Application Spotlight on:

Power & Power Management

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Future Electronics
## MULTI-BEAM XLE Power Connectors

**TE Connectivity**

**FEATURES**
- **Mating Force:**
  - High Power: 5N max. per contact
  - Low Power: 2N max. per contact
  - Signal: 1.7N max. per contact

**Product Dimensions**
- Overall housing envelope dimensions similar to MULTIBEAM XL connectors
- Length expandable depending on number of contacts
- Depth: 0.930” [23.6mm]
- Height at mating face: 0.574” [14.6mm]

**Contact Spacing**
- High power:
  - 0.300” [7.62mm] - up to 300 VAC
  - 0.250” [6.35mm] - up to 150 VDC
  - 0.200” [5.08mm] - for connection to same voltage
- Low power: 0.115” [2.92mm] - up to 300 VDC applications (in groups of 2 contacts)
- Signal: 0.100” [2.54mm] grid

**Application Tooling**
- Right angle plugs: Flat-rock seating tools (no unique tools required)
- Right angle receptacles: Flat-rock seating tools (no unique tools required)
- Vertical plugs: Contact TE for required seating tools
- Vertical receptacles: Flat-rock seating tools (no unique tools required)

**Features**
- Two hot-pluggable power contacts to choose from:
  - 50 Amp high power contact
  - 20 Amp low power contact
- Over 40% lower mating force than original MULTI-BEAM XL connectors
- Over 40% more current in the same overall PCB space
- Low-wear contact design passes Telcordia environmental exposure requirements
- New design allows more angular misalignment

**Applications**
- Modular hot-swappable power supplies
- 1U / 2U servers
- High-end computer & telecommunication equipment
- Power distribution circuit boards
- Power distribution cable assemblies

**Electrical**
- Current carrying capacity:
  - 43 Amp high power contact (over 40% increase compared to MULTI-BEAM XL product)
  - 20 Amp low power contact (occupies 50% pcb space than MULTI-BEAM XL power contact)
- Contact resistance: 0.7 milliohm per contact at rated current

**Mechanical**
- Mis-alignment / gatherability: +/- 2mm radial misalignment

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**Product Specifications**
- Product Specification: 108-2292
- Application Specification: 114-13036

**Material**
- All materials meet RoHS requirements.

**Technical Documents**
MOSFETs feature high efficiency and low leakage currents

Nexperia supplies a range of NextPowerS3 MOSFETs which use its SchottkyPlus technology to provide the high efficiency and low spiking performance usually associated with MOSFETS that have an integrated Schottky or Schottky-like diode, but without the Schottky diode’s characteristic high leakage current.

This makes NextPowerS3 devices particularly well suited to applications requiring high efficiency at high switching frequencies.

The trend in recent years has been to create faster switching MOSFETs in an effort to reduce switching losses and increase the efficiency of switch-mode power supply designs. Faster switching, however, can generate voltage spikes, coupled-gate glitches and the potential for shoot-through, creating EMI and reliability problems. One popular solution has been to integrate Schottky and Schottky-like diodes into MOSFET structures in order to minimise reverse-recovery losses.

The drawback is that Schottky diodes suffer from high leakage current, especially at high temperatures, and this reduces efficiency, shortens battery run-time and impairs the ability to screen for defects in the manufacturing process. Combining fast switching with soft recovery, Nexperia’s NextPowerS3 range addresses each of these concerns, delivering increased efficiency and higher power density, while keeping voltage spikes under control and limiting leakage current to less than 1µA.

APPLICATIONS:
- DC-DC converters in servers and telecoms equipment
- Battery-powered motors
- Voltage regulator modules
- Point-of-load modules
- Power ORing

FEATURES:
- Very low gate charge
- Low switch-node voltage spikes
- No wire bonds or glue
- Qualified for operation at up to 175°C
- Low parasitic inductance and resistance

EMAIL ftm.asia@futureelectronics.com
Reader Response No. 2

MOSFETs combine strong linear-mode performance and low on-resistance for always-on applications

Nexperia’s NextPower Live series of MOSFETs offers reliable linear-mode performance and low on-resistance, making them ideal for applications requiring hot-swap and soft-start functionality.

Rack-mount computers, communications and storage equipment have to maintain continuous operation to support always-on services such as internet web servers. Nexperia’s NextPower Live MOSFETs offer features which are intended to support such applications.

For instance, when a replacement board is plugged into a live system, it is important that the in-rush current is carefully controlled, to protect the components on the board and to ensure that other parts of the system do not experience any power disruption. MOSFETs with strong linear-mode performance and a wide Safe Operating Area (SOA) are required to manage this current effectively and reliably.

In addition, once the replacement board is safely installed, the MOSFET will be turned fully on. In this mode of operation, low on-resistance is of high importance, as it helps to limit temperature rise and keeps system efficiency high.

