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AN-5079
MDB10SV Bridge Rectifier

Summary

The MDB10SV, 1.2 A, 1000 V, single-phase bridge rectifier (hereafter, 10SV), is Fairchild's newly released bridge rectifier packaged in a low profile Micro-DIP socket. It is compatible with its sibling, the MDB10S (hereafter, 10S), making the 10SV a direct replacement for this device or one from another manufacturer with the same footprint. Compared to Fairchild's previously released bridge rectifiers, thanks to state-of-the-art process technology, the 10SV generates less power loss due to its lower instant forward voltage drop, which boosts system efficiency and serves as the major improvement at today's more stringent power saving regulations. As a side note, the 10SV also offers higher average rectified forward current, higher peak forward surge current, and much greater I^2T capability. These features allow the 10SV to be used with better survival capability in applications where higher inrush surge and power delivery is required.

This application note discusses how efficiency can be improved if the 10SV is used in place of 10S or a competitor's bridge rectifier in the same package. Multiple bridge rectifiers are tested and IV curves compared. Then, analyzed how this improved IV characteristic translates to power savings with a real 30 W AC adaptor. With the same power supply we see that the 10SV, which measured an 8% reduction in V_F at 2 A generated a power savings of as much as 66 mW in the 85 V_{AC} low line condition, and an average savings of 30 mW across the voltage range from 85 V to 265 V_{AC}. This 66 mW of savings is achieved without any redesigns, but simply by replacing an existing Micro-DIP bridge with a more efficient MDB10SV.

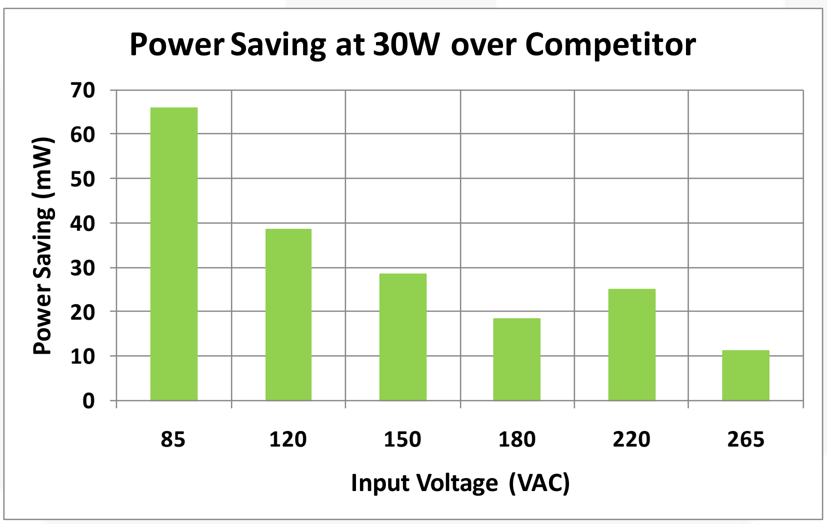

Figure 1. System Power Savings at 30 W when Using 10SV Over Other Parts

The Theory

Typically an AC adaptor has a block diagram like in Figure 2 and the bridge rectifier's input waveforms look like the ones shown in Figure 3, with the voltage measured between the 2 AC inputs.

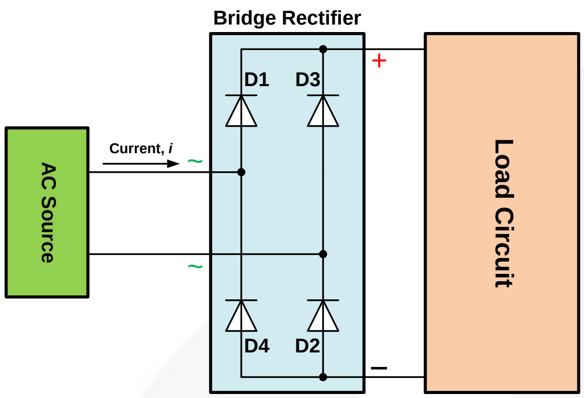

Figure 2. AC Adaptor Block Diagram

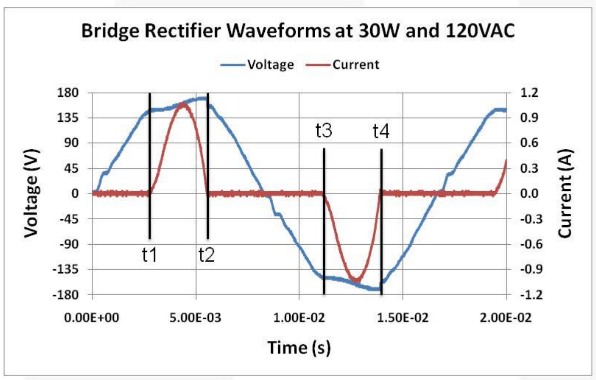

Figure 3. Typical AC Adapter Input Waveforms

The Power loss of a bridge rectifier, P_{BR}, can be calculated:

