INCREASING THE EFFICIENCY OF AN IPM-BASED DRIVE DESIGN

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The ubiquitous Intelligent Power Module, aka IPM, has been a mainstay in motor speed control designs. And with good reason: Such designs are relatively easy and cheap to implement. With onboard gate drivers, protection, and a six pack IGBT array integrated, it takes very little engineering effort to quickly come up with an effective design. Utilizing a stamped lead frame, plastic package, and high-volume components, and given an automated production line, the IPM has all the ingredients necessary to manufacture a low-cost component solution.

However, standard IPMs are not the panacea they would seem to be. Lacking a front end converter - that is, a diode bridge array - and a PFC boost converter section, they fall far short of the mark for highly efficient, IPM-based drive designs. Vincotech has a new IPM module platform that incorporates all these sections - the *flow*IPM-1B. It is a complete single-component solution.

Housed in Vincotech's ruggedized, low inductance, *flow*PIM-1 package, the *flow*IPM-1B meets the application needs of harsh industrial environments.

*flow*PIM 1 package

ARCHITECTURE

Figure 1 shows the schematic of the *flow*IPM-1B. It depicts a complete drive solution featuring a full bridge diode converter, single boost PFC with driver and boost diode, six-pack IGBT stage with driver, shunt resistors, and thermistor.

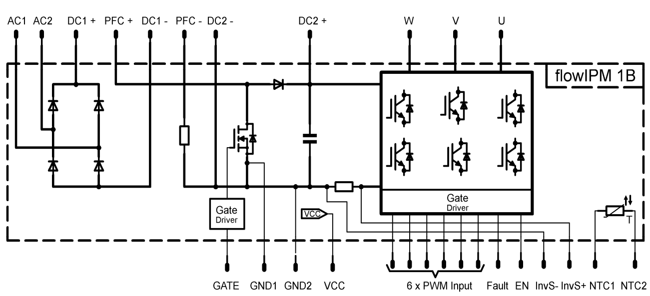

Figure 1

The *flow*PIM-1B offers considerable value and great benefits for low-power drive applications:

- Highly efficient, IPM-based drive design with converter and PFC included
- No external point-to-point connections for switching elements) and low-inductance module design, resulting in far less EMC/EMI than with a discrete solution
- Compact integrated module solution – small footprint that takes very little PCB real estate
- Highly reliable with no interconnections necessary between components
- 100% factory tested
- Reduced time to market with less time devoted to design and testing

PERFORMANCE
Responding to customers' demands and insights gleaned from studies of the market for low-power drives, Vincotech now offers a full lineup of modules with various options. The ultra fast boost diode-based P953A and SiC boost diode-based P953-A10 both contain a 600V/4A/350mΩ PFC mosfet, utilize a 600V/4A IGBT six-pack, and address up to 1KW drive designs. The ultra fast boost diode-based P955-A and SiC boost diode-based P955-A10 use a 600V/10A/190mΩ mosfet alongside a 600V/10A IGBT six-pack, which increases power handling for up to 2KW designs. The switching components are enhanced with Kelvin emitters for faster switching, resulting in lower losses. In combination with a low-inductance design, these features enable the designer to employ a higher switching frequency, resulting in an application that uses smaller and fewer power components such as inductors, noise filters, and the like.

INNOVATIVE POWERFLOW PACKAGE DESIGN
Vincotech engineered the flowPIM-1B pin layout specifically to facilitate PCB design. The control signal pins reside together on one side of the module. Power line pins on the opposite side of the module are grouped by functionality to create a power flow structure.

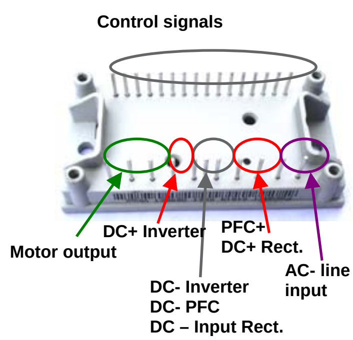

Figure 2

WHY POWER FACTOR?
In a recent article entitled *Explanation of Losses without PFC*, Michael Frisch states, "Adding power factor to a drive design does increase system cost since it requires a few additional components such as a power inductor and additional switching elements – i.e. mosfet, boost diode. However, this small incremental cost in the drive will save the end user in both installation costs and energy savings. When a PFC is not implemented, the input rectifier and capacitor will cause heavy pulsed current from the power grid. This pulsed current flowing through the fuse and power line are proportional with the square of the current (Parasitic Losses = I^2 x R), since real power is linear with the current (voltage x current). If you have twice the current in the half duration you have the same power. However, the parasitic losses are doubled (I^2 * R).

Example:
A power application requires 3.7kW effective power from the grid. The half-wave duration in a 50Hz grid is 10ms. The resulting sinusoidal current in a 230V power line is $16A_{(RMS)}$. The following equation illustrates power loss in a 50 milli-ohm home installation:

Power loss (with PFC) = $I^2 * R = (16)^2 \times 0.05 = 12.8W$

The capacitor is charged for 2ms per half-wave, so the current source will be pulsed without power factor correction. During the capacitor's charging period – that is, 20% or 1/5 of the time - five times more current flows to maintain the 3.7kW power level. This results in a considerable increase in current, with losses rising by a factor of n^2, despite the very short time of just 2ms. Losses actually increase fivefold, as this example attests:

Power loss (no PFC) = $[1/5 * (5*16A)^2 * 0.05\Omega] = 64W$

As a result, the application without PFC cannot be used in a typical 15A installation. The pulsed power surges would cause the drive to increase current by 80 amperes and generate losses of 61.8W. AC power supply line losses were one of the factors in the US electricity blackout in 2002."[1]