APPLICATIONS:
- Blade servers
- Network storage equipment
- Routers, switches and base stations
- Communications infrastructure
- RAID arrays
- Industrial process control systems
- Industrial PCs
- Programmable logic controllers

FEATURES:
- Maximum drain-source voltage: 30V or 100V
- Maximum drain current: up to 120A
- 175°C maximum operating temperature

EMAIL ftm.asia@futureelectronics.com
Reader Response No. 3
Low-profile inductor supports switching frequencies up to 10MHz

Vishay Intertechnology has extended the low-profile, high-current IHLP family of inductors, introducing the IHLP-1616BZ-0H series which is compatible with switching power supplies operating at frequencies up to 10MHz. It also offers lower losses than any other inductor on the market at frequencies of 1MHz and above.

This means that, by using an IHLP-1616BZ-0H inductor, power-system designers can achieve higher system efficiency and potentially reduce the size of a DC-DC converter’s circuitry.

When used in conjunction with a high-frequency power controller, the IHLP-1616BZ-0H inductors enable the implementation of power designs with lower inductance values and thus lower DC losses as well as reduced high-frequency core losses.

APPLICATIONS:
- PMICs for sensors and cameras
- High-current PoL converters
- Battery-powered devices
- Low-profile, high-current power supplies

FEATURES:
- Handles high transient-current spikes without saturation
- High resistance to thermal and mechanical shocks and moisture
- ±20% inductance tolerance

The shielded, composite construction of the inductor keeps buzz noise to very low levels.

Rugged NTC thermistor provides surface temperature measurement at up to 150°C

The NTCALUG01A is a series of Negative Temperature Coefficient (NTC) thermistors from Vishay Intertechnology which offers easy mounting using a ring tongue terminal which may be screwed to the surface of the object to be measured.

The insulated sensor body is mounted inside the barrel of the ring tongue terminal, and it has two stranded, insulated copper leads which provide 600Vrms of insulation in accordance with the NEMA HP-3 type E specification.

The thermistor is therefore suitable for a wide range of surface sensing applications, especially when good electrical insulation and a good thermal contact with the chassis are required.

The sensor body is epoxy-coated and attached to the metal ring lug via a middle buffer layer. The lug is made of tinned copper. The insulated leads are stranded AWG 24 wire with PTFE insulation, and have a diameter of 1.12mm.

The NTCALUG01A thermistors are available with resistance values at 25°C that range from 4.7kΩ to 100kΩ, and with a tolerance of this resistance value between ±1% and ±5%. The operating-temperature range is -40°C to 150°C, and the dissipation factor is 23mW/K.

APPLICATIONS:
- Automotive inlet air-temperature control
- Transmission oil-temperature control
- Engine-temperature control
- Automotive air-conditioning systems
- Airbags
- Frost sensors
- Domestic appliances
- Industrial process control
- Fire alarms
- Heating and ventilation equipment

FEATURES:
- 7.5s thermal constant time
- AEC-Q200 grade 1 qualified
- UL recognised
- 1,500V AC minimum dielectric withstanding voltage between terminals and lug
- 100MΩ minimum insulation resistance between terminals and lug at 500V DC

The shielded, composite construction of the thermistor keeps temperature noise to very low levels.
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This Design Note describes power-management techniques implemented in the ViPerPlus series of AC-DC converter ICs which may be used to minimise stand-by power consumption in household appliances. Use of the ViPerPlus converters enables designers of appliance Switch-Mode Power Supplies (SMPS) to comply with the most demanding energy-saving regulations, through:

- **Advanced light-load management**
- **A clever Zero-Power Mode (ZPM) which enables the appliance to shut down automatically at the end of the operating cycle.**

Examples of the implementation of such techniques are presented, using evaluation boards for two ViPerPlus high-voltage converters.

### Advanced light-load management

ViPer01, part of the ViPerPlus series, combines an 800V avalanche-rugged power MOSFET with a fixed-frequency PWM current-mode controller in a single chip. An integrated high-voltage start-up, sense FET, error amplifier and oscillator with frequency jitter enable the implementation of a complete AC-DC converter application, using a flyback, buck or buck-boost topology, with few external components.

Important features of the ViPer01 help users to comply with energy-saving regulations governing light-load power consumption:

- The low threshold of both the power MOSFET and internal logic circuitry allow the IC to be supplied from a power rail as low as 4.5V.
- The low gate charge of the power MOSFET and low power consumption of the internal logic circuitry mean that the IC draws an extremely low quiescent current.
- Pulse Frequency Modulation (PFM) decreases the switching frequency under light loads, which minimises frequency-related losses.

The way that these specifications affect real-world performance is illustrated in the following sections, which report measurements of ViPerPlus boards' performance in light-load conditions.

