TOPSwitch®*-GX* Flyback Quick Selection Curves

Application Note AN-29

Introduction

This application note is intended for engineers starting a flyback power supply design with *TOPSwitch-GX*. It offers a quick method to select the proper *TOPSwitch-GX* device from parameters that are usually not available until much later in the design process.

Curves estimating the efficiency of the power supply and the corresponding *TOPSwitch-GX* device dissipation are provided. They form a powerful tool for estimating cost and project requirements before even committing to or starting development. This application note is similar to both AN-21 for *TOPSwitch-II* and AN-26 for *TOPSwitch-FX*.

Overview of Quick Selection Curves

The *TOPSwitch-GX* Quick Selection Curves (Figures 1-4) show the expected power supply efficiency and *TOPSwitch-GX* dissipation for typical flyback applications. Power supplies with either a 5 V or a 12 V output, operating with either ‘Universal Input’ (85 VAC-265 VAC) or ‘Single 230 VAC Input’ (195 VAC-265 VAC) are described.

The solid lines in the Quick Selection Curves give a typical efficiency figure for a given load, depending upon the *TOPSwitch-GX* device used. Each solid line efficiency curve extends to the maximum power capability of the device, limited by device current limit. The superimposed dashed lines are contours of constant *TOPSwitch-GX* device dissipation, the intersections of these dashed lines with the solid lines provide the corresponding dissipation at different loads. Interpolation or extrapolation can find the dissipation at intermediate points.

The shaded region indicates the output power where a flyback design at the given output voltage is no longer practical. This limit has been shown at an output current of 10 A and above. Higher output currents are possible but such a design is typically not cost effective due to the size of the output diode and capacitors. Higher output power can be obtained if the output voltage is higher.

The curves can be used for both P (DIP-8), G (SMD-8) and Y (TO-220) packaged devices, however for the P and G parts the dissipation must be limited to 0.85 W. This is due to the thermal constraints of the P package. The P and G parts intentionally have lower current limits than their Y packaged counterparts to match device dissipation to package capability.

QUICK START
1) Determine which graph (Fig. 1, 2, 3 or 4) is closest to your application. Example: Use Figure 1 for Universal Input, 12 V output.
2) Find your power requirement on the X-axis.
3) Move vertically from your power requirement until you intersect with a *TOPSwitch-GX* curve (solid line).
4) Read the associated Efficiency on the Y-axis.
5) Determine if this is the appropriate Efficiency for your application. If not, continue to the next *TOPSwitch-GX* curve.
6) Read the *TOPSwitch-GX* power dissipation from the dashed contours to determine heatsink requirements.
7) If the device dissipation is 0.85 W then the lower cost P/G packages can be considered.
8) Start the design. Use the *TOPSwich-GX* Transformer Design Spreadsheet or PI Expert.
Note: See ‘Selection Curve Assumptions’ for limits of use.

When using the curves for different output voltages the reader should be aware that altering the output voltage will give dramatic changes in efficiency.

For voltages between 5 V and 12 V the data from both curves can be used to extrapolate an intermediate point. Lower voltages will give lower efficiencies and limit maximum power capability. Higher voltages will give higher efficiencies and greater power. For example from the curves a 12 V, 70 W universal design using the TOP249 has an estimated efficiency of 79.5%. If the output voltage were increased to 19 V this would increase to approximately 85%. Similarly an open frame

230 VAC, 250 W design is possible with the TOP249 at an output voltage of 48 V with an efficiency of 84.5%. Note that curves for 19 V and 48 V are not provided.

Selection Curve Assumptions

The Selection Curves are based on specific design assumptions that are detailed below:

- The switching frequency is 132 kHz in all cases.
- For Universal Input the input bulk capacitor is sized at 3 μF/W of the maximum load. For single voltage input the input bulk capacitor is sized at 1 μF/W.
- A V_{OR} (reflected voltage) of 135 V is assumed for all the curves. This is the output voltage reflected by the turns ratio to the primary side.
- A Zener primary clamp used to limit the leakage inductance spike is assumed to provide a constant clamping level of 200 V. Practical implementation may require a parallel RC network to limit Zener dissipation.
- All curves assume a Schottky output diode. The 5 V output curves use a 45 V Schottky diode with a forward drop of 0.4 V. The 12 V output curves use a Schottky diode with a forward voltage drop of 0.54 V.