$$P_{BR} = \frac{1}{T}\left\{\int_{t1}^{t2}\{i(t) \times [v_{D1}(t) + v_{D2}(t)]dt\} + \int_{t3}^{t4}\{i(t) \times [v_{D3}(t) + v_{D4}(t)]dt\}\right\} \quad (1)$$

where;

T is the period of the input sine wave; T = 1/60 or 1/50.

$i(t)$ is the current flowing through the bridge rectifier.

v_{D1} (v_{D2}, v_{D3}, v_{D4}) is the forward voltage drop on D1 (D2, D3, D4).

$t1$ and $t2$ ($t3$ and $t4$) form the conducting time period or conduction angle when both D1 and D2 (D3 and D4) are conducting.

How much power a bridge rectifier loses depends on the current flowing through the bridge, the forward voltage drops of the four diodes and the conduction angles. It can be imagined, and also experiment shows, that for different bridge rectifiers, which are mainly defined by their different forward voltage drops at the same current point, the current wave shapes and the conduction angles does not change, since the rectified input voltage of 85 V_{AC} – 265 V_{AC} is so large and the forward voltage drop difference of different rectifiers is so small that the forward voltage drop difference has no effect on the rectified voltage. The Power Supply Test section demonstrates this. This makes the power loss directly related to the rectifier's diode forward drop: the higher forward voltage drop a rectifier presents, the greater power loss it generates. This simplifies the power loss comparison.

Now let's see how much forward voltage drop the rectifiers present.

Comparison of VI Characteristics

The 10SV, 10S and one competitor part (hereafter, CMPT) with the same footprint are soldered on four coupon boards of the same type and tested using exactly the same equipment, FETtest Model 3400, with the configuration as shown in Figure 4.

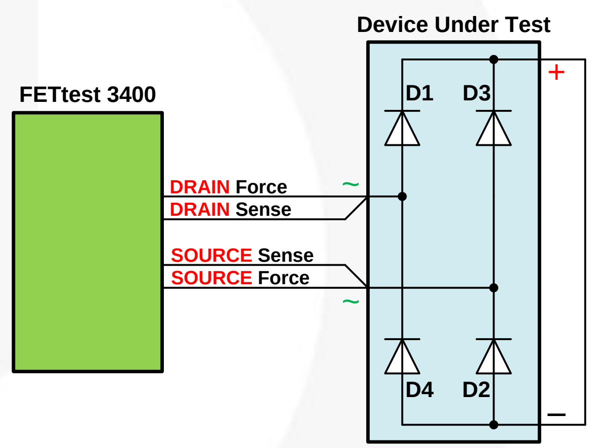

Figure 4. VI Characteristic Check Test Setup

DRAIN and SOURCE in the setup diagram refer to the connection leads on FETtest 3400. For each bridge rectifier (Device Under Test in Figure 4, hereafter, DUT), 41 current points between 10 mA and 10 A are sent from DRAIN, through DUT, back to SOURCE. And another 41 current points between 10 mA and 10 A are sent from SOURCE, through DUT, back to DRAIN. Figure 5 has the VI characteristics of the three DUTs in ±10 A range and ±1.8 A zoomed-in range. The test points with current flowing from DRAIN, through D1 and D2, back to SOURCE form the first quadrant of the VI curve that shows the positive characteristic of diodes D1 and D2 in series; The test points with current flowing from SOURCE, through D3 and D4, back to DRAIN form the third quadrant of the VI curve that shows the positive characteristic of the diodes D3 and D4 in series.

