Technical Article

Next-generation Ceiling and Exhaust Fans Leverage BLDC Drive Technology for Increased Efficiency and High Power Factor

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Key requirements for next-generation ceiling fans include high efficiency, high power factor (PF) and low-input-current total harmonic distortion (THD). Hence, there is a drive toward brushless DC (BLDC)-based ceiling fans in conjunction with a power factor control (PFC)-based input power stage.

BLDC drives have traditionally used discrete circuitry, including a high-end microcontroller, gate drivers, discrete MOSFETs, an auxiliary power supply, and sensing & protection circuitry. TI's DRV10983 is a highly integrated and protected single-chip sensorless sinusoidal BLDC motor controller that can replace all of the circuitry of a BLDC drive. This makes a DRV10983-based BLDC drive solution cost-effective and easy to manufacture.

The TIs Mains Operated 24V, 30W BLDC Motor Drive with Highly Efficient, High Power Factor Power Supply reference design uses this single-chip solution to realize a complete, ready-to-adapt BLDC drive for less than 30 W ceiling fan applications. The input power stage offers a peak efficiency of 91.5% and a power factor greater than 0.95 across a large range of input voltages. The power supply is based on a single-stage buck PFC topology, which not only helps meet the required specifications but optimizes system cost.

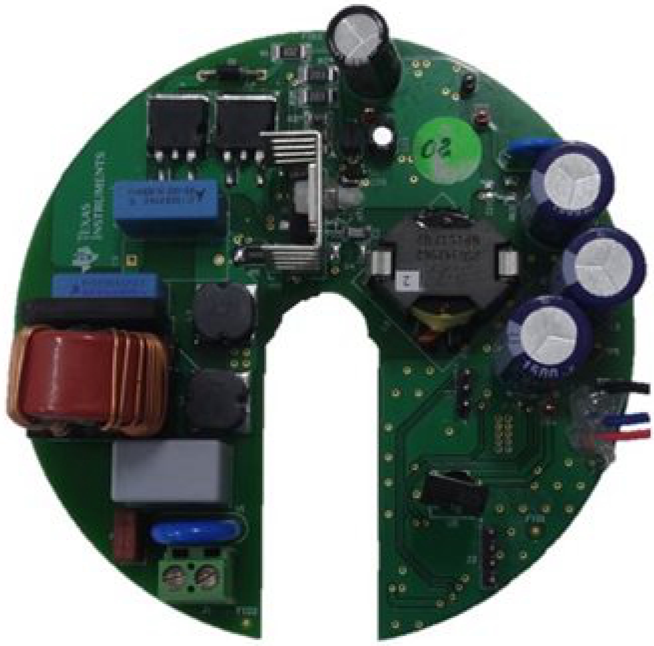

Figure 1. Board Image of TI Design: Mains-operated, 24V, 30W BLDC Motor Drive W/highly Efficient, High Power Factor Power Supply (TIDA-00652)

Circuit description

As shown in Figure 2, the board consists of a buck PFC power stage that converts the 85-230V 50/60Hz input to a $24V_{DC}$ output. The UCC28180 pulse-width modulation (PWM) integrated circuit (IC) controls the power stage. The $24V_{DC}$ generated by the power stage powers the DRV10983, which in turn drives an external BLDC motor to control its speed.

The DRV10983 also generates a 3.3V supply to power the ultra-low-power MSP430™ microcontroller (MCU). The MSP430 MCU transmits the speed reference to the DRV10983 in the form of a 1.5 kHz PWM signal (producing a duty cycle proportional to the desired speed) based on the signal received from the infrared (IR) sensor, which in turn is activated by a general-purpose IR remote control. The MSP430 firmware is easily adaptable to any remote-control button.

