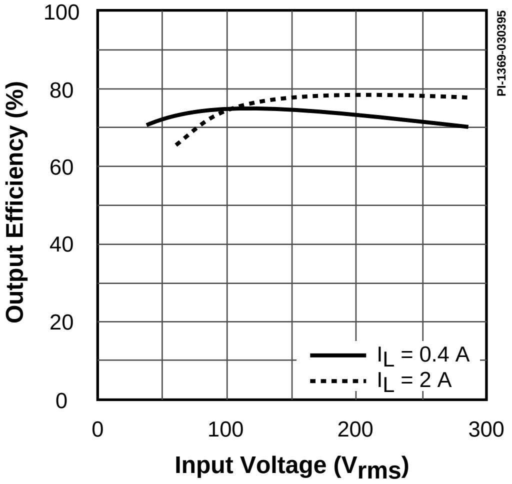


Figure 6. Efficiency vs. Input Voltage.

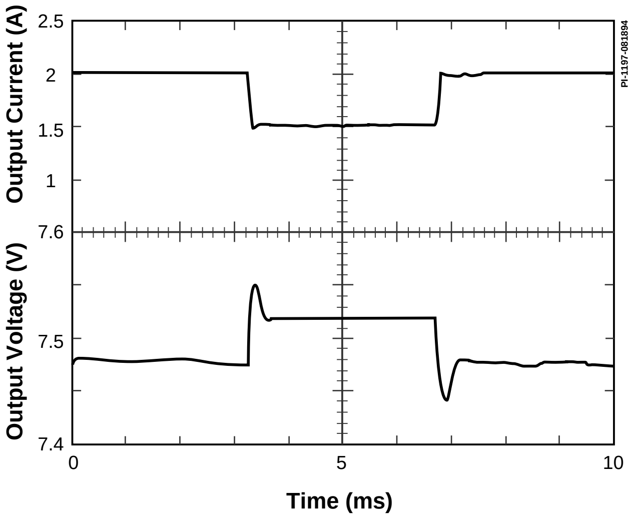


Figure 7. Transient Response.

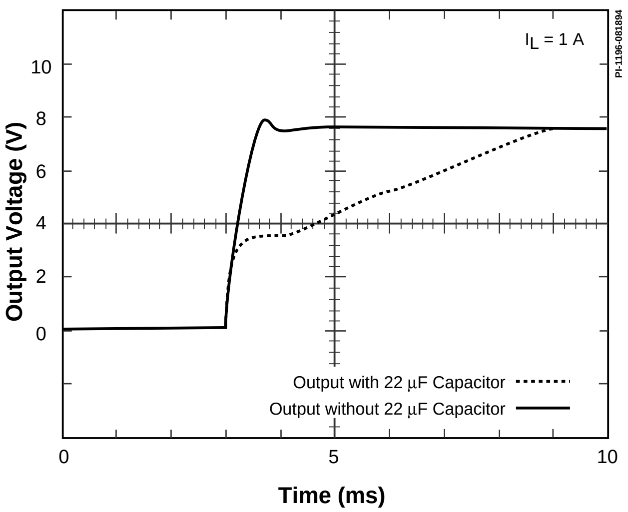


Figure 8. Turn-on Output Voltage Transient.

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