### ViPer01 application performance

An STMicroelectronics applications engineering team tested the operation of the ViPer01 converter using the STEVAL-ISA177V1 evaluation kit, a wide input-range flyback converter which supplies 4.25W to a single 5V output.

In no-load conditions, the board consumes less than 10mW at 230V AC, and its efficiency when supplying a load of 250mW is higher than 60%, as shown in Figure 1.

### Advanced architecture for zero-power consumption

A different ViPerPlus part, the ViPer0P, may be used to design an SMPS for periodic household equipment, that is, devices such as washing machines that have finite operating cycles and that normally remain switched off between cycles. The ViPer0P automatically puts the SMPS into the Off mode at the end of the operating cycle, and consumes less than 5mW in this Off state.

This eliminates the need for the bi-stable electromechanical switches that are commonly used in such designs, increasing system reliability, and reducing the cost of the system. In fact:

- The SMPS can be shut down by a microcontroller supervising the operation of the appliance, and enter a special state in which it supplies no power at its output terminals.
- Once in this state, the SMPS is ready to be manually restarted by the user while consuming less than 5mW from the power line at 230V AC.

This capability is a zero-power function, shown in Figure 2: that is, it enables a system to achieve zero-power consumption as defined by the IEC 62301 standard, clause 4.5. It consists of a special idle state, the ZPM, in which the control IC is totally shut down except for the circuitry needed to exit ZPM. The only parts of the control IC that remain alive are the zero-power logic block, and the 4V regulator which provides the bias voltage to it.

Overall power consumption in ZPM consists of two areas: consumption on the branch ZD1, RG, ZD2, M3; and consumption due to the quiescent current, Iq, of around 1.5μA absorbed by the 4V regulator and the zero-power logic block, plus the output current delivered to an external circuit.
This consumption may be estimated as follows:

\[ P_{ZPM} = V_{\text{in} pk} \left( \frac{V_{\text{in} pk} - V_{ZD1} - V_{ZD2}}{R_G} + I_q + I_{\text{ext}} \right) \]

At an input voltage of 230V AC and assuming worst-case values, \( R_G = 28\,\text{MΩ} \), \( V_{ZD1} + V_{ZD2} = 20\,\text{V} \), \( I_q = 2\,\mu\text{A} \), ZPM power consumption is 4.2mW plus 0.325mW/\( \mu\text{A} \) of current delivered to an external circuit.

A practical example of the zero-power architecture

The demonstration board STEVAL-ISA174V1 is based on the VIPer0P converter IC, and implements a wide input-range, non-isolated, dual-output flyback converter supplying a total of 6.8W, as shown in Figure 3.

![Figure 3: The STEVAL-ISA174V1 evaluation board for the VIPer0P converter](image)

It supplies 4W from a -5V output tightly regulated through a voltage divider connected to the non-inverting input of the error amplifier available at the Feedback pin; and 2.8W to a 7V output, semi-regulated by magnetic coupling through the turn ratio of the two output windings.

The completely characterised board is described in ST’s application note AN4836. The application described here complies with the tightest regulations for energy-conscious designs, such as the European Code of Conduct (CoC) version 5 requirements for external power supplies.

The data shown in Figure 4 show that the application when in ZPM has zero-power input consumption in accordance with IEC 62301 clause 4.5. It is also five-star energy efficient when operating with no load.

The data in Figure 5 show that the equivalent 12V/6.8W SMPS, which is made by connecting the load across the Vout1 and Vout2 lines, complies with the ErP Lot 6 Tier 2 requirements in the Off mode, and with the 10% load efficiency target envisaged by the European CoC version 5.

The STEVAL-ISA174V1 is a demonstration board and does not include an MCU, so the On and Off pins are activated by the user with push-buttons. Evaluation kits which include an MCU are the STEVAL-ISA181V1 and STEVAL-ISA192V1. In these boards, the MCU may be configured to activate the On and Off pins.

**Conclusion**

Today’s power supply units require more sophisticated methods for improving performance to meet the requirement of the latest energy-saving regulations.

ST’s VIPerPlus high-voltage converters use advanced technologies and clever power architectures to meet the need for increasingly efficient electrical power in smart household appliances that have to be connected with an advanced user interface.

VIPer01 applications demonstrate how easy it can be to meet the most stringent energy regulations for continuous-operation household appliances such as refrigerators. On the other hand, VIPer0P applications demonstrate how to build a clever stand-by architecture, including easy interaction with an MCU, to reduce the bill-of-materials cost of a power supply for a household appliance for periodic operation such as a washing machine.

Such an SMPS design also offers high reliability and flexibility, and has a low component count.