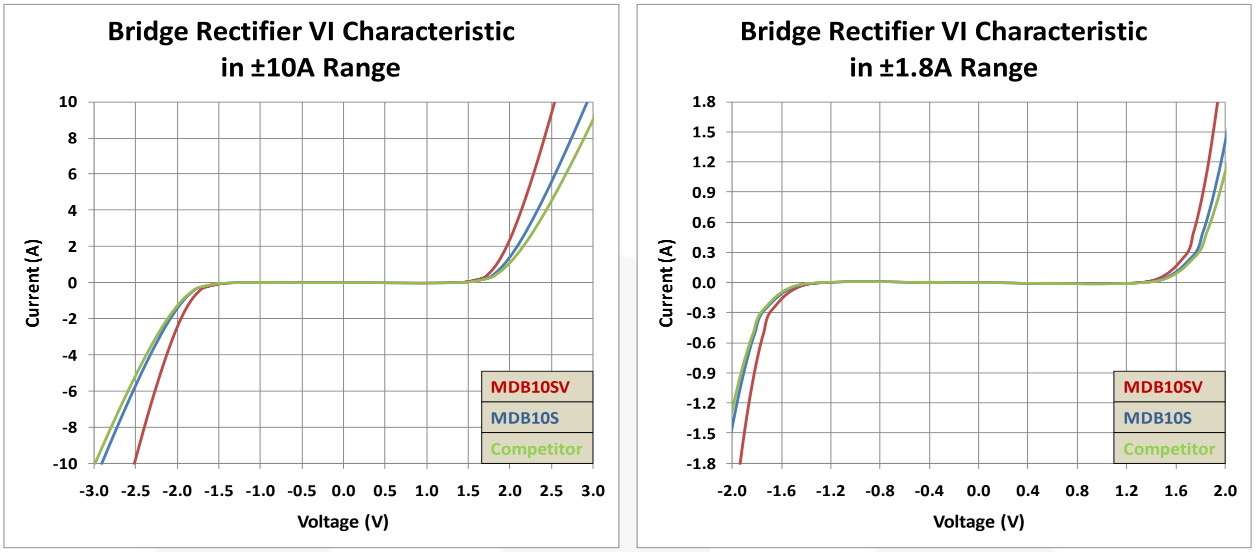

Figure 5. VI Characteristic of the 3 DUTs

From these VI curves, it can be clearly seen that at the same current point, the 10SV presents the lowest forward voltage drop on either pair of conducting diodes (D1 and D2 or D3 and D4).

To more accurately see the voltage drop difference of the 2 devices over the 10SV, the following two charts are created from the VI data.

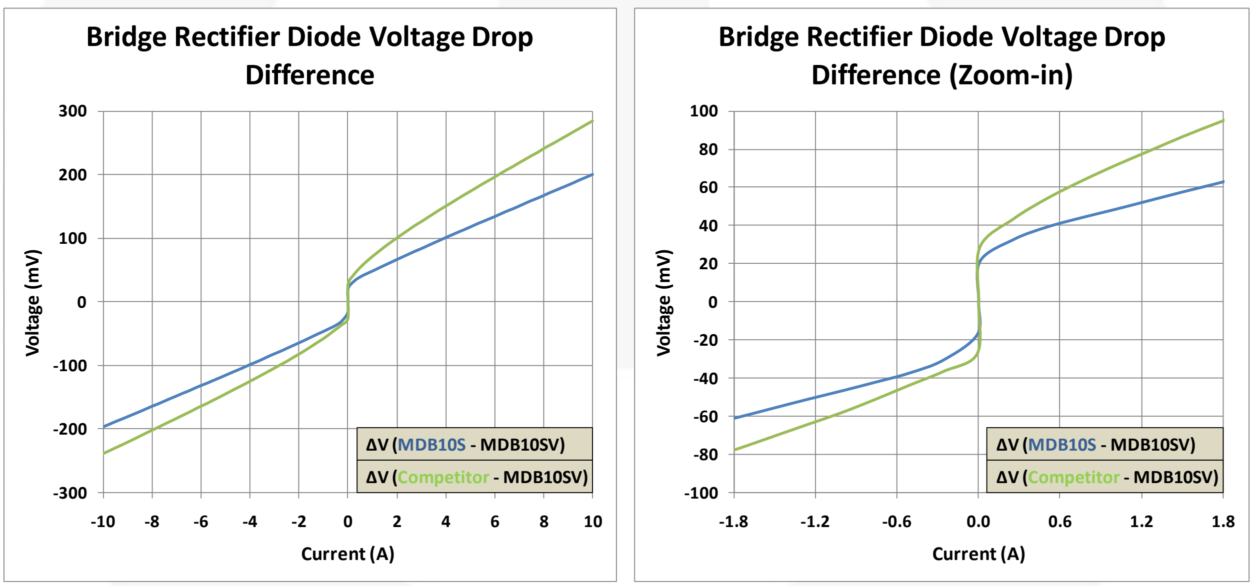

Figure 6. Diode Forward Voltage Difference of the 2 DUTs Over MDB10SV

These charts tell us that the competitor part has 239 mV higher average diode voltage drop at -10 A, 285 mV at +10 A, 78 mV at -1.8 A and 95 mV at +1.8 A.