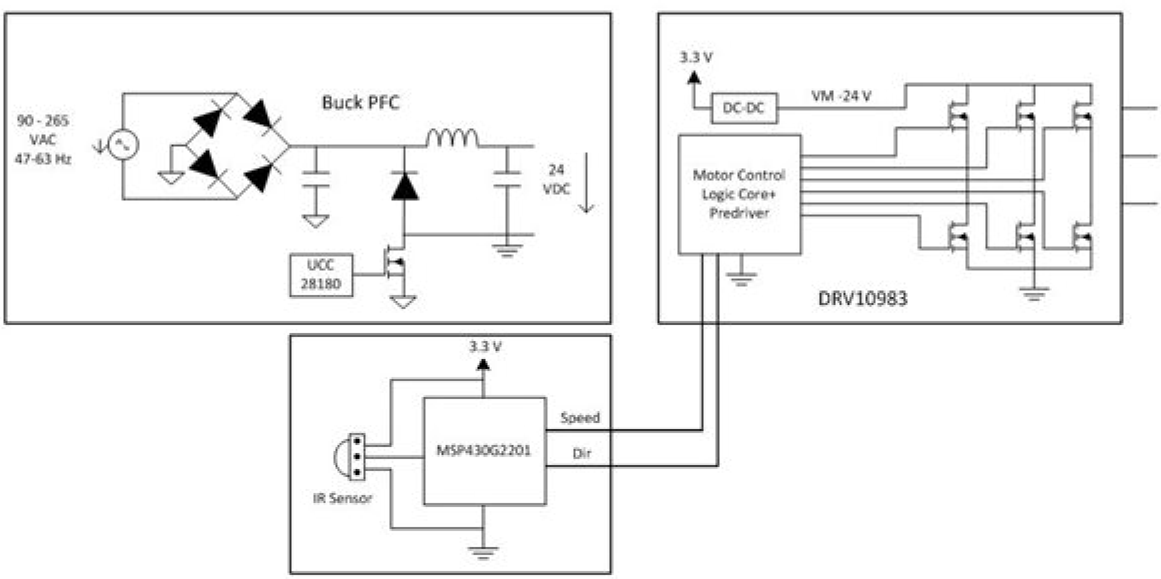

Figure 2. TIDA-00652 Circuit Description

Why $24V_{DC}$ And Not $400V_{DC}$?

A commercial ceiling fan's BLDC drive can have a DC voltage anywhere between 5V and 400V. But given the required power rating of 30W and the availability of a fully integrated drive solution, it is beneficial in terms of cost and complexity to opt for a $24V_{DC}$ solution.

Topology Selection

A $24V_{DC}$-based system is the obvious choice for the application. But you'll need to think about what type of power-supply topology can generate this $24V_{DC}$ supply from a universal-input AC voltage (85-265V_{AC}).

Two main driving factors for topology selection are cost and performance. A two-stage topology comprising a boost PFC circuit that converts the universal input voltage to $400V_{DC}$, followed by a DC/DC supply that converts that $400V_{DC}$ to $24V_{DC}$, will give the best PF and THD performance. The cost of such a power supply will be higher and the efficiency will be lower, however. Thus, the idea to reduce cost by going for a single-chip drive solution will be negated by a two-stage solution.

Another option that comes up is the flyback PFC topology. Although this is a better option for the application compared to a two-stage solution, it also suffers from lower efficiency and higher cost.

A buck PFC circuit seems to be the ideal choice in terms of PFC, THD performance and cost. Being a single-stage topology, it also offers better efficiency.

Figure 3 shows the circuit diagram of a buck PFC circuit, along with some important waveforms that explain the circuit operation. Interestingly, this design uses a continuous-conduction-mode boost PFC integrated circuit (UCC28180) to realize a discontinuous-conduction-mode buck PFC topology. This is possible mainly due to the flexibility offered by the UCC28180. Selecting such a widely used IC also provides a cost-optimized solution.

