Single Point Failure Protection for Motor Drive Control Power Supply

Introduction

Motor drives have dominant presence in the systems used in our day to day life. Ranging from household appliances such as air-conditioners, vacuum cleaners to high end industrial motion control such as CNC machines. One can find electric motor in almost every application. The goal of motor drive manufacturers is to design the most efficient and reliable motor drive solutions. The brain of every motor drive system is its control algorithm. The more reliable is the motor drive control algorithm, the more robust will be the motor drive solution. So it is of utmost importance that the motor drive subsystems be fault tolerant and meet industry functional safety standards. Motor drive's power tree, which is an important subsystem, is no exception to that. Figure 1 shows a typical motor drive control card power tree.

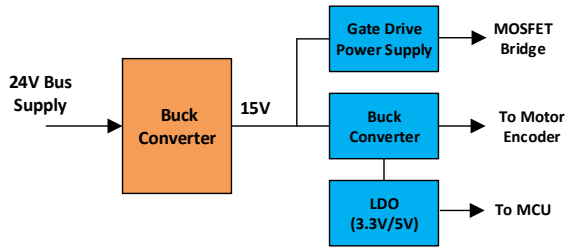

Figure 1. Typical Block Diagram of Motor Drive Control Card Power Supply

The input power supply is typically 24-V DC bus. A buck converter is used to down convert 24 V to generate gate drive power supply and power rail for subsequent DC/DC converter or linear regulators which powers blocks such as control MCU, encoder, voltage supervisors. When it comes to functional safety of the power tree subsystem, one needs to make sure that all the components used in the subsystem are operated within recommended operating conditions and are protected against any system level faults such as over voltage / under voltage on input bus, short circuit on output load etc. In typical block diagram shown in Figure 1, if buck converter fails due to any of the system level fault conditions or device pin shorting, then the same fault event is transmitted to downstream power tree. So in this system, 24-V buck converter becomes common cause of failure (CCF) and requires high diagnostic coverage. CCF can vary based on system architecture and actual power tree.

IEC 61800 Functional Blocks of Subsystem PS/VM

IEC 61800 is functional safety standard for adjustable speed drives. IEC 61800-5-2 / Annex A / Section B.3.2 shows a typical Power Supply (PS) and voltage Monitor (VM) subsystem for a 24-V bus. As shown in Figure 2, it comprises of:

- a series diode to provide protection against input reverse polarity
- a fuse to protect against over current events
- a TVS diode to give protection against transients on 24-V bus
- a series FET which can be controlled using voltage monitor block to cut off power to internal power supply block in case of fault

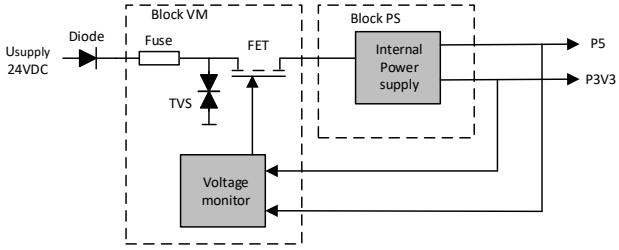

Figure 2. Functional Blocks of Subsystem PS/VM IEC 61800-5-2 Annex A

An e-Fuse: That's All You Need

Most of the functionality of PS/VM subsystem discussed in Figure 2 can be realized using e-Fuse products. An eFuse is a fully integrated protection device that protects against short circuit, overvoltage, undervoltage or reverses polarity events. e-Fuse products also offer system level design flexibility by providing adjustable overcurrent, overvoltage, undervoltage and output ramp rate control. Information about TI's e-Fuse products can be found here. Moreover, most of TI's e-Fuse products are UL2367 recognized which helps designers to meet system level UL certification.