The Power Supply Test

To explore the impact of V_F on power savings in real applications, the following experiment is carried out: the system efficiency of an existing power supply is compared when only the bridge rectifier is changed. An off-the-shelf 30 W AC adaptor is used as the power supply and has specifications as shown in Table 1. Figure 7 has the test setup. The same set of test equipment is used to record the data.

Table 1. AC Adaptor Specifications

Parameters		Symbol	Value	Unit
Line Voltage	Low Line	V_{IN_MIN}	85	V_{AC}
	High Line	V_{IN_MAX}	265	
Line Frequency		f	50 - 60	Hz
Output Voltage		V_O	19	V
Output Maximum Current		I_O	1.58	A

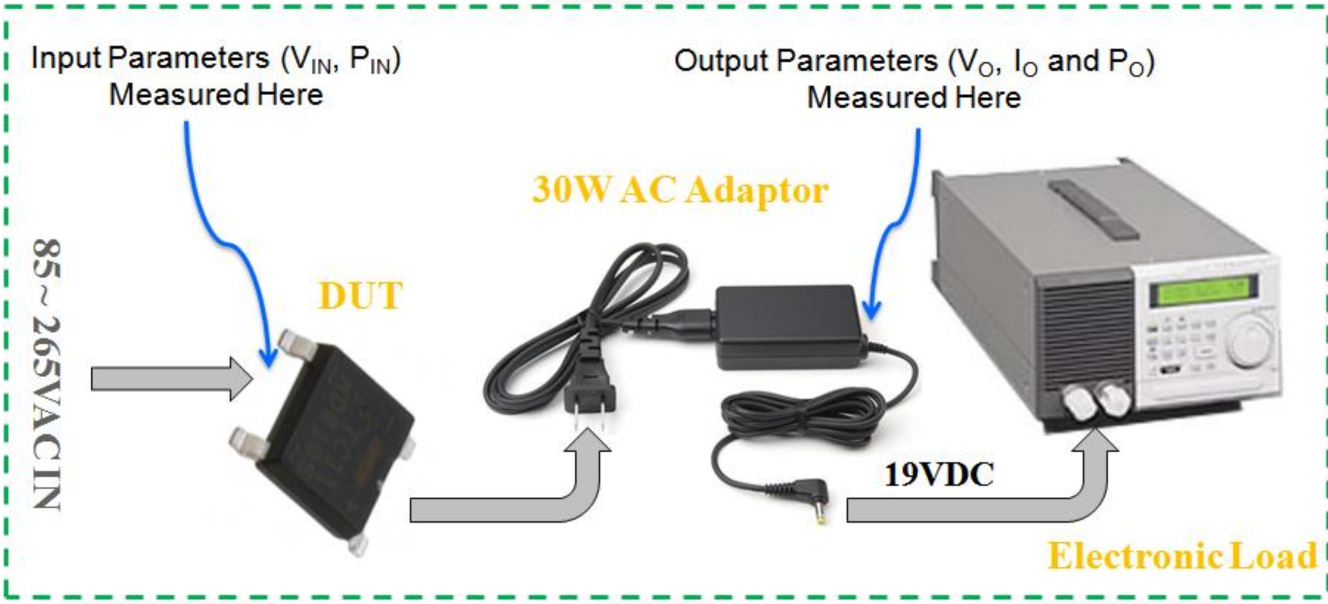

Figure 7. Efficiency Measurement Setup

First, some sample current waveforms are shown in Figure 8. It tells that changing only the bridge rectifier in an application has little effect on the current wave shape and conduction angle as stated in the Theory Section, and therefore a bridge rectifier's power loss is directly linked to it forward voltage drop, V_F.