Besides the design criteria above, typical power supply component parameters used in generating the data for the Quick Selection Curves are provided in Tables 1 to 4. For 5 V designs using the TOP246 or larger the secondary trace inductance must be reduced as the output power increases to limit clamp dissipation. This is reflected in the table data.

The efficiency curves are valid only when using the component values shown in Tables 1 to 4. Changes to these parameters may give different results.

Selecting the correct *TOPSwitch-GX*

This section explains how to select the correct *TOPSwitch-GX* using the curves (Figures 1-4). The procedure uses the curves to estimate efficiency of the power supply and the corresponding dissipation in the *TOPSwitch-GX* device.

Start with the output power of the application on the X-axis. Move vertically to the intersection with the first *TOPSwitch-GX* curve (solid line) and then read the efficiency directly from the Y-axis. From the same intersection point on the *TOPSwitch-GX*

TYPICAL 12 V OUTPUT POWER SUPPLY COMPONENT PARAMETERS									
		UNIVERSAL INPUT (85-265 VAC)							
PARAMETER	**Units**	**242Y**	**243Y**	**244Y**	**245Y**	**246Y**	**247Y**	**248Y**	**249Y**
Maximum Transformer Primary Inductance Lp	μH	2780	1385	923	693	462	346	277	231
Transformer Leakage Inductance	%/Lp	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Secondary Trace Inductance	nH	30	30	30	30	30	30	30	30
Transformer Resonant Frequency (secondary open)	kHz	750	800	850	900	950	1000	1050	1100
Transformer Primary AC Resistance	mΩ	2400	1200	800	700	600	500	400	300
Transformer Secondary AC Resistance	mΩ	30	15	10	8	6	4	2	1
Output Capacitor Equivalent Series Resistance @100 kHz	mΩ	24	18	15	12	10	8	6	4
Output Inductor DC Resistance	mΩ	32	25	20	15	13	10	7.5	5
Common Mode Inductor DC Resistance (both legs)	mΩ	370	340	310	280	250	220	190	160
Core Loss	%/PIN	2	2	2	2	2	2	2	2

Table 1. Typical Power Supply Component Parameters for a TOPSwitch-GX Flyback Power Supply with a Universal Input (12 V output).

curve, interpolate the *TOPSwitch-GX* power dissipation from the constant power dissipation contours (dashed lines).

Some output power levels can be delivered by more than one *TOPSwitch-GX* device. When moving vertically from the X-axis, the first curve encountered will be the smallest, lowest cost *TOPSwitch-GX* device, while the last curve encountered will be the largest, most efficient *TOPSwitch-GX* device suitable for the desired output power.

Thermal requirements and packaging of the proposed power supply may call out for a more efficient device rather than the smallest or lowest-cost possibility. In addition the P and G packages (8 pin DIP) have a practical dissipation limit of around 0.85 W in a 50 °C ambient, giving a device junction temperature of ~100 °C. This ensures that there is adequate margin to thermal shutdown including device variation. Typical temperatures above 110 °C are not recommended. The TO-220 package does not have this limit due to the ability to mount the tab to a suitably sized heatsink.

Example 1: 30 W Universal Application

Consider a 5 V / 30 W power supply with universal input range. From the curves in Figure 2, we can see that the TOP244 can deliver 30 W (X-axis) with an estimated efficiency (Y-axis) of about 67.5%. The projected *TOPSwitch-GX* dissipation is approximately 3.5 W.

Alternatively continuing the TOP245 could be used with an efficiency of 70.5% and a device disspation of approximately 2.5 W. As the dissipation is above 0.85 W, Y packaged devices should be used.

The thermal environment and the available heatsinking must still be evaluated to confirm the choice of device in this application.

Example 2: 12 W Adapter Application

Consider a 12 W, 12 V supply with universal input range. From the curves in Figure 1 we see that a TOP243 or TOP244 could be used, TOP243 with an efficiency of 82% and a device dissipation of 0.7 W or a TOP244 with an efficiency of 83% and a device dissipation of 0.5 W. The TOP242 is ruled out as we require to use the P package and therefore are limited to a dissipation of less than 0.85 W

This is an adapter design in an enclosed plastic box, so the maximum power available from the supply is limited by thermal considerations. The worst-case external ambient (T_{A_EXT}) is

