Get Your Power-Supply Design Right the First Time

Nobody wants to reinvent the wheel, least of all, designers of power supplies. The number of combinations of varying input/output voltages, output current and power requirements, as well as the numerous topologies available for countless applications, can be mind-boggling. Sometimes it feels like every new product needs its own custom power supply which inevitably may require several re-spins to get it to work properly. Even for experienced designers, this can be a challenge; for novice designers, it can be a nightmare! Wouldn't it be great to have, as a starting point, an actual working design that is close to what you need and that only needs a little bit of tweaking?

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Suddenly, a project that you thought would take months could be completed in a matter of weeks (or less). Even better, wouldn't it be nice to use an "off-the-shelf" design that you know will work the first time? In this article, we'll review the applications that are appropriate for different types of power-supply topologies and introduce a new power-supply methodology that accelerates both non- isolated and isolated power-supply design, with the help of a library of readily available reference designs that support applications from 2.5W to 72W.

Isolated DC-DC Industrial Applications

Industrial applications (such as process control, PLCs, SCADA systems and sensors in automation) are characterized by a 24V nominal DC voltage bus that has its history in old analog relays and remains the de-facto industry standard. However, the maximum operating voltage for industrial applications is expected to be 36V to 40V for non-critical equipment, while critical equipment, such as controllers, actuators, and safety modules, must support 60V (IEC 61131-2, 60664-1, and 61508 SIL standards). Popular output voltages are 3.3V and 5V with currents that vary from 10mA in small sensors to tens of amps in motion control, CNC, and PLC applications. Building control systems, including some industrial use cases such as smart building management, interior comfort and air quality management, field devices, and actuators utilize a rectified 24AC input voltage that further justifies the need for wide- input range DC-DC voltage converters.

The flyback topology is commonly used in industrial switch- mode power-supply, isolated step-down designs below 100W. The flyback

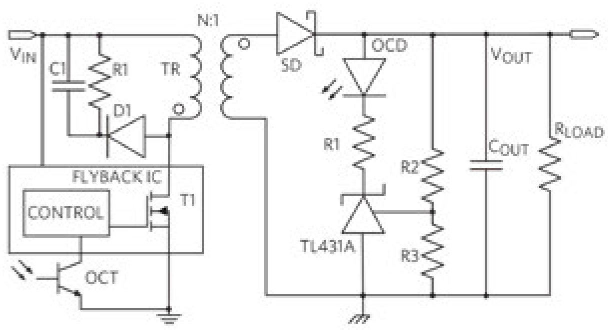

Figure 1: Flyback with Integrated Power Transistor

converter (Figure 1) utilizes a gapped transformer to both transfer and store energy, thereby minimizing the number of output components. However, the high peak currents inherent in its discontinuous operation relegate its use to low-power applications. For output voltages less than 12V, a variation on the flyback using synchronous rectification (MOSFET) is used.

Recent designs of the flyback converter have seen the optocoupler circuit replaced by an IC which uses primary-winding feedback to regulate the output voltage. To speed up the design cycle for this type of power supply, several proven power- supply reference designs are available (typically with > 90% efficiency) using the MAX17690 60V, no-opto isolated flyback controller, for a variety of different input voltage ranges and output voltages and power requirements (Table 1).

Reference Design	VIN (V)	VOUT (V)	IOUT (A)
MAXREFDES1010	19 to 40	24	0.3
MAXREFDES1012	8 to 20	5.3	0.08
MAXREFDES1014	28 to 32	48	1.1
MAXREFDES1040	18 to 60	54	0.25
MAXREFDES1090	8 to 28	12	0.25
MAXREFDES1091	18 to 60	12	0.25
MAXREFDES1100	8 to 28	12	0.5
MAXREFDES1101	18 to 60	12	0.5
MAXREFDES1102	8 to 28	24	0.25

Table 1: No-Opto Flyback Reference Designs

For applications where an output voltage of 12V (or less) is required, a variation on the traditional flyback converter with synchronous rectification on the secondary side is typically used. In this version, the Schottky diode is replaced by a MOSFET (Figure 2). Table 2 lists several reference designs for this type of converter. These designs use the MAX17690 60V, no-opto isolated flyback controller and the MAX17606 secondary-side synchronous MOSFET driver for a variety of different input voltage ranges, output voltage, and power requirements.