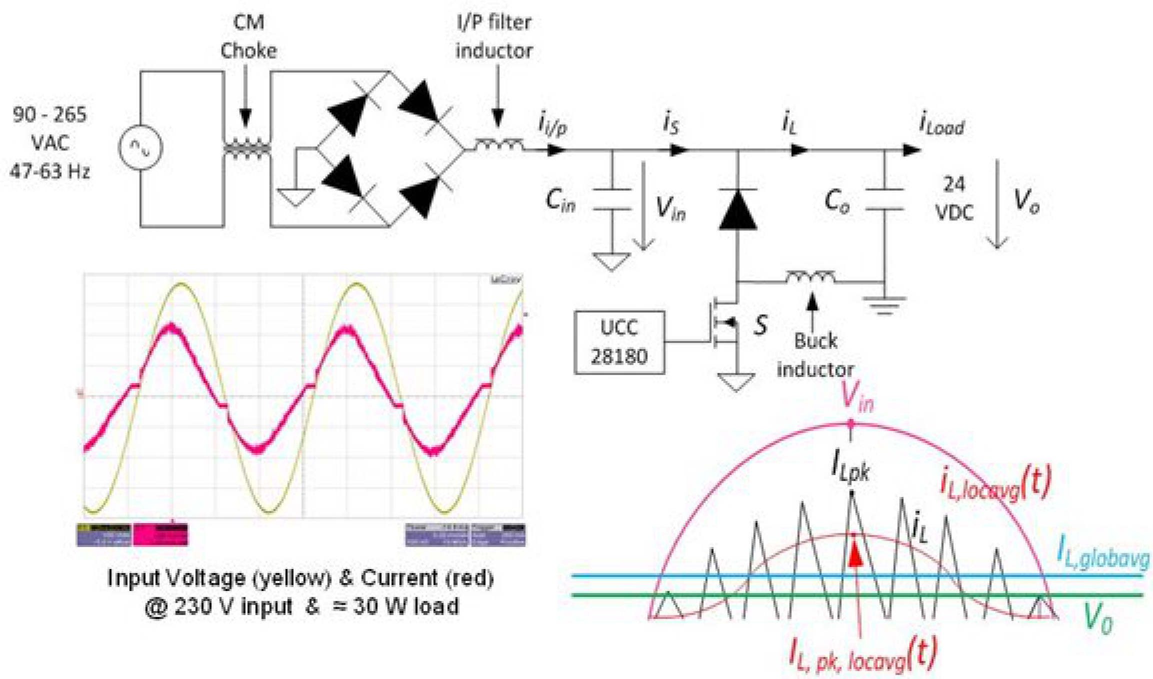

Figure 3. Circuit Diagram of the Buck PFC Topology

Figure 4 shows the efficiency performance curves of the 30W buck PFC power supply. The efficiency at $230V_{AC}$ nominal operation is 91.5%, which is good for the power levels (<30W) under consideration.

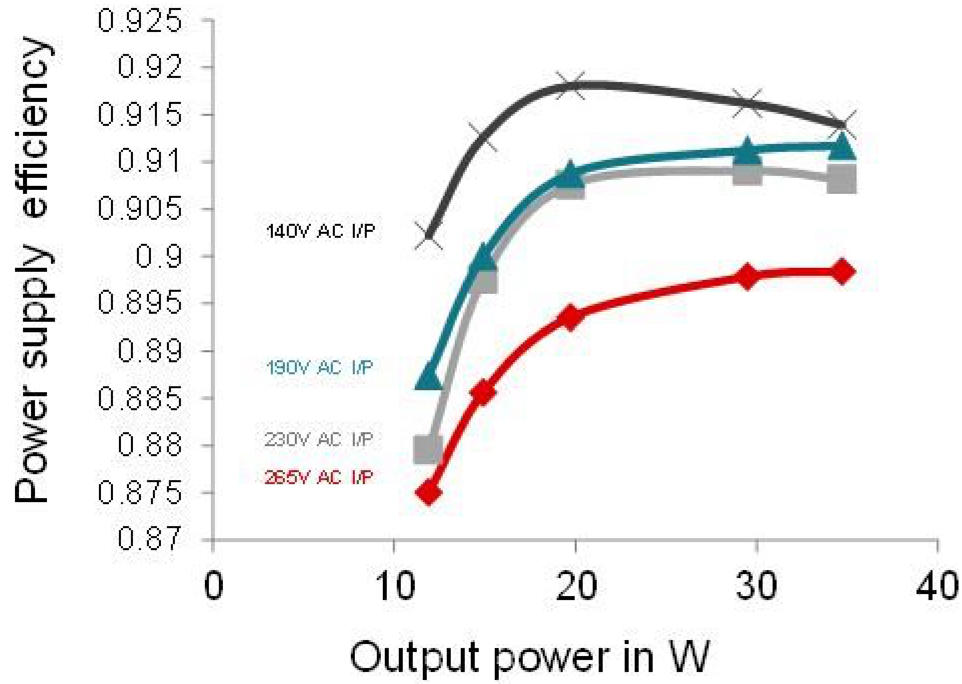

Figure 4. Efficiency Performance Curves

Figure 5 and Figure 6 show the input PF and THD performance of the converter, respectively.