TYPICAL 5 V OUTPUT POWER SUPPLY COMPONENT PARAMETERS									
		UNIVERSAL INPUT (85-265 VAC)							
PARAMETER	**Units**	**242Y**	**243Y**	**244Y**	**245Y**	**246Y**	**247Y**	**248Y**	**249Y**
Maximum Transformer Primary Inductance Lp	µH	2780	1385	923	693	462	346	277	231
Transformer Leakage Inductance	%/Lp	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Secondary Trace Inductance	nH	20	20	20	20	19	16	13	10
Transformer Resonant Frequency (secondary open)	kHz	750	800	850	900	950	1000	1050	1100
Transformer Primary AC Resistance	mΩ	2000	1060	700	600	500	300	200	100
Transformer Secondary AC Resistance	mΩ	12	6	4	3	2	1	0.75	0.5
Output Capacitor Equivalent Series Resistance @100 kHz	mΩ	18	9	6	5	4	3	2	1
Output Inductor DC Resistance	mΩ	6	4.5	3.5	3	2.5	2	1.5	1
Common Mode Inductor DC Resistance (both legs)	mΩ	370	340	310	280	250	220	190	160
Core Loss	%/PIN	2	2	2	2	2	2	2	2

Table 2. Typical Power Supply Component Parameters for a TOPSwitch-GX Flyback Power Supply with a Universal Input (5 V output).

50 °C with an estimated temperature rise of 20 °C inside the plastic box, giving an internal ambient (T_{A_INT}) of 70 °C.

As a *TOPSwitch-GX* in a P-package is desired, from the datasheet we obtain the thermal impedance from junction-to-ambient (θ_{JA}) of 60 °C/W (645 mm^2 / 1.0 sq. inch of 2 oz. copper clad for heatsinking).

We first perform the following calculation for the most cost-effective device. If found unsuitable, we must repeat the calculation for the more expensive device.

$$T_J = T_{A-INT} + (\theta_{JA} \times P_D)$$

For the TOP243P,

$$T_J = 70 + (60 \times 0.7) = 112\ ^\circ C$$

We see that thermally the TOP243P design is not acceptable. Recalculating using the TOP244P.

$$T_J = 70 + (60 \times 0.5) = 100\ ^\circ C$$

With a smaller dissipation the TOP244P is just acceptable. A junction temperature of 100 °C provides sufficient margin for device-to-device $R_{DS(ON)}$ variation.

Example 3: 70 W Universal Application
Consider a 70 W, 12 V power supply with Universal input range. From the curves in Figure 2 we see that there are four possible device choices:

a) TOP246Y: The projected efficiency is 73.8% and the device dissipation is 8 W.

b) TOP247Y: The projected efficiency is 77% and the device dissipation is 5.5 W.

c) TOP248Y. The projected efficiency is 78.5% and the device dissipation is 4.5 W.

d) TOP249Y: This is the least cost effective device but has the highest projected efficiency of 79.5% and the lowest device dissipation of 3.9 W.

The thermal environment and the available heatsinking must now be evaluated to confirm the final choice of device in this application from the short list above. Again increasing the output voltage would increase the efficiency and decrease dissipation (e.g. 70 W, 19 V, 85-265 VAC gives 85% efficiency).

TYPICAL 12 V OUTPUT POWER SUPPLY COMPONENT PARAMETERS									
		SINGLE VOLTAGE INPUT (230 VAC ± 15%)							
PARAMETER	**Units**	**242Y**	**243Y**	**244Y**	**245Y**	**246Y**	**247Y**	**248Y**	**249Y**
Maximum Transformer Primary Inductance Lp	μH	3190	1593	1062	797	531	398	319	265
Transformer Leakage Inductance	%/Lp	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Secondary Trace Inductance	nH	30	30	30	30	30	30	30	30
Transformer Resonant Frequency (secondary open)	kHz	750	800	850	900	950	1000	1050	1100
Transformer Primary AC Resistance	mΩ	5600	2800	1840	1200	1000	800	600	400
Transformer Secondary AC Resistance	mΩ	30	15	10	8	6	4	2	1
Output Capacitor Equivalent Series Resistance @100 kHz	mΩ	24	18	15	12	10	8	6	4
Output Inductor DC Resistance	mΩ	32	25	20	15	13	10	7.5	5
Common Mode Inductor DC Resistance (both legs)	mΩ	370	340	310	280	250	220	190	160
Core Loss	%/PIN	2	2	2	2	2	2	2	2

Table 3. Typical Power Supply Component Parameters for a TOPSwitch-GX Flyback Power.

Other Key Considerations

We have seen how to use the information provided by the *TOPSwitch-GX* Quick Selection Curves. However there are other key factors to consider when completing the power supply design. These can produce results that differ from the predictions of the Quick Selection Curves.