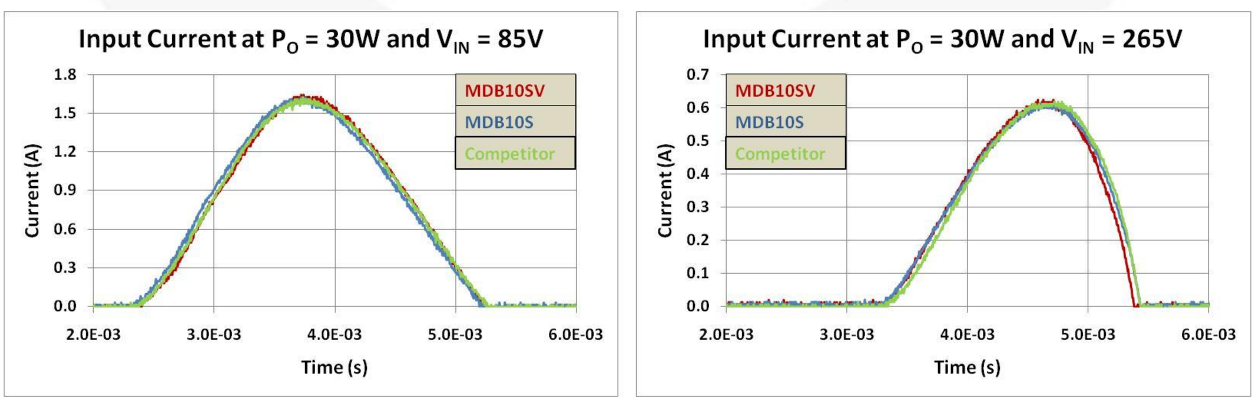

Figure 8. Current Waveforms of Different Rectifiers at the Same Input Voltage and the Same Output Power

Second, the measurement result is presented in Table 2. By comparing the system efficiency and power loss at the same input voltage, the impact of V_F on efficiency can be seen. In this case, the part with lowest V_F, the 10SV, is the best performer in both parameters.

Table 2. Test Data on 30 W AC Adaptor

DUT	V_{IN} (V_{AC})	P_{IN} (W)	V_O (V_{DC})	I_O (A)	P_O (W)	P_{LOSS} (W)	Efficiency η (%)
10SV	85.000	35.200	19.257	1.5789	30.405	4.795	86.38%
	120.000	34.466	19.258	1.5785	30.399	4.068	88.20%
	150.450	34.286	19.258	1.5785	30.399	3.887	88.66%
	180.000	34.648	19.235	1.5784	30.361	4.287	87.63%
	220.000	34.483	19.242	1.5783	30.370	4.113	88.07%
	265.300	34.411	19.245	1.5784	30.376	4.035	88.27%
10S	85.000	35.240	19.255	1.5784	30.392	4.848	86.24%
	120.300	34.482	19.257	1.5783	30.393	4.089	88.14%
	150.000	34.298	19.258	1.5784	30.397	3.901	88.63%
	180.000	34.664	19.234	1.5786	30.363	4.301	87.59%
	220.500	34.505	19.241	1.5783	30.368	4.137	88.01%
	265.300	34.424	19.245	1.5785	30.378	4.046	88.25%
CMPT	85.000	35.257	19.255	1.5786	30.396	4.861	86.21%
	120.300	34.502	19.256	1.5785	30.396	4.106	88.10%
	150.2	34.311	19.256	1.5785	30.396	3.915	88.59%
	180.000	34.666	19.234	1.5785	30.361	4.305	87.58%
	220.000	34.506	19.241	1.5783	30.368	4.138	88.01%
	265.000	34.421	19.244	1.5784	30.375	4.0460	88.25%

With some data manipulation, we get Table 3.

Table 3. Comparison Data

Parameter	V_{IN} (V_{AC})	85	120	150	180	220	265
Power Saving (mW)	ΔP (10S - 10SV)	54	21	14	14	24	11
	ΔP (CMPT - 10SV)	66	39	28	18	25	11
System Efficiency Boost (%)	Δη (10SV - 10S)	0.14	0.06	0.04	0.03	0.06	0.03
	Δη (10SV - CMPT)	0.16	0.10	0.07	0.05	0.06	0.03
Saved Power / Power Loss (%)	ΔP (10S - 10SV) / $P_{LOSS.10S}$	1.11	0.51	0.36	0.32	0.59	0.28
	ΔP (CMPT - 10SV) / $P_{LOSS.CMPT}$	1.36	0.94	0.72	0.42	0.60	0.28

Plotting the data on charts (Figure 9-Figure 12) we can better see how the 10SV reduces power loss and therefore improves system efficiency. Using the 10SV over the 10S and the competitor counterpart can boost system efficiency up to 0.14% and 0.16%, respectively, which is equivalent to a power saving of about 54 mW and 66 mW for a 30 W power supply. All the power savings come from the bridge rectifier. If the 10SV is used in applications that have a higher power output, the power savings will be even greater.