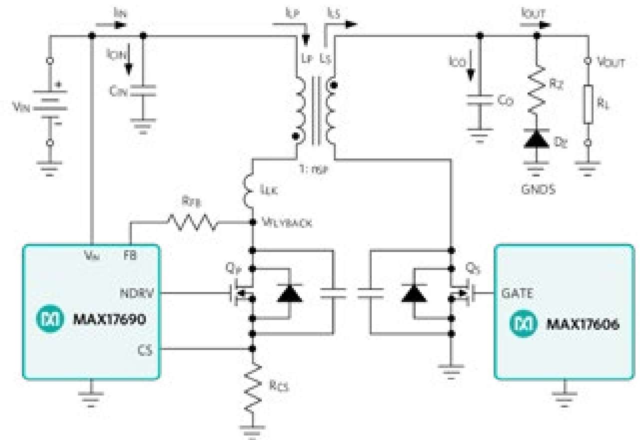

Figure 2: Simplified No-Opto Flyback Schematic with Synchronous Rectification

Reference Design	VIN (V)	VOUT (V)	IOUT (A)
MAXREFDES1002	18 to 36	12	0.5
MAXREFDES1022	10 to 50	5	2
MAXREFDES1086	8 to 28	5	0.5
MAXREFDES1087	18 to 60	5	0.5
MAXREFDES1088	8 to 28	12	0.25
MAXREFDES1089	18 to 60	12	0.25
MAXREFDES1094	8 to 28	12	0.5
MAXREFDES1095	18 to 60	12	0.5

Table 2: Synchronous No-Opto Flyback Reference Designs

Non-Isolated DC-DC Industrial Applications

For step-down DC-DC conversion at lower input voltages (<60V), where safety is not a concern, an isolated power supply is unnecessary. Where higher output current (from several milliamps for sensors to several Amps for motor controllers) is required, a synchronous buck (step-down) architecture (Figure 3) will suffice. Several variations on the multiple-output step-down DC-DC converter for a variety of input voltage ranges and output power requirements are shown in Table 3.

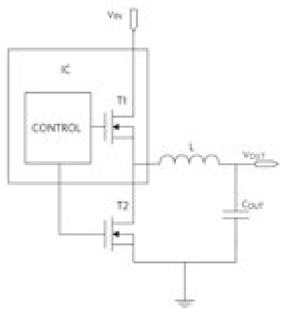

Figure 3: Simplified Synchronous Buck Architecture

Reference Design	VIN (V)	VOUT (V)	IOUT (A)
MAXREFDES1009	37 to 57	5 to 12	0.3 to 1
MAXREFDES1019	24 to 24	-20 to +20	0.05 to 2
MAXREFDES1033	11.5 to 13	3.3 to 5	3
MAXREFDES1039	36 to 51	16 to 24	2. to 4

Table 3: Synchronous Buck Reference Designs

Offline Industrial Applications

Some industrial applications require a regulated DC power supply that is generated from an AC 120V or 240V mains voltage (offline) input (Figure 4).