Factors which can lower the performance:

- Input capacitor tolerance and aging should be taken into account. Lower capacitance decreases the DC input voltage, increasing primary RMS currents and hence giving larger conduction losses in the device chosen.

- In production, the primary inductance of the transformer will also have a significant tolerance. Inductances higher than those in Tables 1 to 4 will cause the power supply to operate beyond recommended design guidelines (K_{RP} too low). Values of primary inductance significantly lower than those in Tables 1 to 4 would lead to higher peak and RMS drain current in the *TOPSwitch-GX* MOSFET. This causes an increase in device dissipation and also causes the device to reach current limit at less than maximum load.

- The Quick Selection Curves assume that the AC Input voltage waveform is a pure sine wave. If the input voltage waveform is distorted, the resultant peak voltage on the input bulk capacitor may be much lower than anticipated. This causes the *TOPSwitch-GX* device to reach current limit or duty cycle limit at less than the maximum possible load.

Therefore, in locations where significant line distortion is expected, the designer should provide a suitable design margin. This can be accomplished by derating maximum output power or increasing the input capacitance.

- Some wattmeters give erroneous readings when the current has a high crest factor. It is important to use an instrument designed for the purpose. The Voltech PM100 is an example.

- Minimum line frequency is important. A low line frequency requires larger carryover periods for the input bulk capacitor, causing high voltage ripple across it. If the line frequency expected to be lower than 50 Hz, the input capacitor should be sized appropriately or the maximum output power be derated.

TYPICAL 5 V OUTPUT POWER SUPPLY COMPONENT PARAMETERS									
		SINGLE VOLTAGE INPUT (230 VAC ± 15%)							
PARAMETER	**Units**	**242Y**	**243Y**	**244Y**	**245Y**	**246Y**	**247Y**	**248Y**	**249Y**
Maximum Transformer Primary Inductance Lp	μH	3190	1593	1062	797	531	398	319	265
Transformer Leakage Inductance	%/Lp	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Secondary Trace Inductance	nH	20	20	20	20	19	16	13	10
Transformer Resonant Frequency (secondary open)	kHz	750	800	850	900	950	1000	1050	1100
Transformer Primary AC Resistance	mΩ	4600	2400	1600	1200	1000	800	600	400
Transformer Secondary AC Resistance	mΩ	12	6	4	3	2	1	0.75	0.5
Output Capacitor Equivalent Series Resistance @100 kHz	mΩ	18	9	6	5	4	3	2	1
Output Inductor DC Resistance	mΩ	6	4.5	3.5	3	2.5	2	1.5	1
Common Mode Inductor DC Resistance (both legs)	mΩ	370	340	310	280	250	220	190	160
Core Loss	%/PIN	2	2	2	2	2	2	2	2

Table 4. Typical Power Supply Component Parameters for a TOPSwitch-GX Flyback Power Supply with a Single Input (5 V output).

- The choice of V_{OR} can affect the efficiency greatly. For example increasing the V_{OR} (turns ratio) may allow a Schottky diode on the output, for higher efficiency, by reducing the diode inverse voltage. However it will increase secondary reflected leakage and therefore clamp dissipation.

Lowering the V_{OR} reduces secondary reflected leakage, reducing clamp dissipation but at the expense of higher primary RMS currents, increasing the *TOPSwitch-GX* conduction losses.

- For low voltage outputs, the secondary currents and their associated losses can become significant. Close attention must be paid to the 'ESR' (Equivalent Series Resistance) of the output capacitor in particular. The values in Tables 2 and 4 for the 5 V Quick Selection Curves (Figures 2 and 4) use capacitors with very low-ESR.

- Energy stored in the leakage inductance is dumped into primary clamp (RCD clamp or Zener clamp) when the *TOPSwitch-GX* turns off. Therefore the efficiency will fall significantly if the leakage inductance is too high. Refer to Example 3 of AN-26 to see how the effective in-circuit leakage should be measured and how secondary trace inductance reflects into the primary. For low voltage outputs at high power, it is critical to minimize leakage inductance.

Factors which can improve performance:

For more experienced designers, there are ways to improve the performance indicated by the Quick Selection curves. Some of these are now mentioned briefly:

- The recommended capacitance per Watt is based on the optimum cost to performance ratio. Better performance can certainly be obtained in terms of efficiency, *TOPSwitch-GX* dissipation and life expectancy of the input bulk capacitor, by using a higher capacitance per Watt than recommended.