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**Table 1: ZPM Input Power Consumption**

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>ZPM Input Power Consumption (mW)</th>
<th>No-load Input Power Consumption (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115V AC</td>
<td>0.8</td>
<td>6.5</td>
</tr>
<tr>
<td>230V AC</td>
<td>3.5</td>
<td>9.1</td>
</tr>
</tbody>
</table>

**Table 2: Efficiency (%)**

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>At an output power of 25mW</th>
<th>At an output power of 50mW</th>
<th>At an output power of 250mW</th>
<th>At an output power of 680mW</th>
</tr>
</thead>
<tbody>
<tr>
<td>115V AC</td>
<td>55.6</td>
<td>60.8</td>
<td>72.2</td>
<td>78.0</td>
</tr>
<tr>
<td>230V AC</td>
<td>51.3</td>
<td>57.0</td>
<td>66.3</td>
<td>71.4</td>
</tr>
</tbody>
</table>

**Table 3: Conditions**

- Power line connected
- IC not switching, most internal blocks disabled
- \( I_{\text{out}} = I_{\text{out}} = 0 \)
- \( V_{\text{out}} = V_{\text{out}} = 0 \)
- Power line connected
- IC switching (in burst mode)
- \( I_{\text{out}} = I_{\text{out}} = 0 \)
- \( V_{\text{out}} \) and \( V_{\text{out}} \) regulated at their nominal values

---

**Fig. 4: ZPM input power and no-load input power of the STEVAL-ISA174V1 board**

**Fig. 5: Light-load performance of the STEVAL-ISA174V1 board**
APPLICATION SPOTLIGHT

Superior Performance with ON Semiconductor’s SuperFET® III MOSFET

SuperFET III MOSFET is ON Semiconductor’s brand-new high voltage super-junction (SJ) MOSFET family that is utilizing charge balance technology for outstanding low on-resistance and lower gate charge performance.

This advanced technology is tailored to minimize conduction loss, provide superior switching performance, and withstand extreme dv/dt rate.

Consequently, SuperFET III MOSFET is very suitable for the various power system for miniaturization and higher efficiency. SuperFET III FRFET® MOSFET’s optimized reverse recovery performance of body diode can remove additional component and improve system reliability.

Check out ON Semiconductor’s Power Supply WebDesigner to get started with your power design.

APPLICATIONS:

- Server and telecom power
- EV charging stations
- Solar/UPS
- LED lighting

FEATURES:

- Higher system reliability in LLC and phase shift full bridge circuit
- Higher system reliability at low temperature operation
- Excellent body diode performance (robust body diode)
- Lower peak Vds and lower Vgs oscillation
- Low effective output capacitance
- Lower switching and conduction losses
- 100% Avalanche tested

$$ \text{Product} \quad \text{Description} \quad \text{Voltage (V)} \quad \text{Current (A)} \quad \text{R}_{\text{DS(on)}} \quad \text{mQ} $$

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>R_{DS(on)} (mQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTH027N65S3F</td>
<td>SuperFET III FRFET MOSFET</td>
<td>650</td>
<td>75</td>
<td>27.4</td>
</tr>
<tr>
<td>NTP082N65S3F</td>
<td>SuperFET III FRFET MOSFET</td>
<td>650</td>
<td>40</td>
<td>82</td>
</tr>
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In addition to super-junction MOSFETs, ON Semiconductor also provides a comprehensive set of standard MOSFETs. This table shows the standard MOSFET portfolio as a result of organic growth and acquisitions. This coverage enables ON Semiconductor to compete directly against all voltages and packages.
Digital controller suitable for interleaved CCM power factor correction circuits

Fully configurable through an intuitive GUI, STMicroelectronics' new STNRGPF01 digital controller for Power Factor Correction (PFC) circuits provides the same level of performance as a DSP, but with a much lower level of complexity and with no requirement for firmware development.

Rugged enough for high-end industrial Switch-Mode Power Supplies (SMPS) as well as high-power home appliances, the STNRGPF01 digital controller features an interleaved Continuous Conduction Mode (CCM) boost PFC topology. Interleaved CCM PFC topologies are necessary when regulating the power for loads above 1kW with reasonably sized magnetic components while supporting current splitting.

The STNRGPF01 splits the PFC management into two or more parallel channels depending on the load condition, therefore ensuring the highest level of efficiency at any load. This allows the size of the EMI filter and inductor to be smaller than when using traditional single-stage PFC controllers. In addition, switch power management is improved and the average current of the output capacitor is reduced.

The STNRGPF01 implements mixed analogue and digital signal control, offering the advantages of a very high-end digital solution: the inner current loop is performed in hardware to realise an analogue Proportional-Integral (PI) compensator, providing for cycle-by-cycle regulation. The outer voltage loop is performed by a digital PI controller with fast dynamic response.

