Improving Power Efficiency and Reliability of Pinball Driver Boards

Load driver boards like Data East PPB and Williams System 11x Auxiliary Power Driver Boards have a design flaw that makes them vulnerable to damage caused by high fault currents. This paper discusses the design flaw, and two new boards with a fix that enhances reliability and power consumption.

Power Board Overview

The original Data East PPB and Williams System 11x Auxiliary Power Driver Boards use TIP36C bipolar power transistor to drive loads such as solenoids. When the transistor turns on, it completes a circuit, which allows current to flow, activating the solenoid.

The TIP36C works ok, if there are no faults. However, if a load is shorted, then the TIP36C is clamping the power supply voltage to ground, causing massive current flow. Fault currents occur when aging insulation on solenoid windings wears out, shorting windings together. There can be other fault causes too. The important thing is that the original driver boards are not designed to survive large fault currents, whatever the source.

Design Flaw

The TIP36C is a power transistor (BJT) rated for 25A. This alone should handle any fault currents, right? Wrong.

The real world current rating of a transistor depends on how it is used. Proper heat sinking must be used to control the temperature rise in a transistor. The original Data East and Williams load driver boards use the transistors standing up, without heat sinks. When used in this way, the TIP36C can only dissipate about 3W without being destroyed.

Power dissipation in a transistor is measured by multiplying the collector current by the voltage across the transistor, VCE (sat). The TIP36C BJT has a saturation voltage of 1.8V at 15A, 4V at 25A. If the fault current is 15A, the power dissipated in the TIP36C is 27W, which is destructive. If the fault current is 25A, the power dissipated in the TIP36C is 100W, which destroys the TIP36C.

Current	VCE (sat)	Power
15A	1.8V	27W
25A	4V	100W

Table 1: Power dissipation in TIP36C drivers under fault conditions. Both exceed 3W which is the real world limit of the TIP36C when used as it is in the original Data East and Williams boards.

Fuses are included on the board to prevent against fault current. Fuses don't blow instantly. At 200% of a fuse's rated current, it can take up to 2 minutes for a fuse to blow. During that 2 minutes, the TIP36C gets hot and may be destroyed if it gets too hot.

Design Fix

This problem is easily solved by using a sufficiently large power MOSFET. MOSFETs have RDS (ON) rating instead of VCE. RDS (ON) is resistance between the drain and source when a MOSFET is turned on. The worst case RDS (ON) for the IRFR4510PbF transistors used on XPIN's new boards is 14 milliohms. The power in a MOSFET is I^2*RDS (ON). If fault current is 15A, then power is 3.15W. If fault current is 25A, then power dissipation is 8.25W. The power dissipation is 8-12x lower than the original board.

Even with limited board space available for heat sinking, the lower power dissipation is enough to reduce the temperature rise in the MOSFETs to ensure that the MOSFETs survive high current faults. Testing on the bench shows that the MOSFETs on XPIN's new load driver boards stay cool even when conducting large fault currents.

Current	Resistance	Power
15A	0.014 ohms	3.15W
25A	0.014 ohms	8.25W

Table 2: Power dissipation in IRF4510PbF MOSFETs used on XPIN's load driver boards. Power and heat are reduced 8-12 times over the original board designs, improve reliability.

Conclusions

XPin Pinball's new replacement boards for the Data East PPB and Williams System 11x Auxiliary Power Driver Board address key reliability issues in the original designs.

Sources

http://www.onsemi.com/pub_link/Collateral/TIP35A-D.PDF
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