- If the intended application is for 100/115 VAC only, the clamp voltage and V_{OR} may be raised by a calculated amount provided no voltage doubler is being used at the input of the power supply. This will enhance the overall efficiency and lower the device dissipation.

- The recommended primary inductances in Tables 1 to 4 are based on the minimum permissible K_{RP} at the maximum power capability of the device. In other words, the primary inductance along any given solid curve corresponding to a particular device has been kept a constant.

  However in an adapter application for example, the output power is limited by thermal considerations to a value much less than the maximum power capability of the *TOPSwitch-GX* device. This presents an opportunity to improve efficiency and lower device dissipation by increasing the primary inductance while ensuring that the K_{RP} at the actual power requirement stays within recommended design limits.

- Since the Quick Selection Curves are based on a *TOPSwitch-GX* junction temperature of 100 °C at low line, full load, better performance is possible if the *TOPSwitch-GX* runs cooler. Good heatsinking will help in achieving higher efficiency.

- Increasing the V_{OR} can be helpful in some cases. A high V_{OR} decreases the reverse voltage stress on the output diodes. This may allow the use of 45 V Schottky output diodes for high voltage outputs, resulting in a significant improvement in the efficiency.

  This step should be taken only after considering the overall impact. It should be mentioned that increasing the V_{OR} causes an increase in the duty cycle and a corresponding reduction in the RMS currents and conduction losses in the *TOPSwitch-GX* device provided the overall efficiency is not adversely affected due to increased clamp loss.

Conclusions

The *TOPSwitch-GX* devices may be considered to be an extension of the *TOPSwitch-FX* family. The P-package options have reduced current limits to match the device current limit to the thermal dissipation capability of the package. This allows for a smaller transformer in adapter designs. However for the same conditions both the P/G and Y packaged devices will dissipate the same power. Therefore the Quick Selection curves are valid for either package (up to the point where current limiting takes place).