The device's dedicated eDesignSuite GUI accepts converter specifications entered by the user, and supplies schematics, a bill-of-materials, and custom binary code which can be loaded into the IC.

Development with the STNRGPF01 is different from the use of DSPs: the designer is not required to write any lines of firmware, to know the device registry and memory map, or to handle interrupt generation and manage priorities.

APPLICATIONS:
- Switch-mode power supplies rated for loads > 1kW
- Industrial equipment
- Home appliances

FEATURES:
- Flexible working frequency up to 300kHz to drive either MOSFET or IGBT
- Configurable phase shedding for high efficiency over a wide load range
- Soft start-up to reduce electrical stress and to manage in-rush current
- UART and I2C interfaces
- Operating-temperature range: -40°C to 105°C

Power driver integrates gate drivers and four MOSFETs in a single package

The MOSFETs, which are in a dual half-bridge configuration, feature low on-resistance of 320mΩ, and are rated for a 600V drain-source breakdown voltage. The embedded gate drivers' high side can easily be supplied by an integrated bootstrap diode.

Because the device integrates multiple power driver functions in a single package, it enables users to achieve designs characterised by their high power density. The PWD13F60 system-in-package has a compact 10mm x 13mm footprint, and is 1mm high.

The PWD13F60 device accepts a supply voltage ranging from -0.3V to 19V. The input pins' extended range allows for easy interfacing with microcontrollers, DSPs or Hall-effect sensors.

APPLICATIONS:
- Motor drivers for industrial and home appliances
- Factory automation equipment
- Fans and pumps
- Lighting ballast
- Power supply units
- DC-DC and DC-AC converters

FEATURES:
- Under-voltage lock-out protection on the supply voltage
- 3.3V to 15V-compatible inputs with hysteresis and pull-down
- Interlocking function to prevent cross-conduction
- Outputs in phase with inputs
- Very compact and simple layout
- Flexible, easy and fast design
High-density AC-DC power supplies housed in low-profile open-frame packages

The VOF-180 series, rated for 180W, has an open-frame package with an industry-standard 2” x 4” footprint and is 0.75” high. The 2” x 4” VOF-225A with a 225W rating is 1” high.

The 275W, 300W, 350W and 550W models, the VOF-275, VOF-300, VOF-350 and VOF-550 series, are housed in 3” x 5” packages. The VOF-275 is 0.75” high, the VOF-300 1.18”, the VOF-350 1”, and the VOF-550 is 1.5” high.

The power supplies support efficient operation in stand-by mode, consuming no-load power as low as 0.5W.

Output-voltage options range from 12V to 58V DC. The power supplies handle a universal input-voltage range of 80V to 264V AC.

Certified compliant with the UL/EN60950-1 safety standards, the VOF series parts also satisfy the requirements of the EN55032 B specifications for conducted and radiated emissions.

APPLICATIONS:
- Industrial systems
- Telecoms equipment
- IT equipment
- Consumer electronics

FEATURES:
- Power factor correction
- 12V DC/500mA fan output
- Over-voltage protection
- Over-current protection
- Short-circuit protection
- 3.37 million hours MTBF calculated in accordance with Telcordia SR-332 issue 3
- Operating-temperature range:
  - -40°C to 50°C at full load with forced-air cooling

Isolated high-voltage flyback transformer optimised for Avago ACPL-32JT chipset

TT Electronics has introduced the HA00-14013LFTR, an isolated high-voltage flyback transformer solution which is ideal for automotive DC-DC converter applications in which size and efficiency are of critical importance.

The flyback transformer, which is used in an isolated version of a buck-boost switch-mode topology, consists of a coupled inductor arrangement. When the transistor is turned on, current builds up in the primary winding and energy is stored in the core. This energy is then released to the output circuit through the secondary winding when the switch is turned off.

The HA00-14013LFTR operates as a step-up transformer for DC-DC converters that require a high isolation voltage between the primary and secondary sides. It is intended for use with Avago’s ACPL-32JT and ACPL-302J gate-drive optocouplers, which are for automotive and industrial applications respectively.

The main reasons for selecting the TT Electronics HA00-14013LFTR are to enable a lower peak primary voltage, for simpler circuitry, and for lower leakage inductance resulting in improved efficiency.

APPLICATIONS:
- Transportation
- Industrial switch-mode power supplies
- Industrial automation systems
- Automotive gate-drive applications

FEATURES:
- 155°C maximum operating temperature
- AEC-Q200 certified
- Compact package
- High-voltage isolation

TT ELECTRONICS
EMAIL ftm.asia@futureelectronics.com
Reader Response No. 10
New line of DC-DC converters offer reliable performance in renewable energy applications

CUI INC

CUI’s AE series of DC-DC converters handles input voltages of up to 1,500V DC

CUI’s Power Group has announced a new line of DC-DC converter modules, the AE series, which provides for reliable operation in renewable energy applications.