Single Point Failure Protection for Motor Drives Control Power Supply

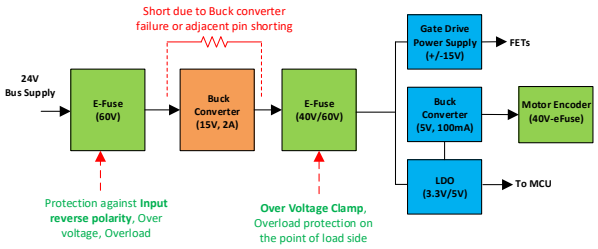

Figure 3. Single Point Failure Protection for Buck Converter

Figure 3 shows block diagram for fault protected motor drive control power supply tree. As discussed in previous section, the 24-V to 15-V buck converter can be a common cause of failure and high diagnostics is required on this block. TI's 40-V or 60-V e-Fuse products can provide system level protection on 24-V power supply bus as shown in Figure 3. This protection can be against 24-V overvoltage / under voltage events or because of the failure on the buck converter side. Figure 4 shows TPS26600 behavior when subjected to input over voltage condition.

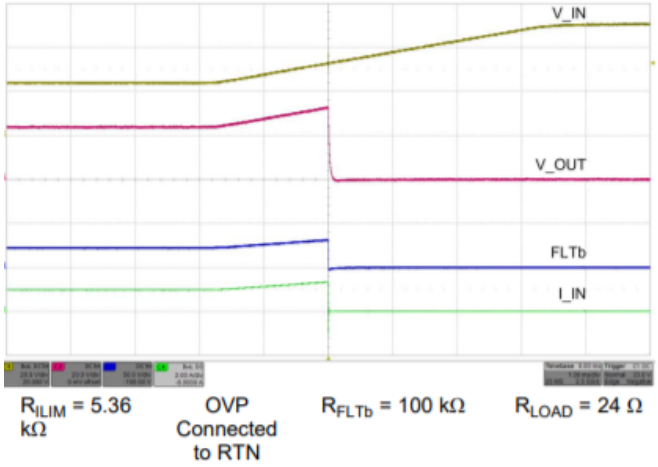

Figure 4. TPS26600 Over Voltage Cut-off Response

An additional TVS diode can be used at input to protect the system against harsh surge events. Additional information on complete system level protection to meet IEC 61000-4-4 and IEC 61000-4-5 using one of TI's 60-V e-Fuse products, TPS2660, can be found in an application report. On the point of load side, especially where power is going out of control board to subsystems like encoder, an additional e-fuse can be used on the encoder side to protect against input reverse polarity due to mis-wiring, short circuit and overload conditions.

Achieving System Level Functional Safety Using TI's e-Fuse Products

Industrial functional safety refers to the overall safety of a system or product if specific commands and functions are executed correctly. With increasing complexity of hardware and software control algorithms, it is becoming challenging to meet functional safety standards on system level. Most of TI's high voltage e-Fuse products are functional safety capable. That means these products have documents available that can aid safety system designs. These documents mainly have information about:

- The failure In Time (FIT) rates of the semiconductor component estimated by the application of industry reliability standards in combination with expert judgement
- The component failure modes and their distribution (FMD) based on the primary function of the device

An example of such a FMD and FIT rate documentation of TPS2660 family of e-Fuse devices can be found at Functional Safety FIT Rate, Failure Mode Distribution TPS2660x.

Conclusion

Motor drives have indisputable presence in our everyday life. Motor drive's efficiency and reliability improvement is thus of utmost importance. All motor drive manufacturers and regulatory standards bodies are aiming towards this. TI's e-Fuse devices are a critical part of power tree when it comes to protect the system against various system level faults. TI's e-Fuse products are also functional safety capable and aid system level safety design.

Table 1. Alternative Device Recommendations

Device	Description
TPS2662	60-V, 800-mA eFuse with integrated input and output reverse polarity protection
TPS2663	60-V, 6-A eFuse with output power limiting and surge protection
TPS1663	60-V, 6-A eFuse with output power limiting
LM7480-Q1	LM7480x-Q1 Ideal Diode Controller with Load Dump Protection

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