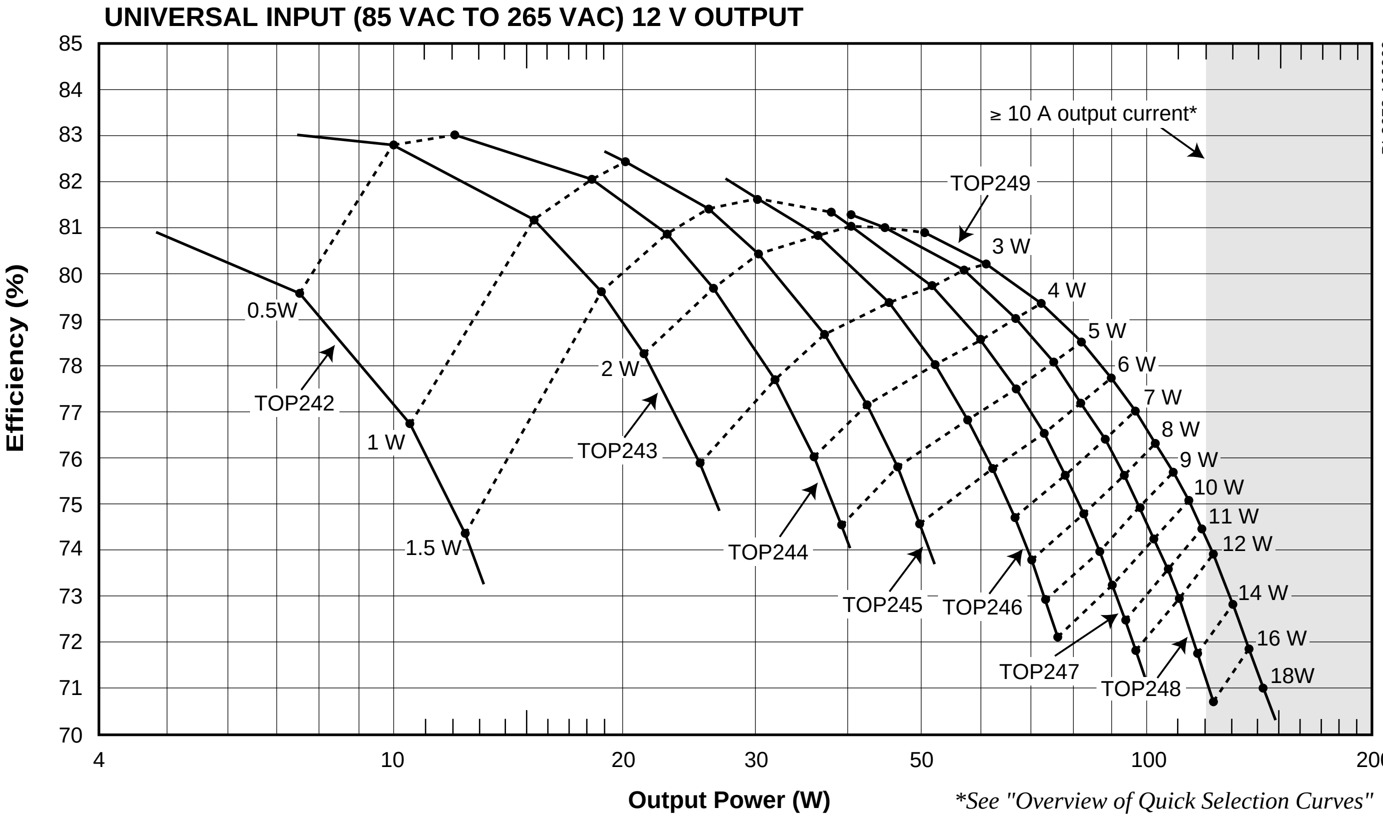

Figure 1. Efficiency vs. Output Power with Contours of Constant TOPSwitch-GX Power Loss for Universal Input and 12 V Output.