Available in board-mount, chassis-mount and DIN rail-mount configurations, the AE series offers power ratings of 5W, 10W, 15W and 40W. Devices in the series support a range of input voltages up to 1,500V DC, and input-ratio ranges up to 10:1.

The new AE models offer 4,000V AC input-to-output isolation. The devices can operate at altitudes up to 5,000m, making them suitable for use in remote installations.

These isolated modules are housed in fully encapsulated packages, the smallest of which measures 70mm x 48mm x 23.5mm.

The AE series has EN62109 safety approvals and conforms to the CISPR22/EN55022 Class A specifications for conducted and radiated emissions. The AE-UW series holds an additional UL 1741 safety approval.

APPLICATIONS:
- Solar power equipment
- Wind turbines
- Renewable energy generation
- Electric vehicle charging stations

FEATURES:
- Output-voltage options: 5V, 9V, 12V, 15V and 24V DC
- Up to 84% efficiency
- Operating-temperature range: -40°C to 70°C at full load
- Over-voltage protection
- Over-current protection
- Continuous short-circuit protection

TT Electronics’ HA19 Common Mode Choke Ideal for EPS Noise Suppression Applications

TT ELECTRONICS

The HA19 common mode choke is designed specifically for noise suppression applications found in the growth and expansion of new generation vehicles such as electric vehicles (EVs) and plug-in hybrid vehicles (PHVs). The HA19 series offer high efficiency and excellent current handling in a rugged construction. It is mechanically robust and features low DC resistance and low temperature rise performance. HA19 is ideal for high efficiency electric power steering EMI applications where size and AEC-Q200 certification is critical.

APPLICATIONS:
- Ideal for high frequency EPS noise suppression applications
- Transportation – Electric Power Steering
- Transportation – Electronic Control Units
- Transportation – Engine Control
- Transportation – Transmission Control
- Industrial – Switch Mode Power Supply
- Industrial – DC/DC Converters

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- Temperature Rise, Maximum 40°C
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Fossil fuels are only available until they are exhausted and when they are burned, they release harmful gases. The role of the electric car is certain to be in our future. But even here, there are challenges ahead, especially when it comes to fuse protection of the battery.

In recent decades, cars have increased in numbers as well as dimensions. They have become more comfortable, more powerful, safer and therefore heavier as well, with mid-range cars already weighing 1.5 tons. It goes without saying that a significant amount of energy will be required to adequately power an electric car of this class in the future.

Thousands of battery cells
This is achieved by interconnecting small battery cells - size 4 VDC/3200 mAh per cell - in parallel and in a row. 100 cells in a row are needed to attain an operating voltage of approximately 400 VDC. The endurance, range and performance of the overall package are then achieved by connecting many of these 400 V strings in parallel. In very powerful electric vehicles, several thousand cells are quickly assembled in this way.

You may recall ...
Not long ago, a smartphone manufacturer in Korea had to deal with a battery problem, which cost them a fortune. A single, small battery led to panic; it even went so far as the smartphone being banned. Airlines declared that this type of mobile phone would no longer be allowed on the aircraft. Ordinary paying passengers were faced with the choice to hand over their mobile phone or get off the plane. Was this panic justified? It’s hard to say. But when you concentrate on the active components, requirements for passive components, the standard Q200, which was introduced in the middle of the 1990s, describes the requirements for passive components, while standard Q100 and its spinoffs concentrate on the active components. These AEC standards are recognized worldwide and are accepted by all the leading manufacturers in the automotive industry.

What about fuses in the context of AEC-Q200?
Specific tests and a set of specifically defined requirements for fuses used in cars were not relevant throughout automotive development history. However, this has completely changed with the introduction of electronic control units and electric drives. Fuses will also be included as a topic in the next update of the Q200 standard.

SCHURTER focused on the high reliability requirements of the aerospace industry, which were developed in cooperation with ESA. This, together with the specifications for other passive components according to AEC-Q200, was also taken into account. Test procedures were developed for fuses, which meet the Q200 set of requirements, by working in close cooperation with key global players in the automotive industry. Fuses manufactured in this way may bear the unrestricted and internationally recognized Q200 "seal of approval".

Company
SCHURTER continues to be a progressive innovator and manufacturer of electronic and electrical components worldwide. Our products ensure safe and clean supply of power, while making equipment easy to use. We offer a broad range of standard products including circuit protection, connectors, EMC products, switches and input systems, as well as electronic manufacturing services. Moreover, SCHURTER is ready to work with our customers to meet their application specific requirements, not covered in our standard range. You can rely on SCHURTER’s global network of companies and partners to guarantee a high level of local service and product delivery.