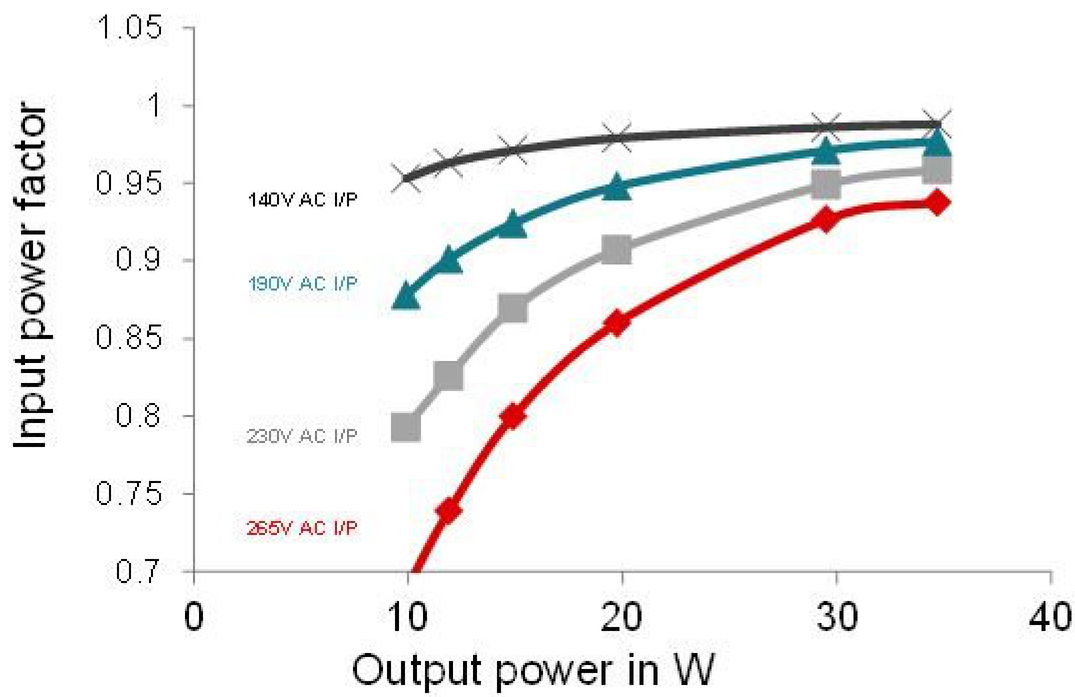

Figure 5. Input PF Performance Curves

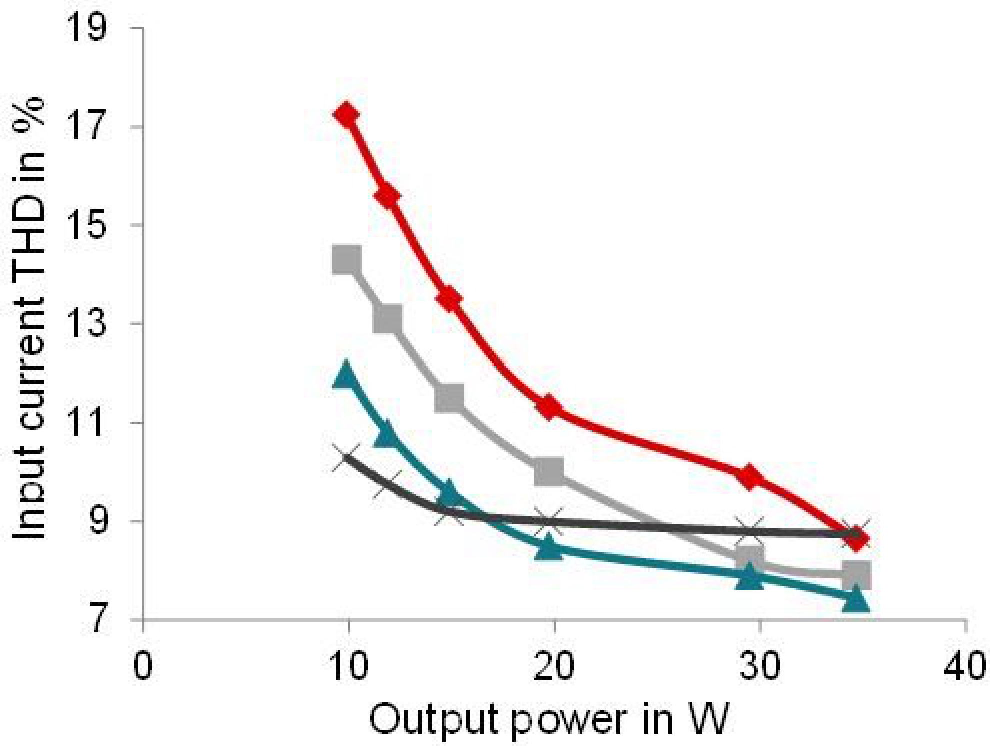

Figure 6. Input Current THD Performance Curves

In summary, a buck PFC solution gives the optimal performance metrics and is the right choice for front-end power supply in applications involving low-power BLDC drives like the modern next generation ceiling and exhaust fans.

Additional Resources:

- Ceiling fans and other fan solutions from TI
- Check out another post on ceiling fan design:
  - Designing and energy-efficient BLDC ceiling fan solution by Milan Rajne
- Overview of TI Motor Drive & Control solutions