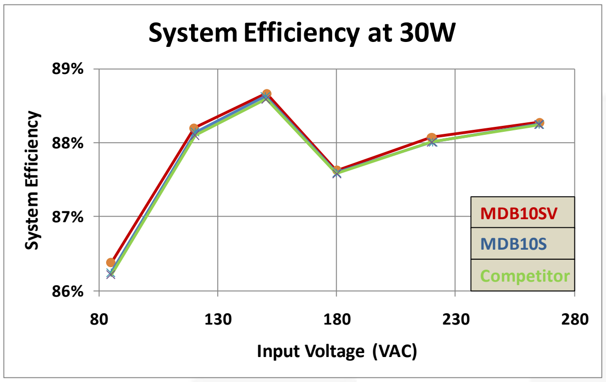

Figure 9. System Efficiency at 30W with Different Rectifiers

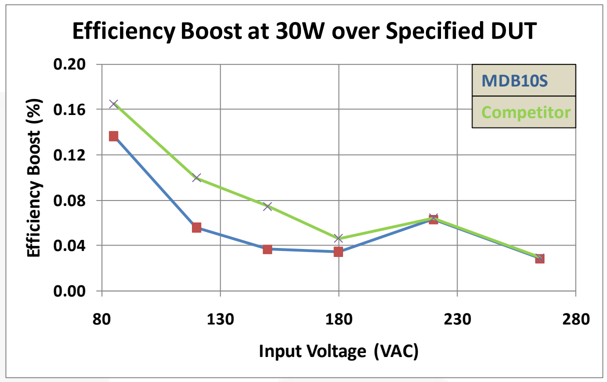

Figure 10. System Efficiency Boost at 30 W when using 10SV Over other Parts

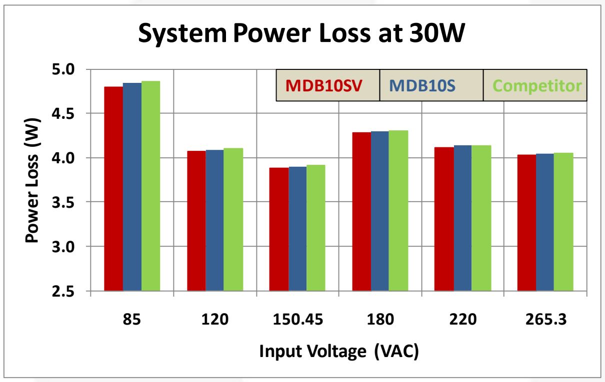

Figure 11. System Power Loss at 30 W with Different Rectifiers

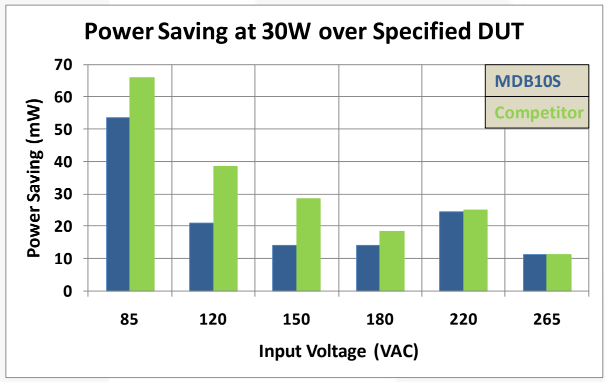

Figure 12. System Power Savings at 30 W when using 10SV Over other Parts

Conclusion

As postulated, the lower diode forward voltage drop of the 10SV results in a lower VI loss and therefore boosts system efficiency. This effect is even more prominent when output power is increased or when input voltage is at the low end of the universal voltage range.

In addition to its direct impact in improving efficiency, the 10SV's higher I^2T specification over parts that have the same footprint makes it a great selection for taking care of startup inrush current. All in all, MDB10SV is an excellent selection for universal off-line power supplies.

Related Datasheets

MDB10SV − 1.2 A, 1000 V, Micro-DIP, Single-Phase Bridge Rectifier

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