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Flyback transformer design: practical guidance on minimising losses

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There are many possible topologies for a Switch-Mode Power Supply (SMPS), but the most popular for circuits supplying a load less than 150W is the flyback converter. Some estimates go as far as to suggest that up to 75% of offline power supplies use the flyback topology.

Many power-system designers are therefore faced with the challenge of developing a flyback converter circuit. To achieve the best performance, satisfy electrical specifications and stay within cost and space limits, the designer will need to implement some form of customisation in the design; and the most important custom element of a flyback converter is the transformer.

In the design engineering community, transformer design and prototyping is generally regarded as a black art. To the uninitiated, the wide range of parameters affecting transformer performance – from selection of core material and size to the arrangement of the windings around the core – can appear confusing. In fact, the process of transformer design can be worked through in an orderly way by applying a small number of important equations, combined with a certain degree of trial and error, perhaps better described as ‘experienced guesswork’.

The team of designers at the Future Electronics EMEA System Design Centre (SDC) in London, UK, has gained much practical experience from its work on the development of custom power supplies for OEM customers. The purpose of this article is to share some of this experience and reveal effective ways to optimise transformer design in flyback converter circuits.

Flyback topology: theory of operation

The flyback converter is an isolated form of buck-boost converter, as shown in Figure 1. It consists of:

- a primary-side switch, typically a MOSFET
- two inductors in the form of a primary and a secondary winding around a magnetic core, as shown in Figure 2. The windings are turned around a plastic bobbin which provides mechanical support and a set of pins for the wire connections and through-hole mounting on a PCB. In its operation the arrangement of the two inductors is more correctly called a ‘magnetically-coupled inductor’. But because of the two separate windings, it is commonly referred to by designers as a ‘flyback transformer’. Strictly this is a misnomer, but for convenience this article will refer to it this way.
- a secondary-side switch, typically a diode
- an output capacitor

Feedback for control purposes across the isolation barrier is generally implemented with an optocoupler and compensation circuitry.

When the primary switch is turned on, current is drawn through the primary winding, generating a magnetic field which is readily transferred through the low-reluctance core to a small air gap in the centre of the core, where stored magnetic energy accumulates. When the primary-side switch is turned off, the stored magnetic energy induces current to flow through the secondary winding and the output diode to the load.

The various advantages of this converter topology explain its widespread adoption:

- Isolation is readily achieved via the flyback transformer and optocoupler feedback compensation.
- Component count and cost are low.
- The turns ratio of the flyback transformer allows for a high ratio between input and output voltages, such as a 3.3V output directly from an AC mains voltage input.
- A single power stage can provide multiple output-voltage rails, of both positive and negative polarity.
- The flyback topology supports both step-up and step-down operation: it is a buck-boost topology.

But there are drawbacks to the flyback converter. The most important are:

- Voltage stress on the MOSFET and output diode are high, and widely variable from design to design.
- Relatively high noise, due to high peak currents and high voltage peaks at both switch elements during switch transitions. The flyback transformer may also contribute noise via coupling across and radiation from the windings.
How converter specification affects transformer design
Optimisation of the flyback transformer is determined by the key parameters specified by the designer, which are:
- Output power
- Switching frequency
- Peak and average current values in the primary and secondary windings (taking account of the worst case of maximum load at minimum input voltage)
- Primary inductance
- Maximum flux density
- Turns ratio

Before the designer can begin the process of designing the flyback transformer, however, the conduction mode of operation needs to be chosen: Continuous Conduction Mode (CCM), Discontinuous Conduction Mode (DCM) or Critical Conduction Mode (CRM). The process of transformer design is the same for all three conduction modes, but in any power converter the operation is different, and fundamentally so in the case of the flyback converter, because the transfer function of the converter is different in each case, affecting feedback compensation.

There is substantial literature available to guide the designer’s choice, so this article does not deal with conduction modes in detail. Practical experience at the Future Electronics SDC suggests that the choice is most often determined by:
- Size and cost pressures, in which case DCM has the advantage because of its lower inductance requirement
- Requirement for low conduction losses and high efficiency at higher output power levels, in which case CCM is preferred because peak and Root Mean Square (RMS) output current are lower for any given output-power value.

A further decision to be taken early in the development process is the choice of core material. The main parameters affecting the choice of core material are maximum flux density, reluctance and cost. For flyback transformers the magnetic material most commonly used is ferrite. This is a cheap material which suffers from low losses at switching frequencies up to around 500kHz. Ferrite cores become saturated at a relatively low flux density, typically around 0.4T. This means that, in designs using a conventional ferrite core, flux density should be kept to a value no higher than 0.3T at the peak primary-side current to avoid saturation.

The causes of losses, and how to manage them
It is a rare power-converter design project in which the engineer’s attention is not firmly focussed on power efficiency, and the minimisation of power losses. In general, loss reduction helps to reduce thermal stress and the need for cooling devices, improves system reliability, and enables the creation of a smaller, lighter and cheaper end-product.