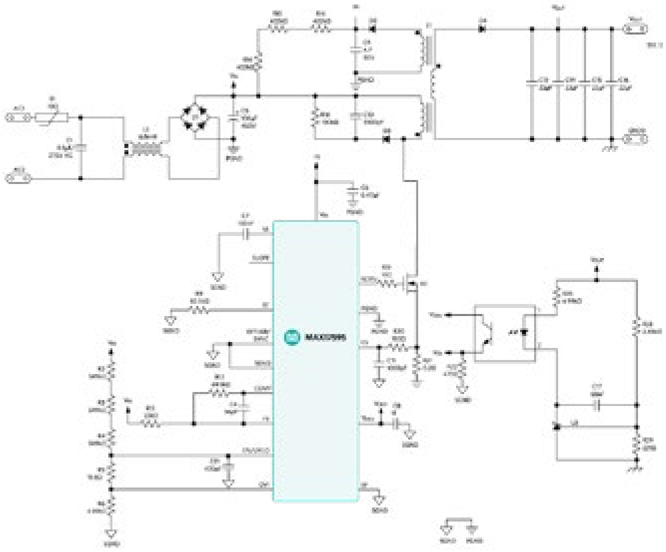

Figure 4: AC-DC Power Supply

Table 4 lists three different reference designs for these applications based on the MAX17595 peak-current-mode controller with output current drives.

Reference Design	VIN (AC V)	VOUT (V)	IOUT (A)
MAXREFDES1013	200 to 240	24	0.5
MAXREFDES1036	195 to 265	4.5	4.5
MAXREFDES1037	103 to 238	24	3

Table 4: Offline Power Supply Reference Designs

Computing Applications

Power supplies for computing applications have a requirement for low output voltages (< 5V for microprocessors and memory devices) with high output current drive. For these applications, the synchronous single output buck architecture is an appropriate solution. Some reference designs that employ this architecture are shown in Table 5.

Reference Design	VIN (V)	VOUT (V)	IOUT (A)
MAXREFDES1054	10 to 55	4	5
MAXREFDES1048	18 to 36	3	3.3
MAXREFDES1034	11.5 to 28	5	5
MAXREFDES1021	2.9 to 5.5	1.8	4
MAXREFDES1020	2.7 to 4.5	0.68	4
MAXREFDES1016	4.5 to 16	1.1	6
MAXREFDES1006	2.7 to 4.5	0.68	4

Table 5: Synchronous Buck Reference Designs

Automotive Lighting Applications

LEDs are taking the automotive industry by storm due to significant advantages over traditional technologies. To be most effective, the LED controller must accommodate a wide input voltage range and have a fast-transient response. A high, well- controlled switching frequency, outside the AM frequency band, is required to reduce radio frequency interference and meet EMI standards. Finally, high efficiency reduces heat generation, improving the LED light system's reliability. Sophisticated headlight systems utilize a boost converter as a front–end to manage both the variabilities of the input voltage (dump or cold-crank) and the EMI emissions. The boost converter delivers a well-regulated and sufficiently high-output voltage (Figure 5). Dedicated buck converters, working from this stable input supply, can then handle the complexities of controlling the lamp's intensity and position by allowing each buck converter to control a single function, such as high beam, low beam, fog, daytime running lights, position, etc.

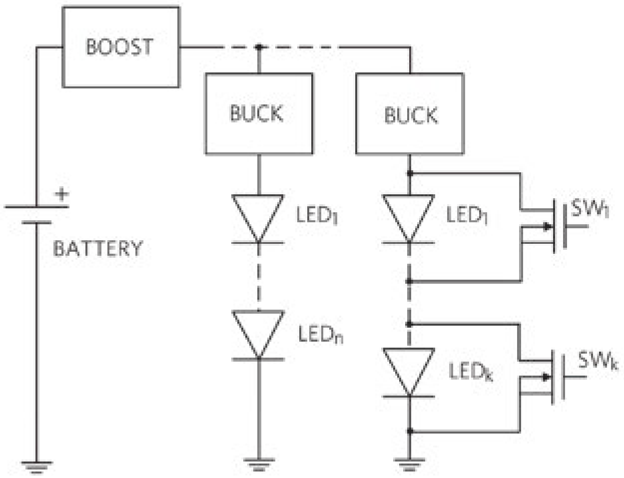

Figure 5: Advanced LED Lighting System

Table 6 lists two reference designs suitable for the automotive lighting application outlined above. The MAXREFDES1017 uses the MAX16990, which is a high-performance, current- mode PWM controller for boost/SEPIC converters with wide- input voltage ranges. The 4.5V to 36V input operating voltage range makes this ideal for front-end "pre-boost" or SEPIC power supplies and for the first boost stage in high-power LED lighting applications. Apart from automotive LED lighting, it is also suitable for use in industrial lighting and for LCD TV and desktop display LED backlights.