RELIABILITY

In conventional designs, high performance/ high reliability and economy are to some extent mutually exclusive. The designer is compelled to strike a balance between performance and reliability on one side of the scale and cost on the other. Obviously, the designer must factor reliability into the cost equation - the last thing a manufacturer wants are field failures, both long and short term. Many low-cost, transfer-molded discrete devices require a copper lead frame because of electrical and thermal conductivity issues. Temperature cycling can cause field failures due to the different inherent thermal properties of copper and silicon. Modules that use a ceramic substrate solve this problem. Of course, this adds costs that are not incurred with discretes or an IPM. However, it results in a solution that remains reliable over the long term, sparing the manufacturer costly warranty returns. What's more, discrete designs require numerous point-to-point solder contacts. Poor solder connections between these contacts also diminish reliability. Up-front savings that come courtesy of discretes quickly vanish when reliability and integrity are factored into the design equation. A low-cost, unreliable discrete design can adversely affect the manufacturer's credibility.

LOWER MANUFACTURING COSTS

Many designers choose a discrete solution based solely on the cost of components, which fails to take the total cost of ownership into account. If we wish to compare and contrast a discrete solution with a single-IPM module such as Vincotech's flowPIM-1B, we must take a step back to see the bigger cost picture. Assembly and material costs pile up because

- Aligning, attaching, and fastening discretes to the heat sink entails manual labor
- Individual electrical isolation material is necessary for each discrete device
- The design mandates individual heat sinks
- Using a single heat sink for discretes requires more holes

To drive down manufacturing costs for designs using discretes, Vincotech now offers its new *Press Pin technology* on the flowIPM-1B and other modules. Modules are simply pressed rather than soldered into the PCB to reduce assembly time and costs.

In an article published in Power Systems Design, Werner Obermaier states, "Vincotech's press fit pin design is well established in the automotive industry and provides a reliable and gas-tight connection to the PCB. Further advantages of press fit technology include reuse of the PCB and design flexibility. The module can be removed without damaging the PCB, thus allowing for the reuse of the PCB with a new module. Design flexibility is guaranteed by the elimination of the need for soldering; the module can easily be mounted on either side of the PCB at no extra cost or effort."[2]

TYPICAL APPLICATIONS

In a typical application, today's modern window air conditioner would benefit by increasing its efficiency. Window air conditioners are consumer appliances, so the manufacturer must pay close attention to cost. The implementation of the flowIPM-1B for the compressor motor inverter enables a universal input voltage from 100VAC ~ 240VAC. This allows the manufacturer to select a single motor for a given BTU size (up to 6500 BTUs)[3] to cover the different voltages required in US, European, and other markets. A smaller, lighter, and more efficient motor driven by a variable power inverter replaces the standard compressor motor. Using a single motor for each model size creates economies of scale, thereby further reducing costs. And the higher efficiency rating helps differentiate the manufacturer's product from the competitors'.

The flowIPM-1B is also an excellent choice for highly efficient, variable speed, pool pump applications up to 2HP. With a computerized controller determining the optimum GPM (gallons per minute) speed for heating water, circulating chemicals, and filtering, energy savings over the typical low-cost, dual-speed pool motor would exceed 60%.

COMPARING COSTS

Many engineers balk at the higher cost of modules over an equivalent multiple-component discrete solution. Vincotech has painstakingly qualified the components used within each module and the entire assembly to ensure it meets all datasheet specifications, including minimum, typical, and maximum values. Using a cheaper discrete part with half of the data provided certainly does not make a product more durable. Vincotech's modules are subjected to rigorous battery of specifications and functionality tests for each type of module. A discrete solution is the sum of its many individual parts, which must be tested collectively. Modules, in contrast, take the guesswork out of the topology, making the design more efficient and reliable and reducing test time during the manufacturing process. All this drives down design and manufacturing costs.

EVALUATION BOARD

Vincotech has introduced a *flow*IPM-1B evaluation board to facilitate engineers' evaluation and development efforts. Patrick Baginski explains the benefits in the evaluation board's manual:

- P950 power module featuring rectifier, PFC, six-pack with driver, and current sensing shunts
- Complete 1 kW PFC circuit with PFC controller (switching frequency settable by resistor)
- 110 VAC – 230 VAC single phase input with 2 stage EMC filter, fuse and NTC inrush protection
- 380 VDC link (settable by resistor)
- Phase 230 VAC motor output
- V TTL-compatible inverting (active low) PWM inputs for the six-pack
- Dedicated enable input (active high)
- Fault output signal (open collector)
- AC/DC converter for powering the PFC controller, measurement circuit and gate drivers in the module
- PCB designed to satisfy IEC61800-5-1, pollution degree 2, overvoltage category III[4] standards

CONCLUSION

Vincotech's new flowIPM-1B module offers an innovative new way to design a highly efficient, PFC-based IPM with very little effort. Vincotech also furnishes the same modules without PFC (1B06INA004SA - 1KW; 1B06INA010SA – 2KW). A manufacturer can use a single board design to offer both standard (without PFC) and premium (with PFC) drives. The single streamlined design creates economies of scale and cuts costs. Beyond that, Vincotech offers the press pin option as well as pre-applied phase change material to further reduce manufacturing costs. A full line of module-based solutions with extraordinary reliability and optional press pins and pre-applied phase change material – all this adds up to best-in-class value. Designers seeking the perfect solution for a low-power, highly efficient drive need look no further.

1. Frisch, Michael. "Explanation of Losses without Power Factor Correction," December 2009
2. Obermaier, Werner. "Mastering Power Modules," Power Systems Design Europe, Oct 2009
3. Electrical energy of a modern air conditioner will consume approximately = BTU rating x 0.2924.
4. Patrick Baginski. "Evaluation Driver Board for P95x, *flowI*PM-1B," December 2010