In a flyback converter, there are many sources of loss, including MOSFET and diode conduction and switching losses, output capacitor ripple-current loss, snubber losses, and input and output filter losses. But in most cases by far the greatest proportion of total losses is attributable to the flyback transformer. There is therefore considerable benefit to be gained from efforts to reduce transformer losses.

It is helpful to start with an understanding of the various sources of loss within a flyback transformer. These are:
- **Copper losses** due to the DC and AC resistance of the copper wire used for the primary and secondary windings.
- **Proximity losses** due to the effect of closely-coupled currents within a strong magnetic field, concentrating current flow in a portion of the copper wire’s cross-section.
- **Leakage inductance:** magnetic field leakage results in electrical power loss. This must also be taken into account in the circuit design, since the level of leakage inductance directly affects so-called ‘snubber losses’. A basic requirement for avoiding magnetic field leakage is to locate the air gap inside the winding.
- **Loss in the magnetic core material** due to the switching action and the inherently hysteretic behaviour of core materials.

**Copper losses**
The amount of loss in a winding’s copper wire is influenced by:
- The current waveform, and the relative sizes of the DC and the AC components
- The overall DC and AC resistance of the windings
- Switching frequency
- Proximity loss

In particular, a high switching frequency and a relatively high AC component in the current waveform will increase resistance due to the so-called ‘skin effect’. The skin effect causes high-frequency AC components to be conducted towards the outer surface of the wire, effectively reducing the cross-sectional area of the conductor, and therefore increasing its resistance. Future Electronics’ practical evaluation of real-world transformer designs operating at switching frequencies below 100kHz has shown that the skin effect – and copper losses – can be minimised by using single-strand copper wire with a diameter of ≤0.5mm.

**Proximity loss** also adds to the losses in copper wiring: in essence, a conductor which carries a high-frequency current induces copper loss in an adjacent conductor by a phenomenon known as the proximity effect. This effect causes copper losses to compound with each additional layer in a multiple-layer winding.

To minimise the effect of proximity losses, therefore, the designer must keep the number of winding layers to a minimum: ideally no more than two or three for the primary and secondary windings, particularly when the current waveforms have a high proportion of AC components, which is the case in DCM operation.

**Leakage inductance** is a function of the number of turns squared (N2) and the winding geometry. To minimise leakage inductance for a given core and bobbin, the designer should choose a core that provides an appropriate cross-sectional area, thus minimising the number of turns required to reach the target inductance.

Another important step is to provide the best possible coupling between the primary and secondary windings. The best results are achieved when the winding widths of the primary and secondary layers are matched, and kept on adjacent layers, or when the secondary layer is sandwiched between two primary windings, as shown in Figure 3.

**Core losses:** energy is required to effect a change in the magnetisation of the core. Not all of this energy is recoverable in electrical form; a fraction is lost as heat. This power loss can be observed electrically as the hysteresis of the B-H loop. The losses are generally proportional with the change in flux density (ΔB) and the square of the switching frequency (fsw2).

For magnetic components in general, there is a trade-off between saturation flux density and core loss.
The use of materials with a high operating flux density offers benefits in the form of reduced size, weight and cost. For example, silicon steel cores typically have saturation flux densities of 1.5-2T. Unfortunately, such core materials also suffer from high core loss.

In contrast, ferrite cores are ceramic materials which have low saturation flux densities in the range 0.25-0.5T. But because their electrical resistivity is high, their core losses are low. Ferrite core materials commonly used in flyback transformers include 3C90 from Ferroxcube and the Magnetics® ‘R’ material, as shown in Figure 4.

Curves showing core losses at various switching frequencies, typically plotted as core loss in kW/m³ over ΔB measured in Teslas, are provided in material datasheets and can be used to estimate the core loss in any given application.

All of the considerations of loss above also have an effect on the calculation of core size. Readily available technical papers explain various methods for determining core size. In Future Electronics’ experience, it is often better to start with a slightly larger core size than strictly necessary, if space and cost constraints allow, since this will reduce the number of turns, core losses and leakage inductance.

In addition, it is best to choose a bobbin for the core of choice which provides the best winding length-to-height ratio: this will minimise the number of winding layers required.

The next step: hands-on prototyping
This article has outlined the important theoretical factors and design decisions that have to be taken into account in developing a design for a flyback transformer on paper. It also provides some guidance drawn from Future Electronics’ practical experience of transformer design, affecting factors such as core sizing and winding arrangement.

With this information to hand, the designer is ready to embark on the practical process of building a transformer prototype in the laboratory, a subject which will be addressed in a second article from Future Electronics’ EMEA SDC.
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