Reference Design	VIN (V)	VOUT (V)	IOUT (A)
MAXREFDES1003	8 to 32	5/24	0.6
MAXREFDES1017	18 to 32	19/24	0.9

Table 6: SEPIC Reference Designs

The MAXREFDES1003 uses the MAX16813 (Figure 6) which is a highly efficient, high-brightness LED (HB LED) driver that provides four integrated LED current-sink channels. An integrated current-mode switching controller drives a DC- DC converter that provides the necessary voltage to multiple strings of HB LEDs. The device accepts a wide-input voltage range and withstands direct automotive load-dump events. The wide-input range powers HB LEDs for small- to medium-sized LCD displays in automotive and general lighting applications.

Portable Applications

Smartphones and tablets are typically powered by rechargeable lithium-ion batteries where the voltage can regularly fall below 1V. The variable battery voltage needs to be converted to a stable DC voltage (which, depending on the design, can be over 10V) to drive low-current LCD displays. A "boost" topology power supply is ideal for this application. The MAXREFDES1018 power-supply reference design, shown in Table 7, uses a boost topology to produce a 13.5V output (with 6mA current drive) from an input voltage range of 1V to 3.3V. It is based on the MAX1606, which is a step-up DC-DC converter that operates from a 2.4V to 5.5V supply voltage but can boost battery voltages as low as 0.8V up to 28V.

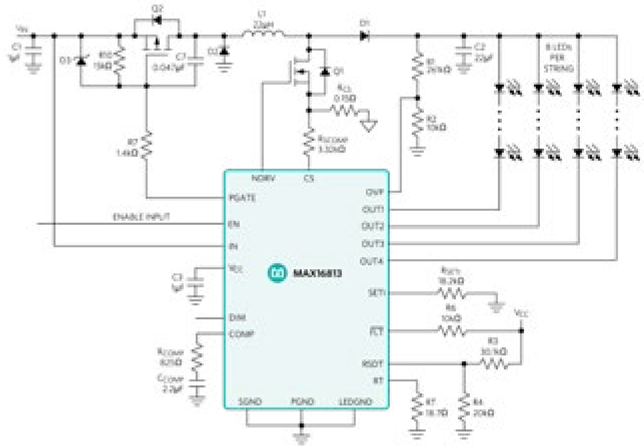

Figure 6: MAX16813 LED Driver

Reference Design	VIN (V)	VOUT (V)	IOUT (A)
MAXREFDES1018	1 to 3.3	13.5	0.006

Table 7: Boost Reference Design

Conclusion

Designing a power supply requires knowledge of the appropriate topology for the given application. Having chosen a topology, it must then be customized for an input voltage range, output voltage, and current drive as required. This can be a time- consuming procedure for the novice and experienced designer alike. In this article, we reviewed the power-supply topologies appropriate to different applications and presented a library of working power-supply reference designs with different current and voltage specifications. These designs may be immediately suitable to meet the requirements for some power-supply designs. If not, they are easily customizable using the design procedures outlined in the documentation. All designs listed include a detailed design note, verified test results, schematics, PCB artwork, and a bill of materials.

Biographies

Michael Jackson has over 20 years' professional experience as an Analog IC Design Engineer and holds the position of Senior Technical Writer at Maxim Integrated. He has a MSEE from Dublin City University.

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