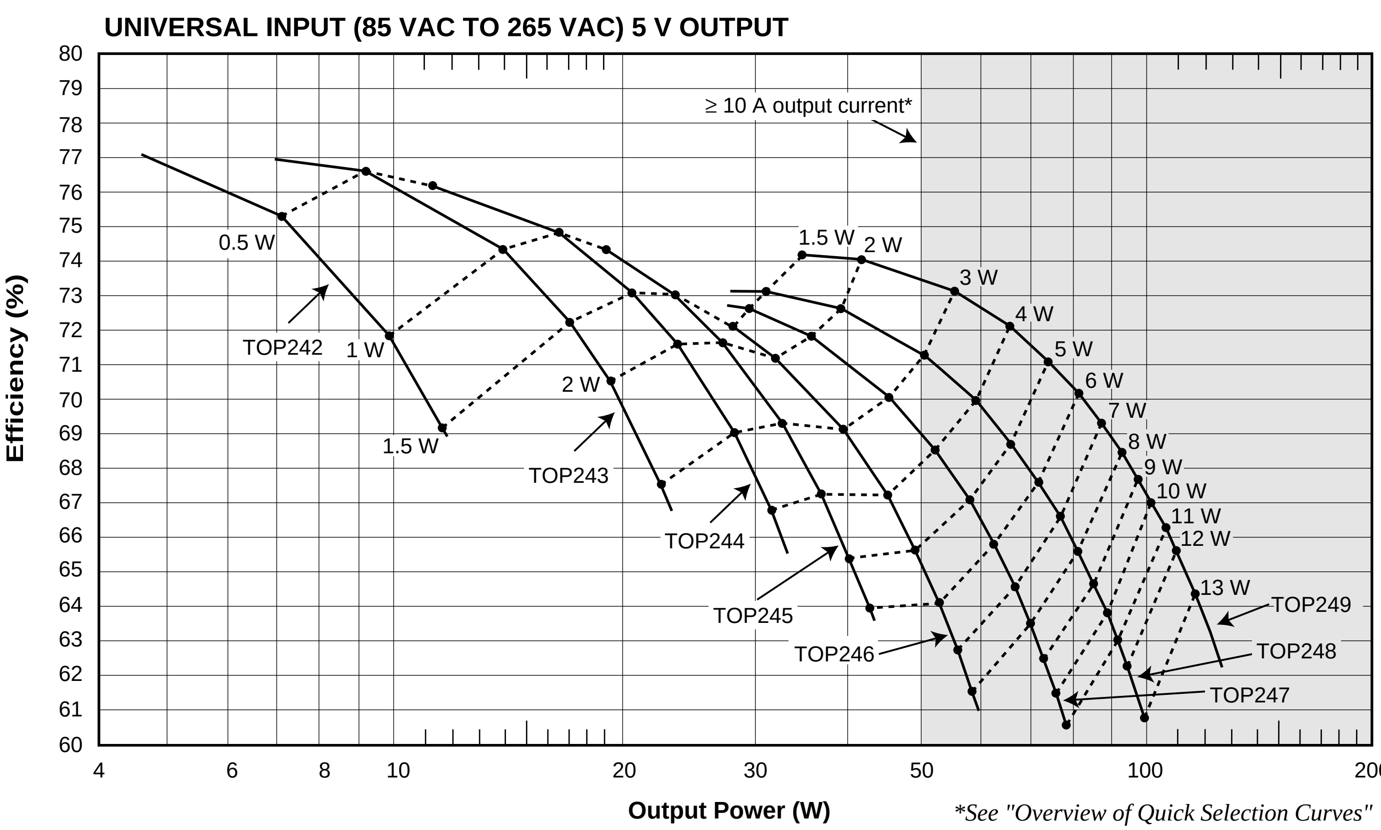

Figure 2. Efficiency vs. Output Power with Contours of Constant TOPSwitch-GX Power Loss for Universal Input and 5 V Output.

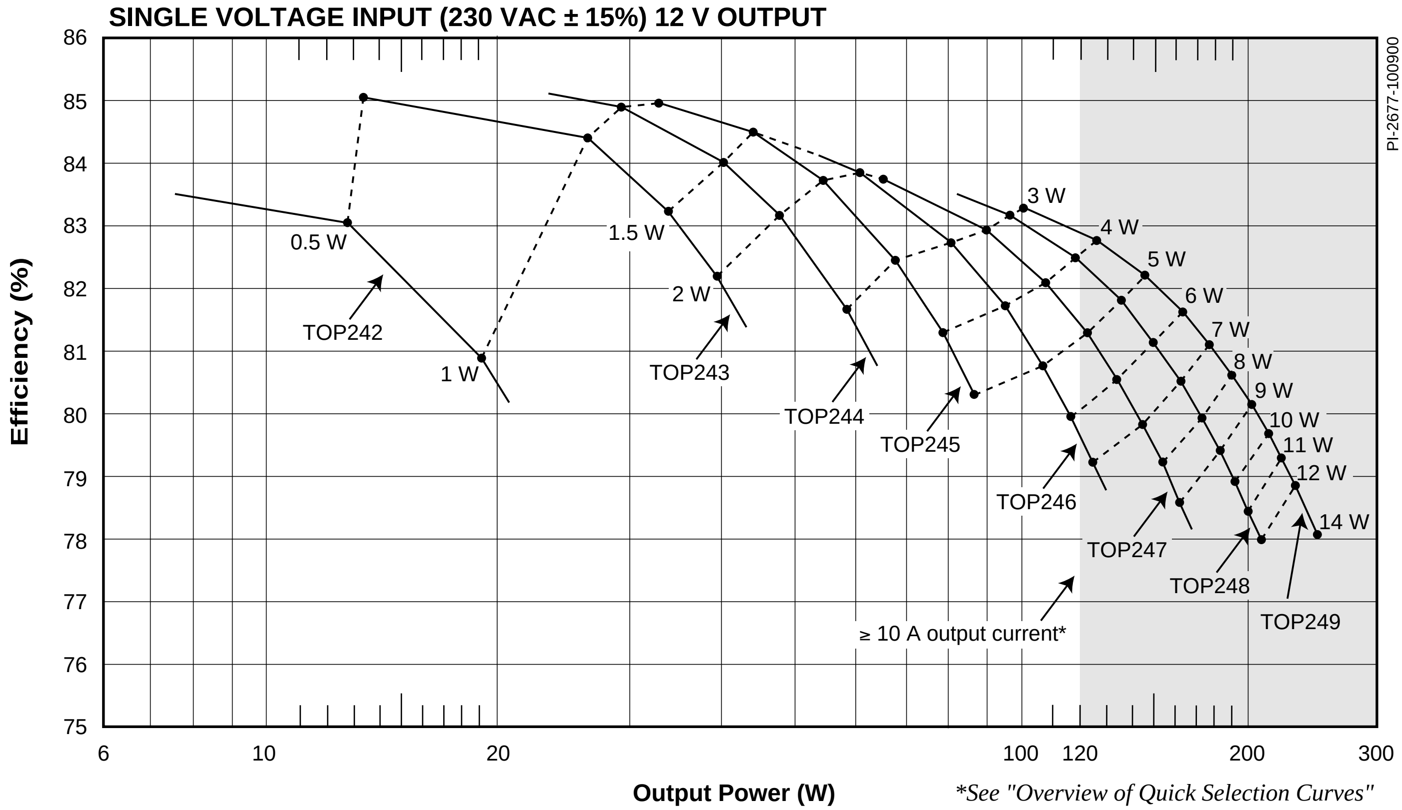

Figure 3. Efficiency vs. Output Power with Contours of Constant TOPSwitch-GX Power Loss for Single Voltage Application and 12 V Output.

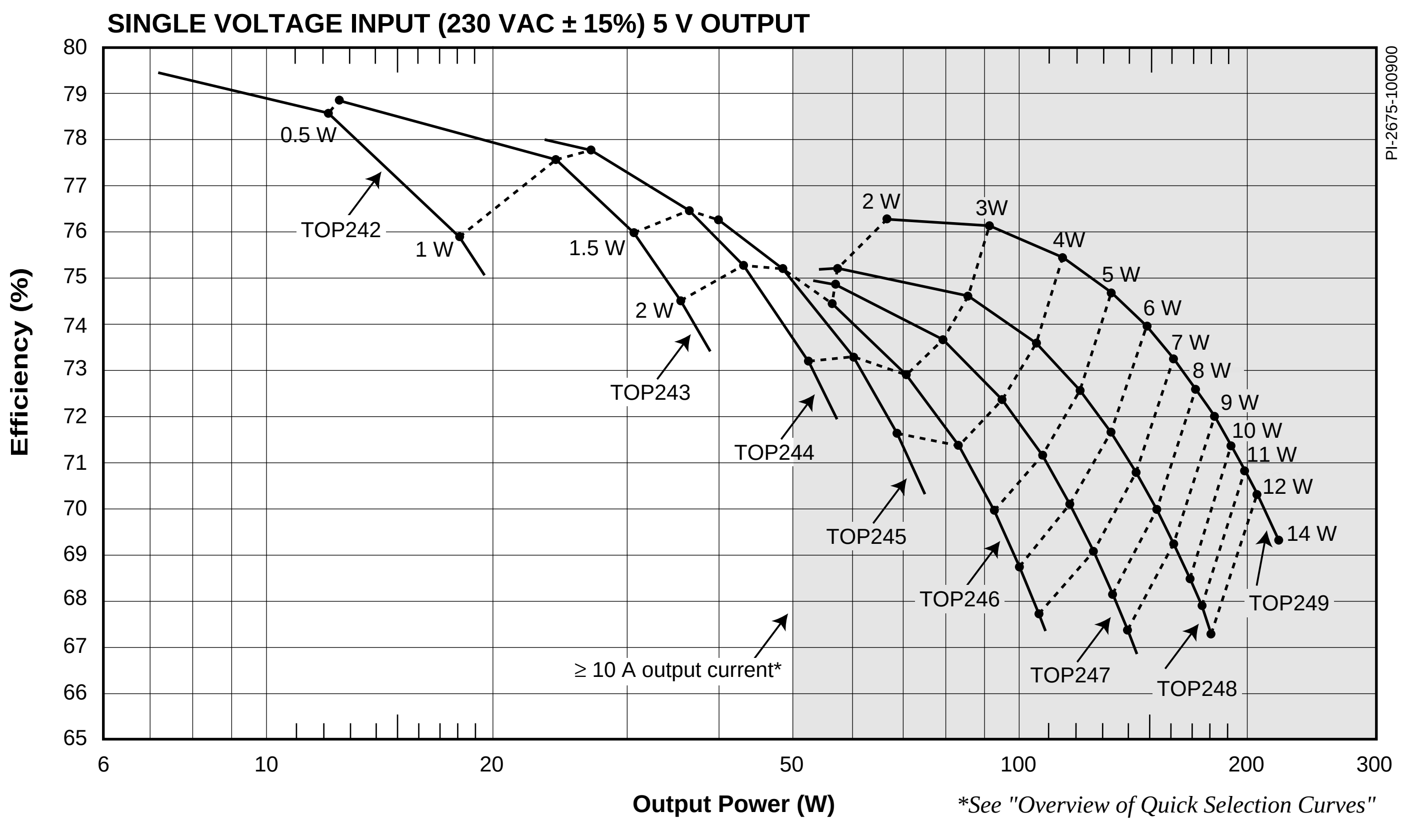

Figure 4. Efficiency vs. Output Power with Contours of Constant TOPSwitch-GX Power Loss for Single Voltage Application and 5 V Output.

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Revision	Notes	Date
B	-	11/00
C	1) Updated package references. 2) Corrected spelling. 3) Updated nomenclature. 4) Corrected heading on Table 4. 5) Corrected *TOPSwitch-GX* reference in figures.	7/01
D	1) Corrected device dissipation for P/G packages.	2/03

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